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Comprehensive Compressed Air Assessments

The 5-Step Process

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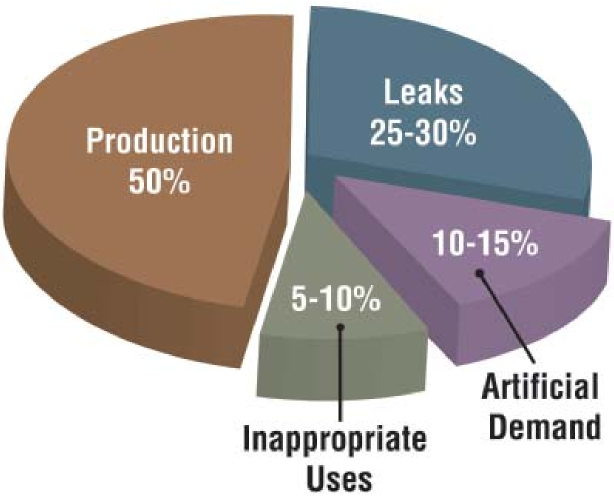
The U.S. Department of Energy estimates that air compressors use as much as 10% of all electricity generated in the United States. Further, the DOE calculates that as much as 50% of this energy is wasted. Compressed air leaks alone account for 25-30% of compressed air use.

Consequently, many industrial companies are identifying ways to lower their compressed air system energy consumption. One of the most popular methods to do so is a comprehensive compressed air assessment, or “air demand analysis.” The objective of this paper is to define the five steps required in a compressed air assessment. We will use a real-world example with system information from a magnetic materials manufacturer to clearly illustrate each step. In the following case, the user achieved a 42% reduction in annual energy costs.



The U.S. Department of Energy estimates that only 50% of compressed air is put to productive use - meaning most air systems have significant energy savings potential.

Step 1: Conduct a Site Survey

It is important to list and understand all the equipment in a compressed air system before installing any measurement devices so that 1) the devices are properly placed, and 2) system dynamics are properly understood. The person responsible for collecting information should note: environmental conditions, physical layout, details on all air system components including clean air treatment, piping, storage, and controls. Processes at the facility should also be documented. Many assessors will have a questionnaire which they complete to compile the details into one document.

Compressor Room #1

- (1) Compressor #1, 60 hp, water-cooled screw compressor with modulation control - *Rated 267 cfm at 125 psig*
- (1) 240-gallon storage receiver prior to air treatment
- Refrigerated air dryer with one pre-filter and two afterfilters

Compressor Room #2

- (1) Compressor #2, 50 hp, air-cooled screw compressor with modulation control - *rated 215 cfm at 125 psig*
- (1) Compressor #3, 75 hp, air-coooled screw compressor with modulation control - *rated at 350 cfm at 125 psig* ***Note: offline during testing period***
- (1) Refrigerated air dryer with pre-filter and afterfilters
- (1) 240-gallon storage receiver after air treatment

Case: This facility had two compressor rooms using rotary screw air compressors from three different manufacturers. They also had a mix of refrigerated air dryers, receiver tanks, and filters. The piping network was made up of 1.25, 1.5, and 2-inch lines.

Both Compressor #1 and #2 were operating in modulation control. Compressor #3 was also using modulation control, but was offline during the testing period.

Step 2: Measure and Quantify kW / 100 cfm

Power, flow, and pressure should be measured for a period of 10 days to obtain an accurate system snapshot (other data points such as pressure dew point [to determine air quality], vacuum, and temperature should be measured as needed based on system requirements). The measurement period should include nights, weekends, or other downtime to identify non-productive demands. True power used by the air compressors is measured using kilowatt meters which monitor amperage, voltage, and power factor. Data loggers should record data points on each air compressor every 0.5 seconds, and average the data over a preset recording interval such as 20-second resolution. A finer resolution may be needed to log specific events.

A suitable Key Performance Indicator (KPI) for all compressed air systems is specific power consumed (kW) per 100 cubic feet per minute (cfm) of compressed air used in the plant. This provides an idea of how efficient a compressed air system is – regardless of varying plant output levels. Recommended systems have a KPI below 21 kW / 100 cfm.

Case: Flow on Compressor #2 was measured by installing a vacuum transducer below the inlet valve but above the airend rotors. The discharge flow will fluctuate proportionally to the inlet vacuum, i.e. a 50% vacuum represents 50% flow. A vacuum transducer could not be installed on Compressor #1, so a flow meter was installed at the discharge of this system prior to the distribution piping. Pressure sensors were installed in both compressor rooms as well.

The measured specific power KPI (kW / 100 cfm) of the existing system was measured at almost 32 kW / 100 cfm. Based on this, there was reason to suspect significant energy cost savings potential.

Step 3: Understand the System Dynamics

The system information collected should be thoroughly analyzed and areas of improvement should be identified. Multiple scenarios should be considered to lower the compressed air system's energy consumption, including an analysis of the major compressed air users within the facility to determine whether compressed air is the most efficient option for each application.

Case: The average compressed air supply was 240 cfm at the required plant pressure set point of 95 psig. The measured compressed air supply range was between 200 and 300 cfm.

Most often, both Compressors #1 and #2 were loaded to maintain plant pressure. The available compressor supply significantly exceeded the compressed air demand. Based on the measured flow profiles during the testing period, Compressor #1 was capable of meeting the average demand without assistance from Compressor #2, but was not capable of meeting the peak demand. As shown in Figure 1, the two units were running in modulation control, which partially opened or closed the compressor inlet valves — creating vacuums at the inlets to match supply to demand. Due to the negative pressure at the inlet valves, the compression ratio was increased which increased the amount of power required per cubic foot of air to meet the set point pressure.

Though the two compressors were maintaining a steady operating pressure, they required extremely high power consumption at partial loads, thus creating the very inefficient Specific Power KPI of 35 kW / 100 cfm.

When Compressor #1 was either manually stopped, or when the unit experienced a failure, pressure in the facility dropped below the minimum required level of 95 psig. During these times the flow meter at Compressor #1 read an average of 50 cfm.

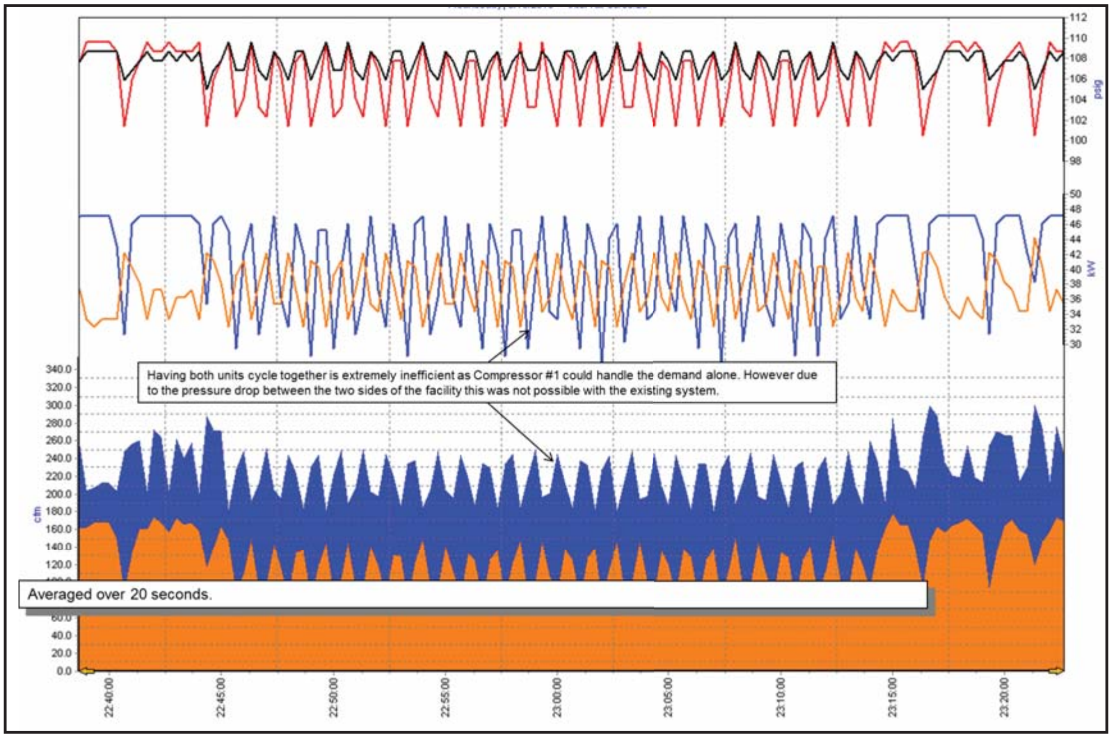


FIGURE 1: Compressors #1 and #2 Running in Modulation Control

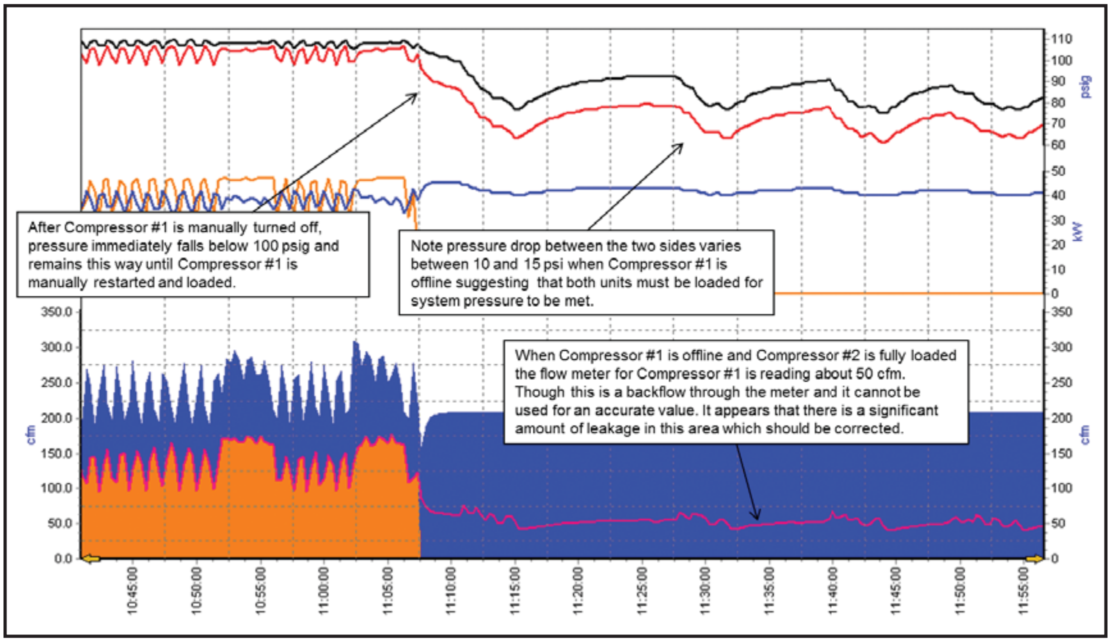


FIGURE 2: Compressor #1 Offline

Proper system control is key to ensuring energy consumption is optimized

This suggests that a significant portion of the air demand in Compressor Room #1 was air leakage. Figure 2 highlights one such day. This graphic also shows the significant pressure drop between the two compressor rooms when Compressor #1 was offline, between 10 psi and 15 psi. This suggests that the piping network (1.25, 1.5, and 2 inch) was insufficiently sized.

The air treatment equipment was working well and no issues were noted. The equipment was sized for worst-case ambient conditions which is a good practice.

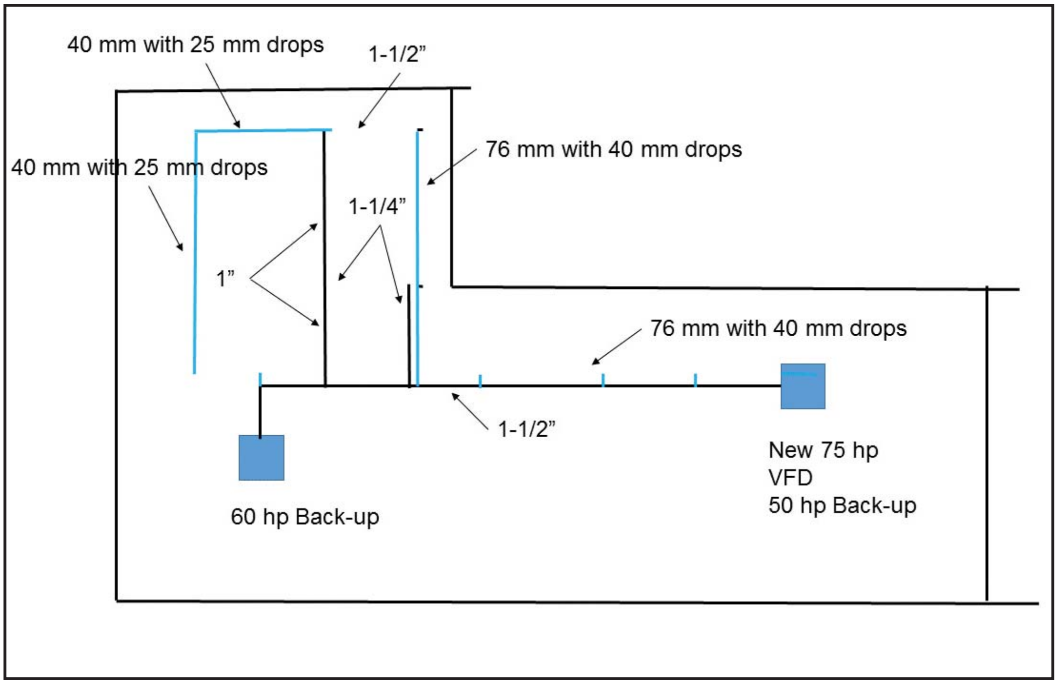
Step 4: Implement a Recommendation to Improve kW / 100 cfm

Many system assessments focus on reducing compressed air consumption by fixing compressed air leaks or through eliminating "inappropriate uses" of compressed air. Using engineered air nozzles, for example, to replace perforated pipe for blow-off applications will reduce compressed air demand. Real energy savings, however, will ONLY be realized if the controls on the air compressors can capitalize on these gains. This includes proper use of a variable frequency drive (VFD). The costs involved with adjusting compressor controls are almost never included in the ROI calculations. Many modulating air compressors will continue to consume the same amount of electricity (kW) within broad ranges of compressed air flows (cfm). Users cannot assume a linear relationship between compressed air use and power consumption.

Case: The following recommendations were accepted and implemented:

1. Installed a 55 kW VFD, air-cooled, rotary screw air compressor able to handle the full air load.
2. Removed Compressor #3, but retained Compressors #1 and #2 for back-up.
3. Reconfigured the piping in the facility to eliminate pressure losses and air leaks.
4. Increased storage with a 1040 gallon dry tank.

The piping was a critical component in the system's optimization. Creating a closed loop allowed for the proper system pressure downstream and required less work for the compressor. With the 55 kW unit capable of providing 389 cfm at 100 psig and sized



Without reconfiguring the compressed air piping (blue pipe in image), the facility may not have met the energy savings required for the utility rebate.

to operate in its most efficient range between 40-85% load, the new specific power KPI was estimated to be 18.56 kW / 100 cfm. This KPI would meet the recommendation to be below 21 kW / 100 cfm, and represented a significant improvement over the existing systems' specific power KPI of 32.14 kW/100 cfm.

Step 5: Verify Performance of kW / 100 cfm

Utility rebate programs sometimes require energy savings be verified by an additional compressed air assessment performed after the air system is optimized. In cases where utility rebates do not require such a degree of verification, facilities should still consider implementing some form of a post-optimization assessment. All systems can be enhanced – even systems designed using air assessment data and that are newly installed. The additional assessment should verify the compressed air assessment findings, as well as assist in identifying additional areas of improvement. Some system controllers actually track and store ongoing energy consumption data, so for many, a review with a master system controller provides enough information for internal evaluation and can be used to verify improvement metrics.

Case: A follow-up compressed air assessment was performed for this manufacturer. The verification results showed that although the overall air demand in the factory had gone up (from 244 to 289 cfm), the 55 kW VFD efficiency was well within the target zone of 18.6 kW /100 cfm KPI. Average operating pressure had also been reduced by 3 psig. Eliminating the water-cooling requirement provided a bonus potential savings of $1,208 per year (calculated based on $0.20/1,000 gal cooling water). The water-cooling cost could be significantly higher depending on the type of water supply. The annual energy savings were verified at $19,165 per year – a 42% reduction for the energy cost and slightly higher than the original estimate.

Conclusion

It is critical to focus on improving the specific KPI

Description	Proposal Estimate	Verification
Annual Flow (cf/year)	128,010,406	130,600,442
Original System: Energy Consumption	685,792 kWh/yr	-/-
New System: Energy Consumption	395,942 kWh/yr (est.)	404,822 kWh/yr
Annual Energy Savings	**289,850 kWh/yr (est.)**	**294,846 kWh/yr**
Energy Cost	0.065 $/kWh	0.065 $/kWh
Original System: Energy Cost	$44,577/yr	-/-
New System: Proposed Energy Cost	$25,736/yr (est.)	$26,313/yr
Annual Energy Savings	$18,840/yr (est.)	$19,165/yr
Original System: Specific Power KPI	32.14 kW/100 cfm	-/-
Specific Power KPI	**18.56 kW/100 cfm (est.)**	**18.60 kW/100 cfm**

of kW / 100 cfm. Compressed air users can ensure return on investments (based on energy savings) on air system assessments by working with firms who measure, at a minimum, power, flow, and pressure over a period long enough to obtain an accurate system snapshot, often 10 days. Further, the data obtained from the assessment must be thoroughly analyzed and recommendations should be made based on conservative estimates of power reduction.

When implementing an optimization plan, it is important to remember that without proper system control, the system's overall energy consumption may not be significantly lowered. In the case described, adding a VFD unit allowed the system to generate compressed air at the lowest acceptable pressure, thereby reducing energy consumption and cost. In many cases, a master system controller is the best solution as master controllers use

Implementing system controls is vital to achieving system optimization and energy savings.

compressors at their most efficient design point or turn them off. However, in this case, without augmenting the piping, eliminating the multiple compressor rooms would not have been an option.

Finally, users that complete a compressed air assessment and optimize their systems will surely reduce energy consumption and see lower operating costs. However, even the best, newly optimized systems can always be further improved. Facilities should be advised that additional savings can be determined by completing a leak detection audit in conjunction with a full evaluation of the demand side of the facility for appropriate use of compressed air. Facilities should determine which services are best suited for them (leak detection, supply side compressed air assessment, and/or demand side compressed air assessment), and develop a plan for how often those services should be performed.

About the Author

***Neil Mehltretter** is a Certified Energy Manager (CEM®). As Kaeser's Engineering Manager he has conducted and overseen thousands of industrial compressed air studies and helped users achieve significant energy savings and operational improvements. He has authored several nationally published articles on compressed air system optimization and is a frequent presenter on energy efficient system design. In addition to his Bachelor's Degree in Chemical Engineering from The University of Florida, Neil is AIRMaster+ certified, has completed the Compressed Air Challenge curriculum, and is a Master Certified System Specialist through Kaeser's Factory Training Program.*

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