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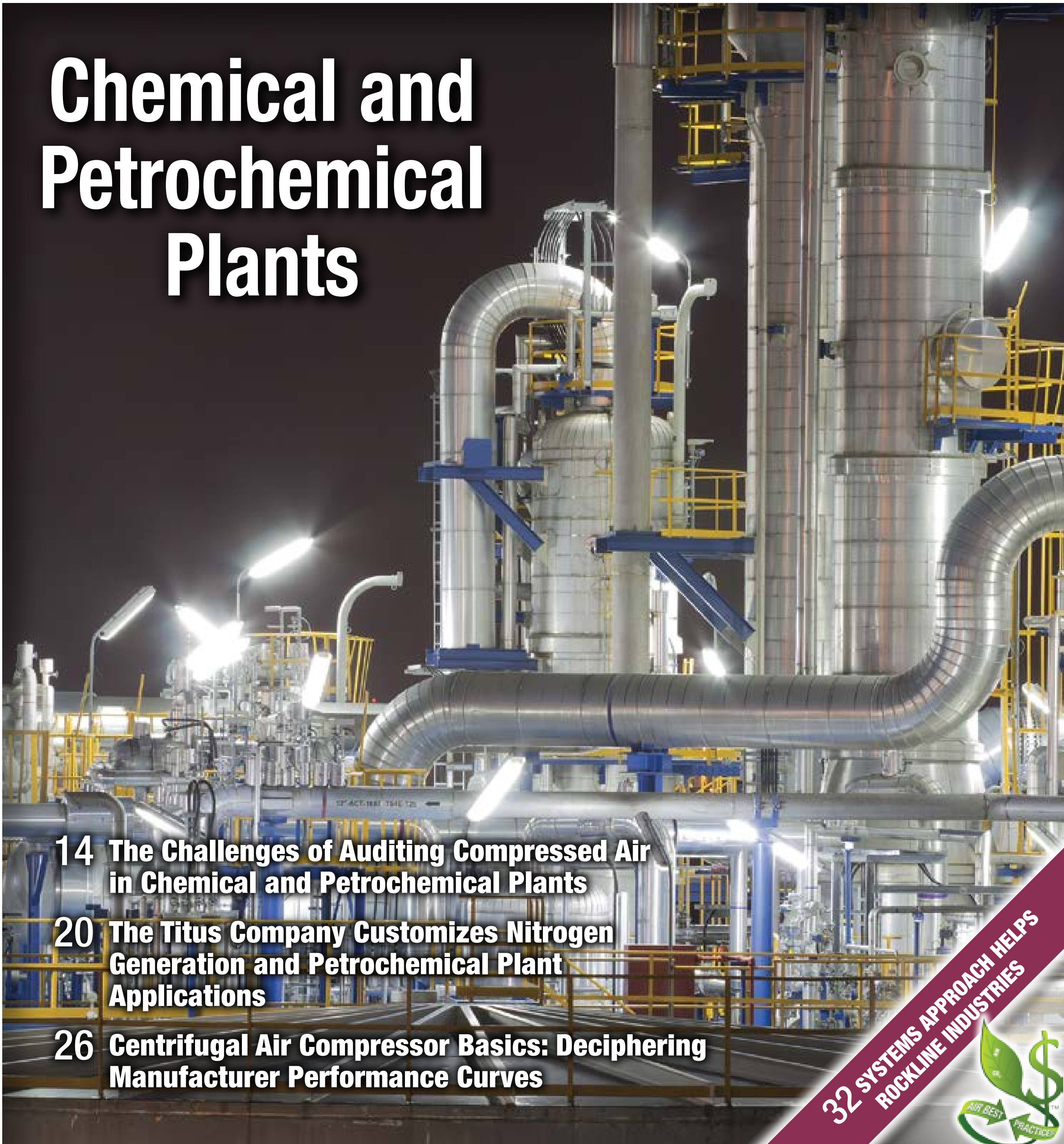

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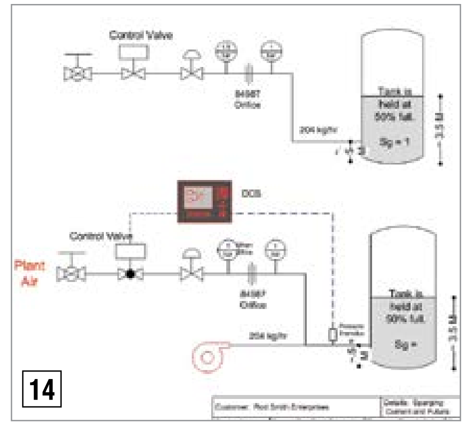

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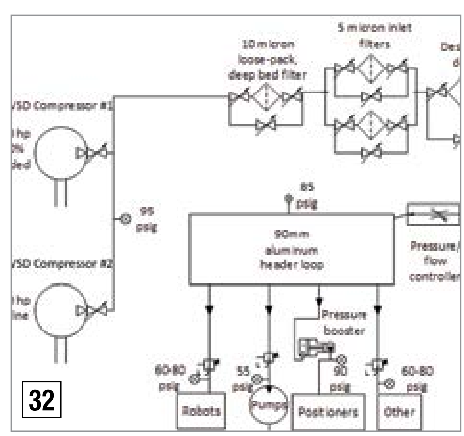


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FROM THE EDITOR | Chemical and Petrochemical Plants

Chemical and petrochemical plants do not have many things in common with most manufacturing plants. Paul Edwards, from Charlotte-based Compressed Air Consultants, Inc., reviews in his article for us this month, how their emphasis on safety, process stability and system reliability impacts compressed air audits. For example, the installation of measurement and monitoring instruments often has to go through rigorous permitting approval processes — making the pre-audit stage incredibly important.

Oil refineries need to dry the carbon dioxide (CO_2) emissions coming from their hydrocracking applications. In our profile of The Titus Company, Stephen Titus walks us through a custom-built internally heated reactivated desiccant dryer supplied to a refinery and James Bowers reviews a nitrogen generation package custom-built for sealing and blanketing natural gas.

Centrifugal air compressors are the workhorses of large process plants in the U.S. Hank van Ormer, from Air Power USA, provides us with a practical auditing article titled, "Centrifugal Air Compressor Basics: Deciphering Manufacturer Performance Curves." The article reviews the operating principles of centrifugal air compressors and provides a guideline for deciphering operating curves helpful to understanding general performance.

Rockline Industries is one of the largest global producers of consumer products, specializing in wet wipes and coffee filters. The company contacted the Arkansas Industrial Energy Clearinghouse after identifying that the compressed air system in their Springdale, Arkansas facility was a potential source of significant energy savings. Andrew Chase Harding and Darin Nutter, from the University of Arkansas, write about how using a systems approach made this a successful compressed air analysis.

Vale (formerly known as INCO), located in Manitoba, Canada, has reconfigured a system of large turbo compressors in their mining, milling, smelting and refining operation, and gained very large energy savings through a series of improvement projects. Ron Marshall, on behalf of the Compressed Air Challenge®, documents an audit of this 100 psi installation which, when new, consisted of five large axial compressors ranging in size between 5760 hp and 2500 hp sending air into hybrid refrigerated/desiccant compressed air dryers.

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INDUSTRY NEWS

EPA Announces 70 Top-Performing Energy Star Certified Manufacturing Plants

Across the country, Energy Star manufacturing plants are leading their industries by saving energy and money, and combating climate change.

The U.S. Environmental Protection Agency (EPA) recently announced that 70 manufacturing plants have achieved Energy Star certification for their superior energy performance in 2014. Together, these manufacturing plants saved a record amount of energy, cut their energy bills by $725 million, and reduced greenhouse gas emissions by more than 8 million metric tons — equivalent to the annual total energy use of more than 650,000 households. From implementing corporate energy management programs to implementing energy efficiency projects, there are many ways plants can save energy with EPA's Energy Star program.

"Energy Star certified manufacturing plants are leading their industries by advancing energy efficiency and making cost-saving improvements while combating climate change," said EPA Administrator Gina McCarthy. "Through their work with EPA, the 2014 Energy Star manufacturing plants are demonstrating that making sustainability and energy efficiency improvements is a smart business decision."

Seven are certified for the first time:

- ConAgra Foods' American Falls, Idaho frozen fried potato processing plant
- ConAgra Foods' Ogden, Utah cookie and cracker baking plant
- Essroc Cement Corp.'s Martinsburg, WV cement manufacturing plant
- Essroc Cement Corp.'s Nazareth, PA cement manufacturing plant
- Lehigh Cement's Glen Falls, NY cement manufacturing plant
- Lehigh Cement's Leeds, AL cement manufacturing plant

- Marathon Petroleum Corporation's Illinois Refining Division petroleum refinery

Since the inception of EPA's Energy Star certification, a total of 139 manufacturing plants have achieved this distinction. These plants have saved over 530 trillion British thermal units (TBtu) in energy, equal to preventing more than 36 million metric tons of carbon dioxide equivalent emissions and saving enough energy to provide the total yearly energy needs of approximately 3 million American households.

For more information about Energy Star certified plants, visit www.energystar.gov/plants.

Atlas Copco High-Pressure Diesel Compressors Help Repair a Cracked Dam

One of the 13 monoliths that make up the spillway of the Columbia River's Wanapum Dam (Central Washington) developed a 65-foot-long, 2-inch-wide crack.

Fixing the crack required 16-inch boreholes through the dam into the bedrock to facilitate the installation of 61-strand tendon anchors. The dam would be further reinforced by installing post-tension anchors along its face below the water line. The project would require a large volume of high-pressure air.

Nicholson Construction was awarded the anchor contract, and the work required up to 3600 cfm at 350 psi in an extremely tight working space. Therefore, they chose six Atlas Copco DrillAir TM XRVS 1300 CD7 high-pressure diesel compressors.

Several Atlas Copco DrillAir TM XRVS 1300 CD7 high-pressure diesel compressors onsite at the Wanapum Dam

INDUSTRY NEWS

Rental Atlas Copco air compressors at the Wanapum Dam

Air Support to Repair the Crack

When the project is completed, 35 tendons will be vertically installed in the monolith piers. There are 77 vertical and angled bar anchors currently being installed. Nicholson Construction project manager BJ Hepworth said: "This process basically stitches the dam together from top to bottom."

The installation process requires many precisely drilled holes.

"Holes that size require so much air capacity that it really limits our options," Hepworth said. "We don't have room for many compressors in that narrow access. The XRVS 1300s we rented from Atlas Copco make it a lot easier to operate, because we need fewer units in the work area."

The two companies have worked together previously.

"We actually just came off a job at a nuclear power site with a similar setup using Atlas Copco compressors," Hepworth explained. "We were more comfortable going with their compressors, since we already knew and trusted them."

The Nicholson team was also familiar with Atlas Copco's support.

"You can run into trouble whenever you're working at jobs that require high-pressure compressors that size. These would need to be running 24/7 throughout the project, month after month," Hepworth said. "We knew Atlas Copco would take care of all servicing and be there to help troubleshoot any bugs we might run into initially. Of all the things that we need to worry about, it's great to know that we don't have to be concerned with the maintenance of the air compressors on this project."

The project, which started in 2014 and will be completed later in 2015, is scheduled in two phases. The first phase was completed in December of 2014 and included installation of a portion of the tendons and anchor bars so the reservoir could be brought back to an elevation of 562 feet. This elevation allowed the dam's two fish ladders to return to normal operations. The second phase will be to return water levels back to an elevation of 571.5 feet and restore full generation capacity (1092 MW).

For more information, visit www.atlascopcorental.com.

BOGE and Central Air Equipment Help Multi-Billion Dollar Company Avert Crisis

In 2007, when Finning International, Inc., the world's largest Caterpillar dealer, moved into its 200,000 sq. ft. Centre of Excellence in Red Deer, Alberta, Canada, the company inherited an aging set of 150-hp compressors that proved very costly to operate and maintain. Necessary for sand blasting and painting, Finning turned to Central Air Equipment (CAE), BOGE America

BOGE air compressors installed by Central Air Equipment at Finning International

INDUSTRY NEWS

Compressed Air Systems' master distributor in Red Deer, for a solution.

CAE carefully reviewed Finning's needs and proposed a BOGE SLF direct-drive variable speed compressor. A visit to one of CAE's local customers' plant allowed Finning representatives to see a BOGE system in action, which included three BOGE S61-2 compressors and a lead variable speed BOGE SLF-75. Finning was suitably impressed with the clean installation of these super-silenced machines as well as the BOGE Airtelligence Plus controller that monitored them.

As Finning was in the process of placing their order for a new BOGE SLF 75-3, the unexpected happened: Finning's second aging compressor failed and their only functioning compressor wasn't sounding too healthy. With Finning facing a manufacturing crisis, CAE stepped in and got the company back up and running with the loan of a BOGE S50-2 machine out of their own stock and a rented diesel compressor.

The loaner and rental compressor were stopgap measures at best. Finning's 450 employees only worked if all manufacturing processes were working, and Finning couldn't afford to be without compressed air. Finning turned to CAE to quickly review the situation and offer recommendations.

CAE's in-depth review went beyond addressing energy savings, which was Finning's initial focus. Their crisis made it clear that reliability and redundancy were also vitally important. In addition to the BOGE SLF 75-3 that was being built for Finning, CAE recommended a set of three lower capacity, smaller horsepower base-load BOGE S50-3 units to complement the SLF 75-3. With this recommendation, there would be adequate total capacity to meet Finning's measured peak load with enough redundancy to cover the plant demands should any one of the compressors go off-line for regular maintenance.

For more information, visit www.boge.com and www.centralairequipment.com.

CASCO USA Honored with Industry Supplier of the Year in Northeast Oil & Gas Awards

CASCO USA recently attended the 3rd Annual Northeast Oil & Gas Awards and received the

Industry Supplier of the Year. The annual Northeast gala ceremony was held at the Westin Convention Center — 1000 Penn Avenue, Pittsburgh, PA, 15222 — where hundreds of oil and gas executives gathered together to celebrate operational excellence, innovations in technology, CSR, health & safety, and environmental stewardship.

The Industry Supplier of the Year Award recognizes suppliers of materials and equipment to the oil and gas industry. Companies that have demonstrated reliability, gone the extra mile to provide the oil and gas sector with impressive customer service, and can show details of their CSR initiatives are rewarded. CASCO USA scored highest in the category with such remarks from the judges as:

"Great supplier in the Northeast region, offering seminar education sessions and a tailored approach to the provision of compressed air systems"

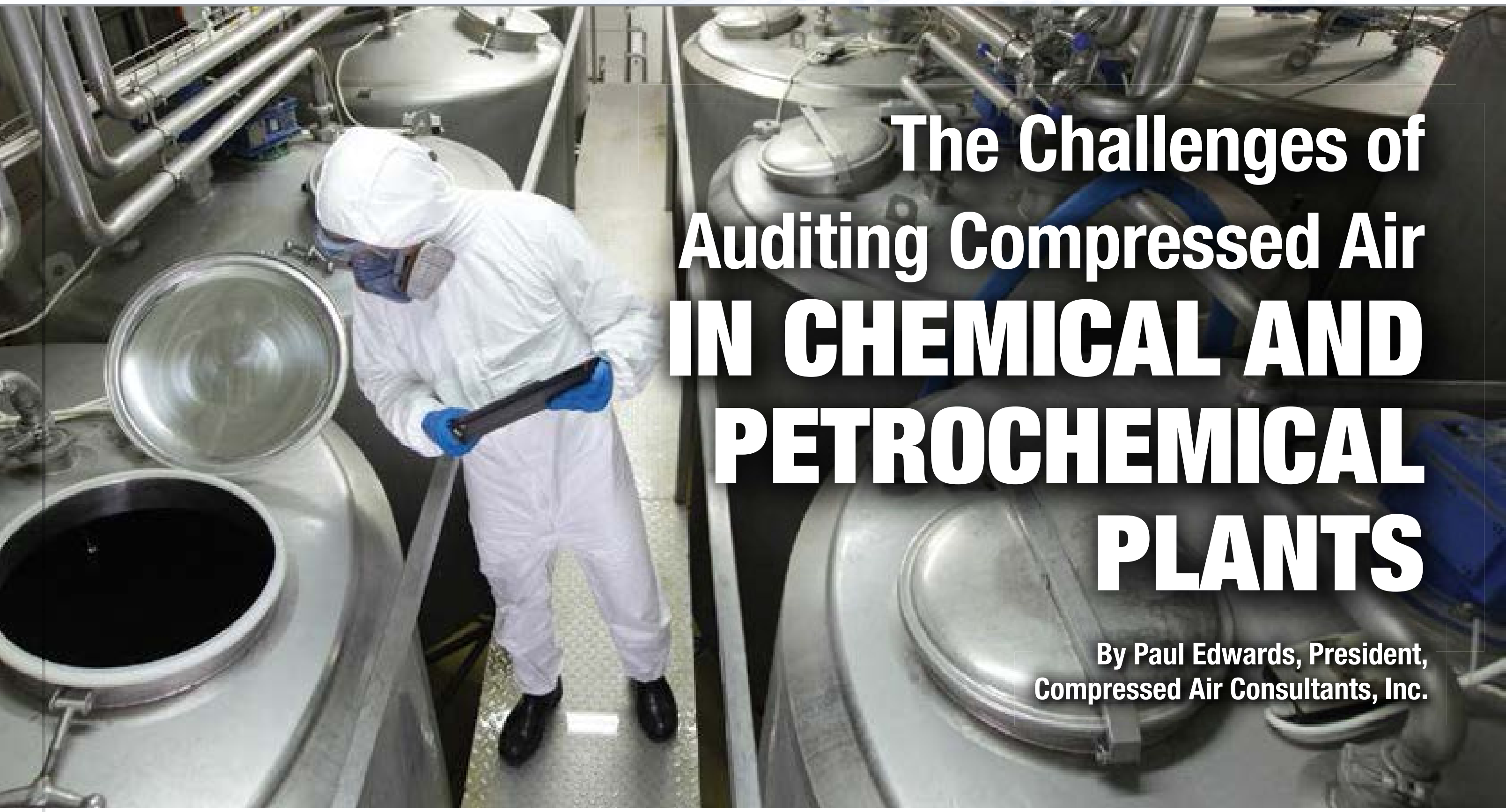
"Leading equipment supplier with audited bespoke solutions. Extremely comprehensive submission, with strong supporting documentation"

About the Oil & Gas Awards

The Oil & Gas Awards recognize the outstanding achievements made within the upstream and midstream sectors of the North American oil and gas industry. The Awards are a platform for the industry to demonstrate and celebrate the advances made in the key areas of environment, efficiency, innovation, corporate social responsibility and health and safety. The Awards show the industry's motivation to develop by recognizing and rewarding the efforts of corporations and individuals.

For more information about the Oil & Gas Awards, all regional awards and award categories can be reviewed on their website at www.oilandgasawards.com.

For more information on CASCO USA visit www.cascousa.com.



The Challenges of Auditing Compressed Air IN CHEMICAL AND PETROCHEMICAL PLANTS

By Paul Edwards, President,
Compressed Air Consultants, Inc.

Compressed air audits for chemical and petrochemical plants have many characteristics in common with audits in other industries, but there are some differences in the way these businesses run that impact the goals of the typical audit and how that audit is conducted. In chemical and petrochemical facilities, the reason for auditing the demand side is different than that of other industries. Additionally, there are frequently applications with opportunities for improvement that are not always seen in other industries.

For starters, chemical and petrochemical facilities are often motivated differently than other industries. There is an even greater emphasis on safety, process stability and system reliability. While these plants like projects that reduce cost, they are much more interested in projects that enhance reliability while reducing costs. Focusing on reliability from a system perspective is of much greater interest to these plants than simply fixing leaks, saving money on lubricant, or other cost-reduction projects.

The plant's emphasis on safety and reliability often creates opportunities and issues not seen in other industries. As a result, creating the greatest benefit for the client requires having an open mind. An auditor must recognize the challenges and limitations of these facilities' business and technical processes, and address them in the system audit.

Unique Safety, Personnel and Approval Process Issues

To start with, chemical and petrochemical process facilities deal with personnel and process safety related issues that are much more rigorous than other industries. Safety training is more than just a site orientation. It can require several days, depending on the activities to be performed onsite, and it requires attendance at an annual refresher course.

> "Chemical and petrochemical facilities are often motivated differently than other industries. There is an even greater emphasis on safety, process stability and system reliability."
>
> — Paul Edwards, President, Compressed Air Consultants, Inc.

Many of these facilities also have safety-instrumented systems that must remain highly reliable/available. These systems often require a strictly controlled minimum compressed air pressure to function properly. For example, the installation of monitoring instruments, even those used to passively collect data from the system, often has to go through a rigorous process for approval. First, the type of instrumentation is evaluated to ensure that it is appropriate for the area of the plant where it will be used. Second, the permitting process will often require an evaluation of how the effort to measure something could potentially impact plant operations. This also means that the pre-audit stage can be incredibly important for improving the efficiency of the audit itself.

Entry into various areas of the facilities often requires some type of sign-in, as the plant has to be able to account for the whereabouts of all individuals onsite at all times. These stringent requirements can often double the time requirement of a particular task or tasks in the facility.

Plants often develop standards in the industry that can have some peculiar effects as well. Some of these standards can result in rather odd circumstances that the compressed air professional doesn't necessarily run into on a regular basis. For example, one plant we worked with has a standard stating any compressed air equipment, owned by the plant, must be rated as a Class I, Division 2 installation, substantially increasing the cost to purchase and maintain the equipment. Whereas, the facility's standard for a rental compressor did not require the same hazard rating.

This created a negative incentive for the plant to install its own equipment. In this particular case, the facility was spending over 1 million dollars per year in rental fees. The audit put together a project that improved the reliability of the overall system, all while taking advantage of the financial burden that the rental compressors created. The project provided an exceptional Return on Investment (ROI) that had support throughout the organization. While the project is still in the approval phase, the client agrees completely with the assessment. In fact, the facility management is currently trying to evaluate whether or not their internal standards can be relaxed to provide an even better ROI.

Coping with Facility Size, Long Runs, and Multiple Compressor Rooms

Auditing the distribution system of a chemical or petrochemical facility is a bit different than other industries as well — for several reasons. First, the size of the facility requires extremely long runs of pipe, meaning pressure drop can be an issue — especially in the remote area of the facilities. Some plants get around this by having multiple compressor rooms. Coordinating the behavior of systems with multiple entry points can be difficult, and a well thought-out plan can be the difference between success and disaster.

Systems with distributed supply points can have pressure drop issues also. Often, there is tremendous value in installing pressure loggers throughout the facility and at the end of the various areas to see how pressure varies in the facility. We've seen plants where the entire facility is elevated 3 to 4 psi because of pressure drop in one small area. And in systems where the supply side is large, optimizing a small percentage of performance

THE CHALLENGES OF AUDITING COMPRESSED AIR IN CHEMICAL AND PETROCHEMICAL PLANTS

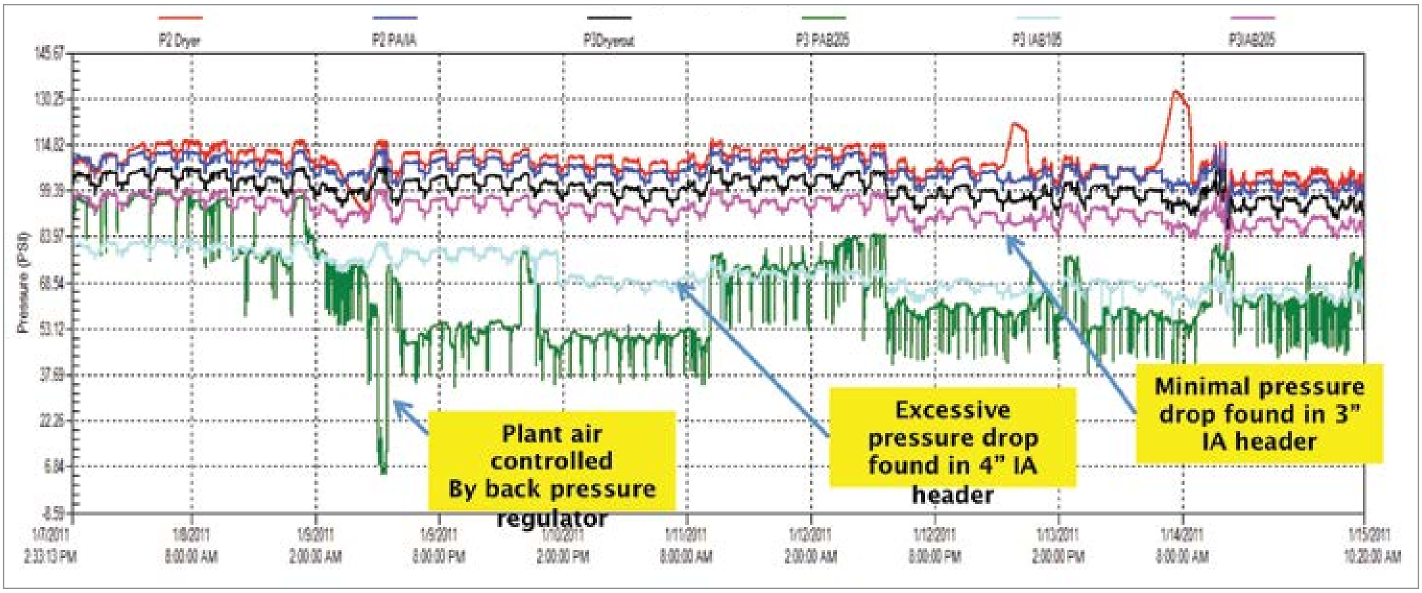


Figure 1: Plant air pressure drops to 9 psi

can be worth hundreds of thousands of dollars. Another common source of excess spending is a "compressed air at all cost" mentality, which results in redundancy upon redundancy and adds cost without increasing reliability.

Auditing the Demand Side — It's Not Always About the Money

Auditing the demand side of these plants is different too. If reliability is the primary goal, then the value of reducing demand may be less dollar-driven. For example, reducing demand may result in lower pressure drop to a particular area of the plant, resulting in a more repeatable performance of control valves. In systems where the demand has grown larger than the dryers' ability to handle it, reducing demand can result in less moisture formation in the system. And, at the risk of stating the obvious, enough demand reduction can put compressors from operating positions into backup positions.

Another challenge of auditing the demand side is that there is often both an instrument air system and a plant or service air system. Part of the demand-side challenge is knowing the source of air for each application. In extreme cases, applications that should be on the plant air system are put on the instrument air system.

The effects of this action can be substantial. As seen in Figure 1, one particular plant supplied the air for the plant and instrument air with the same compressors. The instrument air system was protected by a regulator, which would ultimately reduce pressure in the plant air system if the instrument air system was struggling. As the plant air became less and less reliable, operators started moving the plant air

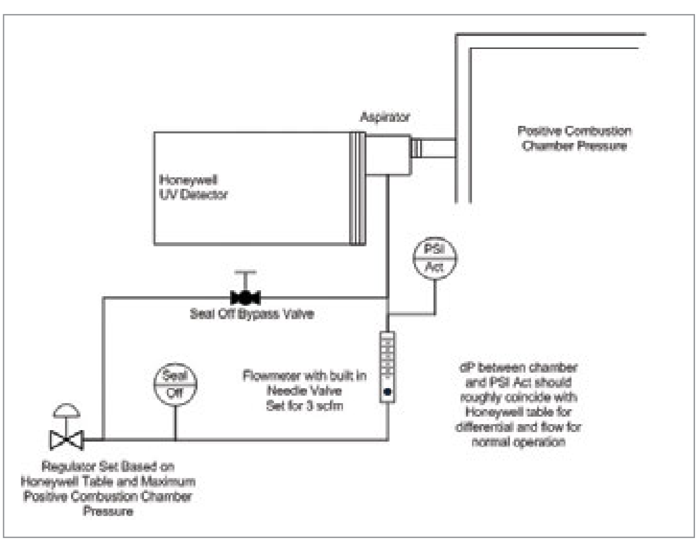


Figure 2: Installation of UV detector

THE CHALLENGES OF AUDITING COMPRESSED AIR IN CHEMICAL

applications over to the instrument air system. The demand-side audit on this particular plant was quite difficult, as the source of the air for the major applications was not always well marked.

Altering Your Audit to Address Unique Applications

The applications in chemical and petrochemical facilities are not seen in general industry. With that in mind, research is often required, as you often find fairly unique applications that aren't common across all industries.

For example, cameras and other imaging devices come from a wide variety of suppliers and have multiple model numbers. These capture images or measure ultraviolet (UV), infrared, or visible light so that operators can understand what is happening in a given process. To provide an end user with the best "view" possible, air is often introduced into the sight tube to keep debris and, in some cases, heat away from the lens.

OEMs each have their own air requirement, and it is often unknown or ignored at the plant level. A fairly typical pressure requirement for some of the UV and infrared instruments we have seen is 3 to 5 inches of water column above the chamber pressure. In the case of some cameras, the OEMs want 5 to 15 psig. One of the reasons for the difference is that the compressed air is acting as a buffer for temperature. With a lens cost of $8,000, users often exceed the recommended air pressure just to make sure.

One way of dealing with the instrumentation can be seen in the setup displayed in Figure 2.

Offering Viable Alternatives for Air Sparging Applications

Another fairly common application in chemical and petrochemical plants that

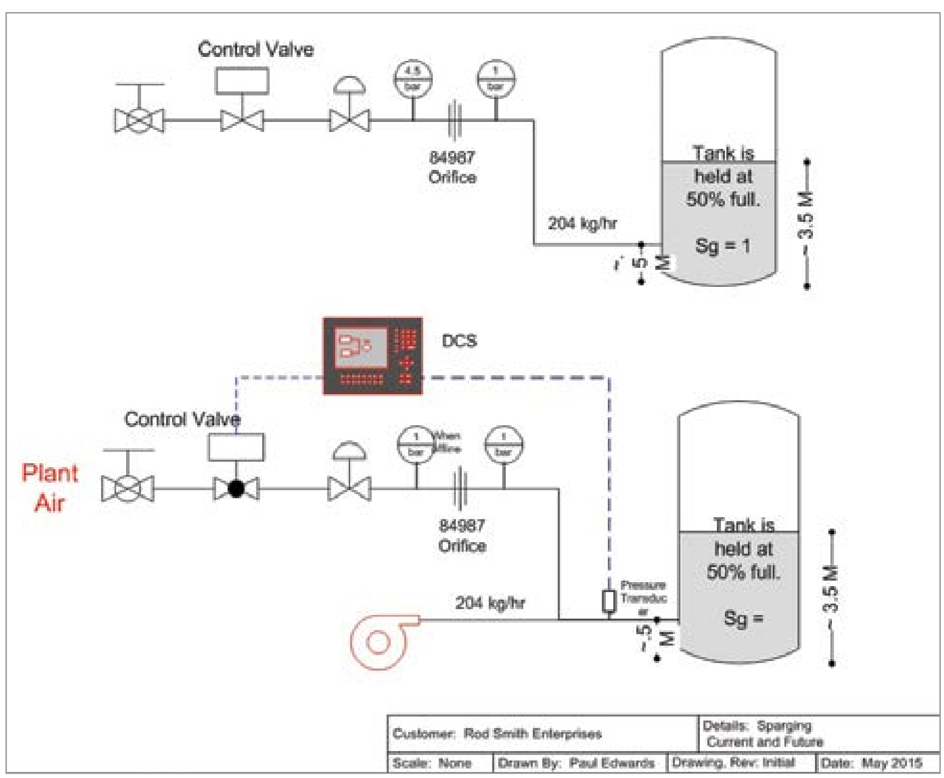


Figure 3: Installing a blower for sparging with compressed air backup

AND PETROCHEMICAL PLANTS

"The applications in chemical and petrochemical facilities are not seen in general industry. With that in mind, research is often required."

— Paul Edwards, President, Compressed Air Consultants, Inc.

has great potential for improvement is air sparging. In this process, air is fed into a tank or vessel to mix contaminant-free air into a tank, helping to reduce the concentrations of volatile organic compounds (VOCs) in the container. Blower air can often be supplied instead of compressed air, but the energy savings in and of itself may not be enough to convince the plant to make the move. Often, an increase in reliability combined with the energy savings motivates the client to move forward.

In the setup shown in Figure 3, the plant was using compressed air to sparge a tank with a product of one. The height of the water column was roughly 10 feet, suggesting that blower air could provide the necessary air to the tank. The solution the plant and the auditor developed was to provide a blower with the compressed air as backup. The plant's internal distributed control system (DCS) system would monitor the air pressure in the supply line. If pressure dipped below an acceptable level, the solenoid valve would open, allowing the plant air system to act as the backup to the blower system.

(It should be noted that when replacing compressed air with blowers, consideration for blower air temperature should be made. Compressed air is usually close to ambient temperature, while blower air can be much higher than ambient air when located near the application point.)

Incentives for Improvement

Auditing chemical and petrochemical plants is indeed a challenge — both commercially and technically. The size of the systems and the magnitude of the problems mean that the potential return can be massive, which provides plenty of incentive for the improvements. It's often important to have as wide a view of the problems as possible, maintaining focus on reliability gains as much as cost reduction. BP

For more information, contact Paul Edwards, tel: (704) 376-2600, email: Paul.Edwards@loweraircost.com.

To read more about ***System Assessments,*** please visit http://www.airbestpractices.com/system-assessments.

The Titus Company Customizes Nitrogen Generation and Petrochemical Plant Applications

By Clinton Shaffer, Editorial Associate, Compressed Air Best Practices® Magazine

The history of The Titus Company is one of all-American entrepreneurial success. After working at Kemp, a compressed air and gas dryer manufacturer, for eight years, Stephen Titus founded The Titus Company in 1986 with his wife, Donna Titus. In the early years, the company operated out of its modest headquarters in southeastern Pennsylvania.

"That's how I got started," Stephen Titus, Co-Founder and President of The Titus Company told the team at Compressed Air Best Practices®. "It was my wife and I, and our three kids. I had the top floor of a rented townhome, and I had a fax machine, a typewriter, a copier, an old drafting table, and a telephone."

Since then, The Titus Company, a distributor and integrator of compressed air and gas systems based in Morgantown, PA, has grown tremendously in size, scope and capabilities. While part of the company still functions as a distributorship, overseeing territories in southeastern Pennsylvania, Delaware and New Jersey, another branch of the company, Titus Air Systems, now operates on a global scale. The company caters to a diverse clientele base, ranging from Amish Country Gazebos to the Royal Navy of the United Arab Emirates.

In our discussions with Stephen Titus and James Bowers, National Sales Manager of Titus Air Systems, we talked about several examples of how The Titus Company provided custom-engineered solutions to various customers. The diversity and complexity of these jobs exemplify how The Titus Company has grown from a small distributorship operating out of a townhome to a thriving compressed air and gas solutions provider capable of tackling highly nuanced applications.

Before the Buzzword: Selling Energy Efficiency in '87

In 1987, representatives from an oil refinery approached Titus because they needed to dry the carbon dioxide (CO_2) emissions coming from their hydrocracking application. The refinery had two uses for the CO_2 coming from their reformer: (1) They could bottle the CO_2 and sell it, and (2) they could use the dried CO_2 to inert certain tanks and processes within their facility.

For inerting, the oil refinery's only alternative to CO_2 was nitrogen, which was simply out of the question.

"The backup is nitrogen," Titus explained. "But nitrogen — in the quantities that they are using it — is very expensive."

Initially, The Titus Company installed an ORIAD© Series internally heated reactivated dryer, which dried the 690 scfm of gas coming in at 90 psi to a -40 ˚F pressure dewpoint. While the installation may have been straightforward, the original selling point was unique for that time period.

"We sold a great deal of the ORIAD© dryers, and we sold them based on energy," Titus explained. "Kemp was talking about energy long before it became a buzzword. The capital cost was higher, but we could prove over time that ORIAD© had a lower lifecycle cost than a pressure swing dryer simply because of the lower compressed air use."

Working on an 8-hour reversal, the ORIAD© only used about 2 percent of incoming compressed air as purge air. In other systems — like a blower purge, convection dryer, or another type of heated dryer — the heated purge air needs to circulate. But, because the ORIAD© dryer was internally heated, the purge air was used to simply sweep the water from the system.

When compared to a typical pressure swing dryer, which might use up to 20 percent of its compressed air supply as purge air, the ORIAD© could yield significant long-term energy savings.

Reverse-Engineering a Derelict Dryer

As the oil refinery developed, it experienced an increase in CO_2 demand. Gradually, they stopped bottling and selling CO_2 and began using it strictly for their inerting processes. That is, however, until the refinery closed in 2008. At that point, the original ORIAD© dryer was left in a susceptible condition, and its internal components rusted out entirely — leaving it in complete disrepair (Figure 1).

Fast forward to 2014. The oil refinery reopened, and it was left without the ability to dry CO_2 for its inerting needs. Because the ORIAD© was left to deteriorate, the original dryer could not function at all. The oil refinery had allocated a little more than $100,000 to address the dryer problem, leaving them in a difficult situation. At that price, they could not afford to purchase a new gas dryer, which would cost an estimated $170,000. Fortunately, by that time The Titus Company had the in-house engineering capabilities and resources to rebuild the original dryer. More importantly, they could do it within the oil refinery's budget.

It was at this stage when the job became much more complex. The dryer had two towers — the East Tower, which needed a total overhaul — and the West Tower, which needed to be replaced. To further complicate the matter, the Kemp line had been acquired and shut down by SPX, meaning that the parts necessary for the rebuild were long out of production.

Figure 1: The refinery's original ORIAD© Series internally heated reactivated dryer after years of disuse

THE TITUS COMPANY CUSTOMIZES NITROGEN GENERATION AND PETROCHEMICAL

Figure 2: The refinery's Oriad dryer revamped by Titus Air Systems

"That was one of the problems when we rebuilt this thing," Titus said when describing the job. "Kemp was no longer around, so we had to basically reverse-engineer the dryer. We had to work with some of our suppliers to build these relatively complicated towers."

Addressing Ambiguous CO_2 Flow

When the team at Titus uninstalled the dryer for an overhaul, they needed to take into consideration the new CO_2 flow at the oil refinery. The flow, which was originally measured at 690 scfm in 1987, had increased significantly since then.

"Currently, the flow is much higher," Titus explained. "The flow meter indicates that it is a little over 800 scfm right now, but the orifice flow meter has been installed since 1987. It has seen 27 years of desiccant dust going through it, which throws off the reading. We believe that it could be up over 1200 scfm right now."

Because the team at Titus knew that the CO_2 flow had increased, but not by how much, they made sure that the maintenance crew at the oil refinery had plenty of options for calibrating the dryer's cycle and reactivation times. The dryer now has 8-hour, 10-hour, 12-hour, 14-hour and 16-hour cycles, meaning it can shift at every 4, 5, 6, 7 and 8 hours. Initially, they started it on a 14-hour cycle. It currently runs on an 8-hour cycle, shifting every 4 hours (Figure 2).

PLANT APPLICATIONS

Fending Off Freezing Conditions

The safety standards governing the oil refinery had also been raised since 1987. Specifically, the engineers at Titus had to work with the refinery to relocate the purge gas ventilation, which used to vent right at the dryer. The new safety standards dictated that the CO_2 had to be vented at least 20 ft in the air.

However, moving 250 ˚F CO_2 up a pipe that was surrounded by ambient temperatures as low as 10 ˚F was a complicated process. The temperature differential between the pipe and the surrounding air caused a lot of condensation, which had to be removed quickly before it froze the piping. This coincided with many of the other issues that the refinery faces during the winter months.

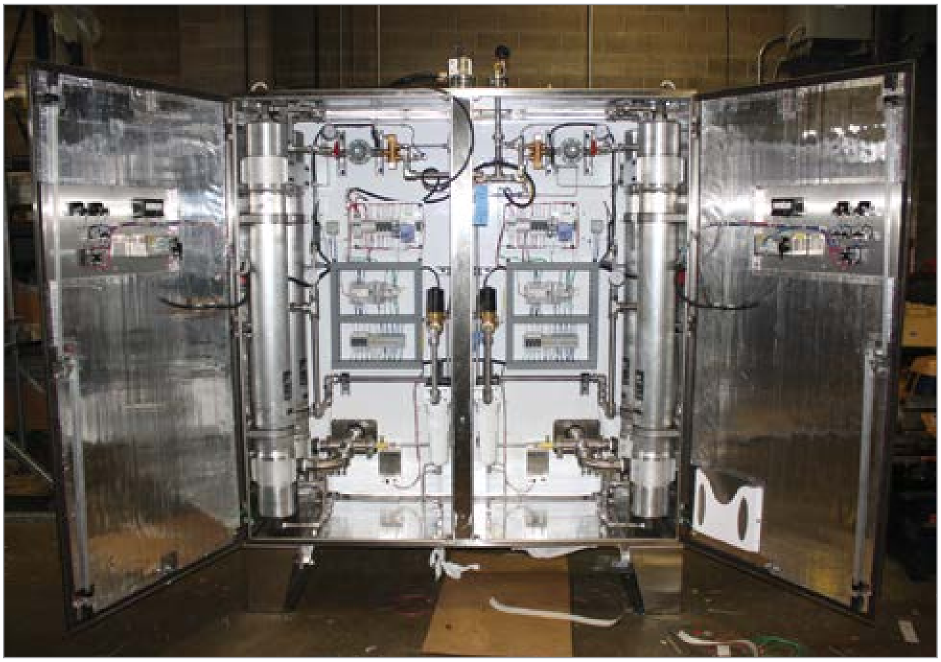


Figure 3: Internal view of the dual nitrogen generation system designed by Titus Air Systems

THE TITUS COMPANY CUSTOMIZES NITROGEN GENERATION AND PETROCHEMICAL

"Keeping an oil refinery running in the winter time is a very difficult procedure," Titus told us. "Typically, the facility's personnel wrap insulation around condensate drains or anything else that has a tendency of freezing up, and they put a steam hose in there to try to keep the whole thing from freezing."

Along the same vein, Titus worked with the refinery to install a steam trace along the purge piping, which is small stainless steel tubing that circulates low-pressure steam. They then insulated the piping and the steam trace together, ensuring that the condensate from the purge line would not freeze. To address any drainage issues, fittings were installed on the bottom of the purge piping, allowing condensate to drain when necessary.

Overall, Titus worked with this oil refinery closely for more than 27 years, helping them with both straightforward and complex CO_2 treatment applications.

Two-in-One: Tackling Footprint and Redundancy Demands

We also spoke with James Bowers, National Sales Manager of Titus Air Systems, about several custom-engineered nitrogen generator installations, the first of which involved a natural gas provider.

According to Bowers, natural gas does not transport as neatly as liquid oil does. Most natural gas fields have multiple compressors that take the gas and boost it to higher pressures for transportation. In these applications, nitrogen generators are used in conjunction with the compressors as a safety measure, effectively sealing and blanketing the natural gas.

For this specific job, the Titus engineers had to design a system that could endure a rugged marine environment with low ambient temperatures. In addition, there were tight footprint limitations, and the application had a 100 percent redundancy requirement. Fed by two independent 15- to 20-hp compressors, the nitrogen generators had to provide 20.8 cfm at 95 percent purity for each side.

"In this case, we looked at it and said we can actually build two nitrogen generators into one enclosure, making it easier to install," Bowers explained. "You get single inlet and outlet connections, and it takes up a smaller footprint. It also eliminated the need to insulate and heat two enclosures."

Clever Engineering Provides Impressive Results

The nitrogen generators, which were packed into one compact 316 stainless steel cabinet, provided a cost-effective and space-efficient solution that protected the system from the marine environment. Stuffing the cabinet with two nitrogen generators, however, provided its own set of challenges.

"When you're working with limited space, you have to come up with clever alternatives in how you run the piping and membranes," Bowers explained. "In this case, there are four membranes, but they are stacked front to back, which is somewhat unique."

The engineers at Titus also had to install two complete sets of filters, which ran front to back, as well as two completely separate electrical systems. There was also the issue of serviceability.

"You also have to take into account that these have to be serviced," Bowers continued. "So, yes, you want to squeeze a lot into a small space, but it also has to be accessible."

The final system can be seen in Figure 3, which visibly demonstrates the clever design. According to Bowers, each system monitored its own oxygen, pressure and temperature levels, and the two separate PLCs communicated with each other to ensure redundancy.

Capacity Overkill Requires Custom Solution

In the midst of a tight-lipped and time-consuming production process at a submarine manufacturing facility, the engineers at Titus made a somewhat serendipitous discovery. The facility's nitrogen generation system was sized for peak demand, which was a relatively rare event. During normal operation, the facility would only use one fifth of its capacity.

Specifically, the manufacturer's total nitrogen capacity was 800 cubic feet per hour at 99.5 percent purity, which would have required 800 scfm of compressed air. Most of the time, however, they only needed 17 scfm. On a 24/7 basis, that overkill in capacity would be gratuitously expensive.

With that in mind, Bowers and his team devised a creative solution to save the manufacturer a tremendous amount or rework and time — in addition to enormous energy savings.

Staging Nitrogen Modules Saves Energy Costs

The nitrogen generation system had five membrane modules, each of which would use compressed air constantly. In order to limit its consumption, the Titus team augmented the design so that the modules could be staged. With the modification, the secondary modules are activated only when the demand for nitrogen exceeds the single module.

"The problem with nitrogen generation is you need to use a lot of compressed air," Bowers explained. "So, the more compressed air you can shut off — the more you can save. It doesn't hurt to have extra capacity — it

PLANT APPLICATIONS

only hurts to consume the compressed air required for the extra capacity."

The modified system keyed on the oxygen content, controlling the solenoid valves on the inlet to cut off the compressed air supply. While Titus could have made the system more sophisticated, they knew that the facility would either need the full capacity, or one fifth of that capacity. So, when the facility shifts to maximum demand, all of the modules are enabled — providing the full capacity of nitrogen to the application. Then, when the oxygen content begins to creep down, the membrane modules stage off to reduce the compressed air demand.

The custom-engineered solution (Figure 4) saved the submarine manufacturer a significant amount of downtime and energy costs. With everything considered, the simple payback was a little less than three months.

Figure 4: Custom-engineered nitrogen generator that stages from one to five modules

Customer Loyalty Through Customized Solutions

From the top floor of a townhome to working on a global scale, the progression of The Titus Company is certainly impressive. Titus now does much more than distribute and integrate catalog products. With an in-house engineering team and a sales force with strong a technical background, The Titus Company provides customized solutions for compressed air and gas systems, nitrogen generation systems, and membrane dehydration systems. They also have their own line of small heatless desiccant dryers and air filters. BP

For more information, contact Stephen Titus, tel: (610) 913-9100, email: setitus@titusco.com; Jim Bowers, tel: (888) 722-5253, email: James.Bowers@TitusAir.com; or visit www.titusco.com.

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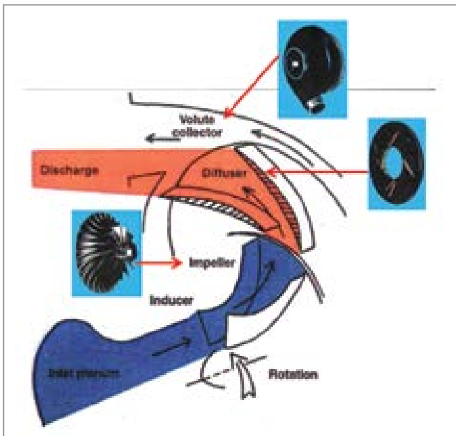
Centrifugal Air Compressor Basics: Deciphering Manufacturer Performance Curves

By Hank van Ormer, Air Power USA, Inc.

In general, this article focuses on the operating principles of centrifugal air compressors, discussing them in simple terms to provide an understanding of application limitations and opportunities. One primary goal is to define often-confusing terminology, such as "rise to surge," stonewall and surge," "mass flow," and "dynamic compression." This article is not intended to be an engineering discussion of the various types and designs of centrifugal and other air compressors, but rather, a guideline for deciphering operating curves and understanding general performance.

	Rotary Screw / Reciprocating				Centrifugal		
400-hp, 2-Stage Positive Displacement Rotary Screw Air Compressors	2,074 acfm	457 bhp	90 psig	400-hp, 3-Stage Dynamic Centrifugal Air Compressors	2,074 acfm	453 bhp	90 psig
	2,032 acfm	537 bhp	125 psig		1,954 acfm	456.3 bhp	125 psig
	2,012 acfm	569.8 bhp	135 psig		1,884 acfm	453 bhp	135 psig
	(-3%)	(+19%)			(-9.2%)	(± 0%)	
	Horsepower follows pressure up or down; volume is relatively stable				Volume delivered follows pressure up or down; horsepower is relatively stable		

Table 1: Effect of discharge pressure (not including type of unloading or part load controls)



1. Air is pulled into the compressor stage by the impeller.
2. Spinning at high speeds, the impeller will rapidly increase the air velocity.
3. The air then passes through a narrow, restrictive opening into the diffuser area, which further restricts the flow in a predetermined manner.
4. As the air velocity slows down, the pressure rises and leaves the diffuser area. It then moves to the next stage or the aftercooler.

Figure 1: Dynamic compression centrifugal operating stage

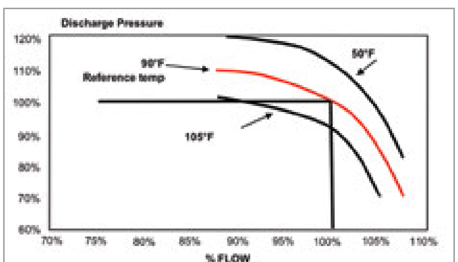


Figure 2a: Effect of inlet air temp on discharge pressure

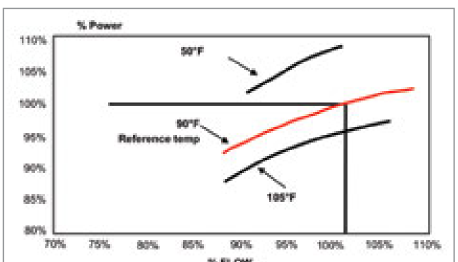


Figure 2b: Effect of inlet air temp on power

Operating Basics: Positive Displacement vs. Dynamic Compression

The most common air compressor in industries today is the positive displacement type — rotary screw, rotary vane, reciprocating, and scroll — in which the inlet compressed air is mechanically trapped in the compression chamber and then mechanically reduced in volume to raise the pressure and temperature (i.e. piston cylinder).

In a positive displacement compressor, the required operating power is mostly driven by flow (cfm), and is somewhat less affected by discharge pressure, or psig (Table 1). A positive displacement performance curve will characteristically be more vertical than a centrifugal performance curve. This will produce relatively constant cfm at the available horsepower.

The centrifugal air compressor, on the other hand, operates over a range of flows and discharge pressures. The operating performance curve is shaped by the selected individual internal components and affected by the operating conditions, such as inlet pressure, inlet temperature, cooling water temperature, and discharge pressure.

Figure 1 shows the process of dynamic compression as applied in a centrifugal compressor operating stage, in which velocity and kinetic energy are converted to pressure and temperature as the flow is restricted. Another term for this process is mass flow —

the power requirement to deliver the rated cfm of flow at the rated pressure (psig) is determined by the weight of the air (some manufacturers also use the term "density").

How Outside Conditions Impact Dynamic Compression (or Centrifugal Compressors)

The power requirement for the dynamic compression process, when the internal design parts are not considered, is basically dependent on the weight of the air going through the machine. Ignoring part loads controls anything else that will increase or decrease the weight of the air going through the stages to final flow, and pressure will have a direct impact on input power.

Increasing the inlet temperature will lighten the total fixed airflow and deliver less usable air, or scfm, to the user (Figure 2a), thereby reducing the input power requirement (Figure 2b). Colder inlet temperatures will produce the opposite effect.

Reducing the inlet pressure (altitude, negative compressor room pressure, dirty/poorly sized inlet filter) will lighten the compressed

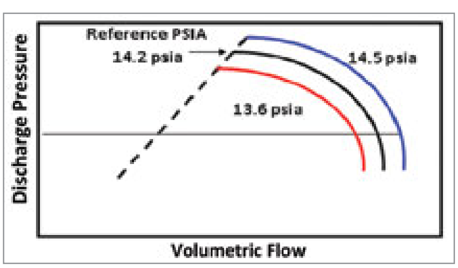


Figure 3a: Effect of inlet pressure

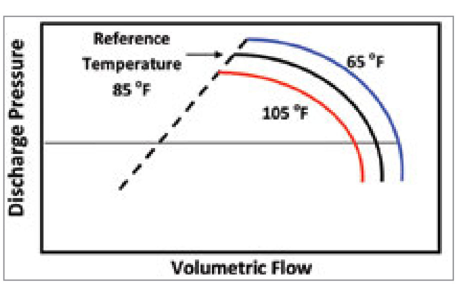


Figure 3b: Effect of cooling water temperature

CENTRIFUGAL AIR COMPRESSOR BASICS: DECIPHERING MANUFACTURER

airflow (cfm) that travels through the stages (Figure 3a). This also results in less usable air (scfm) at a reduced input power requirement. Higher inlet pressure will have the opposite effect.

Increasing the cooling water temperatures will again have the same "lightening" effect on the compressed air through the stages (Figure 3b). It will also reduce the power requirements, just like the previous conditions.

The actual net effect of any of these conditions is dependent on the actual performance curve and aerodynamic characteristics of the design. This is also the case of discharge pressure with a fixed-wheel, impeller, diffuser, or speed compressor stage.

Increasing the discharge pressure will normally have the effect of raising the weight of the compressed air stream through the stages, which will result in less flow of usable air (scfm) at the same input power. Lowering the pressure will often allow more flow at the same or similar power input. Actual machine-specific performance is covered later in this article.

Understanding Centrifugal Manufacturer Operating Curves

Now that we have a fundamental understanding of the differences between positive displacement and dynamic compression, we can begin deciphering the operating curves of centrifugal compressors. The data in the following sections will be discussed in these units of measurement:

- Standard cubic feet per minute (scfm) or Nm^3/hr at full and part loads
- Input power in kW
- Pressures, either in psig or bar (only using psia to convert from icfm/acfm to scfm)

Any activity that lowers the inlet air weight or mass, such as higher temperature, lowers pressure after the filter and will reduce the mass flow, scfm, and input power accordingly. Figure 4 provides samples of typical centrifugal air compressor performance curves.

As displayed in Figure 4, typical centrifugal performance curves bring up some new items to address, including "turndown," "rise to surge," and "stonewall."

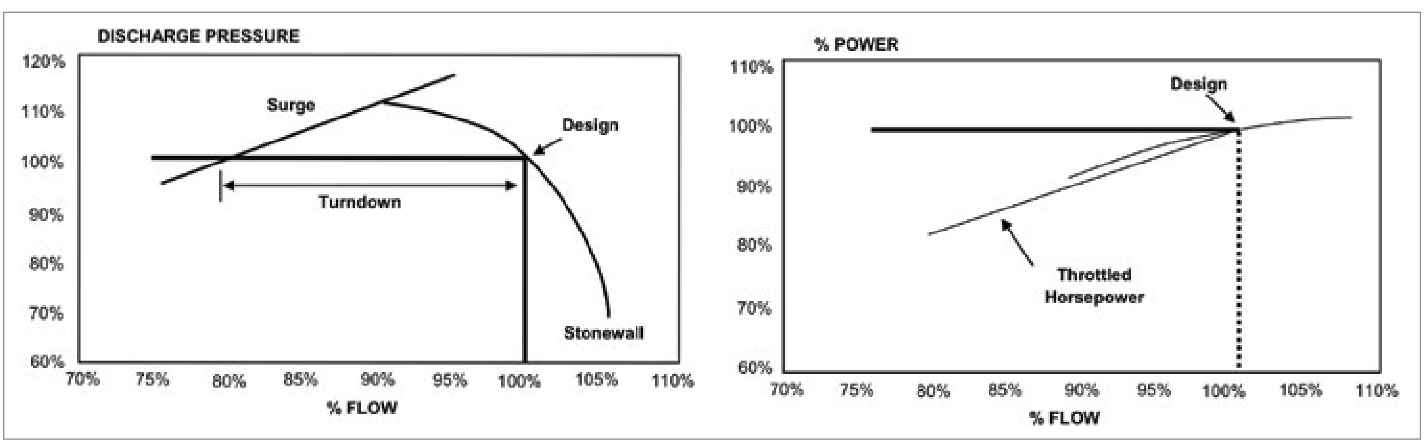


Figure 4: Typical centrifugal performance curves

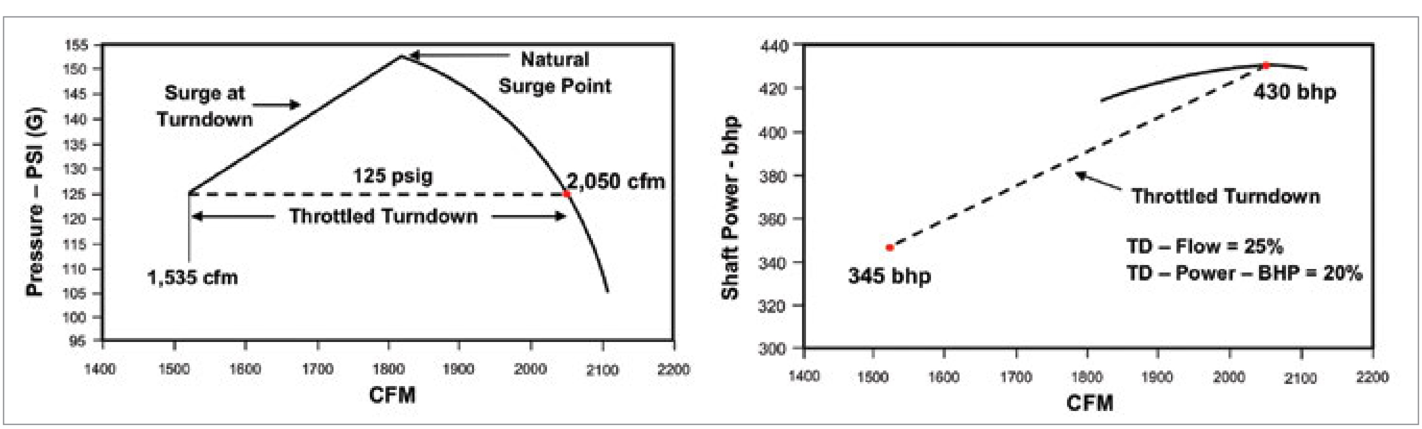


Figure 5: Estimated performance curve for full load compressor at 125 psig

PERFORMANCE CURVES

What Causes Surge?

The centrifugal compressor as used in industry is a dynamic compressor with rapidly rotating impellers accelerating the airflow. The air then passes through a diffuser section, which converts the velocity head into pressure through flow resistance.

In a dynamic or mass flow compressor like the centrifugal, the power to compress the air is basically a function of the weight of the air, the flow, the volume, the temperature, and the head or pressure.

Once the impeller is designed and a speed set, the energy that a pound of air will absorb when passing through the impeller is established. This is true despite variation in inlet temperature, pressure level, throttling, etc. A pound of air will vary in cubic feet by temperature and pressure.

A centrifugal compressor, therefore, will deliver a pound of air with a constant expenditure of energy — winter or summer. The actual volume of inlet air to be compressed will vary for a period of time with the inlet condition of pressure and temperature.

As more compressed air is produced than needed, the centrifugal compressor must unload, or deliver less air to avoid over pressure. Each centrifugal compressor has a maximum pressure it can reach for specific inlet conditions that will cause the airflow to reverse and surge, shutting off the compressor to avoid damage from the resultant vibrations.

Surge is to be avoided (including mini-surges, since these not only set up potentially damaging vibrations, but also cause a very high temperature rise at the eye clearance.)

Defining "Rise to Surge," "Turndown," and "Stonewall"

This is an oversimplification of the surge action, however, since each unit has a rise to surge limit or maximum pressure. Turndown is the percentage below full load flow that the compressor can run without experiencing surge. For example, 15 percent turndown means the unit can run at 85 percent flow or higher, as equipped without hitting surge. At greater turndown, it will be close to or at surge.

At some point, as the discharge pressure falls and the airflow through increases at full load, the physical limitations will not allow more air through the stages — this point is known as stonewall. Continued operation at or beyond this point can cause such high flow rates with greater pressure differential that the impellers will not totally fill the vane areas and a cavitation-like action will occur, creating another type of surge with damaging vibrations.

Operating at surge will set up high vibrations and, if not eliminated, can have a negative impact on the mechanical integrity of the unit, leading to premature failure. Most centrifugals are equipped with vibration monitors and will shut down to avoid this condition.

As the pressure falls and the compressor approaches stonewall, the increase in flow becomes very minimal, and the falling discharge pressure continues to lighten the airflow through the stages, reducing the input power. The most energy-efficient point on many centrifugals is just before stonewall.

CENTRIFUGAL AIR COMPRESSOR BASICS: DECIPHERING MANUFACTURER

Using Manufacturer Performance Curves to Develop Projected Operation Efficiency

With an understanding of the terminology unique to centrifugal air compressor performance curves, you can develop a predictable and probable actual projected operating efficiency based on a manufacturer's performance curve. Figure 5 provides a representation of a sample manufacturer performance curve.

Before delving into the curve, however, a few things need to be outlined:

- Without known operating and site conditions, assume the standard CAGI operating conditions of 68 °F, 14.5 ambient pressure and 0% relative humidity with site conditions of 95 °F, 14.5 psia, and 60% relative humidity.
- The pressure (psig) is clear.
- The flow (cfm) is not clear — most likely it is acfm or icfm when scfm is not stated.
- Power is in BHP (compressor input shaft horsepower) and not motor input horsepower.
- The current new motor is probably a 500-hp class induction motor with a .94 ME (motor efficiency). This is not specific, but the data is necessary to accurately profile the compressor.

Using Figure 5 as presented, the centrifugal compressor delivers:

- 2050 cfm at 125 psig at 430 hp (x .7457 = 321 kW) = specific power of 6.39 cfm/kW
- Turndown 1535 cfm at 125 psig at 345 hp (x .7457 = 257 kW) = 5.97 cfm/kW

The Caveat: Converting Measurements for Consistency

However, there are holes in these results, which include:

- The icfm/acfm should be scfm
- The calculated compressor shaft horsepower is accurate as converted to kW, but it

ICFM/ACFM to SCFM		Create a Multiplier:
Site Condition	Standard scfm	(°F to °R = + 460)
95°F	68°F	100 = (14.2 - .494) x 528°R / 14.5 x 555°R
14.5 psia	14.5	100 = .899 or .90 multiplier
Filter loss	.3 psia	
60% RH	0% RH	
80°F water	80°F Water	
Therefore:	2,050 acfm is equal to 1,845 scfm	
	1,535 acfm (turndown) is equal to 1,382 scfm	

Developing Site Data:

- 14.5 psia - .3 psia inlet filter loss = 14.2 - .494 particle pressure of water vapor removed from 95°F air at 60% RA.
- 460°R + 68°F = 528°Rankine
  460°R + 95°F = 555°Rankine
  For °C (centrigrade) use Kelvin, not Rankine, by adding °C + 273°K

Table 2: Establish a multiplier of .90 to convert icfm/acfm to scfm

	Original Projection	More Accurate Projection	Discrepancy
Full load flow	2,050 cfm	1,845 scfm	
Full load input kW	321 kW	341 kW	
Specific power cfm/kW	6.39 cfm/kW	5.41 scfm/kW	15%
Turndown flow	1,535 cfm	1,382 scfm	
Turndown input/kW	257 kW	280 kW	
Specific power cfm/kW	5.97 cfm/kW	4.94 scfm/kW	17%

Table 3: Input power to motor results comparison

PERFORMANCE CURVES

doesn't take into account any drive motor loss.

- The ME (motor efficiency) is .94 a, 6% loss at full load — a larger loss at turndown.

Table 2 addresses how to convert the icfm/acfm to scfm for comparative purposes.

Input Power to the Motor

To convert BHP (compressor shaft) to projected electric motor input kW, use:

- Input kW = (BHP)(.745) ÷ ME
  - Projected motor ME = .94 at full load
  - Projected motor ME = .92 at turndown
- The projected input power will be:
  - Full load: (430 BHP) (.7457) ÷ .94 = 341 input kW
  - Turndown: (345 BHP) (.7457) ÷ .92 = 280 input kW

After the conversions have been completed, the results in Table 3 demonstrate that the projections can be misconstrued.

When results like this are misconstrued, it may or may not be intentional. The point is to show the importance of detail when evaluating an existing compressor or reviewing several centrifugal units (in addition to other types). It is best to understand and equalize all the various OEM operating performance curves to be able to make an informed decision.

Using Centrifugal Operating Performance Curves to Optimize the Fit to Your System

Working with the OEM supplier(s) and their operating performance curves effectively will help to develop a successful application. In order for the user to provide the OEM supplier the appropriate data, the user should be familiar with the information presented to fully understand and ask for the important additional data.

Here are a couple important questions that you should ask:

- What are the operating characteristics of the impeller/diffuser with regard to surge point, turndown, specific power full load, etc.?
- What is the next set of operating characteristics for a standard impeller/diffuser for more turndown capability? (Probably a higher pressure)
- What are the cost and savings benefits of inlet guide vanes (IGV) as opposed to a standard inlet butterfly valve (IBV)?

Lessons Learned

In summation, this article was written to identify and explain the definitions behind centrifugal performance data and its importance. With this information, the user can work with their local OEM supplier and/or technical engineering groups to select and properly apply a unit to fit the specific site conditions in an optimum manner. BP

This article was adapted from Centrifugal Training Materials provided by Air Power USA. For more information, contact Hank van Ormer at hank@airpowerusainc.com, or visit www.airpowerusainc.com.

To read more about ***Air Compressors,*** please visit www.airbestpractices.com/technology/air-compressors.

A Systems Approach Helps Rockline Industries Retrofit a Compressed Air System

By Andrew Chase Harding, P.E., CEM, and Darin Nutter, Ph.D., P.E.,
Mechanical Engineering Department, University of Arkansas

Rockline Industries is one of the largest global producers of consumer products, specializing in wet wipes and coffee filters. The company contacted the Arkansas Industrial Energy Clearinghouse after identifying that the compressed air system in their Springdale, Arkansas facility was a potential source of significant savings. Experts from the Clearinghouse then began working with Rockline Industries, representatives of the electric utility, and a local compressed air vendor to perform a complete evaluation of the system.

The case study presented below provides the results of a "systems approach," which evaluated both the supply and demand sides of the system to develop the most cost-effective solution for providing high-quality compressed air to the manufacturing processes (1). The main goals of the project were to increase reliability, decrease maintenance, and decrease operating costs of the compressed air system, all while maintaining the quality of the compressed air. Rockline Industries was also incentivized by the electric utility representatives based on energy savings. Overall, the project included piping retrofits, equipment upgrades, pressure control changes, and compressor retrofits. The team also provided measurement and verification of the overall project savings.

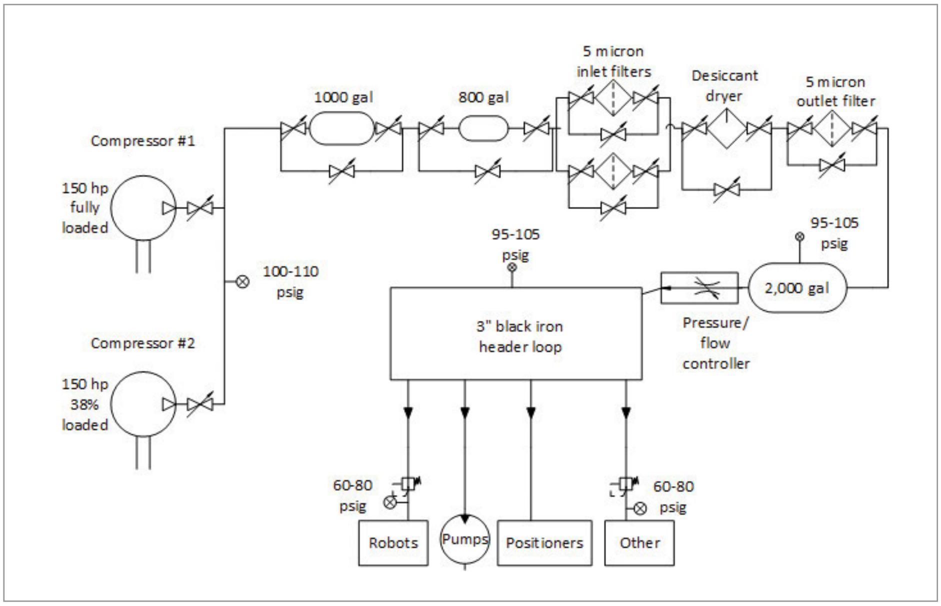


Figure 1: Schematic of the Original System Configuration

The Importance of the Systems Approach for Compressed Air Analysis

The component-level approach is often taken to improve a compressed air system, and it typically involves very specific, short-payback, and easily quantifiable measures (i.e. replacing an old compressor with a more efficient one). The Department of Energy and the Compressed Air Challenge, however, advocate a systems approach as the best practice for analyzing and improving a compressed air system. According to those organizations, the systems approach "requires not only addressing individual components, but also analyzing both the supply and the demand sides of the system and how they interact" (1).

The systems approach includes the following steps:

1. Establish current conditions
2. Determine process needs
3. Gather baseline data
4. Develop potential energy efficiency measures
5. Evaluate financial and technical conditions
6. Implement measures
7. Gather verification data
8. Continue to monitor and assess system

The systems approach can be more costly and time-consuming, but it has the potential to optimize the overall performance of the compressed air system. It also offers the opportunity to implement more savings measures by subsidizing some measures with the savings from others.

Systematically Analyzing Compressed Air Supply and Demand

The existing compressors at the facility were identical 150-hp, single-stage, load/unload rotary screw compressors. The specific efficiency of these compressors was rated by CAGI as 18.7 kW/100 cfm at full load (2), and each of the compressors was capable of producing 678 acfm. Baseline energy usage collected by data loggers indicated that one of the compressors ran at nearly full load, while the trim compressor loaded and unloaded to control system pressure (Figure 2).

The cut-in pressure for the trim compressor was set to 100 psig, and the cut-out pressure was set to 110 psig. The compressor room contained two wet storage tanks, with a total capacity of 1800 gallons. A heated desiccant dryer was also located in the compressor room. Dry air was sent into the plant to a 2000 gallon dry storage tank, which typically remained around a nominal 100 psig. There was also a pressure/flow controller located between the dry storage tank and header loop, but the pressure controls were set to maintain maximum pressure downstream of the controller, essentially bypassing it.

The distribution system consisted of a 3-inch cast iron pipe header loop, which supplied air to all of the end uses in the facility. The main header connected to diaphragm pumps with separate, unregulated drops. There are 12 of these pumps, which are used to move lotions and other fluids. On average, each pump was being replaced about every 2 months, largely due to mechanical failure caused by over-pressurization.

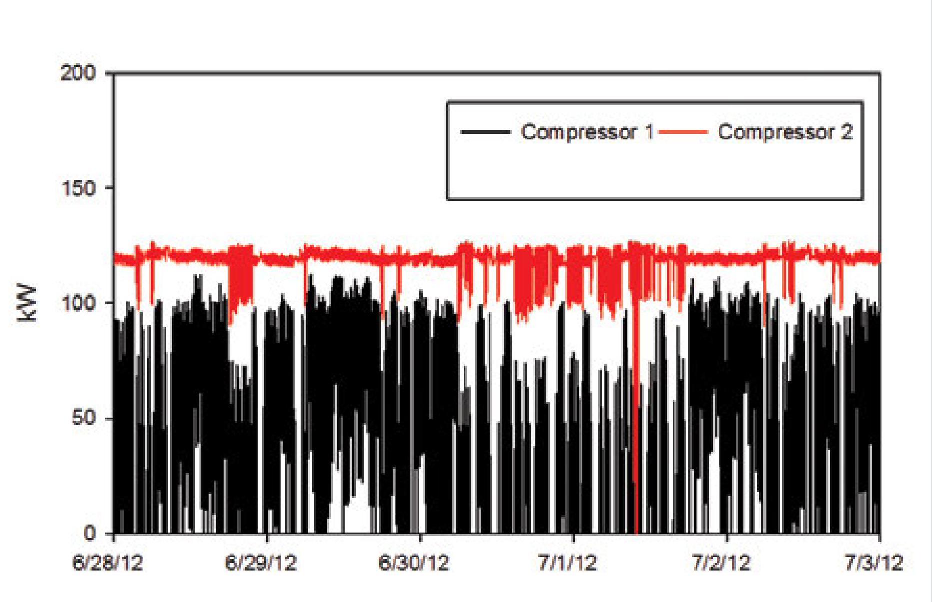


Figure 2: Baseline Data Log of the Existing Compressed Air System

A SYSTEMS APPROACH HELPS ROCKLINE INDUSTRIES RETROFIT A COMPRESSED AIR SYSTEM

Figure 3: Aluminum piping system — The aluminum pipes are blue in color and slip fit connectors are black.

Figure 4: Diaphragm pump header regulated to 55 psig

Reducing Leaks and Eliminating Downtime with Aluminum Piping

The project began by replacing the 3-inch black iron header with a 90-mm aluminum piping system. The old header was more than 20 years old, and the iron pipe had degraded over time. When a recent air compressor event sent oil into the header, the entire plant was shut down for several hours while the bulk of the oil was drained from the piping. When the system started back up, the plant had to deal with excess oil in the system, which was trapped in the pores and rough surface of the degraded pipe.

The new piping system (Figure 3) was selected because the aluminum pipe will not corrode over time. In addition, the time to install the aluminum piping was significantly less than the time it would have taken to install a new threaded or welded steel piping system, thanks to slip fit connections. Lastly, a properly installed aluminum piping system should theoretically never leak, while iron or steel pipe undoubtedly will.

Optimizing Diaphragm Pumps to Reduce Demand

The company turned to a local compressed air vendor to properly size and configure the pumping system. They focused on improving the reliability of the pumps, thereby reducing the annual maintenance costs associated with replacing failed pumps.

Diaphragm pumps are typically rated for a maximum pressure input. This is the pressure at which it is safe to operate the pump. The pumps also typically have a minimum input pressure, which is the pressure below which the pump may stall or cease to operate properly. The pump speed changes with pressure, and the pump flow rate changes accordingly. Therefore, the pump speed and duty can be significantly reduced, saving energy at the cost of time.

If the time penalty is acceptable, then the pressure reduction can yield a significant savings. The company decided that they could reduce the line pressure from 100 psig to 55 psig with no negative impact on production (Figure 4).

Flow Controller and Booster Help Reduce Plant Pressure

The existing system's average pressure was 100 psig, which included about 5 psig of drop through the treatment equipment, and a 10-psig differential from the load/no load controls. This meant that while the compressors were modulating between 100 and 110 psig, the header was seeing a pressure range of 95 to 105 psig. The additional pressure drop of 5 (or more) psig from the last "dirty thirty" (3) meant that end uses were receiving about 90 psig before the trim compressor loaded, and about 100 psig before it unloaded.

The highest pressure end use in this facility includes a set of electropneumatic positioners for pneumatically actuated control valves. These positioners become unreliable when the supply pressure drops below about 90 psig. If one of the positioners fails on low air pressure, it could cause a production line to shut down or generate scrap products. The header pressure was apparently set to provide a minimum of 90 psig to these controllers.

Most of the end uses in the facility, however, were regulated in the range of 55 to 80 psig. The intrinsic air consumption of the

Figure 5: Pressure/flow controller regulating plant pressure to 85 psig (bottom view with tank shown)

A SYSTEMS APPROACH HELPS ROCKLINE INDUSTRIES RETROFIT A COMPRESSED AIR SYSTEM

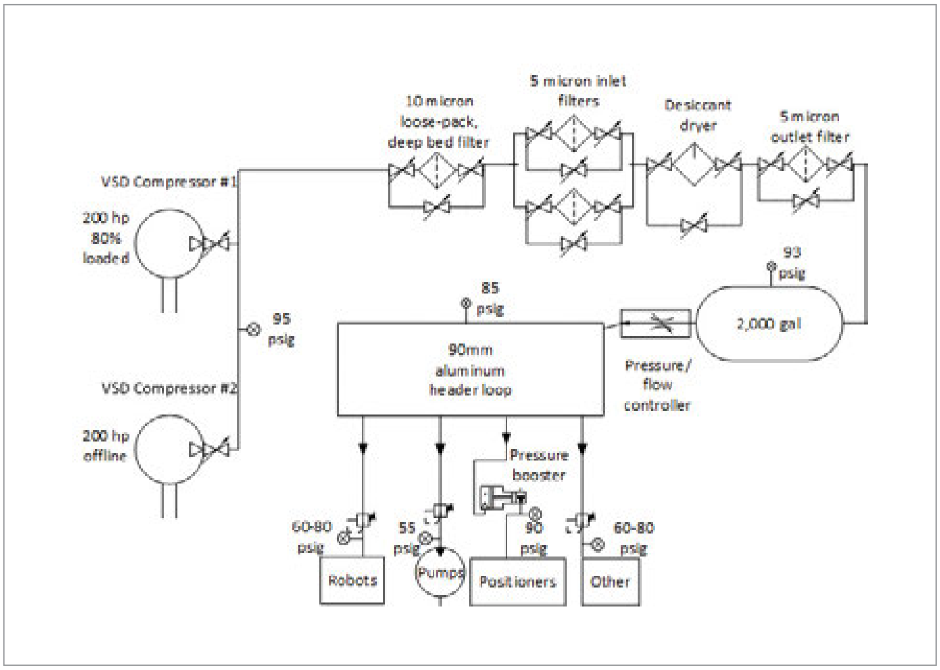


Figure 6: Final Compressed Air System Configuration

electropneumatic positioners is zero cfm (4), since their method of operation is to position an actuator. As long as the actuator is in the same position, no air is consumed. This is the definition of a "flow static" application, which made it a perfect candidate for a pressure booster. A 2:1 pressure booster regulator (5) was installed at the bank of positioners, and set to an operating pressure of 95 psig, ensuring sufficient supply pressure for the devices. The plant header pressure could then be dropped to 85 psig, allowing for a 5-psig drop to the end uses regulated to 80 psig. Plant pressure is regulated by the original pressure/flow controller (Figure 5).

New VSD Air Compressors Improve Energy Efficiency

Rockline Industries installed two identical 200-hp, 115-psig-rated, VSD, single-stage, lubricant-injected rotary screw compressors. The company chose these compressors so it could operate one compressor normally, with the second compressor acting as a 100 percent redundant backup.

The new compressors have a specific efficiency as low as 19.0 kW/100 cfm at full operating pressure, with slightly higher values at full flow and full turndown. They are slightly less efficient at full load than the old compressors, but thanks to VSD technology, they are substantially more efficient at part load than the original compressors.

Analysis of the logged data from the old compressors (Figure 2) shows that the lead/lag control scheme yielded an overall specific efficiency of around 21.8 kW/100 cfm. Analysis of logged data from the new compressors demonstrated an overall specific efficiency of 19.4 kW/100 cfm.

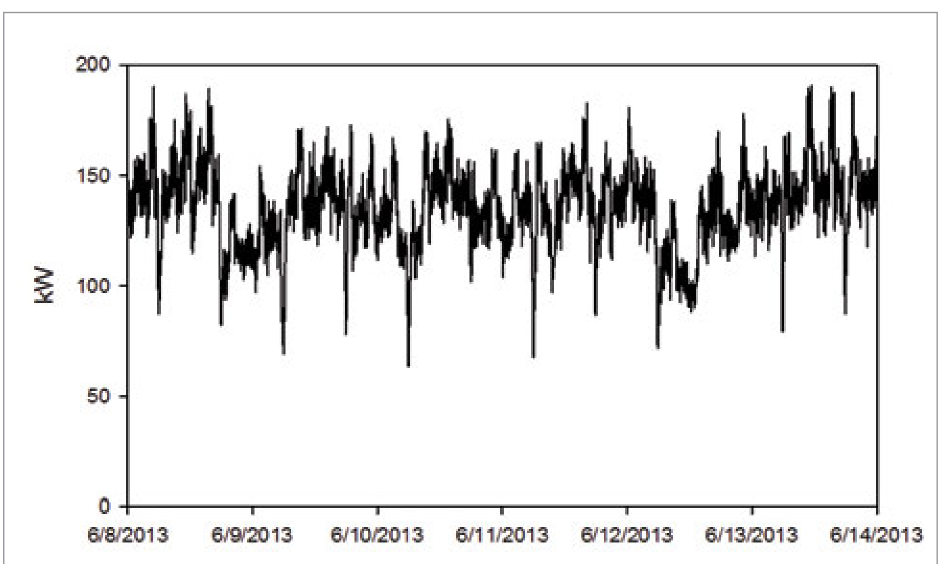


Figure 8: Average Power Recorded for the New System

Figure 7: Mist eliminator filter and associated piping

A SYSTEMS APPROACH HELPS ROCKLINE INDUSTRIES RETROFIT A COMPRESSED AIR SYSTEM

Storage and Piping Changes Reduce Footprint and Maintenance Costs

The two wet storage tanks were removed completely from the compressor room. While this is not a common measure, it made sense in this case. With VSD compressors, the added system volume increases the ride-through time available if the main compressor unexpectedly goes offline and the backup has to start (6), but there is no energy efficiency benefit.

The added storage capacity also came with a significant number of valves, fittings, and potential maintenance issues. Removing these extra tanks simplified the compressor room piping (Figure 7), eliminating the pressure drop associated with them. It also eliminated the need for the two extra ASME pressure vessels to be annually inspected and certified.

Removing the wet storage tanks also created space for a mist eliminator filter (Figure 6). This 10-micron filter has no measurable pressure drop, and removes a significant load from the 5-micron filters that are required upstream of the desiccant dryer. This large filter will reduce the maintenance cost for the 5-micron filters by extending the time between required cartridge replacements. Alternatively, if the 5-micron filters are serviced at the same intervals, the pressure drop will be reduced due to the reduced loading.

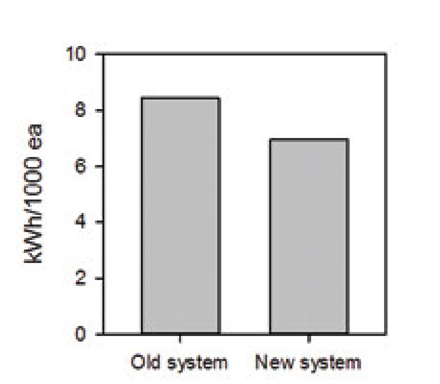


Figure 9: Compressed Air Energy Intensity

Using Data Loggers to Analyze the Results

Data loggers were also deployed to measure the energy consumption, and production data was analyzed to determine the energy intensity of the new system. The average power of the old system was 168.8 kW (Figure 2). The average power of the new system was 121.5 kW (Figure 8). While this difference in average power is not representative of the actual energy savings because of differing production levels, the actual energy savings can be more closely estimated by calculating the energy intensity, or energy per unit of production, for each period. The calculated energy intensities were 8.432 kWh/1000 ea. for the old system and 6.982 kWh/1000 ea. for the new system (Figure 9).

An annual energy savings of over 242,000 kWh was achieved, representing about 17.2 percent of the baseline compressed air energy usage. The average power was also reduced by 47.3 kW between the two logging periods, so the annual demand savings is likely on the order of 500 to 600 kW-mo/year.

The 17 percent savings includes the energy efficiency improvement of the compressors, which was about 11 percent, as well as a reduction in compressed air consumption from the diaphragm pumps, which was about 1.4 percent. The change reduced compressed air use by about 17 percent and reduced annual pump replacement costs by a projected $4,900 annually.

The other 4.8 percent of the baseline system energy usage was saved through the combination of the reduction in artificial demand due to the header pressure reduction and the decreased friction in the new aluminum piping. At an average cost of $0.072/kWh, the project reduced the annual utility cost by just over $19,000.

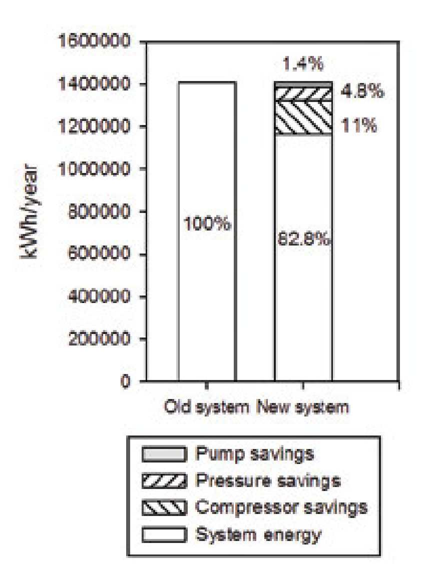


Figure 10: System Energy Breakdown

The maintenance savings detailed above amounted to an annual savings of nearly $7,000. When all four stages of the project were considered, and the utility rebate included, the total cash outlay for the company was just over $70,000, which yielded a simple payback of just less than 3 years. BP

To read more articles about ***System Assessments,*** please visit http://www.airbestpractices.com/system-assessments.

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TURBO COMPRESSOR UPGRADES YIELD ENERGY SAVINGS AT VALE

By Ron Marshall for the Compressed Air Challenge®

Vale, located in Thompson, Manitoba, Canada, has reconfigured a system of large turbo compressors in their mining, milling, smelting and refining operation, and gained very large energy savings through a series of improvement projects. In addition, these projects qualified for some significant financial incentives from their local power utility. Vale is a large, multinational mining company with headquarters in Brazil. Vale's operations focus on the production of iron ore, coal, fertilizers, copper and nickel. The Thompson Manitoba operations consist of mining, smelting, milling, and refining of nickel in a 250-acre complex that employs 1,500 people.

Compressed Air Auditors Assess Vale's Facility

The compressed air for the site is produced in a central powerhouse with utilities piped to the various separate buildings within the complex. When new, the 100-psi compressed air system at the site consisted of five large axial compressors, ranging in size between 5760 hp and 2500 hp. In the past, the total compressed air production reached levels of 48,000 cfm, consuming 9.3 MW of power.

Throughout the life of the site, the operating conditions have changed significantly. As the mines became fully developed, compressed air flow required for production operations peaked, leveled off, and then started to fall. Leakage, however, grew over time due to aging pipes and failing equipment. In the mid '90s, Vale, which was called INCO at the time, suspected that their compressed air system was not running at optimum efficiency levels and called in some expert compressed air auditors. At that time, a new mine was starting up and the powerhouse superintendent was faced with some new load that would exceed the capacity of his existing system. The purchase price of the required new production equipment would cost millions.

Surprising Audit Results Bring Greater Awareness to Compressed Air Use

The powerhouse management was very surprised by the audit results. Of the average flows, more than half was being wasted due to leakage and inappropriate use. Among other things, the auditor recommended formulating a strategy to find and repair leaks in various areas, and installing monitoring instruments to track the compressed air flow to the various usage areas. The powerhouse superintendent went one step further; he started charging the users for compressed air — something that immediately raised the awareness of the high cost of compressed air among the other superintendents. In order to reduce their costs, leakage repair efforts were started with immediate results. Within a few months, the average compressed air flow dropped in half, reducing the total system cost significantly, but also releasing compressed air production capacity. This effort allowed Vale to defer the very expensive purchase of compressors for the new mine.

Eliminating Blow Off with Better Controls and New Trim Compressors

The auditor also recommended a controls upgrade for the turbo compressors to make the operation more efficient. These units were outfitted with sophisticated PLC controllers that increased the compressor turndown range. Turbo and centrifugal compressors have a region of operation where the internal flows in the compression elements become unstable when the compressors are producing flows that are less than full load. Surging can cause damage to the compressors. Better controls allow the compressors to turn down more without surging and keep the units away from inefficient blow off control. Blow off control is where the compressors are false loaded to keep the units from surging. Blow off is inefficient because compressed air that has already been produced is released to atmosphere, wasting the power that was required to compress it initially.

Vale's system had three very large compressors with capacities between 25,000 and 18,300 cfm. These were configured as base compressors, feeding most of the required compressed air. Two other smaller 9000-cfm compressors were used as trim compressors. If the facility needed more compressor capacity than one large base compressor produced, the smaller trim units were started, which consumed much less power than starting another large compressor. Unfortunately, as time passed the trim compressors started to fail and the only remaining alternative was to run two large compressors, with the units running in blow off mode. This inefficient operation significantly increased the compressed air costs.

To improve the situation, Vale's engineering group initiated a project where the old trim compressors would be replaced with a bank of four 500-hp, 2500-cfm screw compressors. The new compressors were purchased with a control system that could be coordinated so that only the required compressor capacity would run at any one time. The units are efficient two-stage units with variable capacity controls. This installation allowed the

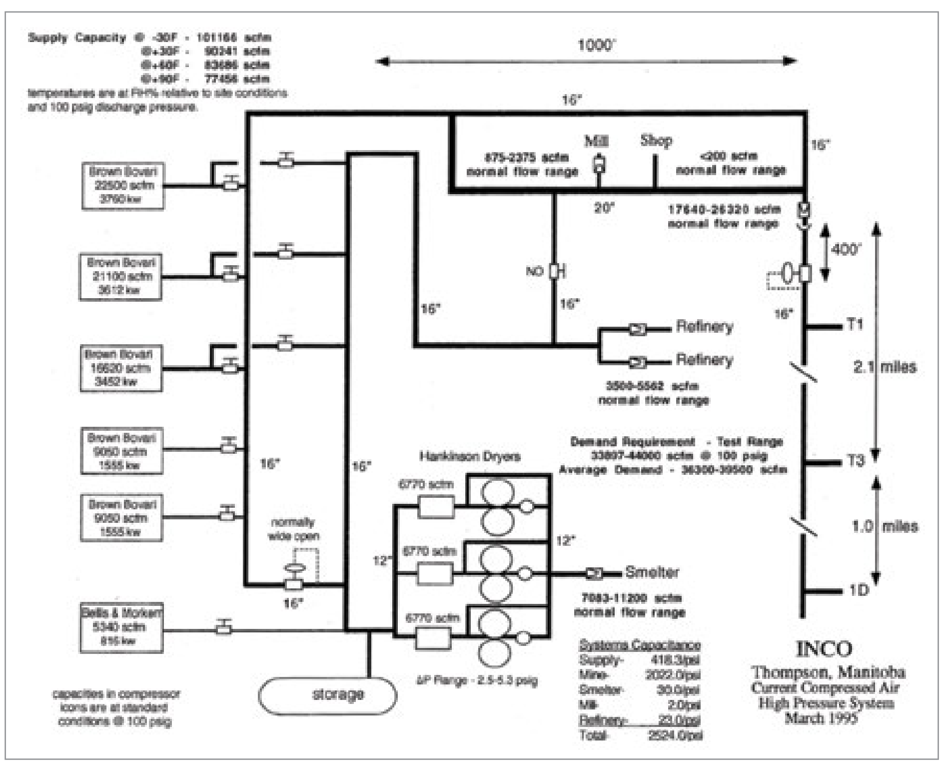

Diagram 1: Excerpt from original audit showed the scale of the very large original system (Audit done by Scot Foss)

TURBO COMPRESSOR UPGRADES YIELD ENERGY SAVINGS AT VALE

compressed air system compressors to exactly match the demand, eliminating the blow off control. The resulting efficient operation saved an average of 1300 kW over running two large compressors, yielding a power costs saving of $530,000 annually. The utility incentive for this project maxed out at $250,000.

Two are Better than One: Replacing Vale's Largest Turbo Compressor

The system ran in a very efficient manner for a period of time until the largest turbo compressor, Unit 5, suffered a catastrophic failure. The compressed air demand at the time was such that the largest of the turbo compressors and the trim capacity was just enough to satisfy the compressed air demand. Running any of the smaller turbos did not provide enough capacity, requiring a second large turbo compressor to be put online. This operation was a step back from the previous mode of operation and decreased the system efficiency. Repair of Unit 5 was estimated at higher than the price of new compressors. A cost benefit analysis showed that purchasing new compressors was the most cost-effective solution to the problem.

Rather than purchasing one new large compressor as a replacement, the Vale powerhouse superintendent decided on two smaller units that totaled the equivalent output of slightly less than Unit 5. These units were purchased with controls capable of coordinating the operation between units so they would share the load and keep the operation away from the wasteful blow off region. Inlet guide vanes were selected as an option, which extended the turn down range of the units, making overall system efficiency better. The units were purchased with airless drains for each stage to eliminate compressed air waste. The inlet of these compressors draws cool compressed air from outside, increasing the throughput of the compressors during cold weather operation. The units have been outfitted with individual flow meters so the performance of the units can be monitored to ensure conditions remain optimum.

Once the new units were started up, the compressed air system efficiency returned to normal. In fact, some additional savings were gained since the two new compressors are more efficient than the old unit. An additional 100 kW of power savings has been verified, qualifying for a $200,000 compressed air incentive from the power utility.

Figure 1: Four large, two-stage, water-cooled compressors with spiral valve control are used as trim capacity.

Wintertime Operation Requires Hybrid Dryers

The Vale site was one of the first installations of hybrid-style air dryers in the early '90s. Hybrid-style dryers are a combination of refrigerated and externally heated blower style desiccant dryers. The type purchased by Vale runs on an 8-hour cycle and is controlled by dew point sensors.

The general compressed air produced by the powerhouse is not dried, but the piping in the smelter is exposed to freezing temperatures in winter, requiring desiccant dried air. This level of compressed air quality is not required in warmer weather. Use of the hybrid dryers allows the less expensive refrigerated quality air to be used in spring, summer and fall seasons where freezing temperatures are not encountered. In winter, the desiccant dryers are activated, adding power costs for the heaters and blowers used to regenerate the desiccant, but eliminating freeze-up problems in the smelter. The dew point controls delay heater and blower operation until necessary, reducing the overall operating cost substantially during partial loads compared to a fixed-cycle heatless desiccant style arrangement.

The Benefits of a Competent Compressed Air Auditor

Vale has proven that substantial savings and deferred capital costs can be gained by having a competent auditor take a close look at the complete system. The awareness of the compressed air waste and how the compressed air is being produced can spur action that can gain some excellent financial benefits. Good compressor control can minimize operating costs, especially when combined with compressed air demand reductions. BP

To read more ***System Assessment*** stories, visit www.airbestpractices.com/system-assessments.

Figure 2: Replacing the old Turbo 5 with two new compressors has saved a significant repair bill, and has made the system more efficient.

Figure 3: Hybrid-style dryers are used onsite to condition the air for the smelter. This is the 10,000 cfm rated refrigerated part of the combined refrigerated/heated/blower desiccant unit.

RESOURCES FOR ENERGY ENGINEERS

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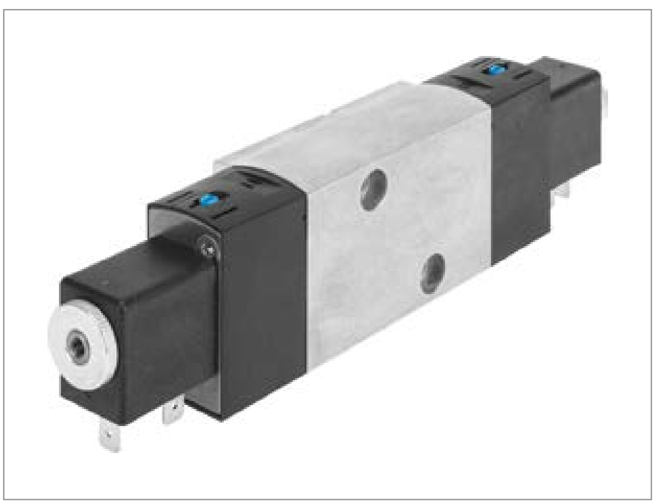
Festo Introduces New Series of NAMUR Valves

Festo recently introduced the VSNC series of NAMUR valves, which replaces two existing products for NAMUR valve applications. With multiple coil options, including Class I, Division 1(FM) or intrinsic safety, the VSNC is an excellent fit for ordinary environments and hazardous locations alike.

NAMUR valves attach to the side of a single or double acting actuator in a process application. By applying a voltage to the solenoid coil, compressed air either opens or closes the valve connected to the actuator. By implementing a NAMUR valve, the effort and exposure of additional tubing is eliminated, as the valve is mounted directly to the actuator.



The VSNC is a strong competitor in price, durability, and environmental tolerance. Available as one unit for 3/2 and 5/2 functionality, the switchable seal doesn't require the storage of additional parts to convert the configuration from one operation to the other. Available in 5/3 options, the VSNC can be used for positioning applications and can be ordered with the mid position as closed, pressurized, or exhausted.

Offering two body types, the VSNC is available with either a brass or stainless steel tube. The higher end model features an aluminum body and a protected exhaust. Festo also offers the coil and the valve as one piece, and all models are available with either 1/4" G or NPT threads. Another feature of the VSNC is the rebreather function that routes treated air from port 3 to the spring chamber. This function enhances the life of the actuator by using clean air instead of air from the environment, which often contains dust and contaminants.

For more information, visit www.festo.com/us.

ENMET Releases New Gas Sampling Monitor

The GSM-60 is a microprocessor-based gas monitor especially designed for use in industrial process, aerospace, pharmaceutical and semiconductor applications. The system incorporates an internal sample draw pump and gas sensors.

The instrument can be custom configured with both internal and external sensors for monitoring a combination of gas parameters, including VOCs, dew point, oxygen and CO_2, or a number of other

TECHNOLOGY PICKS

target gases including O_3, HF, HCl, Cl_2, etc. As an option, this versatile monitor can also be connected to a wide range of remote 4-20 mA toxic or combustible gas sensor/transmitters.

For more information, visit www.enmet.com.

Kahn Instruments Announces New Portable Hygrometer

Kahn Instruments, Wethersfield, CT, a leading manufacturer of advanced moisture-measurement instrumentation, is proud to announce the new Easidew Plus Portable Hygrometer. The Easidew Plus Portable is a faster responding, lower priced, easy-to-use portable instrument for the measurement of dew point in compressed air and other gases over the dew point measurement range of -58 ˚F to +68 ˚F (-50 ˚C to +20 ˚C). It is the latest addition to the Kahn Instruments portable hygrometer family and complements the HygroPort Portable Hygrometer and HygroPort IS Portable Hygrometer.

New and improved features include:

- Rapid spot check measurements to -58 ˚F dew point
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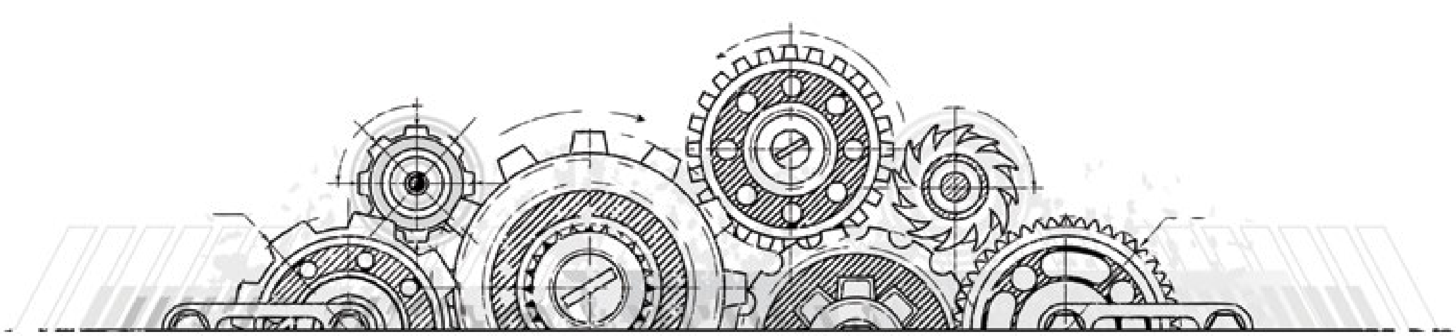
- Rugged NEMA 6 (IP68) polypropylene enclosure with carrying handle
- Integral stainless steel sampling system with particulate filter and sample tubing
- Rechargeable, long-lasting NiMH battery pack — operates up to 16 hours between charges

The measurement accuracy of the Easidew Plus Portable is ±3.6 ˚F, and the



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TECHNOLOGY PICKS

instrument can measure dew point at pressures up to 4350 psig. The Easidew Plus Portable can be used in many moisture measurement applications, including compressed air monitoring, industrial gas manufacturing, instrument air verification, plastics drying, and metal heat treating.

For more information, visit www.kahn.com.

Wahl Instruments Introduces New Thermal Imager

Wahl Instruments, Inc. recently announced its new ultra-high sensitivity Wahl Heat Spy 170 thermal imaging camera. Useful in an array of applications, the Heat Spy 170 is beneficial for electricians, plumbers, building inspectors, facility managers, and MRO employees in a variety of industries.

Wahl Heat Spy 170 Series Imagers now feature SpyLite™ thermal view to reveal only the temperatures above or below a set point. Overlaid on the visible light image, SpyLite™ emphasizes only the temperatures of interest in the scene. Use this unique feature to draw attention to specific concerns or areas requiring further assessment. Utilize the Picture-in-Picture setting to display all temperatures in the scene displayed thermally over the visible image to orient your thermal view with visual landmarks.

Take advantage of the 170's thermal and visible video recording feature to document your temperature surveys as video or image files in any of the four viewing modes, including visible, thermal, SpyLite™, and Picture-in-Picture. Files are stored on the included 8-GB Micro SD card. Use the Bluetooth connectivity feature to transfer files to your PC, manage imager settings and files, or view live video output. Connect a Bluetooth headset to record and play back audio image annotations hands-free.

The 170 Heat Spy has a 384 x 288 detector for more than 110,000 individually calibrated pixels, with a thermal sensitivity of ≤ 0.04 ˚C to distinguish even minimal temperature differences. Coupled with the high resolution 640 x 480, 3.6" LCD touch screen display, the 170 presents a clearly defined image that is excellent for inspections and analysis.

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For more information, visit www.palmerwahl.com.

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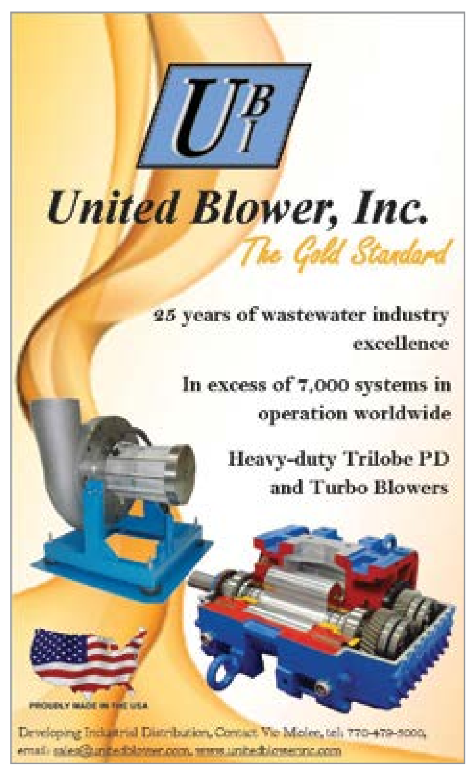

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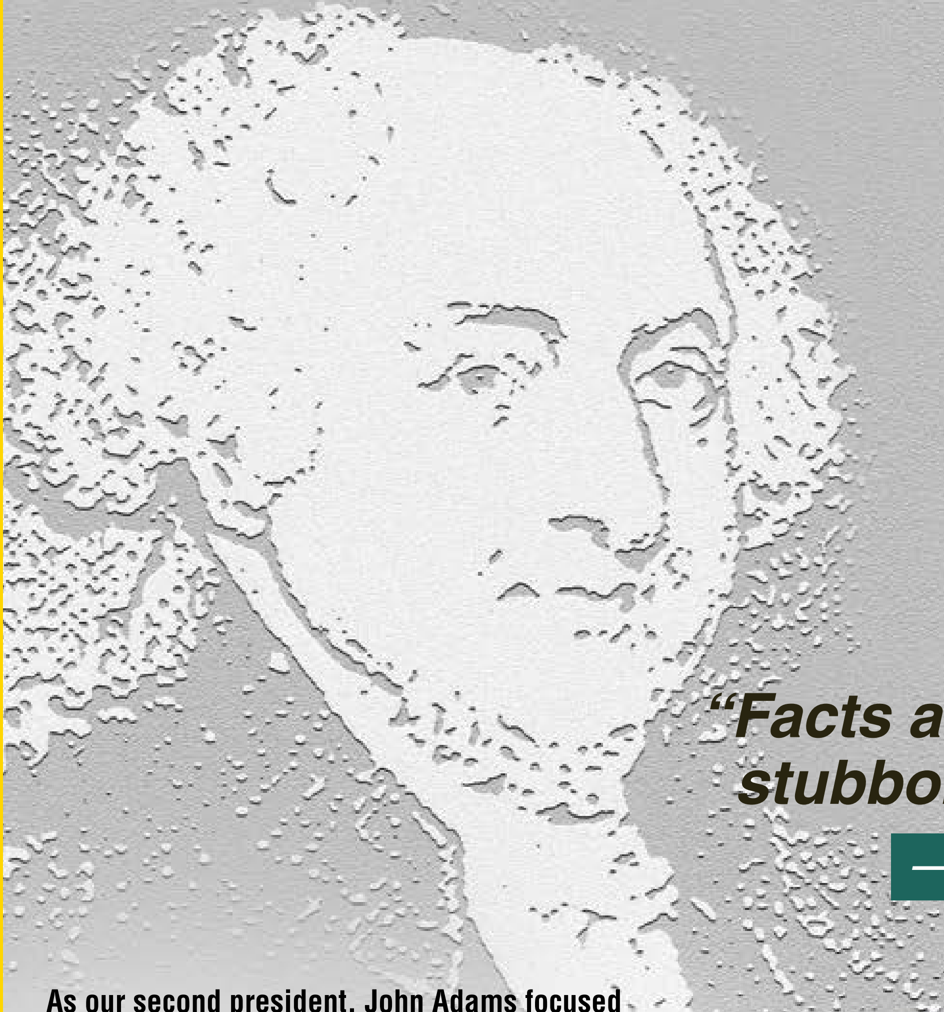

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