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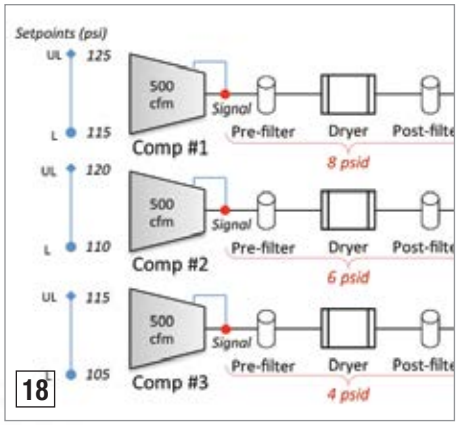

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FROM THE EDITOR | Air Compressor Controls

People are talking a lot about the Internet of Things. The term proudly sports its own acronym (IoT) here in North America, while in Germany the preferred term is Industry 4.0. Whichever term you prefer, it's my humble opinion this will be the defining topic for compressed air systems over the next twenty years. Owners of compressed air systems will be visualizing and managing key performance indicators such as flow, pressure dewpoint, pressure, and specific power. It will become the rule rather than the exception. Production areas will be charged for the actual compressed air they use.

How proficient is your compressed air service provider at helping you receive key performance indicators? Andy Poplin, from Atlas Machine & Supply, provides us with an excellent review of the work they did to help Ahresty Wilmington Corporation manage 16 air compressors totaling 2,500 horsepower. The implementation of their ACES-16 air management system helped deliver an annual energy savings of $151,000.

Chad Larrabee, from Ingersoll Rand, writes about today's status quo in most air compressor rooms — a group of air compressors all running off their individual controllers with different control schemes attempting to coordinate them. He describes an upgrade to a smart system controller as "a conductor of the symphony, directing compressors to respond to one common signal….dynamically matching compressed air supply with demand."

Compressor manufacturers are responding by investing in modern master controllers. Our Associate Editor, Clinton Shaffer, had the chance to learn about Kaeser's new SAM 2 technology. Werner Rauer, Compressors Product Manager at Kaeser, explained, "When looking at the next 10 to 15 years, you need to lay the foundation today. So at this time, we have put a highly capable processing unit in this industrial PC."

We recently caught up with Rick Stasyshan, Compressed Air and Gas Institute's (CAGI) Technical Consultant, and Ian Macleod of the CAGI Centrifugal Compressor Section and member company Ingersoll Rand. Our interview focused on understanding centrifugal air compressor capacity control systems and options available.

Ron Marshall, on behalf of the Compressed Air Challenge®, provides an interesting article titled, "10 Little-Known VSD Air Compressor Tweaks." These measures are examples of strategies he has implemented in his own Manitoba Hydro service territory.

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INDUSTRY NEWS

Pure-Aire Appoints New Sales Manager

Pure-Aire, LLC has announced that Scott Woodward has joined Pure-Aire as their Eastern Regional Sales Manager.

Scott Woodward, Eastern Regional Sales Manager, Pure-Aire, LLC

In this role, Scott Woodward will be expanding Pure-Aire's distributor network throughout the eastern United States and Canada. Scott has over 14 years of experience in the compressed air industry, working with distributors in growing their businesses and bottom lines.

Pure-Aire, LLC is a leader in compressed air drying and contaminant removal systems. Pure-Aire is headquartered in Green Bay, WI, and manufactures cycling refrigerated air dryers, desiccant dryers, flow controllers, closed-loop cooling systems, and other air treatment products.

For more information, visit www.pure-aire.net.

Festo and Graybar Ink National Distribution Agreement

Festo, one of the world's premier automation companies, and Graybar, a leading distributor of electrical, communications, and data networking products and provider of related supply chain management and logistics services, recently signed a national distribution agreement. Under the terms of this agreement, Graybar will distribute Festo pneumatic, electro-mechanical, and process automation components to its customers.

"Graybar's nationwide distribution network along with its strong reputation in the industrial market makes them an ideal distributor for Festo products," said Michael Zakrzewski, Vice President of Sales, Festo U.S.

The new relationship with Graybar is the first national distribution agreement for Festo pneumatic, electro-mechanical, and process automation components in the automation company's more than 40 years of operation in the United States.

"We are pleased to offer Festo products to our industrial and automation customers," said Jeff Netherton, Graybar Vice President, Product Management. "Festo is well known for its innovation in factory and process automation, and we believe this relationship will provide a more comprehensive set of industrial solutions for customers."

For more information, visit www.graybar.com, and www.festo.com/use.

"Graybar's nationwide distribution network along with its strong reputation in the industrial market makes them an ideal distributor for Festo products."

— Michael Zakrzewski, Vice President of Sales, Festo U.S.

MANN+HUMMEL Agrees to Acquire Affinia Group

The MANN+HUMMEL Group, based in Ludwigsburg, Germany, recently announced that they have entered into a definitive agreement under which MANN+HUMMEL will acquire the global filtration operations (excluding its Affinia South America ("ASA") operations) of Affinia Group, the manufacturer of the Wix and Filtron brand of filters. The transaction is subject to customary regulatory approvals. The two businesses will continue to operate separately for the foreseeable future. Terms of the deal have not been disclosed.

Benefits of the Acquisition

- Approximately USD 1 billion added to MANN+HUMMEL's top line
- Companies employ 20,000 worldwide
- Global presence with complementary customer relationships and competencies
- Combined 150 years of filtration know-how

Affinia's filtration business specializes in aftermarket oil, fuel, air, hydraulic, and coolant filters. MANN+HUMMEL is a privately held global filtration expert offering filtration solutions to original equipment and aftermarket customers in both the automotive and industrial sectors.

Complementary Customer Relationships and Competencies

MANN+HUMMEL and Affinia's filtration business have highly complementary competencies and customer relationships. The two companies will bring together the best of on- and off-road and industrial filtration solutions. The acquisition will give MANN+HUMMEL access to market segments such as U.S. heavy-duty and hydraulic filtration.

Alfred Weber, CEO of MANN+HUMMEL Group

INDUSTRY NEWS

Alfred Weber, President and Chief Executive Officer of MANN+HUMMEL, said:

"This acquisition fits perfectly with our corporate strategy. It will enable us to grow globally and provide ample opportunity for growth and development for all of our people. MANN+HUMMEL and Affinia's filtration business will serve customers better through a seamless, comprehensive portfolio ranging from passenger to heavy-duty and industrial to hydraulic filtration solutions thanks to a combined 150 years of filtration expertise.

Upon closing, we look forward to working with the current management and people of Affinia, who have done a tremendous job over the past years. For all these reasons, I firmly believe that this is the right deal, with the right logic, at the right time."

Business Rationale

The acquisition will enable access to larger global markets with improved growth possibilities, and will allow the company to better serve its customer base with a broader product portfolio. Affinia's filtration business allows MANN+HUMMEL to enter the heavy-duty segment in the U.S., with a full range of filtration products and distribution focused on this segment, as well as providing significant growth opportunities in the hydraulic filter aftermarket. This opportunity will create additional value for MANN+HUMMEL, its employees, and its customers.

Communities and Ecosystems

MANN+HUMMEL is a global company, with deep roots and heritage in many parts of the world. As a family-owned business, MANN+HUMMEL is people-oriented and believes in making a positive impact in the ecosystems in which it operates. With the acquisition of Affinia's filtration business, MANN+HUMMEL looks forward to welcoming new associates and communities into their global family. With the addition of the unique features brought by Affinia's filtration business, MANN+HUMMEL intends to continue being an important contributor to the overall development of the filtration industry.

For more information, visit www.mann-hummel.com.

Endress+Hauser Announces New Representation in Mid-Atlantic

Eastern Controls, Inc. (ECI) and Endress+Hauser have teamed up to provide customers with a single-source supplier for all sales, service and solutions in all markets and industries in the Mid-Atlantic area, including Metropolitan New York, Eastern Pennsylvania, New Jersey, Delaware, Maryland, and Northern Virginia.

This strategic alignment between Endress+Hauser and Eastern Controls means an unrivaled offering of products, services and solutions for customers across all industries and applications. ECI offers its customers a diverse and complimentary line of process control and instrumentation equipment, along with services and solutions to support its customers. ECI's strength is in its people, who take pride in recognizing customer needs and providing solutions to meet their customers' most challenging process measurement needs.

"Eastern Controls is proud to represent Endress+Hauser," said Cliff McLaughlin Jr., President, Eastern Controls, Inc. "Combining one of the largest instrument manufacturers in the world with the premier process controls representative in the Mid-Atlantic region creates an extremely talented, passionate,

and dynamic team of industry experts. We are extremely excited about our partnership with Endress+Hauser and look forward to supporting our customers' requirements with some of the finest products available to the market."

Coinciding with this strategic venture, Eastern Controls has acquired Philip R. Walker Associates of Cockeysville, Maryland. This new addition combines all of the talent, experience and product offerings of both companies under the umbrella of Eastern Controls. Both firms have served the Maryland and Washington D.C. area for over 40 years.

In addition, Eastern Controls, Inc. will also become the new home of Endress+Hauser's PTU® (Process Training Unit). The PTU features Endress+Hauser instrumentation and is controlled by Rockwell Automation's PlantPAx™ system designed for the purpose of educating customer technicians, engineers, customers, and sales personnel. The PTU includes numerous fully functional flow, pressure, temperature, level and analytical instrumentation throughout the 5,000 square feet of classroom and hands-on training space.

"Partnering with a preeminent organization like Eastern Controls enables Endress+Hauser to thrive in local markets we serve," said Kevin Lavelle, Regional Sales Manager - Northeast, Endress+Hauser. "Eastern Controls offers an unmatched portfolio of services and solutions in the Mid-Atlantic market."

About Eastern Controls

Since 1969, Eastern Controls has been the Mid-Atlantic's premier manufacturers' representative and distributor of process control and instrumentation equipment. The foundation for our continuing success is our extensive product offerings and inventory, our outstanding sales, technical, and applications support, and our 24/7 service capabilities.

For more information, visit www.easterncontrols.com.

About Endress+Hauser

Endress+Hauser is one of the largest instrument manufacturers in the United States' industrial automation industry — specializing in automation solutions for the Chemical, Food & Beverage, Oil & Gas, Water and Wastewater, Life Sciences, Power and Energy, Primaries, and Pulp and Paper Industries. Endress+Hauser, a Switzerland-based company, first began operations in the U.S. in 1970. Since that time, Endress+Hauser has continued to invest in its U.S. operations — investing an average of 10% of its annual revenue into its infrastructure.

For more information, please visit www.us.endress.com.

Atlas Machine Helps Ahresty Save $151,000 WITH MASTER CONTROLS

By Andy Poplin, Atlas Machine & Supply

Ahresty Wilmington Corporation (AWC) was founded in 1988 and is located in Wilmington, Ohio. Currently AWC employs over 900 people with sales totaling $192 million. They have grown steadily, all while continuously improving and staying on the leading edge of technology. AWC is a tier-1 automotive supplier servicing their entire customer base in the United States. AWC has established an efficient and integrated production system that incorporates die-casting, finishing, machining, and assembly operation using just-in-time production methods to provide its customers with quality products at a competitive price. AWC's expertise is highly valued by all of their automotive customers in the United States who have recognized Ahresty Wilmington Corporation with several quality, delivery and productivity improvement awards.

Growing Compressed Air Requirements

As is the case with most manufacturing facilities, AWC's original compressed air system was a fraction of the size of what it is today. When production began in 1989, the entire operation was supported by two 50-hp rotary screw compressors. After 25 years of steady growth and expansion, the requirement increased to 2,500 horsepower. A total of 16 compressors — located in four different compressor rooms — is now relied on to support the 24/7/365 production needs at Ahresty.

It should be noted that prior to Ahresty's most recent plant expansion, a comprehensive compressed air audit was performed by Atlas Machine & Supply's Engineered Solutions

UNIT#	ROOM#	HP	PSIG	MODEL	COMPRESSOR TYPE	COMPRESSOR CONTROL
1	1	50	100	SSREP50	Flooded Rotary Screw	Load/No Load
2	1	50	100	SSREP50	Flooded Rotary Screw	Load/No Load
3	1	50	100	SSREP50	Flooded Rotary Screw	Inlet Modulation
4	1	50	100	EBH99H	Flooded Rotary Screw	Inlet Modulation
5	1	50	100	EBH99H	Flooded Rotary Screw	Inlet Modulation
6	1	50	100	SSREP50	Flooded Rotary Screw	Load/No Load
7	1	100	100	EAPSMC	Flooded Rotary Screw	Variable Displacement
8	1	50	100	SSREP50	Flooded Rotary Screw	Load/No Load
9	1	200	100	EAUSPD	Flooded Rotary Screw	Variable Displacement
10	2	150	125	EBQ99F	Flooded Rotary Screw	Inlet Modulation
11	2	200	125	EBU99A	Flooded Rotary Screw	Inlet Modulation
12	3	300	100	EAU99P	Flooded Rotary Screw	Variable Displacement
13	3	300	100	EAU99P	Flooded Rotary Screw	Variable Displacement
14	4	300	100	EAU99T	Flooded Rotary Screw	Variable Displacement
15	4	300	100	EAU99T	Flooded Rotary Screw	Variable Displacement
16	4	300	100	EAU99T	Flooded Rotary Screw	Variable Displacement

Group in order to establish a baseline of the amount of air that was being consumed by the plant and identify how much additional horsepower would be required to support the plant sufficiently. The results of this analysis indicated an additional 3,500 scfm would be required to operate the existing production equipment, as well as the new die-cast production lines and machining centers.

Strong consideration was given to making the transition to centrifugal compressors at this time, but the plant ultimately chose to stick with the technology that they were satisfied and familiar with. The plant now had everything they felt they needed — clean, dry and reliable compressed air with sufficient backup. We at Atlas knew more could be done to improve efficiency and to more closely monitor their large air system.

Post-Expansion Audit

From the follow-up audit, the objective of Atlas Machine's Engineered Solutions Group and AWC was to identify opportunities for any supply-side or demand-side energy savings. Therefore, power, flow and

ACES-16 air management system is powerful energy optimization tool.

ATLAS MACHINE HELPS AHRESTY SAVE $151,000 WITH MASTER CONTROLS

pressure were monitored for a 7-day period. An ultrasonic leak assessment was also performed throughout the plant.

Supply-Side Findings

On average, the plant consumed 7,275 scfm out of the available 10,700 scfm. During peak production periods, the air usage would spike above 8,000 scfm. The average power required to generate the compressed air was 1,641 kW. The average dynamic efficiency for the entire assessment period was 4.4 scfm/kW. Projected yearly energy consumption was over 14 million kW-hours at a cost of over one million dollars. The combination of the plant size and having 16 compressors distributed throughout four rooms made it impossible to prevent "load sharing" among the running compressors.

OPPORTUNITY	AIR SAVINGS (SCFM)	ENERGY SAVINGS (KWH/YEAR)	COST SAVINGS ($/YEAR)
Air Leaks	380	661,200	49,590
Cabinet Coolers	80	139,200	10,440
Vortex Vacuum Pumps	60	104,400	7,830
Parts Cooling/Drying	90	156,600	11,745
Total	610	1,061,400	79,605

Demand-Side Findings

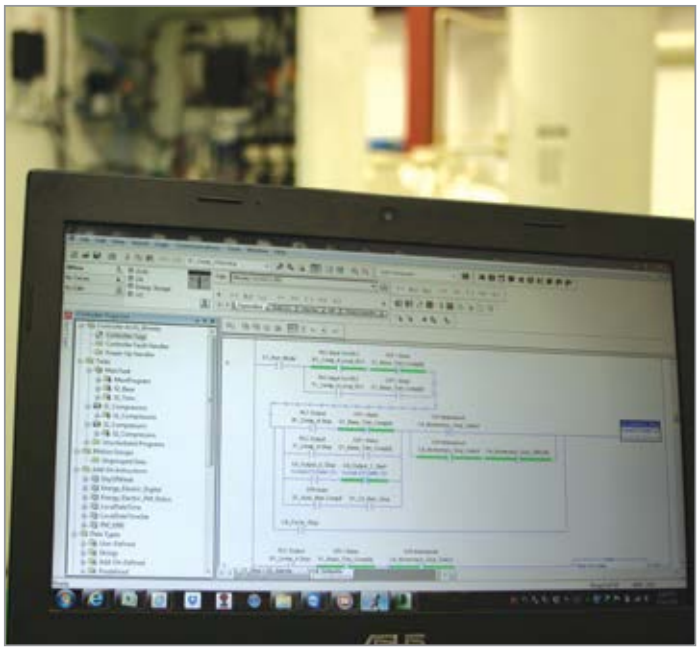
Many demand-side conservation opportunities were identified as a result of the audit as well. Corrective measures have not yet been implemented, but the table to the left illustrates additional potential savings.

Supply-Side Solutions

The obvious corrective action to reduce the excessive load sharing was to design and install a master control system. Ahresty selected Atlas Machine's Allen Bradley RSLogix 5000 based ACES-16 energy management system. By eliminating all inlet modulation and controlling turn valve (variable displacement) actuation, along with only starting compressors when necessary, yearly energy consumption has been reduced by over 2 million kW-hours.

Of course, when compressors are no longer permitted to modulate or "turn down," maintaining tight pressure control is far more difficult. Our solution was to add 6,000 gallons of compressed air storage along with a pressure/flow controller in Compressor Room 2. These changes effectively converted Compressor Room 2 into a dedicated trim station. From an economical and functional standpoint, utilizing existing assets (Compressor 10 and 11) in conjunction with Atlas Machine's BFC-3000 would deliver better pressure control with a quicker return on investment than adding a large variable speed compressor.

The strategy of having a "base system" (forces compressors to run fully loaded in draw-down state) being supplemented by stored compressed air from the "trim system" actually improved pressure control.



A real-life look at the ACES-16 energy management system

An Atlas Machine technician hard at work on an ACES-16 platform

ATLAS MACHINE HELPS AHRESTY SAVE $151,000 WITH MASTER CONTROLS

Subsequently, this allowed the plant to operate at 4 psig lower pressure than previously. An additional 250,000 kW-hours of energy have been conserved by eliminating this "artificial demand."

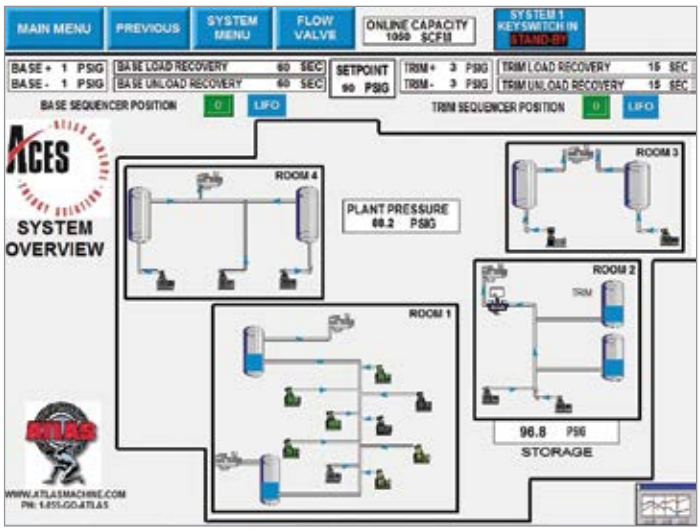
In addition to controlling the starting and stopping of each compressor, the ACES-16 automation package monitors and trends compressor power, pressure, flow and dew point in each compressor room. By monitoring the system operating parameters 24/7, AWC's preventive and predictive maintenance program will be enhanced, and knowing immediately if there is an upset condition and where it originated will have an even greater benefit. Therefore, supply-side failures can be addressed before they become demand-side production problems. Each compressor room is equipped with a 10-inch touch screen in order to provide system visibility from each corner of the building.

Controls Yield Huge Energy Savings for AWC

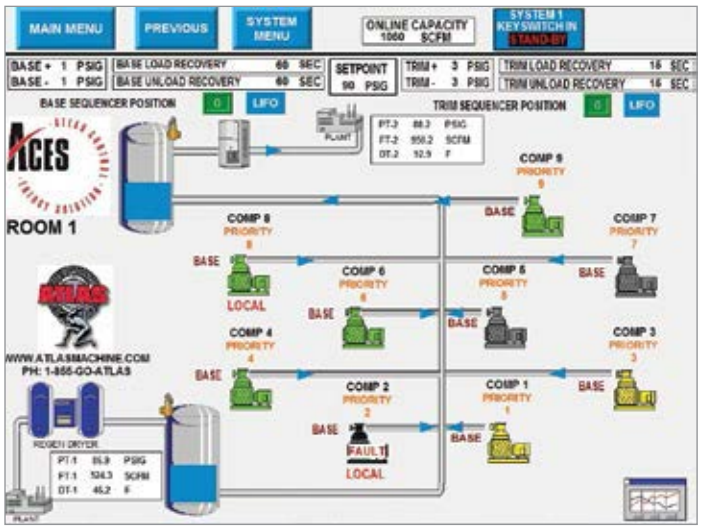
The control and integration project yielded yearly savings of $151,000 to AWC. The estimated rebate from Dayton Power & Light is $75,000. Thus, the entire turnkey air management solution — including installation and commissioning — will have a simple payback of slightly over 1 year when the rebate is factored into the equation. Atlas Machine's ultimate goal is to continue to build our partnership with Ahresty in order to optimize the compressed air system to the point where Compressor Room 1 (600 hp) is no longer required to support current production demands at all.

About Atlas Machine

Atlas Machine and Supply, Inc. is a fourth generation family-owned business established in 1907. Atlas is headquartered in Louisville, KY, and has four additional branches located throughout Indiana and Ohio.



With its 15-inch touch screen, the ACES-16 provides system status "at-a-glance."



Drilling deeper into operational metrics through a simple tap of the screen.

> "Atlas Machine's ultimate goal is to continue to build our partnership with Ahresty in order to optimize the compressed air system to the point where Compressor Room 1 (600 hp) is no longer required to support current production demands at all."
>
> — Andy Poplin, Atlas Machine & Supply

BFC-3000 V-Notch flow controller combines fast response with precise control.

Atlas currently employs more than 200 employees who are dedicated to providing world-class service and solutions to virtually every industry.

Our Industrial Products Group (IPG) is one of the country's leading distributors of compressed air equipment, parts, service and rental equipment. In addition to selling and supporting some of the most reputable equipment lines in the world, we engineer and manufacture customized state-of-the-art, in-house solutions.

The Machine Shop is an industrial repair service provider that offers a variety of solutions to industry. Our full-service machine, weld, thermal spray, and grind shops can complete most repairs under one roof. We also have teams of field machining experts ready to handle challenges worldwide. Known best for our rapid response, our field machinists are armed with the best equipment in the industry and are prepared to tackle your toughest problems. BP

For more information, contact Andy Poplin, Compressed Air Sales Manager, Atlas Machine & Supply; office: (502) 584-7262, mobile: (502) 595-8318; email: apoplin@atlasmachine.com; or visit www.atlasmachine.com.

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

Managing Multiple-Compressor Systems: Utilizing Controls to Improve Performance

By Chad Larrabee, Ingersoll Rand Company

An unmanaged control scheme for a bank of air compressors is a recipe for unnecessary consumption of power, as well as increased or unplanned maintenance. Controlling air compressors with only their on-board controllers can cause one or more of the following problems:

- Too many compressors are running.
- The wrong combination of compressors is running.
- Pressure is higher than it needs to be.

How does this occur? A look at signals, differentials and set points is the first step to understanding the complexity of a system operated only by on-board controllers. Consider the one line diagram for a given system (Figure 1).

Each compressor has its own pressure signal located at the discharge of the compressor and before the air treatment equipment (filters and dryer). To ensure each compressor is "aligned" from a control perspective, each pressure transducer would need to be perfectly calibrated with each other (Figure 2).

Also influencing the control scheme is the amount of differential pressure (or pressure drop) measured between the discharge of the compressors (signal location) and the receiver tank downstream of the air treatment equipment. Unless all of the air treatment equipment and associated piping have exactly the same pressure drop, the control of the compressors will not be aligned. Unfortunately, this is almost never the case due to different characteristics of air treatment equipment, field piping configurations and maintenance intervals. With mismatched differentials and

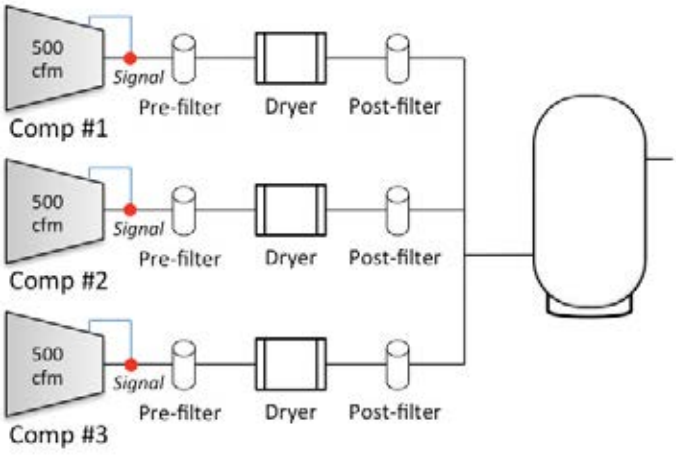


Figure 1: A three-compressor system with filtration and dryers with signal location for each compressor (to simplify, distribution system is not shown).

signals, too many compressors run, wasting energy and increasing maintenance intervals needlessly (Figure 3).

Finally, the control of the compressors is influenced by the set points for the compressor control. If the compressor is fixed-speed, it will be controlled by an inlet valve usually in a load/unload control mode, meaning the valve is 100 percent open or 100 percent closed. Typically the set points for the load point and unload point are 10 psi apart. If the compressor is controlled by the speed of the motor, using a variable speed drive, the "set points" become a "target pressure." With multiple compressors in local control, the set points are cascaded over a wide range, causing the first compressors to operate at elevated pressure to maintain the set point cascade control scheme (Figure 4).

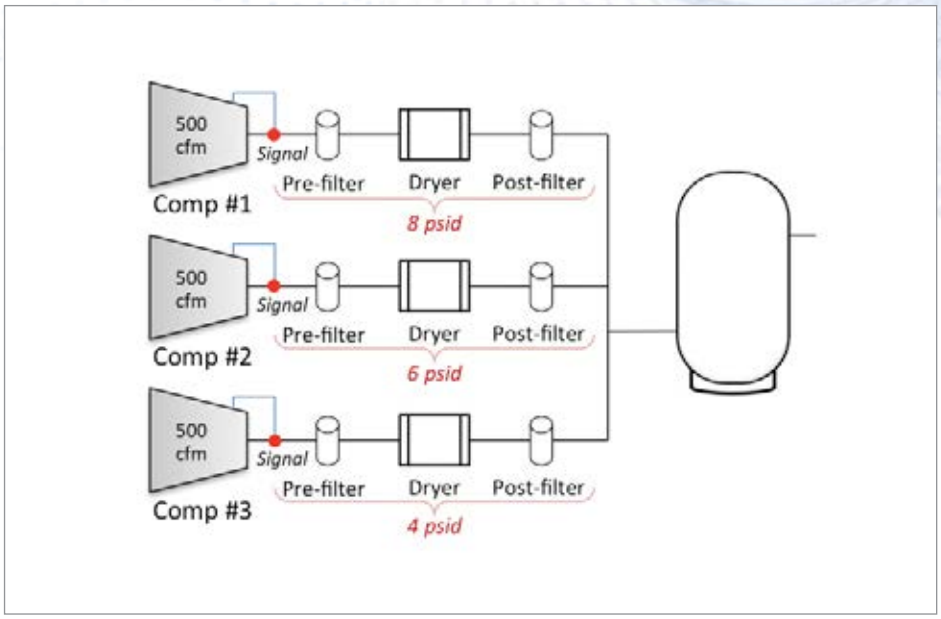


Figure 2: The differential pressure for each series of air treatment is shown.

Cascade control schemes increase power consumption in a system due to the elevated pressure. In the example in Figure 4, the last compressor to start is set at the plant's minimum allowable pressure, 90 psig. However, the first compressor to turn on and consequently the last one to turn off with reducing demand is set to load at 115 psig and to unload at 125 psig. In low demand situations, the system can be running at 25 to 35 psig above the minimum required pressure. This would generate about 15 percent more energy consumption at the compressor than is required for the demand. Additionally, unregulated demand in the plant would now consume more cubic feet per minute (cfm) at the elevated pressure level, increasing waste. Elevated pressure wastes energy and creates artificial demand in the system.

Exerting Control with Smart System Controllers

How can you align the signals, differentials and set points to eliminate waste and elevated pressure? A system controller will act like

MANAGING MULTIPLE-COMPRESSOR SYSTEMS: UTILIZING CONTROLS TO

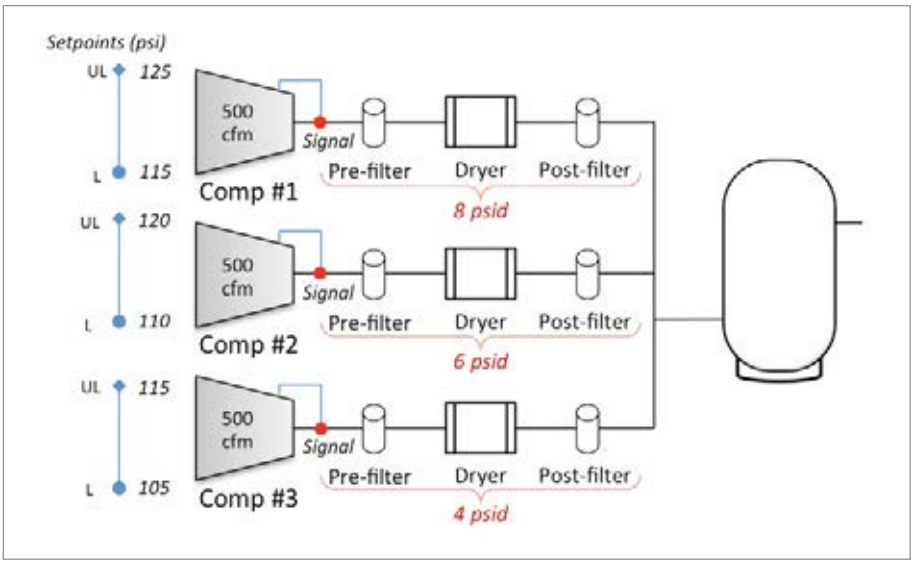


Figure 3: The set points are now shown with a 10-psi delta at the controller, but the effective differential is reduced with the pressure drop across the air treatment equipment.

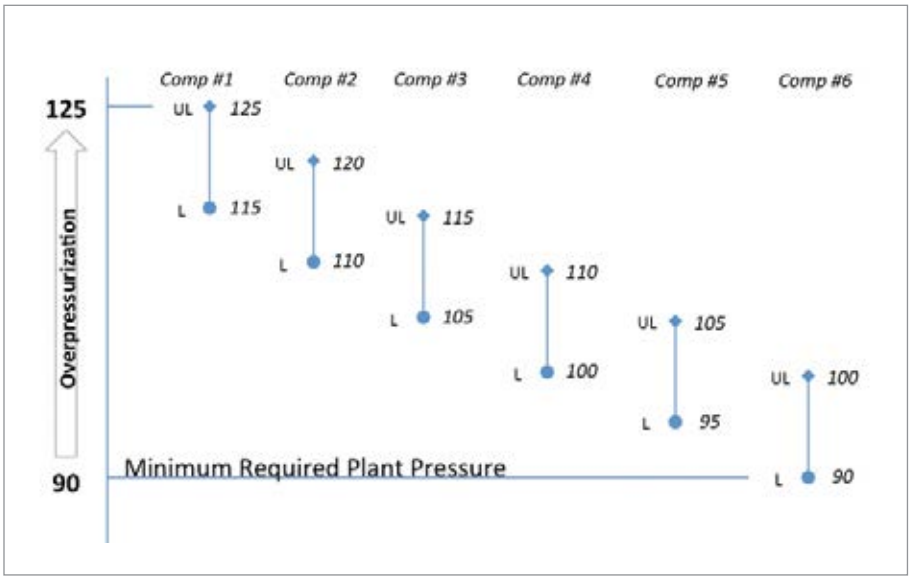


Figure 4: The set points for a six-compressor system are shown with system pressure as much as 35 psi over the required pressure.

a conductor of the symphony, directing compressors to respond to one common signal, one common pressure band, and accommodate differentials. A system controller with the right algorithms and logic will dynamically match compressed air supply with compressed air demand and operate only the compressors required to provide a more energy-efficient combination.

In the past, multiple compressor systems were controlled using a rudimentary sequencer focused on balancing the use of the compressors for equal run hours. While the sequencer had a common signal and pressure band, it did not have the intelligence to account for rate of change or size of compressor. As a result, compressors may run needlessly or in the wrong combination — even with sequencing.

A smart system controller builds in intelligence, accounting for rated capacity of each compressor, as well as purposeful delays and iterative checkpoints to ensure it is responding to what is happening in the system. In addition to dynamically matching supply with demand, increased functionality is built into some system controllers to ensure improved efficiency and fewer compressors running.

An example is anti-cycling control. Suppose the pressure signal is dropping at a certain rate based on a system demand event calling for more air. As the pressure decreases back at the signal location, the controller may load another

"A system controller will act like a conductor of the symphony, directing compressors to respond to one common signal, one common pressure band, and accommodate differentials."

— Chad Larrabee, Ingersoll Rand Company

IMPROVE PERFORMANCE

compressor to meet the demand, however the pressure signal continues to decrease. This can happen due to the start permissive on the compressor, which is the time it takes a compressor to start and deliver air at rated pressure.

A sequencer would have already turned a second compressor on — and maybe a third — within the first additional compressor's start permissive. Then the extra compressors would run and cycle needlessly until they meet their run timer permissive and shut down. With a system controller, the intelligence accounts for the rate of pressure drop, indicating how large the event was and if it is continuing. If another compressor is not necessary, the controller allows the start permissive to complete and pressure signal to rise again without jeopardizing the minimum required pressure.

System pre-fill is another differentiated control scheme supported by some system controllers. Pre-fill provides an energy-efficient method of increasing pressure to normal operating levels upon system start. This feature avoids the potential for all compressors to inefficiently start and load in an attempt to quickly get the system pressure up to normal levels.

Additionally, system standby mode offers the ability to keep compressors "offline" to minimize losses due to system leaks in pressurized systems that are idle during non-productive periods.

The Benefits of Remote Connectivity

Effective system controls can be applied to any brand of compressor and linked for monitoring and control with many existing Distributed Control Systems (DCS). Many manufacturers develop and supply their own monitoring and graphical user interface to visualize what is happening in the system with data trends reported as needed. Additionally, remote web-based control is usually available with this type of system.

Remote communications have multiple benefits. Consider an air compressor with no remote connectivity generating an alert or tripping on alarm during a lower production shift where seasoned maintenance staff members are not available. The plant production would be at risk as the plant personnel must now react to the interruption in compressed air supply. Depending on the degree of documented procedures, valuable production time could be lost while an emergency service is located and a service provider is contacted and dispatched.

And consider the reaction of the senior maintenance manager if he or she is contacted during his or her personal time. Now consider the same scenario but with a mobile alert notification built into the control system where the alarm immediately notifies the service provider. The service provider can quickly assess the situation remotely, reviewing the operating parameters, the nature of the shutdown, and even restart the compressor if such permissions are given. The speed and quality of response increases dramatically.

This is a real scenario, and it highlights the many solutions remote connectivity provides:

- Information and monitoring
- Alerts and notifications
- Diagnostics
- Full remote control

Automated Alerts Help Monitor System Performance

In addition to accessing the system status for performance and health monitoring, the remote solution would also offer the ability to assess key operating parameters and trends

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MANAGING MULTIPLE-COMPRESSOR SYSTEMS: UTILIZING CONTROLS TO IMPROVE PERFORMANCE

with graphical capabilities, indicating potential failures early. Therefore, maintenance can be planned, and the likelihood of an untimely alert or trip is reduced.

The reporting function of controllers can also be programmed to send emails daily with critical operating parameters to key personnel or the service provider. In the past, traditional maintenance managers have hung a clipboard on the compressor with a pencil or pen attached. Each hour, maintenance personnel were required to scroll through the local controller screen and record the operating parameters on the clipboard. The sheets were collected daily and promptly stored in a place no one could ever find when needed. Consider accessing that record automatically every hour, or at any interval the user desires, and recording it to a PDF document that can be emailed and/or stored electronically for easy retrieval.

Checklist for System Controls

- ❒ Controls any brand of compressor
- ❒ Dynamically matches the supply with demand using the most energy-efficient combination of compressors
- ❒ Priority control for custom sequence selection and automation
- ❒ Anti-cycling control
- ❒ System pre-fill control
- ❒ Zone control and pressure balance function for compressors not co-located
- ❒ Equal run hours control option
- ❒ Communicates with DCS
- ❒ Web-enabled monitoring and control

Chad Larrabee, Director of Services Marketing - North America, Ingersoll Rand

For planned maintenance, a maintenance scheduler should also be specified. Reminders and planners are possible so no maintenance is missed, creating confidence in uptime and reliability of the equipment.

Controls continue to advance with the increased focus on improved productivity and sustainability. Perhaps a call to your vendor may be in order to improve your operating system to maximize reliability and efficiency.

About Chad Larrabee

Chad Larrabee is director of Services Marketing in North America for Ingersoll Rand's Compressed Air & Gas business unit. He is responsible for all parts and service offerings, including the advanced services of system assessments for optimization and removing waste in compressed air systems. Larrabee has 23 years of experience in the compressed air industry and currently serves as Education Committee chairman for the Compressed Air and Gas Institute. BP

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To read more about ***Compressor Controls,*** please visit www.airbestpractices.com/technology/compressor-controls.

Air Compressor Control for INDUSTRY 4.0

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

We are in the midst of the fourth industrial revolution, or, as it is known in Germany, Industry 4.0. In broad terms, the concept describes manufacturing facilities where all of the machines — including the air compressors, along with their corresponding sensors and air treatment equipment — communicate with each other autonomously, recording performance metrics to a local controller, a wireless network, and an external database. These communicative abilities are enabled by the Industrial Internet of Things (IIoT), in which intelligent, networked devices link everything back to a main data hub.

A factory with that type of machine-to-machine communication and real-time data analysis has the foundation for two essential future-oriented capabilities: Predictive maintenance, and continuous energy efficiency optimization.

> "When looking at the next 10 to 15 years, you need to lay the foundation today. So, we have put a highly capable processing unit in this industrial PC."
>
> — Werner Rauer, Compressors Product Manager at Kaeser

Kaeser's newly introduced SAM 2 master control system

Perhaps the most important aspects of an Industry 4.0 compressed air system are its master controller, and the ability of the units to collect and communicate data. As the central hub of intelligence, the controller constantly monitors compressed air system performance and displays vital parameters in real-time. In addition, these comprehensive system controls have the ability to use that information to efficiently and reliably guide compressor performance, and provide the information to management.

Earlier this year, Kaeser Compressors introduced its new master control system, Sigma Air Manager 2 (SAM 2), which boasts a bevy of upgrades geared for Industry 4.0. The team at Compressed Air Best Practices® Magazine was fortunate enough to speak with Kaeser's Werner Rauer and Michael Camber about SAM 2. During our conversation, they discussed the development of the controller, its new capabilities, and how it fits within the context of Industry 4.0.

Future-Oriented Capabilities, Years in the Making

In 1998, Kaeser put an industrial PC inside a standard air compressor. The PC provided the basics: analog and digital inputs and outputs, connectivity, and some memory, enabling Kaeser personnel to evaluate the compressor, using both historical and current data. Two years later, the company developed the first Sigma Air Manager (SAM), an improved "watch dog" for compressed air systems.

During the following years, SAM's software evolved on a frequent basis to provide the customer with the latest in technology — until the hardware could no longer support additional functions. SAM 2 is the required next step in development, and provides a dramatic improvement in hardware to allot for the complex computing capabilities required by Industry 4.0.

"When looking at the next 10 to 15 years, you need to lay the foundation today," Werner Rauer, Compressors Product Manager at

AIR COMPRESSOR CONTROL FOR INDUSTRY 4.0

Kaeser, explained. "So at this time, we have put a highly capable processing unit in this industrial PC."

The boost in computing power allows SAM 2 to communicate with the compressor room much faster — gathering more details at more data points (10 to 18 million data points per day per compressor). This provides three things:

1. More energy-efficient and reliable supply of compressed air
2. Remote monitoring and data extraction for making management decisions
3. Predictive maintenance capabilities

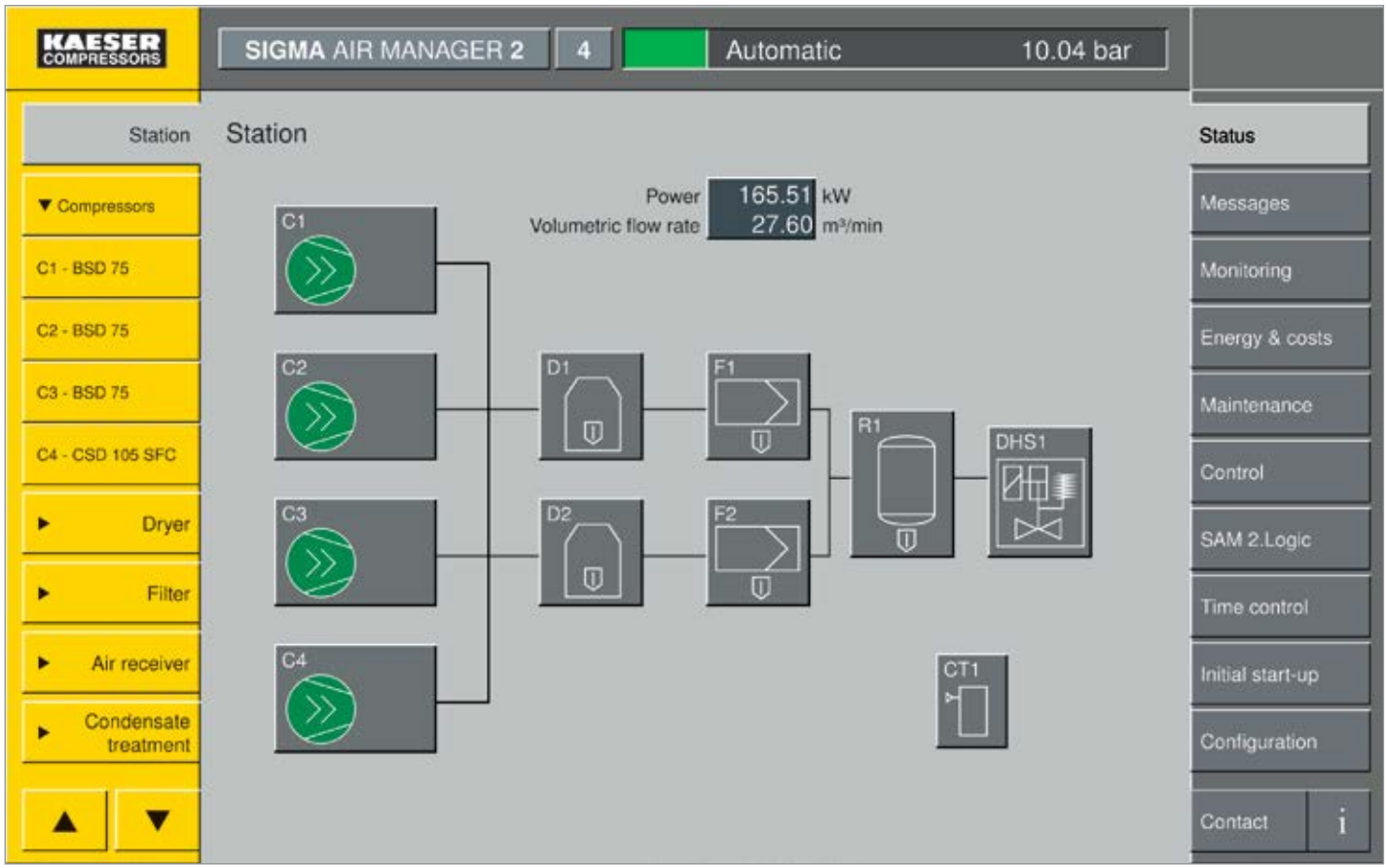
"[The] predictive maintenance capabilities could — if the customer chose the option — activate an automated service response," said Michael Camber, Marketing Services Manager, Kaeser. "So, if there is a problem with one of the units, the system would know which compressor, which parts to pull, create a service order, and have someone dispatched to the location — before the customer knew there was a problem."

SAM 2's newest core feature, the 3D^{advanced} Control scheme, helps optimize energy efficiency on a continuous basis. The 3D^{advanced} Control provides real-time analysis of how the compressed air system worked in the recent past, how it is operating now, and — in similar fashion to a chess computer — the controller then calculates thousands of possible operating scenarios. After running the numbers, the controller selects the best configuration and acts accordingly — all within a split second.

Touch Screen, Automated Reporting and Advanced Networking

Many end users requested a color touch screen for simple navigation (think iPad). Now integrated into SAM 2, the touch screen provides a live piping and instrumentation (P&I) schematic of the compressed air system, displaying each component and its status.

Built-in, automated reporting capabilities are in high demand, so SAM 2 — like its predecessor —can send email alerts as part of a preventative maintenance schedule, or for emergency situations. It also provides added security, leveraging radio frequency identification (RFID) technology on equipment



Pictured is a screen shot of the P&I schematic provided by SAM 2.

cards to prevent unauthorized personnel from gaining access.

SAM 2's advanced networking capabilities run through industrial Ethernet. With that connectivity, you can examine your system's performance directly from your laptop (and eventually your smartphone). Additionally, SD and CF cards are no longer necessary, as the control system features a large internal memory capable of storing system data as far as one year back, depending on the system.

Connecting to the Cloud

While end users can store data locally, they get the most out of SAM 2 by connecting to the cloud. The automatic and continuous energy optimization and predictive maintenance functions are dependent on analyzing and acting on the massive amounts of data collected by SAM 2. By constantly uploading operational data to the secure Kaeser Data Center, located at Kaeser's headquarters in Coburg, Germany, end users can benefit from in-depth analysis and performance recommendations.

"It's one thing to have the data, but you also need the processing power and the algorithm to actually do something with the data," Rauer explained. "So it's not just a matter of storing it, but you have to actually crunch the numbers, and that's what the Kaeser Data Center is doing."

Let's say, hypothetically, the Kaeser Data Center had a two-year history of your compressor's operation. If you were monitoring motor temperatures, the logic would compare ambient temperatures with motor temperatures. If it is the same ambient temperature for three days in a row, but the motor increases in temperature on the third day, SAM 2 would detect the issue and send an alert.

"All of these algorithms will be there in the future, and it will automatically raise the flag," Rauer said. "Then, either with or without human interaction, the Data Center will spit out a report, a recommendation, or it will send a service tech on his way. That is the future when you are talking about the massive amount of data that the controllers in the compressors and the individual sensors will provide to the data center."

Installation and Integration

To account for the ever-changing demand of modern manufacturing facilities, SAM 2 is modular, allowing the end user to easily adapt the controller to changes in the plant equipment.

"It used to be that we had the SAM 4, SAM 8, and the SAM 16, and every time you matured from four compressors to six, you had to remove the old hardware and put new hardware on the wall," Rauer explained. "With today's technology, you do the upgrades pretty much with software only."

"Plug-and-play" capability has reduced physical integration time compared to the older version of SAM. Industrial Ethernet cables are much easier to install than cumbersome relays, and the controller arrives pre-programmed using information from an extensive customer questionnaire.

"It used to be that you had to program the SAM once you installed and connected it," Camber explained. "Now, given the correct parameters of the equipment that is going to be connected, we do the programming here so that when it arrives it is ready to connect and run. That's something new and cost-effective for the customer."

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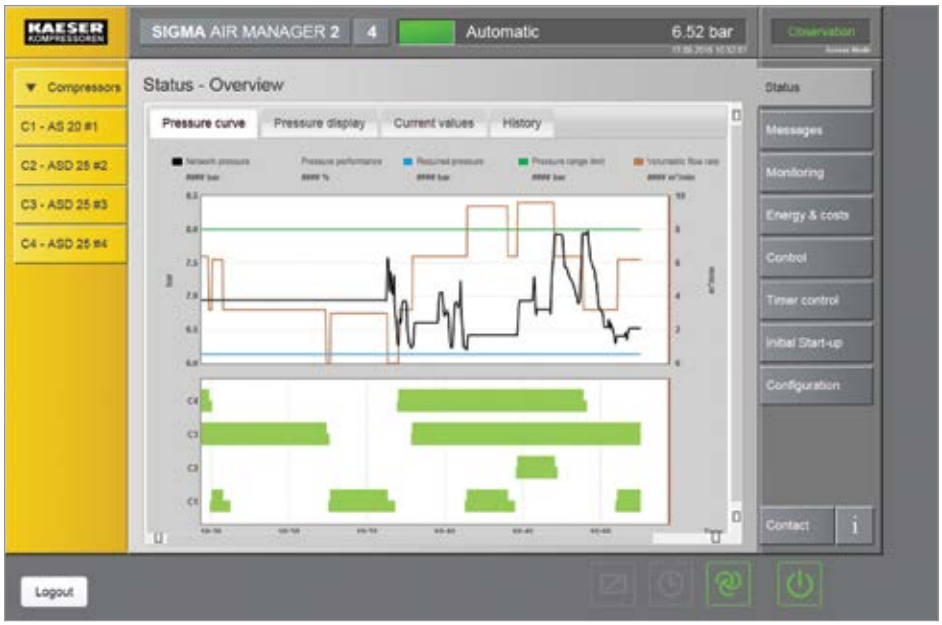

The real-time charts on SAM 2 help put compressor performance into context.

SAM 2 provides end users with energy costs in real time.

Even with plug-and-play capability, the controller still takes some time to acquire enough historical data for the controller to manage the compressed air system optimally.

"When you start it up for the first time, [SAM 2] doesn't even know where it is, and it has no history," Rauer explained. "Based on our experience, it takes a minimum of twenty minutes, maybe an hour. SAM is looking at what is going on with your pressure, what is going on with your supply, and it calculates how the pressure is reacting to different compressor configurations and fluctuations in the system."

What Types of Systems Can SAM 2 Control?

Compatibility is an important topic, not only in regards to brands, but in terms of the size and type of compressor system. SAM 2 can control compressor, blower, and vacuum systems with up to 16 machines, along with the auxiliary equipment. According to Rauer, it can monitor "dryers, drain traps, dew point meters, and flow meters." Whatever it is, you just have to add I/O modules.

The most robust monitoring capabilities come naturally with modern Kaeser compressors. However, SAM 2 is capable of monitoring most any brand compressor, along with older units, so long as you provide the I/O.

"We can certainly also hook up 1984 Kaeser units, and competitive units," explained

"System dynamics is probably the most important, but it's never talked about other than by some experts on LinkedIn."

— Werner Rauer, Compressors Product Manager at Kaeser

Rauer. "But in order to do that, you need to have a compressor that allows remote control and provides some feedback in terms of motor running, load/unload, and whether it has a malfunction or not."

SAM 2 can also distinguish and properly apply three differently sized variable speed drive units — in particular with a Kaeser system where everything from the SAM and the onboard Sigma Control 2™ compressor controller all the way to the Siemens Sinamics drive is understood and monitored.

Managing Important System Metrics

SAM 2 has the ability to monitor nearly every aspect of a compressor system. The real trick is to evaluate the most important metrics.

During our conversation, Rauer explained what a sample report would include: "I can pick a day, and [SAM 2] tells me how many hours the compressor was either loaded or unloaded (total hours), how many kW-hours it consumed, the energy cost based on how much I pay for it, and then it spits out the total volume for the timeframe — how many millions of cubic feet it was. And then, the most important one, the specific power, which will be in kW/100 cfm."

According to Rauer, the most important metrics to monitor are: pressure, flow, power, cost, and, most importantly, system dynamics.

"System dynamics is probably the most important, but it's never talked about other than by some experts on LinkedIn," he explained. "When people have a very flat average use over the whole day, it is way different than when you have a facility that routinely uses a ton of compressed air all at once. You have two choices to manage it: You either have lots of compressors that you need to turn on just to do this, or you store the compressed energy in a dedicated storage receiver tank. Both of those have a different solution in terms of energy savings."

In regards to optimizing energy efficiency, the team at Kaeser had another important message: SAM 2, or any other master controller, will not be the ideal solution *every* time.

"Without studying the system dynamics, and doing an air demand analysis, it's very difficult to just simply say: 'Yes,

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"Compressed air is very important to our manufacturing process and managing its reliability and energy-efficiency is critical."

– Patrick Jackson, Director of Global Energy Management, Corning Inc. (feature article in June 2014 Issue)

"Compressed air is the #1 kW user across our 35 factories."

– Doug Barndt, Manager Demand-Side Energy & Sustainability, Ball Corporation

"Demand Side" and "Supply Side" information on compressed air technologies and system assessments is delivered to readers to help them save energy. For this reason, we feature Best Practice articles on when/how to correctly apply **air compressor, air treatment, piping, measurement and control, pneumatic, blower and vacuum technology.**

Industrial energy managers, utility incentive program managers, and technology/system assessment providers are the three stakeholders in creating energy efficiency projects. Representatives of these readership groups guide our editorial content.

"Each of our 10 production plants has an Energy Coordinator who is part of the corporate energy team."

– Michael Jones, Corporate Energy Team Leader, Intertape Polymer Group (feature article in July 2014 Issue)

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SAM 2 will help,'" Rauer told us. "I say the same thing about flow controllers: 'No it's not *always* the best solution.' SAM can only employ what you give it to deal with. If you give it four identically sized compressors, you cannot expect a miracle in improved power performance if none of them has a good specific performance to begin with, in particular in part-load."

Only a comprehensive system analysis will help determine what will help improve your facility's energy efficiency and reliability.

"It's really about overall best practices, and a lot of it has to do with pressure," Camber explained. "There are certain physical facts that if you are running at higher pressures, your specific power will not be able to get as low as if you were running at a lower pressure, generally speaking. So, it's really about looking at a particular system and optimizing it."

Energy Management and Quantifying Results

While SAM 2 provides detailed analysis, it does not provide, or quantify, energy savings. Instead it gives end users a "continual energy audit," which is a major advantage over a one-time, weeklong audit.

As part of the continuous energy auditing, SAM 2 generates simple and easy-to-read graphs and charts. Data collection is a major part of Industry 4.0 and IIoT, but understanding the data is not always an easy task. SAM 2's reports help end users understand exactly what is going on with the compressed air system, and they make that information available to everyone. This facilitates data analysis and simplifies finding trends in power consumption, system performance, and energy efficiency.

Laying the Groundwork for Industry 4.0

Laying the foundation for the future-oriented capabilities of Industry 4.0 is important, and that is exactly what Kaeser has done with SAM 2. While the compressor control system currently only monitors the supply side of a compressed air system, the hardware and intelligence is now in place to start branching out to every facet of the system — including countless end-use applications.

As tighter energy management regulations — like ISO 50001 — become more commonplace, it will be vital to have a firm grasp on how and where compressed air is used. In addition to providing comprehensive oversight of the supply side, SAM 2, in the future, will be able to report on where, when and how much compressed air is used at any given point of use, along with the amount of energy required.

"The Department of Energy is looking into ISO 50001 as well," Rauer told us. "Every company needs to be responsible for knowing what type and the amount of energy they are using in each part of their plant."

SAM 2, with its ability to determine the best way to control a compressed air system, and its energy monitoring features, could help adhere to that standard. Depending on the system, it could also provide a significant ROI — especially for facilities with fluctuating system dynamics. BP

For more information contact Michael Camber, tel: (540) 898-5500, email: michael.camber@kaeser.com, or visit www.us.kaeser.com.

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Understanding CENTRIFUGAL AIR COMPRESSOR Capacity Controls

By Rick Stasyshan and Ian Macleod, Compressed Air and Gas Institute

Compressed Air Best Practices® (CABP) Magazine recently caught up with Rick Stasyshan, Compressed Air and Gas Institute's (CAGI) Technical Consultant, and Ian Macleod of the CAGI Centrifugal Compressor Section and member company Ingersoll Rand.

CABP: Gentlemen, thanks for the series of articles on centrifugal compressors. Why have you selected centrifugal compressor capacity controls for this interview, and can you give a brief introduction?

CAGI: CAGI and our centrifugal customers all share a common interest and goal — to maximize the compressor system efficiency and optimize the system energy usage. Since the capacity controls on a centrifugal compressor are a bit more complex than positive displacement types of compressors, consulting a factory-trained technician is always recommended. The members of the Centrifugal Compressor Section of CAGI can provide that assistance.

Centrifugal compressors are dynamic, and each has a characteristic curve of rising pressure as capacity decreases. Without any control system, the compressor would operate along this natural curve. A centrifugal compressor's flow and pressure are typically controlled by a combination of an inlet control device and an unloading valve (UV).

CABP: Can you summarize how these devices work in combination to achieve the desired results and share what options might be available?

CAGI: Well, since a centrifugal compressor's controls are a bit more complex, we will walk readers through the systems and the options available.

Solutions for Inlet Regulation

The inlet can be throttled on a dynamic compressor to continuously reduce the capacity of the compressor. The minimum flow is determined when the pressure ratio reaches the pump limit and the machine reaches maximum pressure. The regulation range, or turndown, is determined by the design of the machine. For example, turndown is affected by the number of stages and the impeller design. Regulation range is also affected by external factors, such as inlet air conditions (temperature, pressure, and humidity), and coolant temperature.

Inlet Control Devices

The following are two methods for throttling the inlet:

Inlet butterfly valve (IBV): The inlet butterfly valve may be driven electronically or pneumatically, and as it closes it creates a pressure drop across the valve, effectively reducing the inlet pressure into the compressor and throttling the compressor's ability to make pressure and subsequently flow.

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Inlet Guide Vanes or (IGVs): The inlet guide vanes may also be driven electronically or pneumatically, and are a series of radial blades arranged in the intake. These vanes, in the wide-open position, are parallel to the airflow, and at fully closed are at 90 degrees to airflow. As the guide vanes are rotated from full open to partially closed, they cause the drawn-in gas to rotate in the same direction as the impeller. The pre-swirl changes the incidence angle of the incoming air as it approaches the inducer section of the impeller, effectively reducing the energy required to produce pressure and flow. The use of IGVs can effectively throttle the compressor with the added benefit of being more efficient. Depending on where you are operating on the compressor curve, a user may see up to a 9 percent efficiency gain over standard IBV throttling.

The load set point of a centrifugal compressor is typically at a given pressure, so when the system pressure falls below a given level, the compressor will load.

Control and Regulating System for Centrifugal Compressors

1. Auto-Dual Control (See Figure 1)

The standard regulation is achieved by means of an inlet butterfly valve (IBV), or inlet guide vanes (IGVs) and controller.

The compressor discharge pressure set point will be set at the desired level and the IBV or IGVs will modulate the compressor inlet to maintain constant discharge pressure over the control (B→C) range.

At the minimum throttle point (C), the IBV or IGV valve stops closing, allowing the discharge pressure to rise to the unload set point. At this moment the compressor will unload, the IBV or IGV will close, and an unloading valve fully opens.

The compressor remains in the unloaded condition until the compressor resumes load at full flow and the cycle is repeated. Reloading time varies in this control method, and depending on the system's storage capacities relative to the demand swings, it may be advisable to install measures (additional compressed air storage) to protect the process and the compressor against short cycling.

If the compressor does not need to reload within a fixed time period, the unit may be configured to power down and stop. The controller will automatically restart and load in response to the system pressure falling to the load set point (A).

2. Constant Pressure Control with Modulating Unloading Regulation (UV) (See Figure 2)

This control method uses the IBV or IGV, a modulating UV, and a controller.

The compressor discharge pressure set point will be set at the desired level, and the IBV or IGV will modulate the compressor inlet to maintain constant discharge pressure over the control (A→B) range.

At the minimum throttle point (B), the position of the IBV/IGV is maintained as fixed, and the unloading valve (UV) starts to modulate open.

In this way, a constant discharge pressure is maintained over the full operating range of the compressor (A→C).

Some controls can also provide for a maximum unloading valve (UV) position to be programmed. This allows the owner to minimize inefficient operation during periods of low demand by limiting unloading operation to a point between (B→C).

The constant pressure control system is designed to continuously control the air output while keeping the net pressure fluctuations to a minimum. Constant pressure is critical in many applications.

Impact of External Factors on Regulation

CABP: You mentioned that regulation could be impacted to a large degree by external factors, such as counter-pressure, suction temperature, and cooling temperature. Perhaps a future interview on this topic may be in order, but could you give us a sneak preview and condensed version of these impacts?

CAGI: The effect of variables on centrifugal performance is easily shown graphically.

"Surge control and protection are available for both auto-dual and constant pressure control systems. In fact, as part of system start-up, technicians manually surge the compressor to set up the control system."

— Rick Stasyshan and Ian Macleod, Compressed Air and Gas Institute

Typical turndown ratios for a centrifugal design are 30 to 40 percent while operating in auto dual mode. The percentage depends on inlet air conditions as mentioned above, and will typically be larger at cold temperatures and smaller in hot summer conditions. In centrifugal design there is a trade-off between the aerodynamic efficiencies and turndown. Larger turndowns can be achieved, but result in lower aerodynamic efficiency. This analysis has to be made in cooperation with the manufacturer based on required flow profiles to determine optimum system design.

The figures on page 37 show the effect of variables like inlet temperature, inlet pressure and cooling water temperature.

How Surge Occurs in Centrifugal Compressors

CABP: You mentioned the phenomenon of surge. Can you elaborate on when this could potentially occur?

CAGI: Surge is the phenomenon of aerodynamic instability that can occur in centrifugal compressors. The pressure rise in centrifugal compressors is created by imparting high velocity (kinetic energy) to the flow path of air through the impeller. The later conversion of velocity to pressure (potential energy) occurs in the diffuser, and possibly in the volute, if the compressor is so equipped.

Due to this limitation, any single compression stage cannot increase the pressure head above a limit of about 2.5 ratios (depending on design).

If the centrifugal compressor experiences surge during compressor operation, it is considered to be running in an unstable condition. Manufacturers take into consideration surge events when designing their compressors, and thus the occurrence of a single or even multiple surges will not reduce

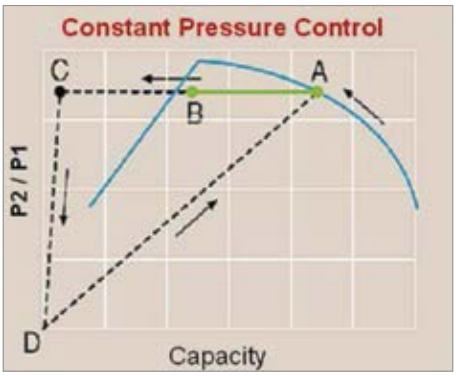

Figure 1

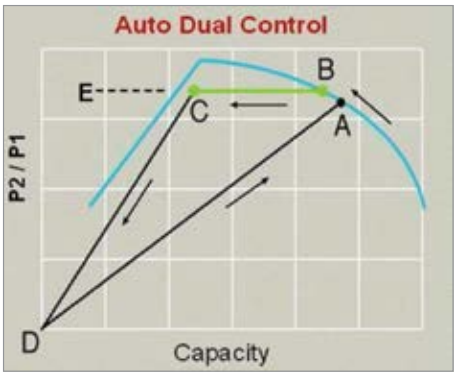

Figure 2

the life or damage the compressor. A qualified technician should be called if repeated surging is occurring. Manufacturers all use surge anticipation control to ensure reliable operation. There are several different methods to accomplish surge control.

Surge Control and Protection

CABP: How do you control and protect from these situations arising during operation?

CAGI: Our members have designed surge control and protection into their products. Surge is a situation that can be avoided. Surge

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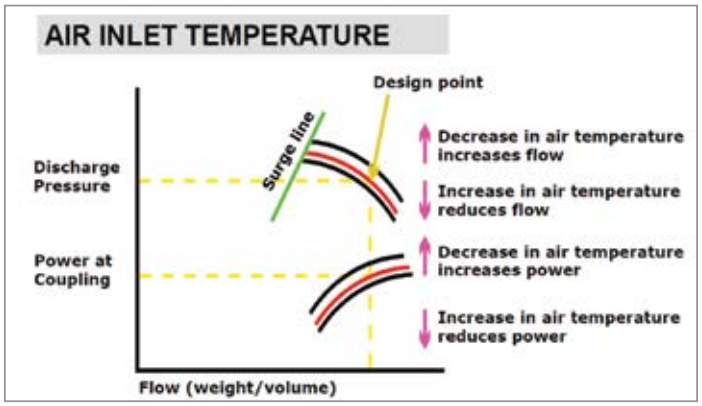
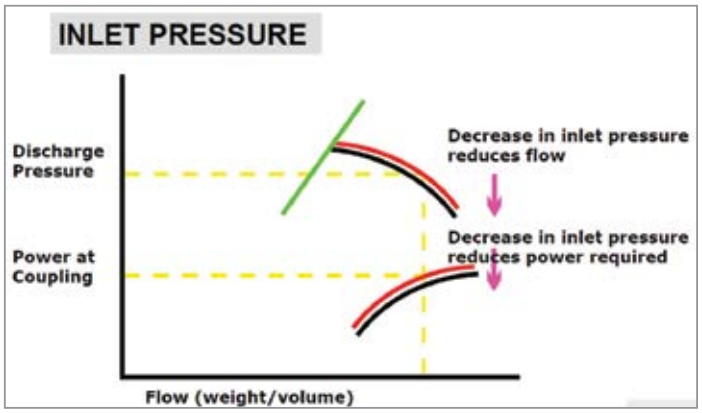
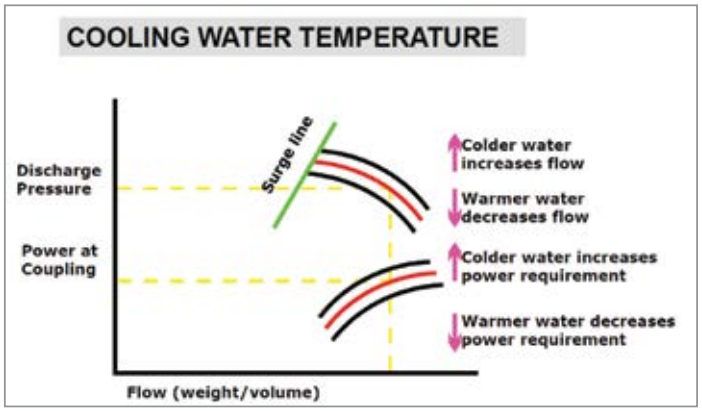
control and protection are available for both auto-dual and constant pressure control systems. In fact, as part of system start-up, technicians manually surge the compressor to set up the control system.

1. Motor current control:

The motor current can be correlated with compressor flow. As flow decreases, the motor current will also decrease. This can be correlated to the surge point of the compressor. With this control, when the motor reaches the minimum current set value, the unloading valve will start opening to prevent the compressor from surging. This method is simple and straightforward, however, it does not always optimize the actual turndown range of the compressor.







2. Surge anticipation control optimization:

To optimize surge anticipation control, the controller monitors the actual position of the surge line with respect to the existing ambient inlet conditions, and prevents the compressor from surge by opening the unloading valve when the compressor flow reaches the surge point. This control optimizes the turndown and allows the compressor to run at actual turndown based on existing ambient inlet conditions.

Modern control systems employed by most manufacturers result in trouble-free, reliable and efficient operation. With several control methodologies to choose from, customers can optimize their centrifugal compressor performance to suit the application needs. Understanding the impact of environmental conditions on compressor performance allows for further improvement in reliability and efficiency.

CABP: Thank you for this overview. Can you tell our readers how they can get more information or assistance on these topics?

CAGI: CAGI's Centrifugal Compressor Section members, including Atlas Copco, Cameron, FS Elliott and Ingersoll Rand, have trained engineers to assist and guide users through selecting the right size and options of the centrifugal compressor for their operation. A compressor system assessment is recommended when upgrading and/or replacing existing systems to assure that system performance is maximized. Our members can also assist in the operation of existing equipment and systems.

For more detailed information about CAGI, its members, compressed air applications, or answers to any of your compressed air questions, please contact the Compressed Air and Gas Institute. CAGI's educational resources include e-learning coursework on the SmartSite, selection guides, and videos, as well as the Compressed Air & Gas Handbook. BP

For more information, contact the Compressed Air & Gas Institute, tel: (216) 241-7333, email: cagi@cagi.org, or visit www.cagi.org.

To read more about ***CAGI,*** visit www.airbestpractices.com/standards.

10 LITTLE-KNOWN VSD AIR COMPRESSOR TWEAKS

By Ron Marshall for the Compressed Air Challenge®

KNOW PRESSURE COMPRESSED AIR CHALLENGE

The introduction of rotary screw air compressors controlled by variable speed drives (VSDs) is one of the best energy efficiency innovations introduced to the industry in the past few years. This style of compressor control can significantly reduce the energy wasted by compressors running in the unloaded condition. But the type of VSD control offered by various manufacturers can differ, and some of these differences can affect the efficiency of the system. This article discusses some little know tweaks to VSD compressor control, including some using hidden features that can sometimes be implemented to enhance the savings gained by the installation of this type of compressor.

Note that these measures are examples of strategies implemented in the author's Manitoba Hydro service territory. Where adjustments were made, the suppliers of the equipment were consulted so as not to affect the lifespan or proper operation of the equipment.

1. Coordinate Target and Start/Stop Levels

VSD controls typically have four main pressure settings. Three of these are to control the start/stop or load/unload pressure bands that are used when the compressor runs below minimum speed. The remaining one is to set the VSD target, which is where the compressor will hold its discharge pressure while varying its speed. There are various default settings programmed into these controls when they come from the factory — some resulting in less than optimum compressor operation.

Some manufacturers lock the VSD target to the "start" setting so they are exactly the same. Others allow independent adjustment of the VSD target to any setting within a set limit. Where independent adjustment is allowed, there are some conditions that may cause problems. If the target pressure is accidentally set above the start/stop or load/unload setting, the compressor will always run fully loaded —

"The introduction of rotary screw air compressors controlled by variable speed drives (VSDs) is one of the best energy efficiency innovations introduced to the industry in the past few years."

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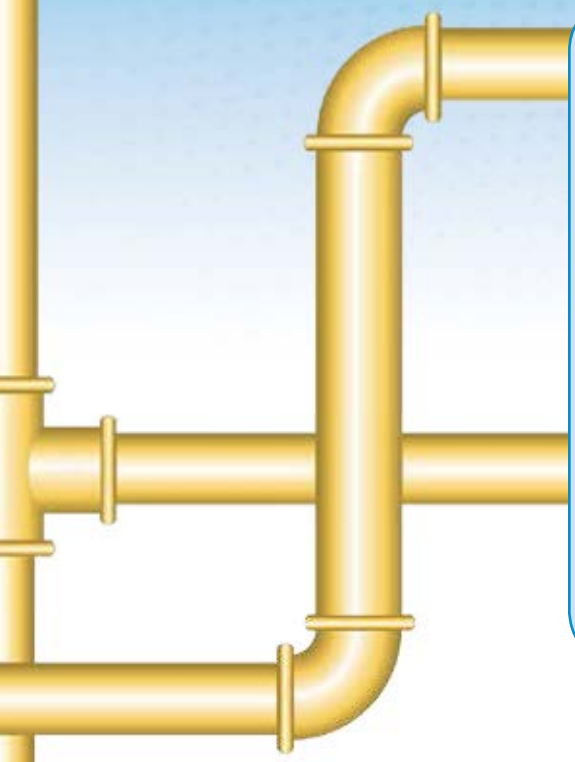

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an inefficient condition for a VSD compressor — and will start/stop or load/unload between the two set points. If the target set point is inadvertently set lower than the pressure band, then the VSD will run at minimum speed while between the high and low set points. However, it will not run in its variable range unless the pressure falls well below the pressure band, another undesirable condition.

If the target set point is somewhere between the high and low set points, it is very common to see this setting exactly in the middle, and then the compressor will immediately ramp to full speed whenever the compressor is called upon to start. It will first try to quickly push the pressure up to the target pressure, and it will then reduce speed to regulate the pressure. This condition increases the start/stop frequency of the compressor and causes fast-changing fluctuations in the pressure, sometimes an undesirable condition. This configuration also often causes the target pressure to be higher than required, therefore causing the compressor to consume more power due to higher average discharge pressure. In the Manitoba Hydro territory, customers are encouraged to set the target pressure at or near the start/load point, resulting in slower compressor cycling, and more stable lower pressures.

2. Decrease Start/Stop Frequency by Widening the Pressure Band

Stable and constant pressure is the ultimate goal in controlling any compressed air system. Those of you familiar with load/unload control will realize that the system pressure is controlled between two set points: the load, and the unload point. This type of control causes a sawtooth pressure waveform if viewed on a time-based pressure data plot (Figure 1, pg. 40). VSD compressors, on the other hand, will keep the pressure at a constant target pressure by speeding up or slowing down the compressor motor.

But the compressors can only slow down so much, with the turn down limited by the characteristics of the compressor components. The main thing causing this limitation is the compressor motor, which cannot cool itself adequately at excessively low speeds. A second limitation is the screw compression element, which must maintain a certain minimum rpm or else internal losses (leakage back through the element) will become excessive. To address this problem, any VSD compressor will have a certain minimum speed where variable speed control is taken over by some other control method.

A common way of controlling VSD compressors at flows below minimum speed is to start/stop or load/unload the compressor. This control mode also produces the typical sawtooth waveform of the load/unload control mode. Since compressor manufacturers recognize that this sawtooth waveform produces undesirable fluctuations in pressure, some manufacturers tend to supply compressors with very narrow pressure bands, sometimes only 3 to 4 psi wide. Unfortunately, a very narrow pressure band, if installed on a system with minimal storage

10 LITTLE-KNOWN VSD AIR COMPRESSOR TWEAKS

capacity, will result in excessive compressor starts and stops, and sometimes excessive lubricant carry over.

When VSD compressors were first introduced, some suppliers were promoting "unlimited starts and stops" capability. However, common sense dictates that introducing a mechanical device to say 50,000 to 100,000 starts per year in the first few years of its life can greatly reduce the life of the controls and the compressor components.

Widening the start/stop pressure band and adding significant system storage will reduce compressor cycle frequency when operating below minimum speed and allow run times long enough to heat the compressor up to operating temperatures. Typical rule-of-thumb sizing used around the Manitoba Hydro area is 10 gallons of storage installed for each cfm at compressor minimum speed. Introducing a wider pressure band of 10 psi means the maximum start and stop frequency is about once every 4 minutes at 50 percent of minimum speed.

By the way, if your compressor is spending too much time in the minimum speed range, you may need to resize your compressor, or problems may result. At minimum speed, too little heat is generated. This is a direct result of good efficiency, which can allow excess moisture to accumulate in the compressor lubricant. In a standard compressor, the heat of compression normally drives off this moisture.

3. Eliminate Unloaded Run Time by Reducing Unload Timer Setting

The control of VSD compressors varies across manufacturers. Some makes of compressors immediately shut off when the pressure reaches the "stop" level, while others continue to run in the unloaded state. Others still may have a mode selection setting somewhere in the control that allows you to select whether the compressor immediately turns off or not. One brand counts the number of starts per hour and allows shut down when conditions allow, saving power.

When in the unloaded state, screw compressors — be they fixed speed or VSD — continue to consume energy while producing no air, reducing the overall efficiency of the unit. Often, when good compressed air design practices are followed, conditions exist where the run timer can be greatly reduced, or even set to zero to avoid this wasteful condition. This tweak needs to be cleared by your compressor supplier to avoid warranty issues. If the compressor has a wide enough pressure setting, and large enough storage to work with the number of starts and stops can be limited, you can avoid problems due to excessive cycling and still allow more efficient operation.

4. Install Remote Pressure Sensing

It is common to see VSD compressors hold a very precise pressure at their discharge, while the plant pressure sags due to pressure

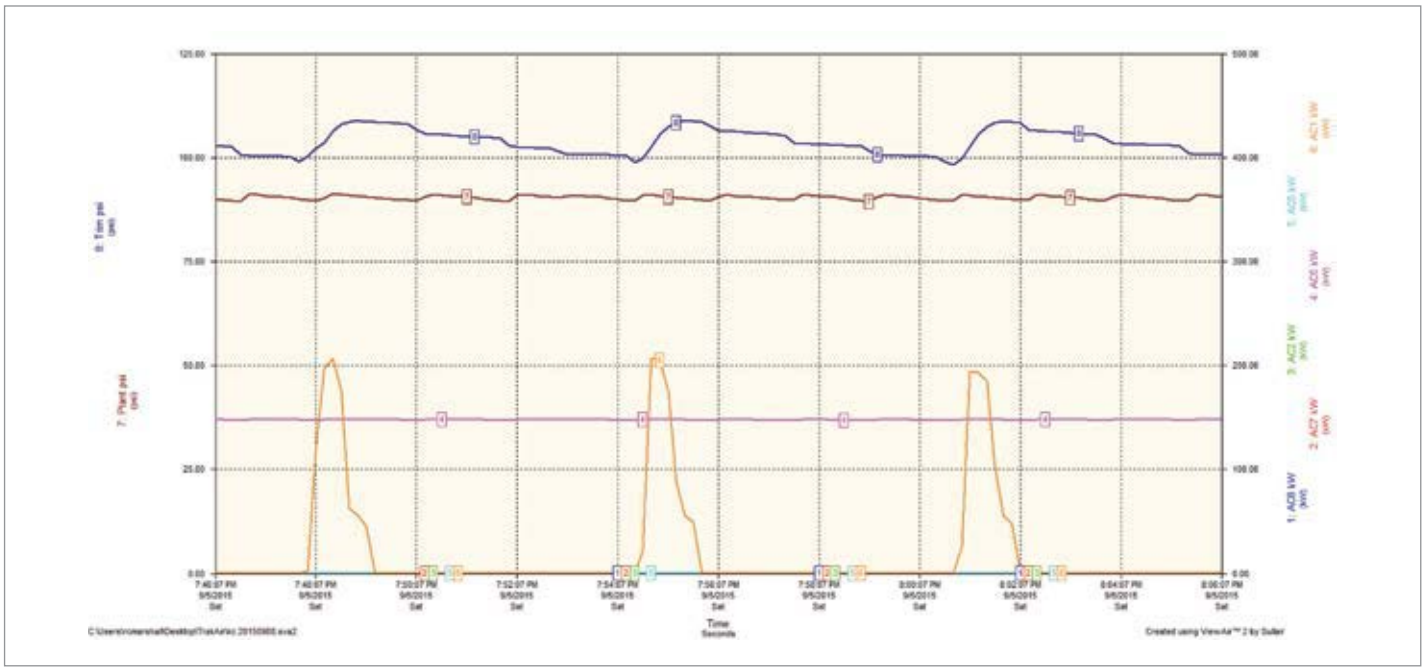

Figure 1: Typical sawtooth waveform results in higher than required average pressure, causing the compressor to go to full load when starting increases the cycle frequency.

differentials across piping, filters and air dryers. These pressure differentials may be small when flows are low, but large during plant peak demands. Since having a stable plant pressure is the ultimate goal, it is a good idea to make the pressure sensing of the compressor remote, where is can be done safely without exceeding the pressure capability of the compressor. Adding a remote pressure sensor allows the VSD to "see" past any pressure drops in the compressor room and precisely regulate plant pressure.

This measure also saves energy because the target pressure can be set exactly where it is needed rather than at an artificially high level to compensate for the worst case pressure differential. When flows are low, there is minimal pressure differential across clean-up components: Therefore, the compressor keeps its discharge low. During higher flows, the compressor will automatically increase its discharge pressure to compensate for the pressure differential, but only during these conditions.

5. Adjust PID Control Settings

Sometimes when remote sensing is implemented, or when the characteristics of the compressed air demand contains widely varying loads, the compressor will constantly overshoot and undershoot the target pressure. There are some conditions where this instability results in the compressor having unstable control, causing a regular sinusoidal pressure output as the compressor tries unsuccessfully to meet target pressure. Because of the nature of compressed air, it acts like a spring, has momentum, and bounces around inside the pipes. Consequently, it is sometimes hard to control pressure precisely. For these reasons,

10 LITTLE-KNOWN VSD AIR COMPRESSOR TWEAKS

Best Practices for Compressed Air Systems Second Edition

Learn more about VSD compressor control

This 325 page manual begins with the considerations for analyzing existing systems or designing new ones, and continues through the compressor supply to the auxiliary equipment and distribution system to the end uses. Learn more about air quality, air dryers and the maintenance aspects of compressed air systems. Learn how to use measurements to audit your own system, calculate the cost of compressed air and even how to interpret utility electric bills. Best practice recommendations for selection, installation, maintenance and operation of all the equipment and components within the compressed air system are in bold font and are easily selected from each section.

VSD compressor manufacturers put PID control algorithms in the compressors to help tune out these problems and stabilize the pressure. But the manufacturers simply tune the default settings to average conditions, and your system may have different characteristics (Figure 2).

When a VSD compressor is constantly undershooting and overshooting, the mechanical and electrical stresses are negatively affecting the compressor. If you find that this is happening on your system, you should ask your supplier to come and make careful adjustments. It is rare to find a system that cannot be adjusted by tuning the PID loop and/or adding storage receiver capacity.

6. Set Timed Pressure Levels

Some VSD compressor controls have internal scheduling capabilities where different pressures can be programmed during different times of the week or day. In addition to this, some controls allow different pressure levels to be programmed to respond to the position of an external switch. In this way, the compressor can be programmed to operate at low pressure — say during nights and weekends — but increase the pressure during main shifts. Also, an external switch can be used to trigger higher short-term pressure levels during occasional events that need higher pressure, such as 110-psi tire filling, but allow the system to return to normal 90-psi operations during average conditions. This saves energy by reducing artificial demand and average compressor discharge pressure.

7. Eliminate Minimum Speed Modulation

Some VSD compressors also have inlet modulation controls that are used to gain very low turn-down capabilities (in the range of 12 percent of full load) to gain better pressure control through the full range of compressor operation. Unfortunately, like fixed-speed compressors, the application of modulation on VSD compressors results in less than optimum efficiency levels. In some cases, these modulation controls have been inadvertently adjusted to restrict inlet flow within the variable range of compressor operation.

In the Manitoba Hydro territory we encourage our customers to eliminate modulation of VSD compressors by adjusting the modulation setting well away from the target and start/stop pressure band. This requires adjustment by the compressor supplier and sometimes more system storage to reduce start/stop frequency, but it often increases system efficiency.

8. Increase Minimum Speed Settings

If you examine the CAGI curve of some compressors, you will see that the efficiency (kW/100 cfm) of most VSD compressors drops off as the compressor nears minimum

"When a VSD compressor is constantly undershooting and overshooting, the mechanical and electrical stresses are negatively affecting the compressor."

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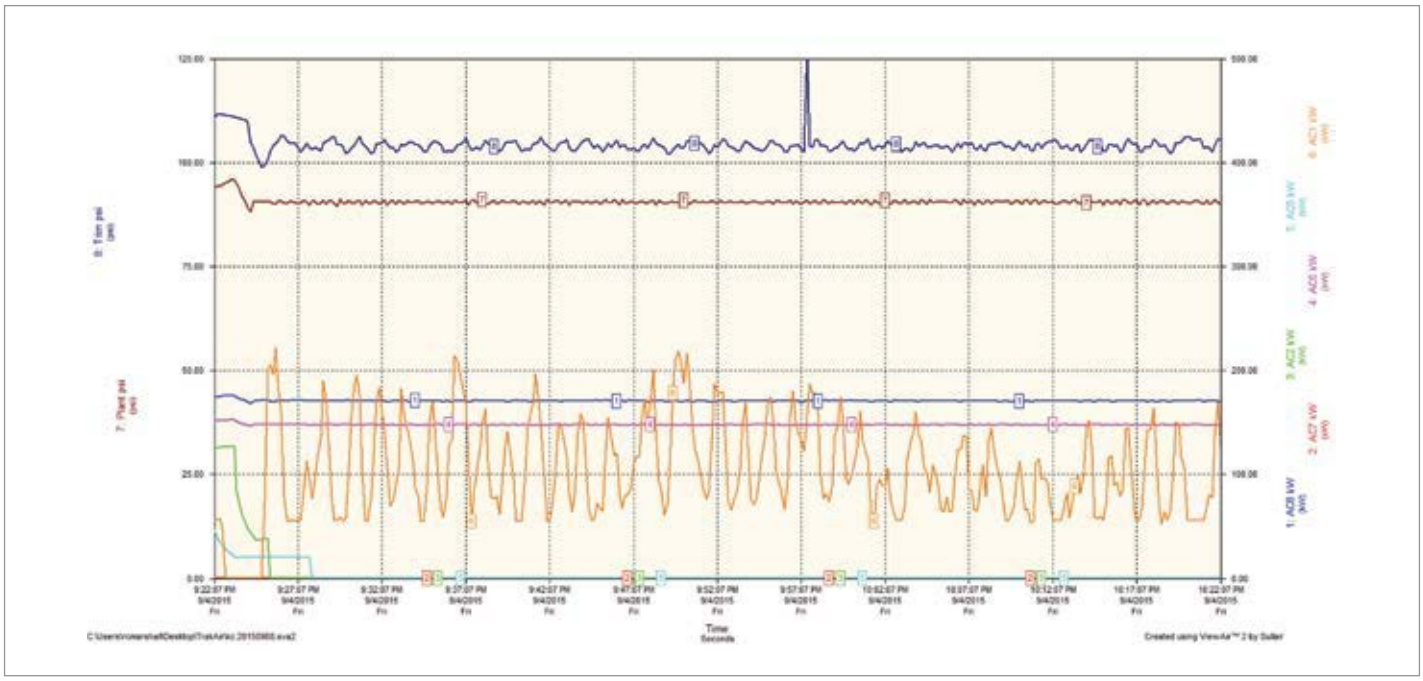


Figure 2: This compressor (orange line) exhibits instability, requiring an adjustment of the PID parameters.

speed. This efficiency degradation varies with the make and model of compressor, and appears to be more pronounced for smaller compressors of 75 hp or less. Often manufacturers will limit the minimum speed of their brand of compressor to keep the units out of the inefficient range. Where this is not done, the compressor controls may have a minimum speed setting hidden in the control parameters that can be adjusted to keep the compressor at more efficient, higher minimum speeds. This adjustment comes with a trade-off, reducing the variable band.

In the Manitoba Hydro territory we ask our customers to increase their minimum speed settings, where applicable, and add larger storage to compensate for this change to make the compressors more efficient. Adjustment of minimum speed is done by the compressor supplier.

9. Reduce Maximum Speed Settings

Sometimes a compressor that is too large is purchased by a company in anticipation of higher future production levels. If a large compressor is installed in a system with high peak loads, the compressor may contribute to the facility peak demand charges, costing additional electrical costs.

Some VSD compressors have a maximum rpm setting where the compressor's maximum kW can be temporarily reduced. When done in conjunction with additional storage capacity, this adjustment can reduce electrical costs.

10. Pair VSD Compressor with Smaller Compressor

Often, when a VSD compressor is installed that is too large for the load, the unit will spend most of its operating time in start/stop mode below the variable range. Most manufacturers will tell you that long-term operation in this mode is not desirable due to reasons already mentioned. This often occurs in systems feeding automotive repair shops or the like where the average load may be very light (10 to 20 percent), but peak flows will occur during operation of large pneumatic tools. In these cases, where resizing the compressor is not practical, it may be wise to install a much smaller compressor, which could also be VSD controlled to feed the very light loads, but have the large compressor set to run during high loads. In this way, each running compressor, either large or small, would match the operating condition and run within the optimum loading range, saving expensive future repair costs. BP

For more information, contact Ron Marshall at info@compressedairchallenge.org.

To read more about ***Compressor Controls,*** please visit www.airbestpractices.com/technology/compressor-controls.

RESOURCES FOR ENERGY ENGINEERS

TECHNOLOGY PICKS

Sullair Releases Centrifugal Compressors

Sullair, an industry leader in innovative compressed air solutions since 1965, announced centrifugal compressors are now available through Sullair distribution channels. Sullair and IHI, two industry experts, have been part of a joint venture since 2004 designing, producing and selling advanced centrifugal compressors. The line, branded Sullair powered by IHI, will be supported by key distributors throughout North, Central and South America.

"Our centrifugal compressor line allows us to expand into new markets and applications," said Brian Tylisz, Vice President of Oil Free and OEM at Sullair. "Sullair is well known in the 5 to 600 hp rotary screw range. Now our centrifugal line gives us access to enhanced technology, allowing us to expand up to 30,000 hp."

Sullair offers two families of centrifugal compressors: the T-series and f-series. T-series compressors come in complete packages, with models ranging from 168 to 2,306 hp, producing flows from 553 to 11,772 cfm. f-series compressors are available in both packaged and non-packaged options — custom designed to meet the user's specific needs and available from single stage up to four stages, offering flow rates up to 118,000 scfm. Both series offer 100 percent oil-free air, a highly efficient design to reduce energy usage, and horizontal split design gearbox, allowing easy access to all moving parts and simplifying maintenance.

Pictured is a T-series centrifugal compressor from Sullair's very first installation in Midland, Michigan.

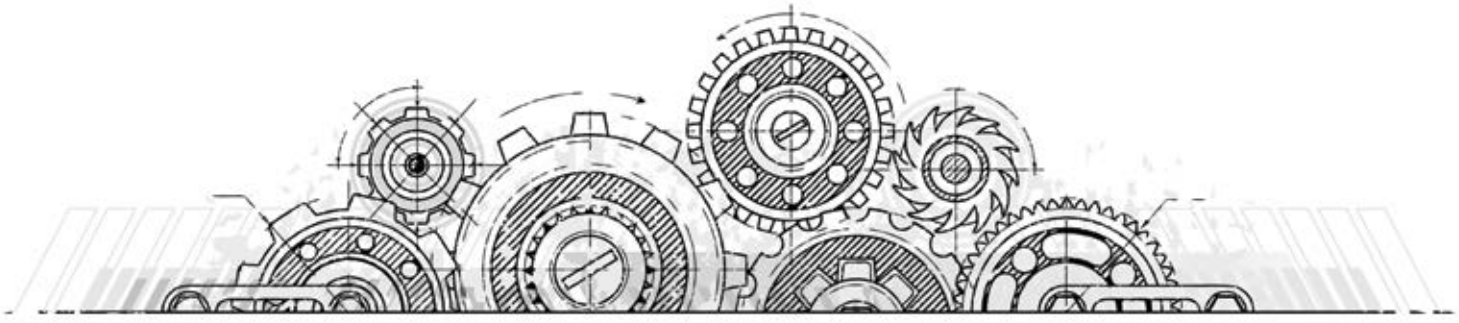
Centrifugal compressors are heavily used in steel mills, petrochemical, chemical, oil and gas, air separation and automotive industries, among others. Sullair centrifugal compressors are an addition to an already extensive line of portable and stationary rotary screw air compressors, compressed air treatment equipment and rotary screw components for OEMs. Globally, IHI and IHI-Sullair have produced more than 10,000 centrifugal compressors. IHI has been supplying centrifugal compressors since 1970.

For more information, visit www.sullair.com.

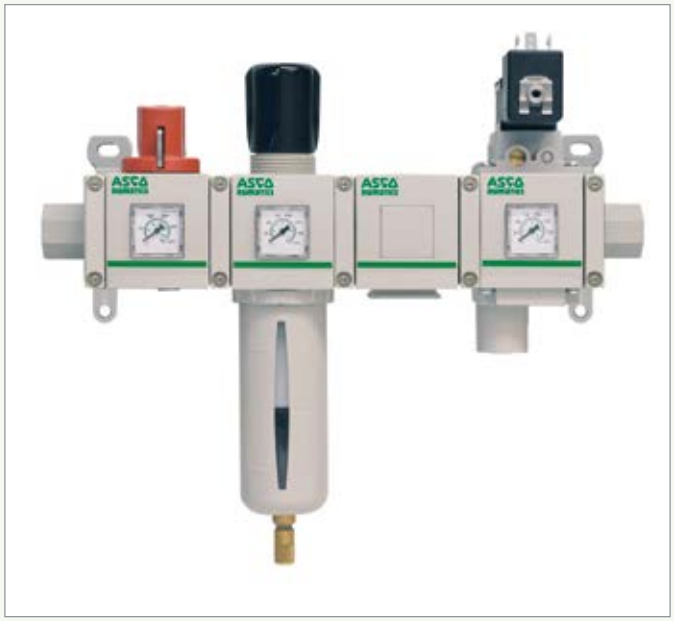
ASCO Numatics Introduces New Filter, Regulator and Lubricator (FRL)

ASCO Numatics is introducing its 652 Series filter, regulator, and lubricator (FRL) line of air preparation products. The 652 Series features high flow characteristics and the widest high- and low-temperature ratings of any FRL — making it ideal for a broad range of applications.

"With the highest flow rates in the industry, our all-new 652 Series FRL assures original equipment manufacturers (OEMs) and maintenance managers that air preparation products from ASCO Numatics will optimize their machine performance," said Robert W. Kemple, Jr., executive vice president, sales and marketing –



TECHNOLOGY PICKS



ASCO Numatics' 652 Series filter, regulator, and lubricator (FRL)

Americas, ASCO Numatics. "In addition, the 652 Series' extended high- and low-temperature capabilities (-40˚ C to 80˚ C) allow it to be specified across a broad range of applications, including those within harsh environments."

These modular FRL products have robust construction and are easy to assemble, mount, and position. In addition, their new manifold endplate flanges allow the maintenance technician to pull the manifold assembly out of service without disconnecting the piping. The product line is available in three port sizes, ranging from 1/4 inch to 1/2 inch (NPTF, G, or R threads).

The 652 Series incorporates front-facing, easy-to-read, low-profile gauges. It is the only product of its type to also offer these gauges on its shut-off isolation valves and slow-start/quick-exhaust valves. Optional integral pressure range indicators allow the user to easily set the red/green color indicators to the desired pressure range. The 652 Series not only meets the need for a small footprint, but also results in clean lines and robust, modern-looking equipment.

An optional pressure regulator with reverse flow check permits the design engineer to place the regulator between the valve and cylinder. This allows air to be exhausted back through the regulator without causing damage or reduced life. Additionally, an optional 3-micron pleated pre-filter has been added to the line's coalescing filters and coalescing filter/regulator combination units. This filter eliminates the need for a separate particulate filter unit, reducing cost, size, and weight.

"Our new air preparation products are the perfect fit for applications in the automotive and tire, packaging, food and beverage, and process industries requiring high flow, wide temperature characteristics, highly reliable operation, and easy installation and service," said Kemple.

For more information, www.asconumatics.com.

Sullivan-Palatek Announces SP16 Compressors

Sullivan-Palatek, Inc. recently announced that its SP16 Series 75, 100, 125 HP Industrial Electric Compressors are now available for distribution.

The newest member of the SP-Series, the SP-16, offers features that optimize size, efficiency, and operation.

The new SP16 series covers all applications possible — from 75 psig up to 250 psig — in a single stage, making it one of the most versatile packages on the market. Packages come standard with across-the-line starters, and optional Y delta, SSRV and VFD available.

An air after-cooler moisture trap with auto drain is now standard. An oversized air inlet valve, air inlet filter, and robust air oil cooling maximize package efficiencies.

RESOURCES FOR ENERGY ENGINEERS

TECHNOLOGY PICKS

Pictured is the SP-16 Series Compressor, the newest member of Sullivan-Palatek's SP-Series.

Compared to its predecessors, the SP16 has a much smaller footprint and is considerably quieter during operation. Without an enclosure, the compressors can operate at 72 to 76 dBA. With the enclosure, the machine operates at a whispering 66 to 72 dBA.

The new air end, designed and manufactured in-house, features oversized inlet and discharge ports, adding to the overall efficiency of the package. Robust bearings designed for maximum B-10 life, quiet-running gears, and precision-cut rotors all combine for the ultra-low Dba levels without a canopy.

End user interface is enhanced with the use of the new Q1 microprocessor. The Q1 has all the features of its predecessor the T1, but now includes a more detailed fault history of system snap shots, and current transformers capable of interface with all motor wiring.

The new Q1 also has the enhanced display with more parameter features shown during operation.

For more information, visit www.sullivan-palatek.com.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TECHNOLOGY PICKS

FilterSense Baghouse Controller Addresses Portland Cement NESHAP

The B-PAC™ series of Baghouse Performance Analyzers & Controllers offers a combination of features to help the bulk powder processing, air pollution control and dust collection processes at cement plants meet regulatory NESHAP compliance, while simultaneously reducing operating costs and improving the process.

The controllers tightly integrate control, sensing and high-speed digital signal analysis to provide time and money saving diagnostics, including: zero, span and sensor self-checks to EPA Standards; the ability to detect/locate filter leaks weeks before emissions are visible; the ability to detect/locate failed pulse solenoids that can lead to plugged filters; and the ability to instantly detect/locate ruptured or frozen pulse-jet diaphragms.

Optional FIlterWARE™ provides further automation of compliance EPA Report Generation and record keeping. The controllers are easy-to-use, high-quality, heavy-duty products designed for long-life in harsh process environments. A series of models for small cartridge collectors to medium, multi-compartment baghouses are also available.

For more information, visit www.filtersense.com.

The B-PAC™ baghouse performance analyzer and controller

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APPLICATIONS ENGINEER

We have an exciting opportunity at our Industrials – Americas Group Headquarters in Quincy, IL, for an Applications Engineer. This position works with product management, outside sales, distribution, and customers in developing complete air compressor systems that meet their needs from a performance, installation, and implementation standpoint. This position will focus heavily on compressed air system audits and translating audit data into optimized system design and compressed air best practices. This position will also support the marketing of system solutions and products to potential customers to encourage the specification of Gardner Denver products. Will take the lead role in preparing written proposals, proposal drawings and diagrams, bid packages and ongoing project / sales support for custom system design.

Abilities and qualifications should include:

- Bachelor's degree in Engineering (Mechanical or Electrical) or other applicable discipline
- Five + years' experience in the application and design of compressed air systems and strong background in air audits
- Aptitude for both technical and commercial requirements of project management
- Strong customer relations, strategic thinking, and analytical skills
- Proactive and proficient at leading cross-functional teams
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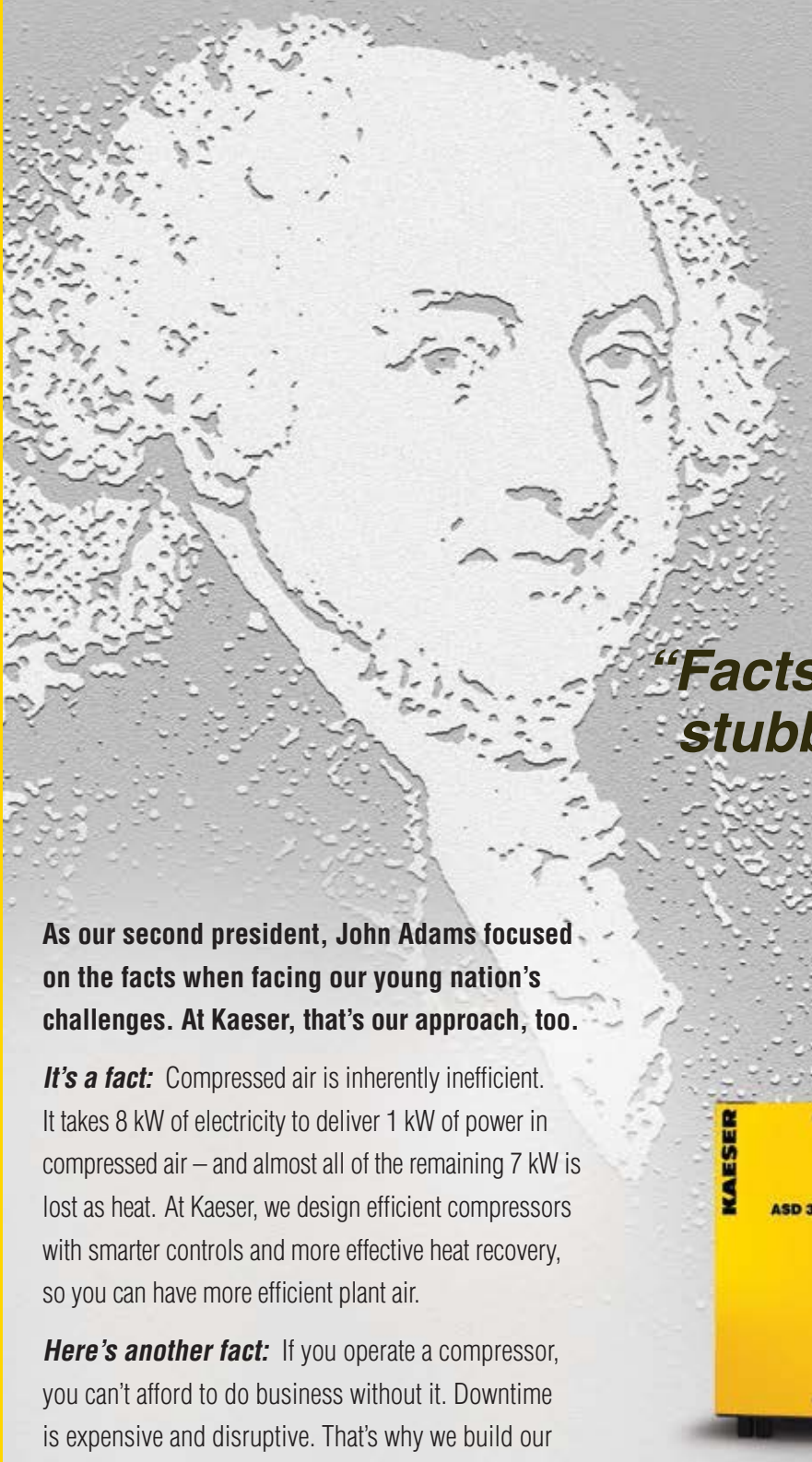

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