The Magazine for ENERGY EFFICIENCY in Compressed Air Systems

COMPRESSED AIR BEST PRACTICES

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September 2017

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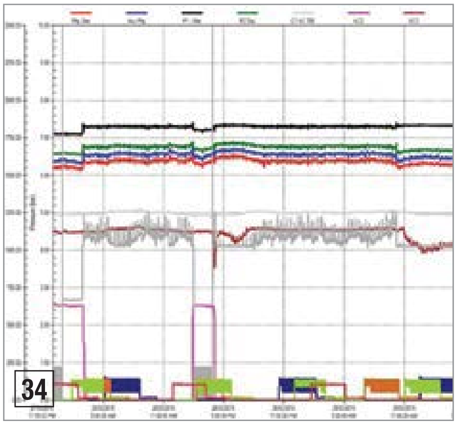

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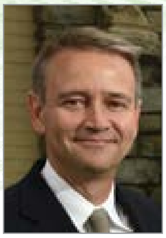
FROM THE EDITOR | System Optimization



Centrifugal air compressors can be an excellent choice, in certain applications. The Members of the Centrifugal Compressor Section of the Compressed Air & Gas Institute have provided us with an article reviewing how to apply them under variable and low load working conditions.

The Trulite Glass and Aluminum Solutions manufacturing plant is located in Ontario, Canada. Alan Brossault and Jan Hoetzel (Airleader) provide us with a very interesting compressed air system assessment story about the work they performed there. This remarkable assessment project reduced energy consumption by 83 percent and was verified by the utility who awarded an incentive check of $147, 428 CND.

We return to the topic of centrifugal air compressors with an article from Tim Dugan, P.E., titled, "Centrifugal Air Compressor Controls and Sizing Basics." This well-structured article reviews centrifugal air compressor basics, performance curves, control mechanisms and discusses sizing topics.

An electronics manufacturing firm, requiring Instrument Air Quality, is the subject of a system assessment articled provided by Ron Marshall. A relatively new plant built in 2012, the system consists of three large 1,000 kW base load centrifugal air compressors, a 500 kW centrifugal, and a 500 kW VSD rotary screw air compressor. The energy costs to run the compressed air system are $2.3 million. I hope you enjoy this system assessment article.

Thank you for investing your time and efforts into ***Compressed Air Best Practices***®.

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Atlas Copco Acquires Glauber Equipment's Air Compressor Business

Atlas Copco, a leading provider of sustainable productivity solutions, has acquired Glauber Equipment Corporation's air compressor-related business. Glauber Equipment is an Atlas Copco compressed air distributor and service provider located in Lancaster, N.Y.

"The strong team at Glauber Equipment will be a great addition to our group," said John Brookshire, president of Atlas Copco Compressors LLC. "Adding Glauber Equipment to our team provides us with direct connections to our customers and an increased focus in Upstate and Western New York."

Glauber Equipment sells, rents, installs and services Atlas Copco products, including air compressors and ancillary equipment, to industrial manufacturers and other customers. The company has provided blower, air compressor and vacuum systems in the region since 1960, serving customers in the food and beverage, pharmaceutical, environmental, chemical, textile, agriculture and other industries. Sixteen Glauber Equipment employees are joining Atlas Copco.

About Atlas Copco

Atlas Copco is a world-leading provider of sustainable productivity solutions. The Group serves customers with innovative air compressors, vacuum solutions and air treatment systems, construction and mining equipment, power tools and assembly systems. Atlas Copco develops products and services focused on productivity, energy efficiency, safety and ergonomics. The company was founded in 1873, is based in Stockholm, Sweden, and has a global reach spanning more than 180 countries. In 2016, Atlas Copco had revenues of BSEK 101 (BEUR 11) and about 45,000 employees.

Atlas Copco's Compressor Technique business area provides industrial air compressors, vacuum solutions, gas and process compressors and expanders, air and gas treatment equipment and air management

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Planning, installing and operating the Sigma Air Utility system is Kaeser's responsibility, allowing users to save on the investment and maintenance costs of a compressed air system.

systems. The business area has a global service network and innovates for sustainable productivity in the manufacturing, oil and gas, and process industries. Principal product development and manufacturing units are located in Belgium, the United States, China, South Korea, Germany, Italy and the United Kingdom. For more information visit www.atlascopco.us.

Kaeser Sigma Air Utility Program

Kaeser's Sigma Air Utility (SAU) program offers many advantages of a cost-effective, energy-saving compressed air supply without the need for any initial capital investment. Planning, installing and operating the system are Kaeser's responsibility. This allows users to save 100% of the investment cost for a compressed air system and removes the burden of having to allocate staff and funds for maintenance and servicing work. As a leading compressed air solutions provider, Kaeser assures maximum air system efficiency and reliability at all times. Naturally, it is also in Kaeser's interests to continually adapt the station to meet changing operating conditions and incorporate the very latest technological innovations.

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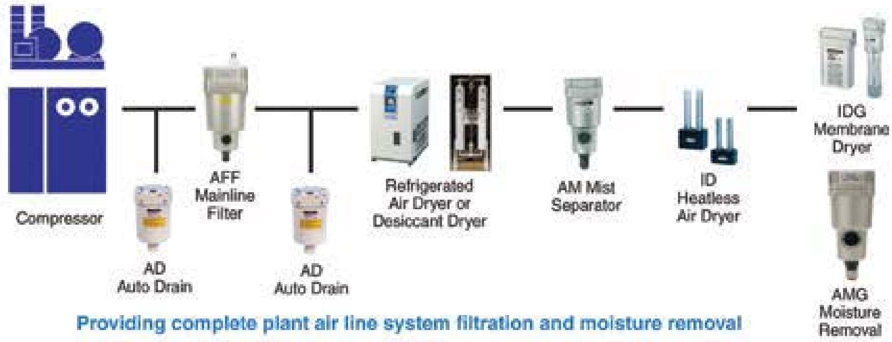

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air. Should consumption exceed the amount, a specified surplus air charge is applied.

Sigma Air Utility represents a highly attractive option for compressed air supply when existing equipment is at the end of its depreciation cycle and/or rapid energy efficiency improvements are desired. It is not unusual for end-users to achieve long-term savings of 30% or more.

About Kaeser

Kaeser is a leader in reliable, energy efficient compressed air equipment and system design. We offer a complete line of superior quality industrial air compressors as well as dryers, filters, SmartPipe™, master controls and other system accessories. Kaeser also offers blowers, vacuum pumps, and portable gasoline and diesel screw air compressors. Our national service network provides installation, rentals, maintenance, repair and system audits. Kaeser is an ENERGY STAR Partner.

For more information, visit www.kaesernews.com/SAU. To be connected with your local authorized Kaeser representative, please call (877) 596-7138.

Kobe Steel Opens Air Compressor Service Company in Philippines

Kobe Steel, Ltd. has established a company in the Philippines to dispatch supervisors and provide engineering services for its nonstandard air compressor business. Named Kobelco Machinery Philippines Inc. (or KMP), the new company has opened and is now in full operation.

KMP is headquartered in Makati City, Metro Manila and employs 21 people. It is a wholly owned subsidiary of Kobelco Machinery Asia Pte. Ltd. in Singapore, who in turn is 100% held by Kobe Steel.

The new company provides an optimal framework for supervisor dispatch services and engineering work for Kobe Steel's

The staff of Kobelco Machinery Philippines with President Miyoshi Sagesaka (back row, second from the left).

nonstandard air compressor business in the region. Supervisors are in charge of the installation, commissioning and after-sales service of nonstandard air compressors, or custom-engineered air compressors.

Through KMP, Kobe Steel can further grow its nonstandard air compressor business and strengthen its supervisor dispatch services. Kobe Steel has increased the number of supervisors in Japan (Takasago Works), the United States (California) and China (Wuxi). The Philippines is now the fourth country where Kobe Steel has local supervisors. By increasing staff and improving their mobility, Kobe Steel aims to increase orders for air compressors and after-sales service in the region.

In addition, KMP enables Kobe Steel to optimize its engineering work. Kobe Steel can transfer work currently undertaken at Takasago Works in Japan to KMP and also divide some of the work between the two locations. This framework enables Kobe Steel to choose the best location to carry out engineering work and meet the requirements of its customers. Engineering work covers the design of OEM parts and arrangements for their procurement.

As one of the world's leading manufacturers of air compressors, Kobe Steel plans to expand its services in the region through KMP in the Philippines and set down roots in areas of demand to grow its global business.

Background Information

Under its medium-term management plan launched last year, Kobe Steel is expanding its air compressor business as a growth strategy of its machinery-related businesses. In fiscal 2020, Kobe Steel aims to achieve air compressor sales of 130 billion yen, an increase of more than 40 percent compared with fiscal 2016. To achieve this goal, Kobe Steel plans to make further progress in the estimated 1-trillion-yen world market for nonstandard air compressors.

In April, it opened a large-capacity 40 MW air compressor test facility. Furthermore, Kobe Steel is responding to the global market by reinforcing its supervisory functions involving after-sales service. It is increasing the amount of its design work, while lowering design costs. Kobe Steel is also appointing local staff to provide onsite engineering services.

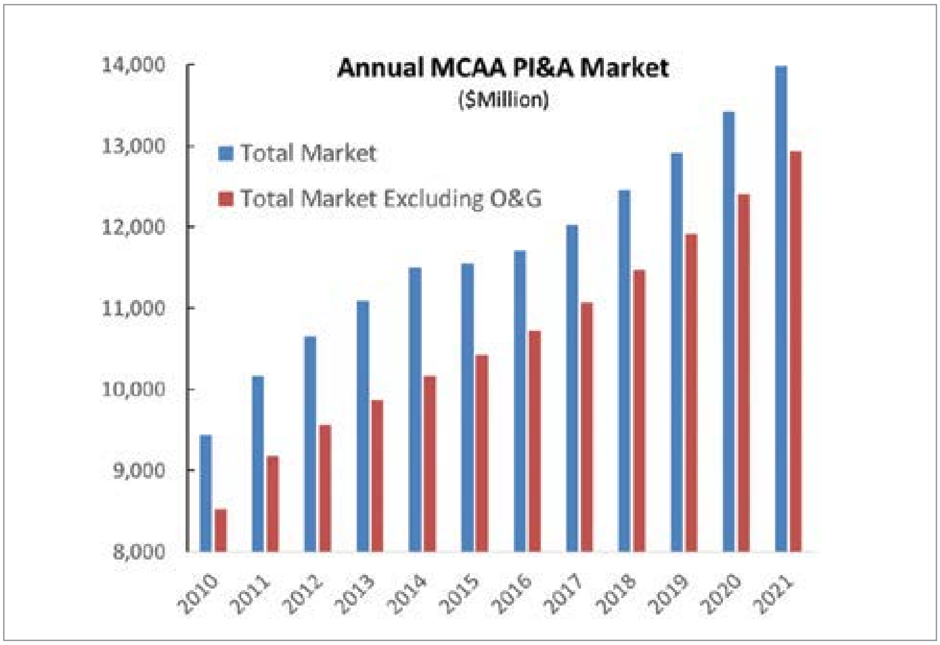
For more information, visit www.kobelco.com.

INDUSTRY NEWS

MCAA Market Forecast Projects Industry Increase to $14 Billion by 2021

The 2016 Process Instrumentation and Automation market in the United States, valued at $11.7 billion, is projected to grow 3.6% by 2021 to a total of $14 billion.

The Measurement, Control & Automation Association (MCAA) has published its Annual Market Forecast for 2017. The report, prepared by the analysts at Global Automation Research, focuses on the Process Instrumentation and Automation (PI&A) markets in both the United States and Canada. Twelve industry segments and product categories are examined in-depth, with a forecast timeline extending to the year 2021.



The Process Instrumentation and Automation market in the United States is projected to reach $14 billion by the year 2021.

Growth will be concentrated in five industries: chemicals, electric utilities, oil refining, food and beverage, and pharmaceuticals. The cumulative market gain will be $2,282 million over the forecast period. The chemicals industry market gain will be the largest at about $850 million. The next four fast-growing industries will add over $1 billion in market gain. The market gain of the remaining slow-growing industries will equal about $340 million.

Oil and gas spending is expected to be essentially flat in 2017, and then increase through the end of the forecast period. The five-year CAGR is forecast to be 1.4%.

The 2016 Canadian PI&A Market value was $1,211 million, versus $1,202 million in 2015. Gains in non-oil and gas industries were negated by the continuing drop in oil and gas spending through 2016. The market is forecast to grow at 3.8% CAGR over the five- year forecast period, reaching $1,458 million in 2021. Six industries — chemicals, food and beverage, electric utilities, oil refining, W&WW and pharmaceuticals — as a group, will grow at a 4.8% five-year CAGR. Economic forecasts suggest the Canadian GDP will remain above 2% over the forecast period, creating a strong base for continued growth in PI&A spending.

As the voice of the measurement, control and automation industry, MCAA provides industrial manufacturers and distributors the best community and resources for business effectiveness and growth through unsurpassed market and business insights, unique networking opportunities, effective employee onboarding and development programs and unbiased, affordable market data. This report is included in annual membership but can be purchased by non-members for a fee. Please contact MCAA for purchase details or visit https://themcaa.org.

Alliance Board Adds Congressmen, Tech Business Leaders

The Alliance to Save Energy's Board of Directors elected seven new members, including members of Congress and business leaders in the technology and manufacturing sectors, to help lead the organization's work to advance energy efficiency in the United States.

The newly elected members are:

- Sen. Lamar Alexander (R-Tenn.)
- Rep. Dave Reichert (R-Wash.)
- Paula R. Glover, President & CEO, The American Association of Blacks in Energy
- Bert Van Hoof, Partner – Group Program Manager, Microsoft
- Andreas Schierenbeck, CEO, Thyssenkrupp Elevator AG
- Mayrose T. Sylvester, President & CEO, Current, powered by GE
- Steve Wright, General Manager, Chelan Public Utility District

Alliance President Kateri Callahan welcomed the new board members, saying, "The Alliance is very fortunate to be led by policy makers and innovative business leaders who are tireless champions of energy efficiency and who work hard — on a bipartisan basis — to drive energy productivity gains, which in turn, creates jobs, increases prosperity and helps the environment."

"We're particularly pleased to be adding two senior Republicans to our bipartisan

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honorary board as we continue to work with Congress on advancing smart policy," she added. "And we're thrilled to have these true innovators working in the technology, manufacturing and energy fields joining our leadership as we navigate the tremendous changes taking place in the energy space. Technology is creating enormous opportunities for how we produce, deliver and consume energy. The experience and wisdom of these new board members will help keep the Alliance at the forefront of that movement."

Sen. Alexander, who chairs the Senate Appropriations Subcommittee on Energy and Water Development and holds a seat on the Energy and Natural Resources Committee, has long been a champion of energy efficiency, having cosponsored the Smart Manufacturing Leadership Act among other bills. His state, Tennessee, is home to 27,529 energy efficiency jobs, according to the Department of Energy (DOE).

"The Alliance to Save Energy does important work to encourage energy efficiency and a healthier and cleaner environment," Sen. Alexander said. "Government-sponsored basic energy research is one of the most important things our country can do to improve energy efficiency, encourage innovation, help our free-enterprise system create good jobs and make America more competitive in a global economy. I will continue to work in Congress to ensure funding for energy research is a priority."

Representing a district supporting 3,441 jobs in energy efficiency, Rep. Reichert has cosponsored legislation to benefit taxpayers, non-profits and governments through energy efficiency tax deductions. Reichert is a senior member of the tax-writing House Ways and Means Committee, where he chairs the Subcommittee on Trade.

Rep. Reichert said, "Job growth, national security, and a clean environment can be achieved through innovative, alternative energy solutions. The purity of the air we breathe and the conservation of our natural treasures are issues impacting all of us. In my home state of Washington, we have already seen some of our nation's most innovative minds create energy-efficient companies that work to create jobs and keep my region and the country clean, green and pristine."

Paula R. Glover, President & CEO at The American Association of Blacks in Energy, leads the national office and provides strategic direction and leadership for the organization. With a strong background in government and regulatory affairs in the energy industry for both electric and natural gas distribution companies, Ms. Glover was appointed to the National Petroleum Council in 2014 by former Energy Secretary Ernest Moniz.

Bert Van Hoof, Partner – Group Program Manager at Microsoft, is a seasoned technology executive recognized for starting and growing award-winning businesses across a variety of industry segments and technology areas. His incubation efforts around the Internet of Things (IoT) led to several new cross-company initiatives and to Bert's latest role in Microsoft Azure, where he is helping organizations put the Internet of Things and Microsoft's Intelligent Cloud to work across a variety of industries, including Smart Buildings and Smart Cities.

Andreas Schierenbeck, CEO at Thyssenkrupp Elevator AG, began his career in 1992 as a control center software developer, followed by positions in commissioning, project management and business development. Since then he has led efforts in major technology companies focused on building technologies and automation.

Maryrose Sylvester, President & CEO of Current powered by GE, a first-of-its kind startup within the walls of GE blending advanced energy technologies like LED and solar with networked sensors and software. Backed by GE's industrial strength Predix platform, Current works with a broad ecosystem of development partners to make commercial buildings and industrial facilities more energy-efficient and productive.

Steve Wright, General Manager, Chelan Public Utility District, has led the development of a community-based Strategic Plan, encompassing aggressive energy efficiency programs. Throughout his career in the energy industry, Wright has held several Administrator/CEO roles, including with the Bonneville Power Administration where he oversaw substantial increases in energy efficiency investments, and BPA was named a Star of Energy Efficiency award winner from the Alliance to Save Energy in 2004.

About the Alliance to Save Energy

Founded in 1977, the Alliance to Save Energy is the leading energy efficiency coalition in the nation – a nonprofit, bipartisan alliance of business, government, environmental and consumer leaders advocating for enhanced energy efficiency across all sectors of the economy. Our mission is to promote energy efficiency worldwide to achieve a healthier economy, a cleaner environment and energy security. For more information, visit http://www.ase.org.

Applying Centrifugal Air COMPRESSORS FOR VARIABLE LOADS

By the Compressed Air & Gas Institute Centrifugal Compressor Section

Introduction

Most compressed air applications have varying demand based on the process for which the compressed air is being used. There are many choices of compressor technology and types of controls that can be used for variable demands. Some examples are rotary screw compressors with inlet valve control: variable speed drives: load/unload control; or centrifugal compressors with variable inlet guide vanes. However, in many cases, the efficiency of the overall compression process can be reduced significantly during lower flow demands, leading to more power per unit of air flow being delivered. It is very important to evaluate different available options and see how a plant can run most efficiently.

Centrifugal compressors can be a very good choice for certain applications where the variable demand can be met within the turndown range of centrifugal compressors. Centrifugal compressors are well known for their reliability, efficiency and air quality. Let us now understand the centrifugal technology and its use in variable demand with a varying load application.

CAGI Compressed Air & Gas Institute
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Members of the CAGI Centrifugal Compressor Section

- Atlas Copco Compressors
- FS Elliott
- Hanwha Techwin
- Ingersoll Rand

Centrifugal Compression

Centrifugal technology uses dynamic compression, where air is drawn between the blades of a rapidly rotating impeller and accelerates to high velocity. The air is then discharged through a diffuser, where the kinetic energy is transformed into static pressure. Most dynamic compressors are turbo compressors designed for larger volume flow rates. The flow and pressure in dynamic compressors is controlled by an inlet device (Inlet Guide Vane or butterfly valve) and an unloading valve. The turndown in dynamic compressors can be 30 to 35% or more depending on the inlet ambient conditions. Turndown, also known as throttle range, is the flow range of a centrifugal compressor as compared to full load capacity. For example, a compressor with a full load design point of 1000 cfm and 30% turndown, can modulate capacity to 700 cfm prior to unloading. Centrifugal compressors have variable flow rates and variable pressure characteristics.

Many centrifugal compressors use Inlet Guide Vanes (IGVs) to control the suction flow based on the demand requirement. IGVs redirect the air flow by pre-whirling to the suction, hence, an IGV is more efficient (9% better than a standard butterfly valve at partial loads) and offers more turndown.

Since you are not reducing the speeds to achieve required turndown in centrifugal compressors, a standard motor can be used. Special motor and frequency drives are not necessary.

The following are two possible control methods that can be used with centrifugal compressors: auto dual control or constant pressure control. Depending upon the application, you can choose which control is more suitable.

Auto-Dual Control (See Fig. 1)

- The standard regulation is achieved by means of inlet guide vanes and controller.
- The compressor discharge pressure set point (B) will be set at the desired level and the throttle or IGVs will modulate the compressor inlet to maintain constant discharge pressure over the control (B→C) range.
- At the surge control point (C), the IGVs stop closing, allowing the discharge pressure to rise to the unload set point. At this moment, the compressor will unload (IGVs close and unloading valve fully opens).
- The compressor remains in the unloaded condition until the system pressure declines below the preset load set point (A), the compressor resumes load at full flow, and the cycle is repeated.
- Re-loading time may be variable depending on capacitance.

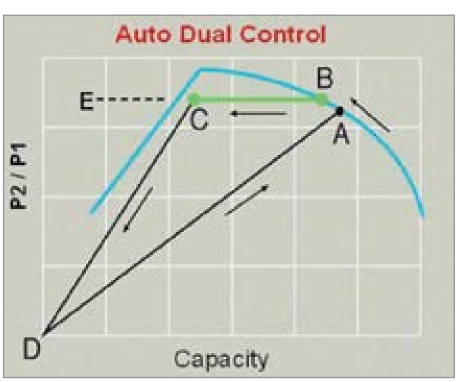

Fig. 1

APPLYING CENTRIFUGAL AIR COMPRESSORS FOR VARIABLE LOADS

If the compressor does not need to reload within a fixed time period, the unit will stop automatically. The controller will automatically re-start and load in anticipation, when the system pressure falls to the load set point (A).

Constant Pressure Control (See Fig. 2)

- This control method uses the inlet guide vanes (IGVs), unloading valve (ULV), and controller.
- The compressor discharge pressure set point will be set at the desired level and the IGVs will modulate the compressor inlet to maintain constant discharge pressure over the control (A→B) range.
- At the surge control point (B), the position of the IGV is maintained fixed, the unloading valve starts to modulate open, and the excess compressed air is exhausted to atmosphere.
- 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 (ULV) position to be programmed. This allows the plant to minimize inefficient operation during periods of low demand by limiting blow-off operation to a point between (B→C).

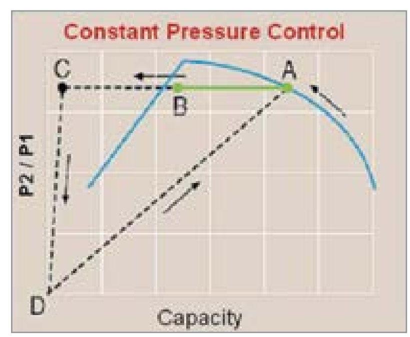

Fig. 2

The constant pressure control system is designed to continuously control the air output while keeping the net pressure fluctuations to a minimum.

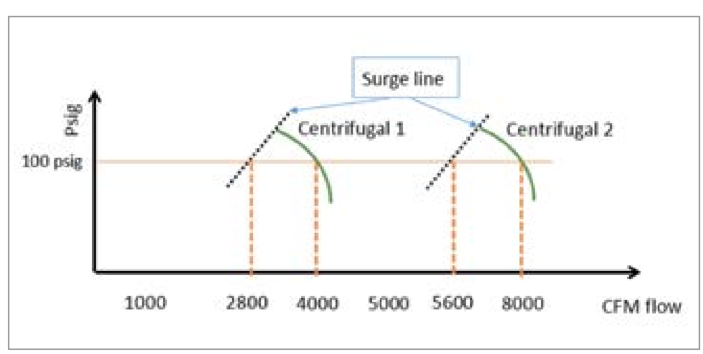

Fig. 3

Example:

Plant has 8000 cfm peak demand, 5800 cfm average demand, and 3000 cfm minimum demand during weekends at operating pressure of 100 psig.

As shown in figure 3, we have selected two 4,000 cfm centrifugal compressors to meet the peak demand. During peak demand both compressors will run at full load. When the flow demand is reduced to the average demand of 5800 cfm, the two centrifugal compressors will close the inlet guide valve and run in its turndown range without exhausting any compressed air to atmosphere.

During the weekend, when the demand reaches to minimum flow, one centrifugal compressor will stop and only one compressor will run in its turndown range. With this combination, the centrifugal compressors will work most efficiently and save a plant significant energy.

Adding a central master controller will further provide more control over the operation of each compressor and a master controller will make sure that each compressor is running at its most efficient zone.

Conclusion

This is just one example to demonstrate increase plant efficiency and energy savings. When a plant's demand pattern has been determined, the proper selection of centrifugal compressors with a master controller can be made. Proper equipment selection will ensure a plant's compressed air system is reliable and efficient. BP

For more information visit www.cagi.org

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Canadian Glass Plant Optimizes AUTOCLAVE COMPRESSED AIR

By Alan Brossault

Alan Brossault and Jan Hoetzel led the compressed air system assessment at Trulite.

The Trulite Glass and Aluminum Solutions manufacturing plant in Ontario (Canada) manufacturers high end commercial glass products in it's high tech production facility. The facility uses a large amount of electricity to manufacture laminated glass in the autoclave process. This process is the largest consumer of compressed air in the facility which made compressed air a major target in reducing energy costs for the facility. As the volume of compressed air in the autoclave is significant, the system is constantly pressurized with large 150 HP air compressors to reduce production times and fill times of the autoclave.

The current compressed air system operates as two systems. The autoclave system uses 190 psi which consists of two 150 hp fixed speed air compressors that are used to pressurize the large autoclave vessel during the lamination process. The plant side that operates at 110 psi to supply various manufacturing and lifting processes which uses a 150hp variable speed compressor. One PRV is connected between the two systems which allows for higher pressure air to be supplied to the plant system via the PRV at 110 psi in the event the plant compressor needs repairs, etc. In theory, this works well until the autoclave indexes which creates a huge draw of air which drains the system near the 75-80 PSI mark before recovering. This in turn shuts down production equipment due to the minimum requirement being 95 psi to the plant processes.

Due to rising energy costs and problematic compressed air issues, a compressed air study was performed of the system identifying some major deficiencies within both the autoclave side, 190 psi high pressure [HP] system and the plant side 110 psi low pressure system [LP] system. The most obvious issues with the system were:

- Lack of storage causing large pressure swings.
- No control of the compressors causing excessive idling.
- Grossly oversized plant VSD compressor on the lower pressure side of the system.

Low and High Pressure Compressed Air Systems

The low pressure system had no storage installed to buffer the oversized variable speed compressor which when combined with the load being less than the minimum output of the compressor caused large pressure swings. The compressor virtually operated in a load/no load manner starting and stopping constantly to try and maintain a steady pressure.

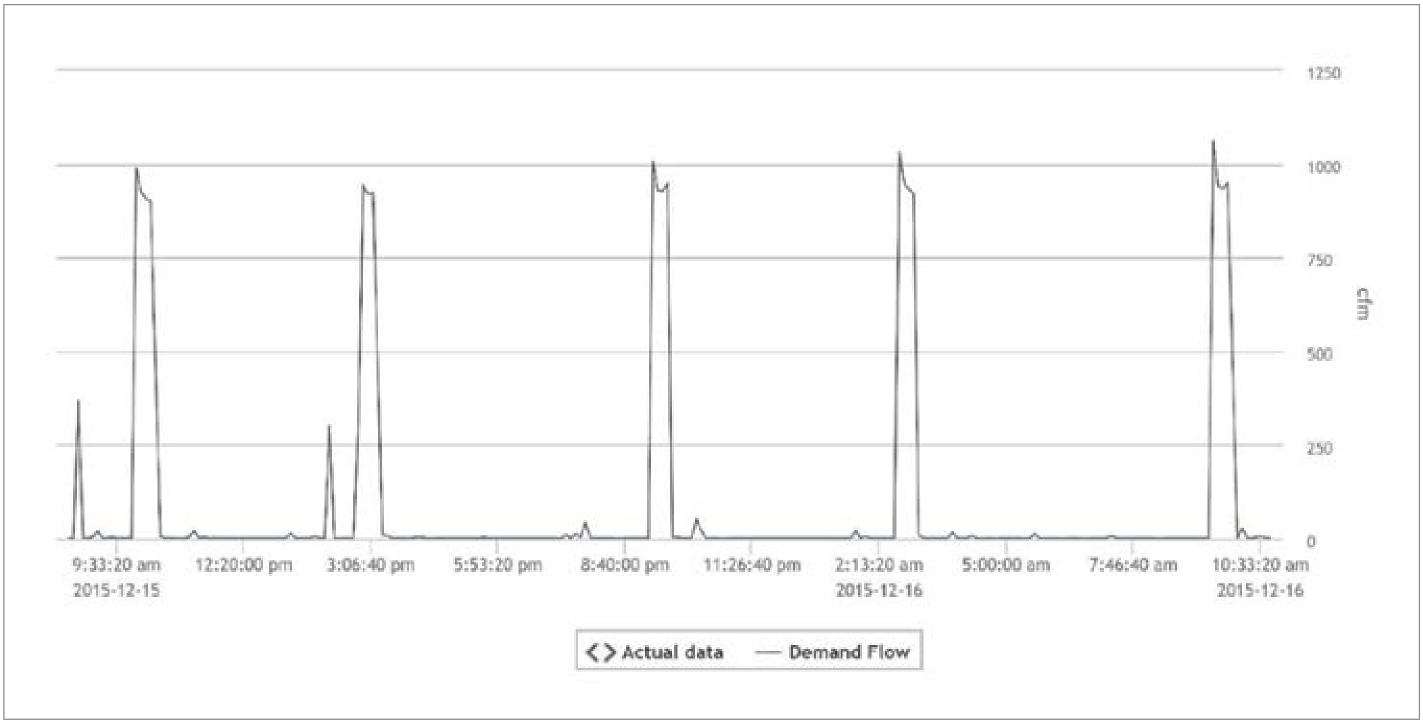
The high pressure system had one air receiver which was placed beside the autoclave to try and buffer the pressure swings caused by the filling of the vessel during the lamination process. The size of the receiver was not sufficient to stop the pressure from decaying beyond the clients needs during the initial fill which caused quality issues and alarms.

Secondary to the HP process issues caused by the lack of storage, the compressors ran inefficiently as they were always running unloaded to be ready to produce air and keep the pressure up. The idle times had been set to long and load/unload setpoints set so close that they could never stop and go into auto restart. The service provider explained to us that these settings were in place to try and keep the pressure up during various purge and process events in the autoclave, having the units off and restarting to provide the air requirement took to long to do so.

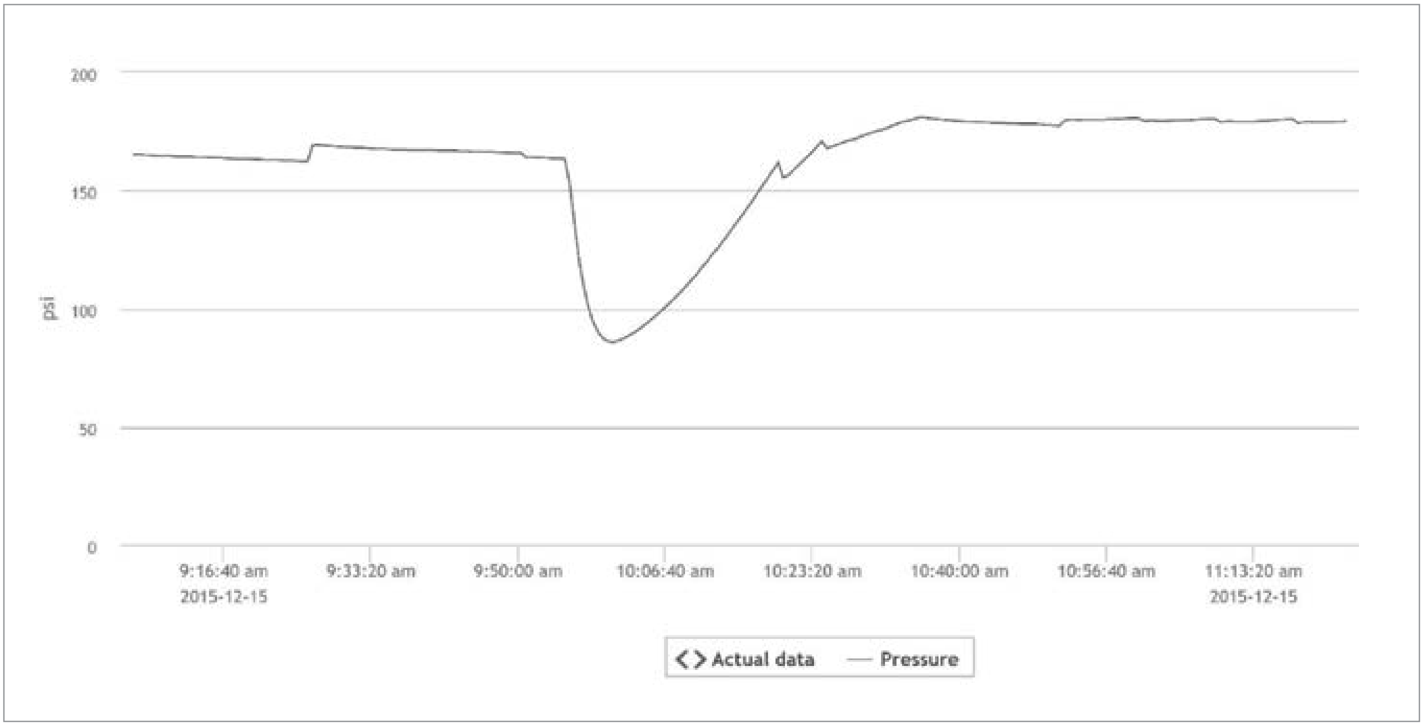
Plant-Side VSD Air Compressor

Regardless of the path we chose for this system the 150hp VSD compressor that was ramping up and down to supply air to the plant system had to go. The plant load was well below the minimum for this compressors output which was causing drive issues due to the ramping as well as consuming much more energy than needed. Our analysis via the Airleader audit system provided us the information we needed to choose a correct size of machine. A 60hp

CANADIAN GLASS PLANT OPTIMIZES AUTOCLAVE COMPRESSED AIR



Typical autoclave system CFM trend over 24 hours showing large gaps between the cycle requirements.



Pressure graph for autoclave cycle showing the decay of pressure due to the large draw of air.

VSD was chosen for the plant demand which would allow for some growth while providing the right amount of air in the best power curve of the VSD.

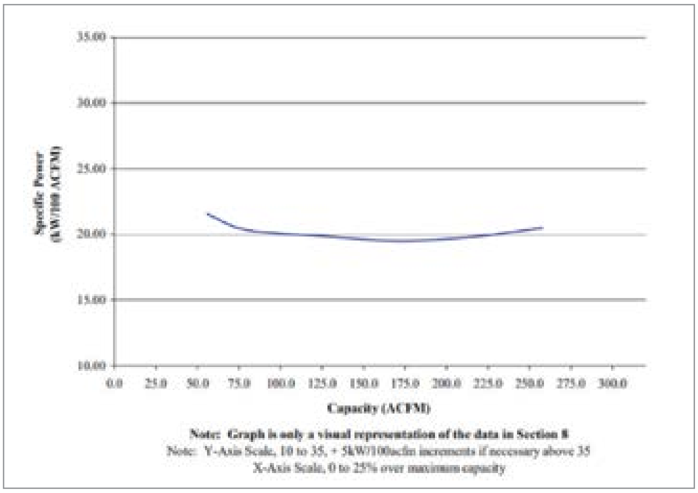
Compressed Air Storage

The plant side [LP] system was given storage to allow for 5 gallons/ cfm of air required and provide a smooth system for the VSD to trim. On the autoclave side of the [HP] system we recommended tripling storage from 2560 to 7680 USG. This allowed time for the compressors to respond when the autoclave began its large fill requirement. Secondary to this, the new storage now allows the HP system to back-up the LP plant system without issues in pressure which is done via a regulator controlled from the Airleader master controller which regulates air to the plant side if the plant compressor should fail and the plant pressure gets to 95PSI. This also provided savings to the client by not having to bring in rentals for a compressor issue in the plant as well as eliminating the cost of purchasing a backup unit. With the previous system the storage was not enough on the HP system causing the pressure to decay to 75-80 psi before starting to recover during an autoclave cycle. Now that the system has more storage the pressure never decays below 100 psi allowing this air to be regulated to the plant side at 95psi eliminating need for the purchase of a backup compressor.

Autoclave System

The autoclave system had many variables including the initial surge to fill the large autoclave vessel, some additional purge air, as well as varying requirements for variances in product. Different products had very different pressure and flow requirements for compressed air. Knowing this information we knew right

CANADIAN GLASS PLANT OPTIMIZES AUTOCLAVE COMPRESSED AIR



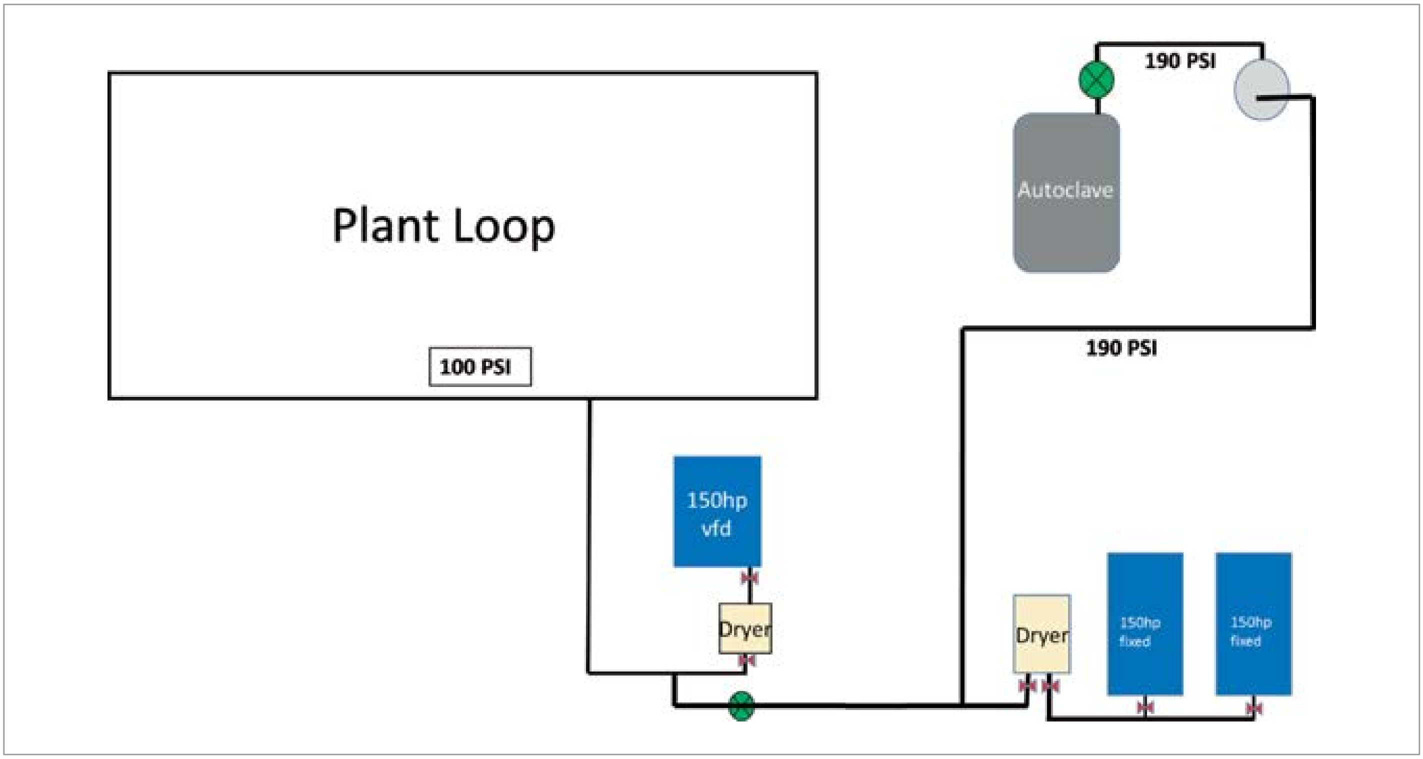
Specific Power charts from CAGI Data Sheets are very useful.

away a master controller was required if we wanted to stop compressors and choose the right compressors to fulfill the process.

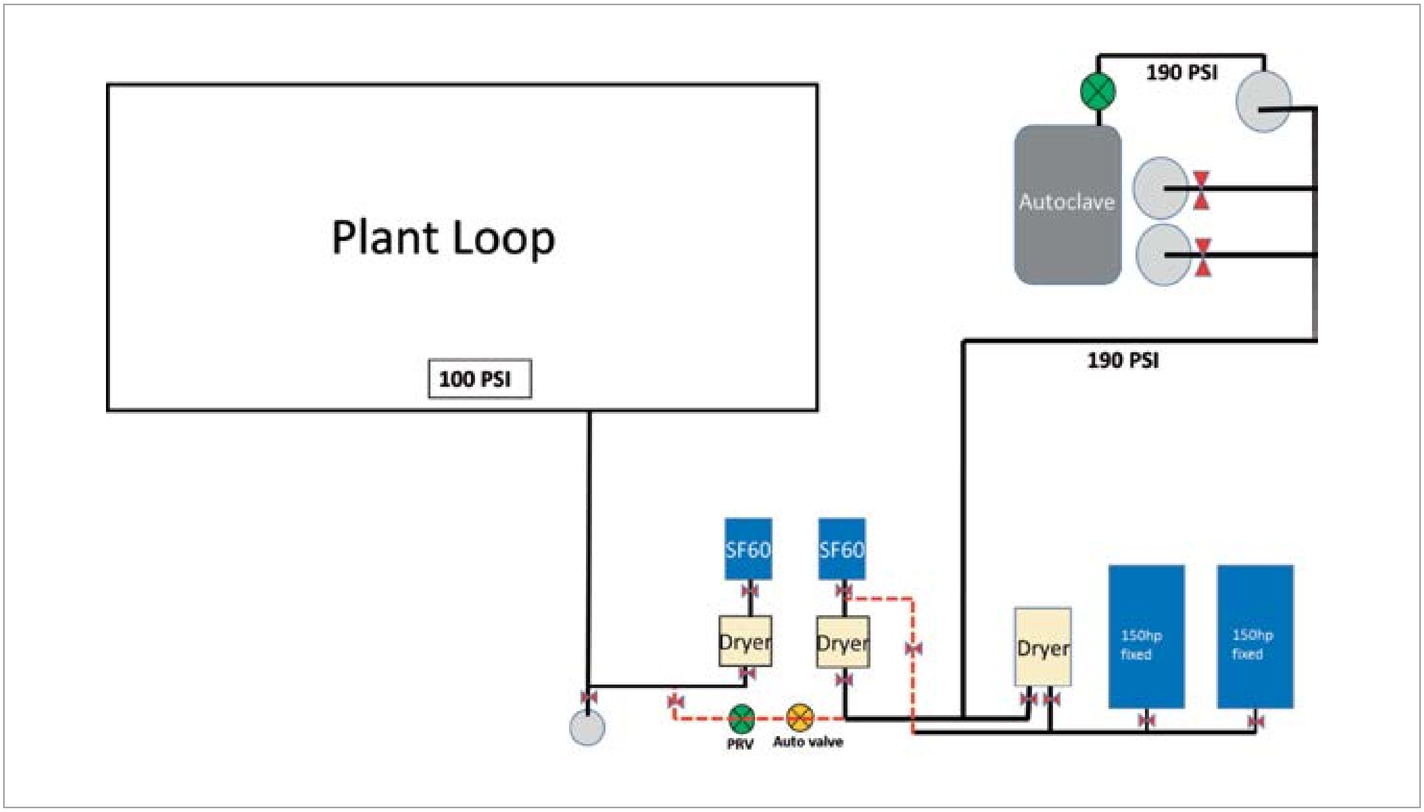
After analyzing the variances in product requirements via the Airleader software, along with information provided by the plant, we decided on a 60hp VFD to trim the cycle purges and work within the requirements of each product recipe. The existing two 150hp compressors would be used simply for the initial surge and one unit for a particular product that requires a secondary fill. Although a 60hp VFD trimming against a 150hp fixed speed would normally put the system into a large "control gap", this process is unique in which a small VFD covers the complete process properly for leaks and short purges that require small amounts of air. A large VFD would be below its minimum much like the old plant system VFD was. The client procured the compressors and tanks along with an Airleader master controller which was then implemented.

Once installation was completed Compressor Management Inc. took over the commissioning and setup of the system to operate as simulated by the Airleader software. The new system no longer runs the 150hp in constant idle to trim the purge on the autoclave and pressure issues have been eliminated. In fact, more than 90% of the time the two 150hp units are now stopped and off waiting for the Airleader Master Controller to give a start command when required resulting is secondary maintenance savings benefits. The client now watches his system from his desktop via the Airleader webserver and calls for assistance long before a breakdown or production is interrupted by a compressor problem.

CANADIAN GLASS PLANT OPTIMIZES AUTOCLAVE COMPRESSED AIR



Old System



New System

Maintenance Manager John McGraw (far right), receives on behalf of Trulite, a $147,428 (CND) energy incentive check, for the compressed air retrofit project, from representatives of the local utility company.

System Summary

Now that the technical reviewers have completed the post analysis, the client has received the $147,428 CND incentive cheque for the project from the local utility supplier. The system now runs trouble free with online visualizing of the whole system ensuring reliability and peace of mind while providing a total energy reduction of 83% which reduced the kWh's by 2.3 million annually. BP

Annual KWH

Base case before project 2,824,522 kWh

New energy costs after project 481,122 kWh

Total annual savings for the client 2,343,400. kWh

For more information contact Alan Brossault at email: abrossault@compressormanagement.com. For more information on Airleader master controllers visit www.airleader.us

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Centrifugal Air Compressor CONTROLS AND SIZING BASICS

By Tim Dugan, P.E. President, Compression Engineering Corporation

Introduction

Larger air compressors, typically over 500 hp, in refineries, pulp and paper plants, chemical and other processing plants often have high-speed, multi-stage air compressors called "centrifugal" air compressors. As seen from a total system perspective, they are not much different than screw air compressors. They compress air to plant pressure from atmospheric conditions, and deliver it to the dryer. These types of air compressors have no internal wearing parts, besides bearings and seals, and are very reliable and efficient, at their best efficiency point.

Centrifugal air compressor flow rate is relatively constant at a given pressure and inlet temperature, at full load. In common screw air compressor parlance, they are considered "base-load", meaning they should be running at full capacity all the time. That is a simplified, but correct view of how one should see most applications of centrifugal air compressors, if in fact there are properly controlled screw air compressors used as "trim", and their inlet conditions are relatively constant. However, in most actual systems with centrifugal air compressors, they are not running base-loaded, and inlet conditions change dramatically throughout the seasons. Sometimes, centrifugal air compressors are in a centrifugal-only system, where they are oversized and at a poor part-load efficiency point, with one running and one in back-up. Or there are multiple units running at different parts of a large plant air system, running independently, sometimes efficiently and sometimes not. Or they are in mixed screw / centrifugal systems where they are running in parallel with the screw air compressors, also at part load. In our view, a common reason for these less than optimal applications is the lack of knowledge of controls and maintenance by most vendors, technicians and engineers who are more familiar with screw air compressors.

In this article, I aim to describe the essential way a centrifugal air compressor is controlled and how to size one properly. In order to do so, I need to cover some basics, as follows:

1. Describe centrifugal air compressor basics.
2. Describe a centrifugal air compressor's curve.
3. Describe centrifugal air compressor control.
4. Discuss implications for air compressor sizing.

Centrifugal Air Compressor Basics

A centrifugal air compressor develops pressure by accelerating a gas from the center of the impeller, through the "impeller", by centrifugal force, and then slowing it down in a "diffuser" through expansion. The velocity energy is converted into pressure energy (by Bernoulli's principle, pressure is inversely proportional to velocity squared). See Figure 1.

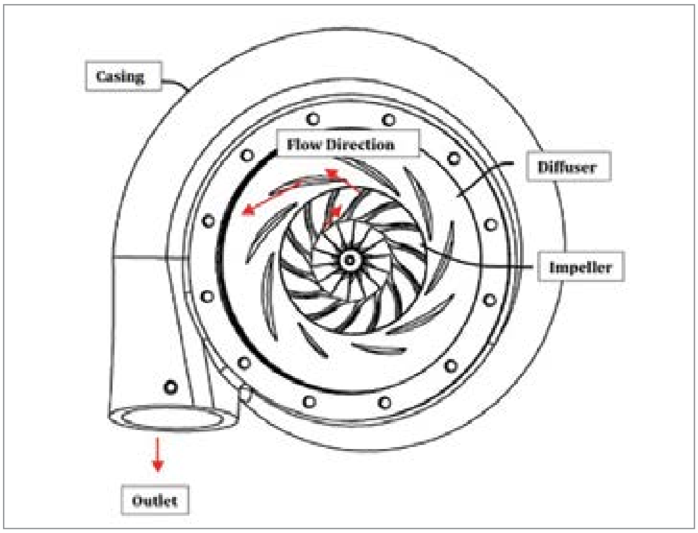

Figure 1. The basic internal structure of a centrifugal air compressor.

CENTRIFUGAL AIR COMPRESSOR CONTROLS AND SIZING BASICS

Typical centrifugal plant air compressors have three stages, because they typically can compress about 2:1 to 3:1 per stage, and a plant air system needs about an 8:1 pressure rise. They have intercoolers between stages and an aftercooler after the third stage. Modern centrifugal air compressors are reliable, efficient and compact. They are mounted on a common base with driver, gears, coolers, piping and controls all integrated. Modern controls manage the air compressor capacity and reliability at a relatively constant pressure, making it easy to "set it and forget it". See Figure 2. The basic components are:

1. Motor
2. Bull gear with pinion gears to drive air compression stages.
3. Inlet throttling valve or inlet guide vanes (IGVs)
4. First air compression stage
5. Intercooler 1
6. Second air compression stage
7. Intercooler 2
8. Third air compression stage
9. Aftercooler
10. Blow-off valve
11. Check valve
12. Control panel

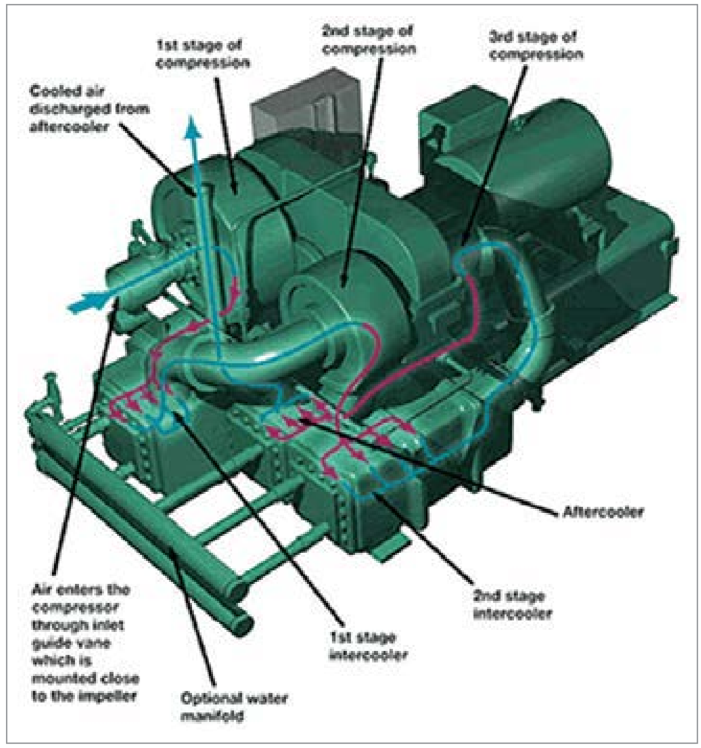

Figure 2. This diagram maps the basic internal processes of a centrifugal air compressor.

Centrifugal Air Compressor Performance Curves

As described above, a centrifugal air compressor develops pressure via velocity. If the velocity changes a small amount, pressure changes significantly, theoretically by the square of velocity, as in a centrifugal fan or pump. As shown in Figure 3, dropping the speed by 13% drops the pressure 20%. That is why packaged centrifugal air compressors typically don't have variable speed drives. Plant air systems require constant pressure. Also note the drop of efficiency occurring at the far right side, called "stonewall", or at the far left, near the "surge" line.

So what is *"surge"* anyway? It is an aerodynamic term describing the phenomena when the flow reduces and the pressure differential across the first stage gets too high and flow temporarily "backs up". It is caused by aerodynamic "stall", or "separation". With an air foil on a plane, too high of an angle of attack can cause boundary layer separation and stall. Similarly, in a centrifugal air compressor, too low of a flow or too high of a pressure differential changes the angle of attack within the impeller, creating separation and surge. This causes air compressor flow instability and shocks the bearings and gears, as well as system pressure instability. In a typical centrifugal plant air compressor, this is usually caused by the inlet density and flow dropping due to excess throttling, hot air, a clogged intake filter, or a combination of these. You don't want to go there.

Centrifugal air compressor controls are supposed to be set conservatively to avoid surge. In newer air compressors, a surge control line is developed based on "polytropic head", a pressure value normalized for temperature. A skilled technician "surge tests" the air compressor, and enters the surge control limits in "feet". Then, an offset from the value is entered. If the polytropic head reaches the offset value, the air compressor controller starts to open the blow-off valve to avoid surge. In older air compressors, surge testing is done to determine the motor current resulted in surge (motor current drops as the inlet is throttled), and an offset current value is also entered. If current drops to this Amp level, the same surge control prevention starts. However, motor current can be an inaccurate determiner of surge, particularly if the surge testing was done on a cool day. A centrifugal air compressor will surge "earlier" (based on Amps) on a hot day than on a cold day.

Centrifugal air compressor delivered flow, or "capacity", is dependent on inlet density. If the density drops due to higher inlet temperature, the volume flow actually reduces. The lower mass flow reduces the ability of the first stage impeller to develop velocity through momentum, and the inlet volume flow (in icfm or m3/hr) drops. This is in contrast to positive displacement air compressors, where inlet volume flow is not affected by inlet density. Delivered mass flow, related to standard conditions, (scfm or nm3/hr), always drops linearly with inlet density, even if inlet volume was constant. Thus, inlet density reduction from elevated inlet temperature creates a "double jeopardy" for centrifugal air compressors, dropping both icfm and scfm. Figures 4 and 5, actual curves of an identical air compressor at 50 and 90˚F inlet, show this. The ratio of delivered flow is 1 – 4342/4798 = 9.5%. If the inlet flow was constant, the drop would only have been due to inlet temperature, 1 - (460 + 50) / (460 + 90) = 7.3%. Inlet volume flow dropped by 2.2%.

Inlet temperature increase also drops the "head" of the curve, and the air compressor's effective "turn-down". Turn-down is the available throttle range of a centrifugal air compressor, without blow-off. The natural rise to surge (not throttled) drops from 150 psig to 140 psig when inlet temperature rises from 50 to 90˚F. The drop causes the effective turn-down to drop from 2,100 scfm (4,800 – 2,700) to 1,600 scfm (4,300 – 2,700). This turn-down is pretty good compared to typical centrifugal air compressors (37% to 43%). This is due to the high "rise to surge" of this air compressor. If a different impeller was selected, one at the optimal efficiency at full load and pressure, less rise to surge on the natural curve would possibly result, and less turn-

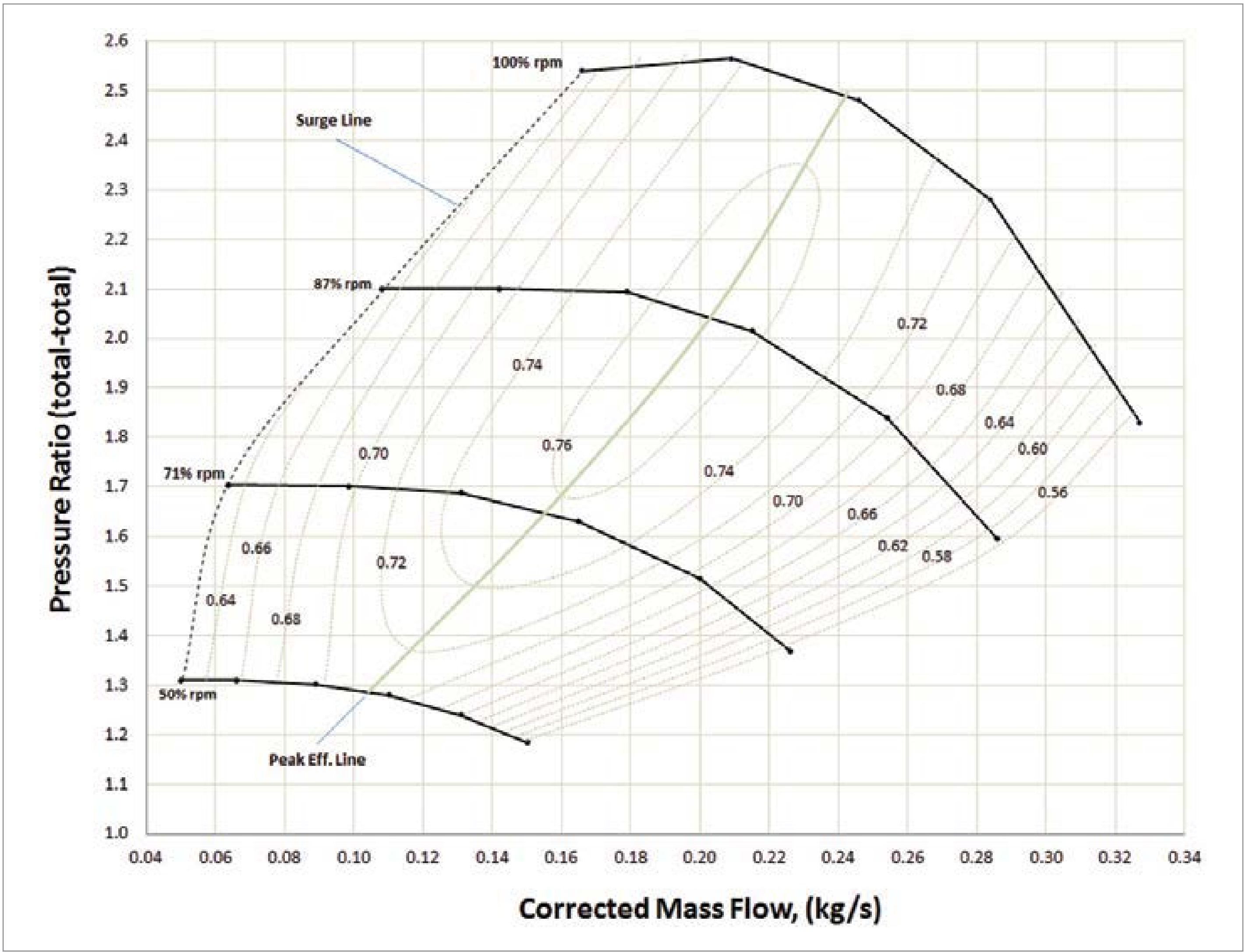

Figure 3. Typical 1-stage centrifugal air compressor curve.

CENTRIFUGAL AIR COMPRESSOR CONTROLS AND SIZING BASICS

down on inlet throttle. But having too much rise to surge puts the air compressor at a slightly less efficient point. A balanced aero selection achieves both good full load efficiency and good turn-down.

Realistically, the air compressor controls would not let throttling without blow-off to occur right up to the theoretical surge line. Based on experience, I use a conservative 25% offset. That is, I assume the flow turn-down capability of the air compressor is only 75% of the ideal curve turn-down, 1,575 scfm at 50˚F inlet (33%) and 1,200 scfm at 90F (28%).

Power is also impacted by inlet temperature. It drops by 7.3% in the same temperature increase, the same as the icfm drop. Thus, specific performance (bhp/icfm) is not impacted by temperature, just the raw power and flow. Also note the throttling on IGVs provides lower power than on an inlet butterfly valve ("IBV"). This is due to more effective pressure reduction and pre-swirl with IGVs vs. more turbulent IBV throttling.

Centrifugal Air Compressor Control

For readers who are familiar with older screw air compressor controls, centrifugal air compressor controls are a refined version of upper-range modulation and unloading, with a minimum throttle limit, as follows:

1. Pressure is the primary control independent variable in centrifugal air compressor control. Pressure generally controls the inlet valve or IGVs, adjusting air compressor capacity to stabilize with system demand. The mode of control is "proportional-integral-derivative", or "PID". It essentially tries to target and keep the pressure at the set point plus or minus a fraction of a psi. In some centrifugal air compressors, particularly gas compressors, part load is controlled by a recirculation valve. We are describing plant air compressors in this article. They generally don't use recirculation control.

2. As capacity is reduced at constant pressure, the air compressor gets close to its minimum throttle point, called the *"surge control line",* as shown in Figure 4. As the compressor gets close to the surge line, current is dropping and polytropic head

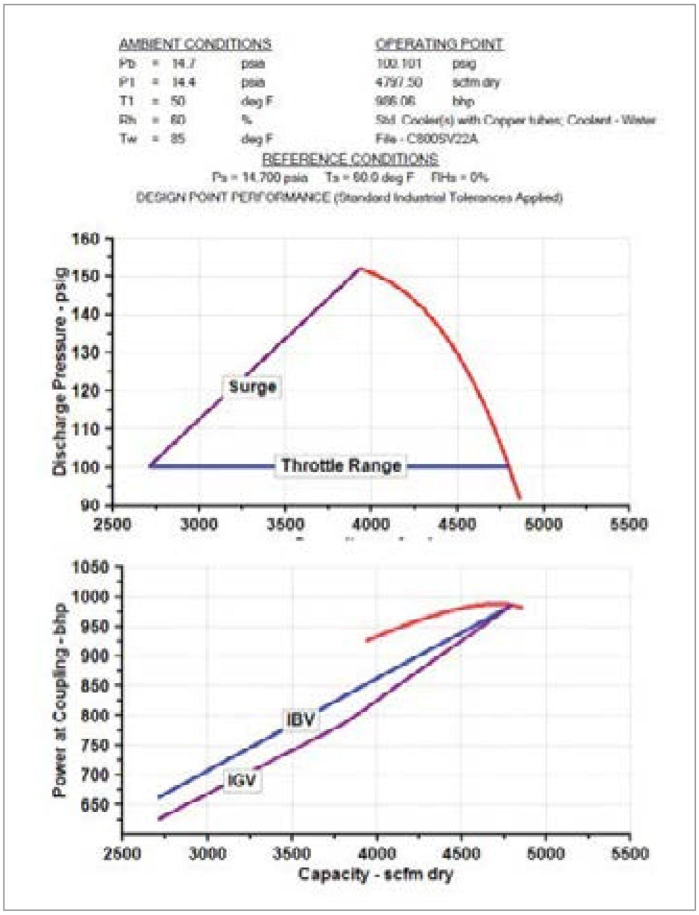

Figure 4. Typical Multi-Stage Plant Air Centrifugal Air Compressor Curve, 50˚F inlet.

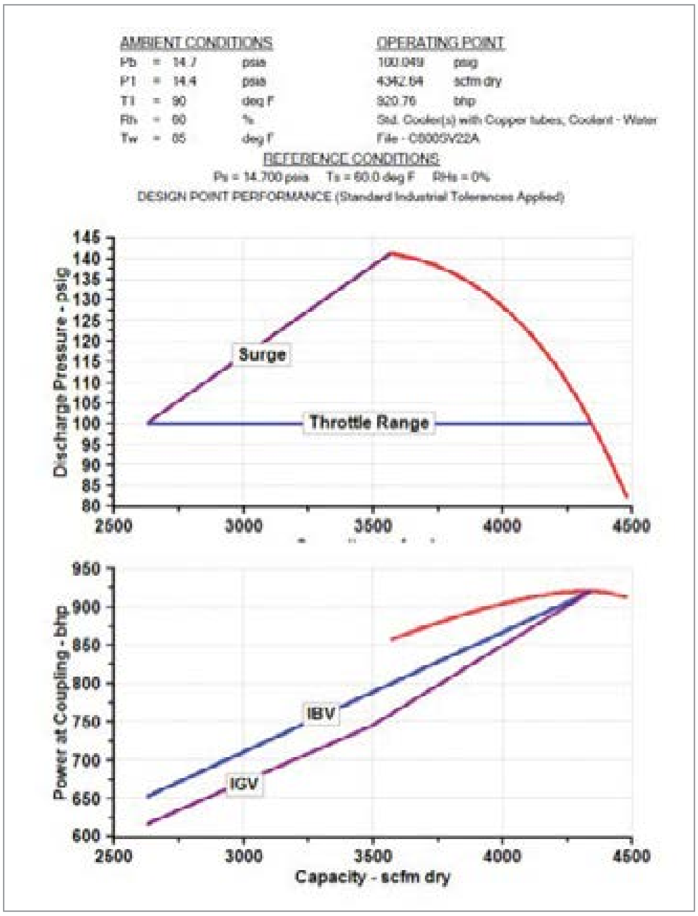

Figure 5. Typical Multi-Stage Plant Air Centrifugal Air Compressor Curve, 90˚F inlet.

is rising. The controller keeps the air compressor from surging by starting to vent the blow-off valve. By this time, pressure usually rises past the primary set point. The curve shows an idealistic way the air compressor might operate, constant pressure all the way to the surge line. In reality, it hits an offset from the surge line, and sometimes pressure is allowed to rise and control the blow-off valve with the IGV at min position. In other controllers, both valves are stroked simultaneously as the air compressor approaches the surge line, and pressure is kept constant.

3. There are two basic control modes, *"continuous run"* and *"low demand"* or some other term meaning the same, like *"dual control.* In "continuous run", the air compressor will continue to run in part blow-off mode indefinitely.

4. In *low demand* mode, the air compressor is allowed to "unload" or go "offline" after the blow-off has exceeded a certain level for a period of time. The inlet valve or IGV shuts completely and the blow-off valve fully opens. After a period of time unloaded, the air compressor shuts off.

5. In some less than optimal control scenarios, pressure is solely controlled by the blow-off valve, not the inlet valve. This is very wasteful, resulting in constant power at all capacity levels. This might have occurred due to manual adjustment of the air compressor, or surge controls not allowing the air compressor to modulate.

Implications for Air Compressor Sizing

The four main takeaways effecting centrifugal air compressor sizing are:

1. Get an accurate flow profile of your system, using a mass flow meter, before sizing a new air compressor.

2. Make sure you have an air compressor large enough in capacity to serve your peak flow (scfm) on your hottest day. But don't grossly oversize your air compressor, or you will run into blow-off most of the time. See #2.

3. Select an air compressor with sufficient turn-down, without blow-off, to match to your load variance. If the load drops to 50% of peak often, you will have no choice but to allow some blow-off, if you are sizing a single centrifugal air compressor to your system. Consider a multiple air compressor system if load varies much.

4. Make sure you have a large enough motor for the full capacity on the coldest day. BP

For more information, contact Tim Dugan, tel: (503) 520-0700, email: Tim.Dugan@cmop-eng.com, or visit http://compression-engineering.com.

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Compressed Air Audit Discovers PROBLEMS AT ELECTRONICS FIRM

By Ron Marshall, Marshall Compressed Air Consulting

An electronics manufacturer with a very large compressed air system recently had a compressed air audit done in their plant to assess system efficiency. The audit discovered the system had been designed to be extremely efficient, yet some previously undetected problems were causing less than optimal operation. Despite being located in a tropical environment, this plant utilizes heat recovery to help reduce the overall energy consumption.

The objective of the study was to quantify and report:

- Current operating costs
- Current operating air usage profile
- Recommendations for improvements
- Estimated potential savings if improvements were made

Oil-Free Centrifugal Air Compressors and Blower Purge Desiccant Dryers for Instrument Air Quality

The plant was originally built in 2012 to manufacture electronic components. The plant owners were interested in qualifying for LEEDS Platinum status for the facility, so quite a number of innovative design features were initially implemented in their industrial processes and utility systems, including the compressed air system.

The compressed air system consists of three large 1,000 kW base load centrifugal air compressors rated at 6,400 cfm each, plus two smaller trim air compressors, a 500 kW centrifugal air compressor (3,200 cfm) and a 500 kW (2,750 cfm) variable speed drive screw air compressor. The base air compressors have been designed for heat recovery duty with special heat exchangers engineered to keep the air compressors cool, yet output a supply of 60 °C (140 °F) water for heat recovery. The heat is then sent to the process for heating treatment chemical baths.

The centrifugal air compressors have been connected to a sophisticated air compressor controller designed to optimally control the air compressors for maximum efficiency. All centrifugal air compressors have been outfitted with inlet guide vanes to improve the air compressor power turn down when producing less than rated flow.

The plant requires instrument quality air for their processes so desiccant air drying is used. Four large desiccant dryers, rated at 6,200 cfm each, process the air before it enters the plant. The dryers selected are heated blower style units of purgeless design. The dryers use no compressed air whatsoever during the normal desiccant regeneration cycle, other than pressurizing the towers. The units feature closed cycle cooling of the desiccant, after the heater operation, rather than using the normal 2% flow of compressed air. At the end of the cooling cycle the dryer blower directs cooling air in a closed cycle through the hot desiccant bed and also through a water cooled heat exchanger to return the desiccant to ambient temperature in anticipation of the next drying cycle.

The compressed air is cooled before it enters the air dryers with a double system of liquid cooled heat exchangers, one set directing the heat to the heat recovery system, the other providing back up cooling to ensure the compressed air temperature never exceeds the rating of the air dryers. A dual system of filters, installed in series, has been installed both before and after the air dryers.

Both wet and dry storage receivers have been installed in this system totaling 20,000 gallons to help with system stability. Airless drains are used exclusively on the air compressors and all storage receivers, filters and air dryers.

The system was designed to supply a very clean and dry flow of compressed air into the plant to power the industrial processes and machines. Two sets of filters have been installed, one set before and one after the air dryer, to ensure no contamination enters the air dryer and no desiccant dust is passed from the air dryer to the plant. The air is filtered to the 0.01 micron level with 0.1 mg/m3 oil, 99.999% lubricant retention rate.

The piping system consists of all stainless steel components to prevent the contamination of the compressed air from piping scale after it leaves the powerhouse. The piping system within the plant is arranged in a system of loops to reduce pressure loss across the very large production facility.

Two smaller air compressors, one unit being VSD controlled, are supposed to be available to achieve efficient flow turn down of almost 100% before any base air compressor must unload. These two trim units were not in service due to mechanical problems.

An innovative high-pressure storage system was part of the original design with the intention of providing emergency standby air in case of a power outage. This system utilizes a booster air compressor and 850 psi compressed air stored in a 4,000 gallon storage receiver. Due to high flows this storage capacity, calculated to be over 30,000 cubic feet, would last about 3 minutes at full plant flow in a power outage, or on failure of a base air compressor, enough time to conduct emergency shut down operations or start another air compressor.

An onsite nitrogen generation system is installed using a significant flow of 100 psi compressed air. This system consumes compressed air at low pressure and produces Nitrogen through a cryogenic process to a pressure of about 60 psi. A centrifugal booster is used to bring the Nitrogen pressure back up to 100 psi for use in plant operations.

Initial Findings

Data loggers were placed on all running air compressors and all air dryers to assess the energy input of the system. Pressure loggers were placed at various points starting at the air compressor discharge, after the air dryers and selected points within the plant to assess the pressure gradients. A full leakage audit was done at the site with assessment of various end use applications.

The site characteristics were found as follows:

The plant electrical cost is about 7.7 cents per kWh, making the total electrical cost of operation about $2.3 million USD.

COMPRESSED AIR AUDIT DISCOVERS PROBLEMS AT ELECTRONICS FIRM

Description	Hours /Day	Days /Year	Hours /Year	Min cfm	Ave cfm	Max cfm
FAB	24	365	8760	8640	10200	11520
N2	24	365	8760	0	4440	5500

Figure 1. Air Compressor System Demand Profile

Item	Hours	kW	kWh
Peak		3805	
Total Plant	8760	3279	28,728,113
N2 Booster	8760	150	1,314,000
Total			30,042,113

Figure 2. Air Compressor System Electrical Consumption

Item	Hours	Equiv kW	kWh	Saved
MET Jacket 1	8760	318	2,785,680	$ 214,185
MET Jacket 2	8760	350	3,066,000	$ 235,738
Total Recovered		668	5,851,680	$ 449,923
Total Remaining	8760	2409	21,102,840	
Percent Remaining				78%

Figure 3. The heat recovered from the compressed air system reduces the electrical operating costs.

The heat recovery system saves significant equivalent electrical power. In this site not all air compressor heat is used, only about 22%, but this is a significant accomplishment in a hot location. The remainder of the heat goes to a cooling tower.

The general assessment of the compressed dry air (CDA) system is there is excellent efficiency in the production of compressed air due to the recovery of heat to the process and the fact the base air compressors are running near the most efficient point, almost fully loaded. The air compressors are equipped with inlet guide vanes. If they are used correctly, the inlet guide vanes provide good efficiency for a significant range of flow turn-down. Condensate drains on the air compressors are zero air loss type saving operating costs. The premium efficiency heated blower air dryers save significant power compared to standard heatless dryers due to purgeless operation and closed cycle cooling, especially due to dew point control and use of pre-coolers.

On the demand side there are low levels of leakage because the plant is fairly new, but these are likely to increase over time unless some system of detection and repair is implemented. Some applications using compressed air for blowing and vacuum are items one should investigate for conversion to blower or central vacuum duty. Some low-pressure problems are occurring in various areas of production.

Air Compressor Control

The compressed air audit found the control of the existing air compressors was good, but less than optimal. The plant load profile is fairly flat, therefore, the control of air compressors need not be too complex. A sophisticated air compressor control system had been installed, designed to properly control and coordinate all the base air compressors, but this system was out of service due to some undesirable characteristics. The system was originally set for when there was a power outage the control called for the start of too many air compressors at one time, tripping the main breaker in the powerhouse. This event causes a long outage and disastrous effects in the production area so the decision was made to remove it from service. It turns out some adjustments of this control could eliminate this problem and allow the control to be turned on.

Having the air compressors controlled individually causes pressure regulation issues. The local controls will accurately regulate the pressure at the discharge of the air compressors where they sense the pressure, but this allows the plant pressure to sag across the dryer and filters differential. This causes lower than desired plant pressure during peak flows, one of the causes of low-pressure complaints. It can be seen in Figure 4 the discharge pressure (black line) is fairly well regulated, however, the pressure in the plant sags to lower levels. This pressure differential forces the system pressure higher to compensate, increasing energy consumption due to artificial demand.

Another problem with local control is the operation of air compressor blow-off. Centrifugal air compressors must blow off to protect the units from surge at low flows. This blow-off wastes compressed air. Control of the air compressors with an air compressor controller shares the load between units, equally modulating the inlets to better prevent blow off. This would only happen when all the air compressors are fully modulated. With the local control each individual air compressor determines locally if it needs to blow off, therefore optimum control does not happen. Occasional blow-off was occurring (Figure 5).

Compressed Air Dryers and Filters

The installed desiccant air dryers are premium efficiency units using electrically heated regeneration, ambient air main cooling and airless secondary cooling. Typically heated blower style desiccant dryers have a purge consuming peak flows of 8% of the dryer rating, occurring just before the dryer switches sides, this flow is used to cool down the desiccant to prevent a dew point spike (hot desiccant does not remove moisture). The existing dryers have no such cooling purge, they use a closed cycle loop of water cooled to remove the heat. The units run the towers in parallel for a period of time before starting to regenerate the saturated desiccant, this prevents any dew point spike associated with hot desiccant. The units also use dew point control, rather than a fixed

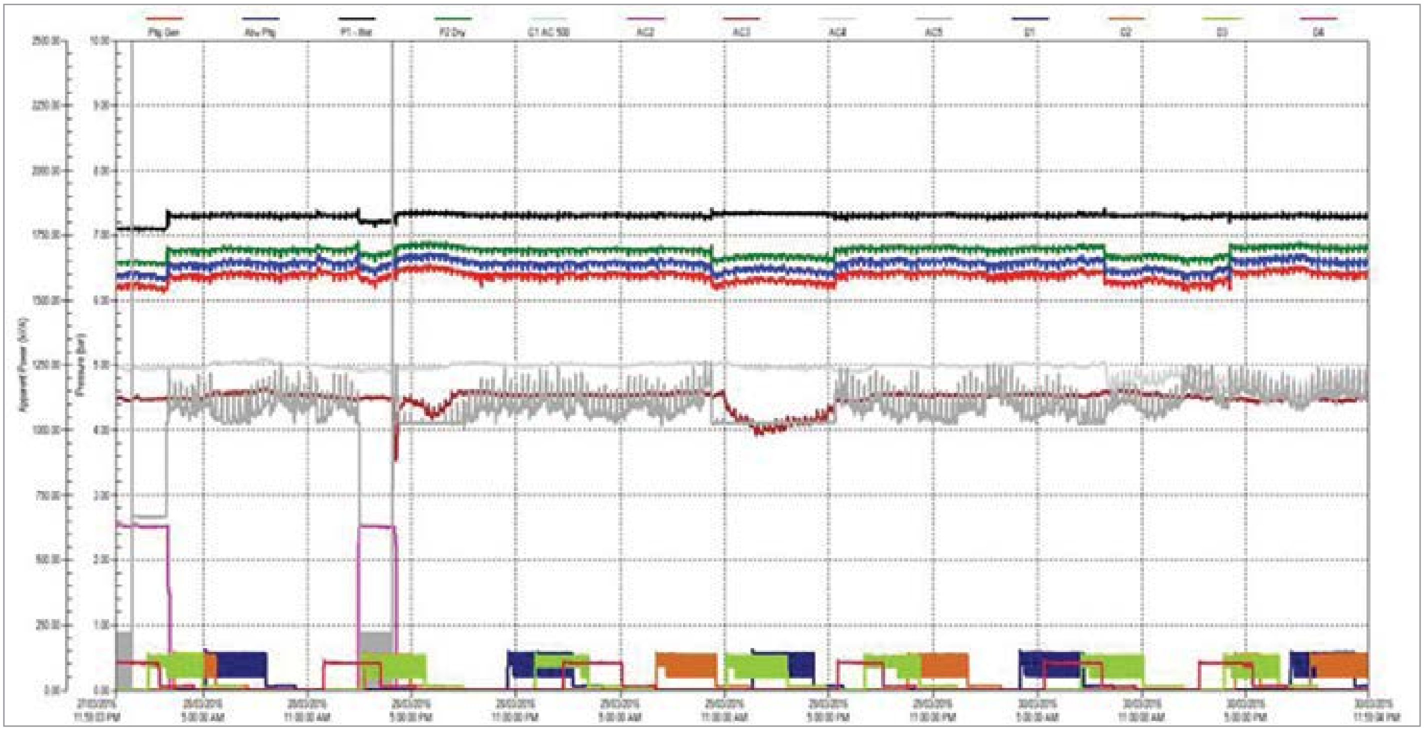

Figure 4. The discharge pressure (black line) stays regulated while the plant's pressure sags to lower levels.

cycle, to delay the tower regeneration until the desiccant in the active side is totally saturated, thus saving heater power.

The installed dryers are rated at 6,185 cfm each with onboard heater power rated at 135 kW. The four air dryers were only consuming a total of 94 kW, including blower power, considerably lower than the approximately 740 kW consumed by a heatless fixed cycle desiccant dryer at 15% purge.

This lower power consumption is partially achieved by pre-cooling the compressed air before it enters the dryer. A primary cooler using process cooling water reduces the 40˚C inlet air temperature by about 6˚C and sends the heat to the heat recovery system. A secondary chilled water cooler further reduces the inlet temperature by another 11˚C to about 23˚C. This cooling consumes extra energy, estimated at about 43 kW equivalent loading for each dryer on the cooling water and chilled water systems (172 kW total). The cooling, however, saves approximately 50 kW for each dryer (200 kW total) by allowing the dew point controls to delay the regeneration cycle.

A water separator removes any water condensing out of the coolers before it enters the dryer. Reducing the temperature by 11˚C removes about 65% of the water vapor. Since the dryers are on average processing about 65% of their rated flow capacity, and less than rated moisture capacity, the dew point controls very effectively turn down the power consumption.

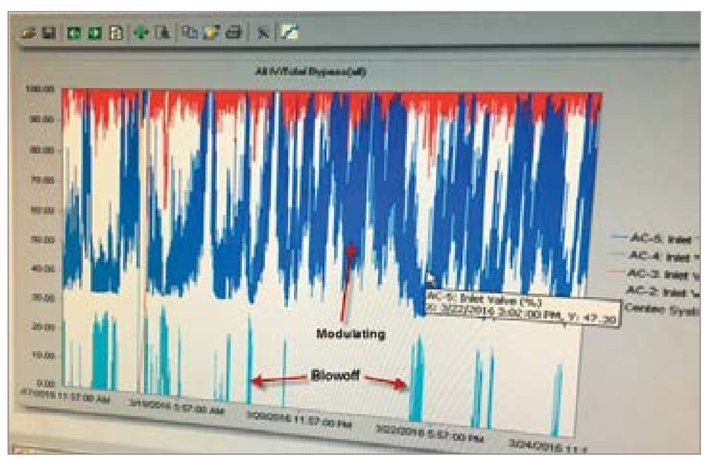

Figure 5. The local control causes each individual air compressor to determine locally if it needs to blow off, sacrificing optimum control.

These dryers are more complex than normal, however, and are subject to failures of internal components so careful monitoring should be done. Data logging showed the following previously undetected issues:

- One of the dryers was showing unbalanced regeneration cycles where one side requires considerably more heat than the other side. This is a sign of an internal leak. If the air compressor amp profile is examined closely (Figure 6) a pattern of flows can be seen matching up with the heating cycle of one of the dryer towers. Based on the amp change the estimated leakage flow

COMPRESSED AIR AUDIT DISCOVERS PROBLEMS AT ELECTRONICS FIRM

is 260 cfm average (360 cfm peak) occurring at all times when the faulty side is pressurized (about 72% of the time).

- Another dryer was found to have a burnt out heating element.
- The pressure differential across the coolers and dryers was showing about 7 psi (0.48 bar), much higher than expected for lightly loaded units. Basic measurements were done on one dryer using a gauge to measure the pressure at each drain. The measurements suggested most of the pressure differential is across the first cooler. This pressure differential causes higher air compressor discharge pressures and introduces an energy higher energy cost to the whole system. This is subject to some additional investigation.

In oil free compressed air systems some method of filtering is required to remove the ingested particles passing through the air compressor inlet filters and to catch the remaining free water in the air stream after the coolers. Any filtering represents a pressure loss. Having excessive filtering causes extra energy consumption and reduces the available compressed air pressure at the end use. If this filtering is not adequate or is not properly maintained fouling of downstream processes is a possibility.

The following filtering exists at the air dryers:

- Pre-filter - 0.01 micron, 0.1 mg/m3 oil, 99.999% retention rate
- Pre-filter - 0.01 micron, 0.1 mg/m3 oil, 99.999% retention rate
- After-filter - 0.01 micron, 0.2 mg/m3 oil, 99.99999% retention rate

The first two filters were found to have exactly the same filtering characteristics. The primary job of these pre-filters is to remove any free water coming from the pre-coolers. The air compressors are oil free so the oil-filtering characteristic is unimportant. One of these filters is redundant and causing unnecessary pressure differential. Reconfiguration of the filtering is recommended.

Nitrogen System

A nitrogen system is installed at site using a significant flow of 100 psi compressed air. This system actually consumes compressed air at about 73 psi and produces Nitrogen output at about 58 psi, requiring the output to be boosted with a separate turbo air compressor. The air being supplied this system is already dried to a minus -40˚C level, yet the system has an additional desiccant dryer at the front end of the process. This dryer negatively affects the system pressure during CDA system peak loads because high pulse flows must be consumed to fill the dryer towers prior to tower switchover. The regulation of the 100 psi air to the lower 73 psi level, the double drying of the air, and the boosting of the nitrogen represent a considerable energy loss to the plant, reducing system efficiency.

The nitrogen system represents the biggest single load on the CDA system consuming an average of 4400 cfm or about 30% of all the compressed air produced. In addition, a Nitrogen booster consuming 150 kW is used to boost the produced nitrogen to about 8 bar for distribution to the plant.

Some research was done on the generator in use. The system is an APSA (Advanced Products Supply Approach) type unit using a cryogenic

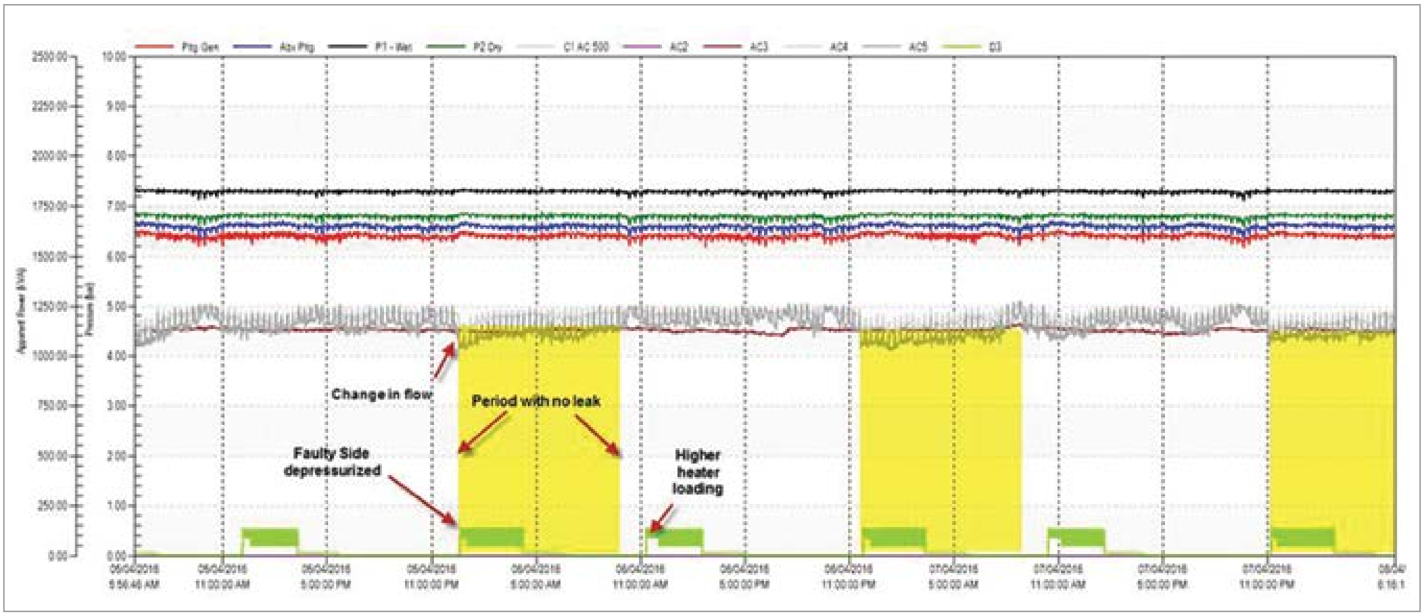

Figure 6. This graph shows the pattern of flows matching up with the heating cycle of a drying tower.

distillation process. On systems like these there is always a large dryer on the front end of the process to remove water vapor and carbon dioxide using a desiccant air dryer.

The research showed a few interesting facts:

- Nitrogen pressure outputs are available for APSA systems in three distinct pressure levels as high as 10.5 bar.
- Nitrogen systems typically are designed with their own stand-alone input air compressor operating at low pressure.
- This stand-alone air compressor system does not usually come with an air dryer.

An investigation of this system and redesign was recommended. A stand-alone system would likely consume much less energy.

End Uses

Brief inspection of these areas found almost every production machine has two input pressure regulators causing extra, unneeded pressure differential during peak flows. Some internal machine piping appears to be undersized, likely causing more pressure differential. These components force air compressor discharge pressures higher, decreasing system efficiency.

As discussed previously, the end use pressure most often determines how much compressed air is consumed by a given compressed air powered device. These devices will operate the most efficiently and more reliably if the compressed air pressure is properly regulated at a constant pressure. To ensure a constant pressure the regulators feeding the device need to be properly installed, sized correctly and adjusted appropriately.

Figure 7. Having two pressure regulators in series causes excess pressure differential and poor pressure regulation.

An issue at this site is the number of pressure regulators. It appears each down drop from the main distribution lines has a regulator. The problem with this is the production machines often also have an input filter/regulator. This means there are two regulators in series, and one of the regulators is redundant. Having two regulators in series causes excess pressure differential and poor pressure regulation.

A sign of problems is when the input regulator is observed to be "tracking" the supply pressure (adjusted wide open). It is likely most of the input regulators in the plant are in this condition. A regulator adjusted wide-open presents a pressure restriction affecting how the next regulator will work.

We inquired about any applications causing pressure complaints in the plant. One item identified was robotic loading in a Clean Room and is discussed here as an example. The input of this machine had half-inch regulators appearing to track the main system pressure. Indicator tags showed a wide range of variation for acceptable input and a "do not operate" tag was displayed.

On further inspection under the machine, another regulator was discovered in the machine itself set for 87 psi. This regulator would need at least 97 psi input pressure to accurately regulate. A filter was also present having no indication if the element had ever been changed, a possible source of additional significant pressure differential would affect the second regulator accuracy. After the regulator the compressed air fed into a questionably sized length of stainless steel tubing, then to the robotic arm.

Blowing and Vacuum

There were a significant number of blowing applications found in the plant. These were typically pipes with holes drilled used to keep product free from any debris potentially dropping from the process. The site used quite a number of low-pressure blowers in their process and could easily adapt similar units for product blow off.

Also in service were compressed air powered vacuum generators. These units were configured in continuous use and could likely be replaced by a central vacuum system.

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> **"These devices will operate the most efficiently and more reliably if the compressed air pressure is properly regulated at a constant pressure. To ensure a constant pressure the regulators feeding the device need to be properly installed, sized correctly and adjusted appropriately."**
>
> **— Ron Marshall, Marshall Compressed Air Consulting**

COMPRESSED AIR AUDIT DISCOVERS PROBLEMS AT ELECTRONICS FIRM

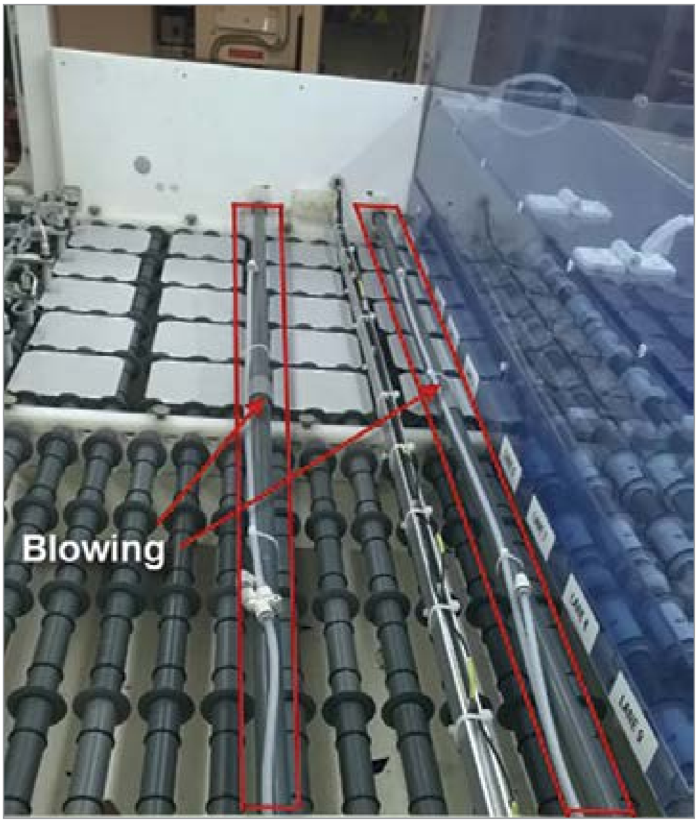

Figure 8. Two blowing pipes with holes stretched across two conveyors. Only one has product, while the other blowing is wasted.

Proposed ECM's	cfm	kWh
Reduce artificial demand	200	382,374
Reduced blowing	300	573,561
Reduce leakage	325	621,358
Better compressor control	0	704,363
Repair Dryer Leak	260	497,086
Total	**1085**	**2,778,742**
Nitrogen System - input compressor	0	1,104,023
Heat recovery potential	0	21,102,840
Adsorption chiller potential	0	2,637,855

Figure 9. Potential Energy Conservation Measures

Leakage

Leakage detection was done in the plant using an ultrasonic detector. Quite a number of leaks were detected on fittings and hoses in the plant, all items subject to mechanical stress during normal production. Considering the plant was fairly new, less than 5 years into production, the leakage levels were found to be low. There, however, was no formal leakage detection and repair program in the plant to address the growing number of leaks occurring every day. Of concern was the leakage of nitrogen, considerably more costly than compressed air, and represents a suffocation hazard if leaks occur in a closed space.

Savings Estimates

The following items were identified for potential improvement at the plant. A number of items such as the Nitrogen system and additional heat recovery are identified as potential future improvements.

Recommendations

The following are recommendations mentioned in this report for future action:

1. Analyze pressure problem areas in the plant with data loggers.
2. Lower machine pressure regulator pressure to recommended settings.
3. Investigate conversion of blowing devices on production machines.
4. Investigate conversion of vacuum pick-ups to central vacuum.
5. Modify problem areas by removing redundant regulators and upgrading supply capacity.
6. Develop connection sizing standard to prevent pressure differentials due to undersized pipe.
7. Start a leakage detection and repair program, train staff, add leakage to quality assurance procedures during machine maintenance.
8. Better adjust the air compressor controller, adjust VSD air compressor and return to service.
9. Repair leakage in dryer 3, repair dryer 4 heater.
10. Investigate high-pressure differential on dryer pre-cooler.
11. Investigate filter requirements, remove redundant filter, set up element replacement schedule.
12. Install better differential gauges for filters.
13. Service faulty dryer drains.
14. Consider installing air compressor flow meters and power meters on air compressors and dryers to enable efficiency monitoring.
15. Investigate improving Nitrogen system efficiency by using standalone air compressor or higher generation pressure, review the need for 8 bar nitrogen in process.
16. Investigate additional heat recovery BP

For more information contact Ron Marshall, Marshall Compressed Air Consulting, tel: 204-806-2085, email: ronm@mts.net

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


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RESOURCES FOR ENERGY ENGINEERS

TECHNOLOGY PICKS

New Kaeser Oil-Free Rotary Screw Air Compressors

Kaeser Compressors has launched a new line of oil-free rotary screw air compressors. The new CSG-2, DSG-2 and FSG-2 series are engineered for the lowest life cycle costs possible.

The CSG-2, DSG-2 and FSG-2 models cover flows from 192 to 1,774 cfm, pressures from 45 to 145 psig, and horsepower from 50 to 450 hp. Available air-cooled or water-cooled, these new two-stage oil-free air compressors have been designed with energy efficiency, easy maintenance and low noise levels in mind. Models are up to 9% more efficient than the competition.

The core of these versatile models' top performance is their premium, two-stage compressor airend. The rotors' special coating can handle temperatures up to 575°F. This highly abrasion-proof coating will not wear, providing reliable sealing and protection. This means compressed air delivery and energy consumption remain consistent, even after years of operation. Stainless steel rotors in the second compression stage help guarantee compressed air quality and significantly increase service life.

The CSG-2, DSG-2 and FSG-2 series are available in a range of 50 to 450 hp and in air-cooled and water-cooled models.

Units come standard with Sigma Control 2™. This intelligent controller offers unsurpassed air compressor control and monitoring with enhanced communication capabilities for seamless integration into plant control/monitoring systems and the Industrial Internet of Things (IIoT).

Additional features include IE3 premium efficiency motors with PT 100 sensors to measure and monitor winding temperatures for maximized motor switching frequency and minimized idling. The hydraulic inlet valve eliminates replacing pneumatic diaphragms, resulting in reduced service costs and downtime. Fiber-free pulsation dampeners keep pressure losses to an absolute minimum, maintain consistent air quality and prevent compressed air contamination. Built-in heat recovery options give sustainable energy savings and contribute to lowering a plant's carbon footprint.

About Kaeser

Kaeser is a leader in reliable, energy efficient compressed air equipment and system design. We offer a complete line of superior quality industrial air compressors as well as dryers, filters, SmartPipe™, master controls, and other system accessories. Kaeser also offers blowers, vacuum pumps, and portable gasoline and diesel screw air compressors. Our national service network provides installation, rentals, maintenance, repair, and system audits. Kaeser is an ENERGY STAR Partner.

For more information, visit www.kaesernews.com/oil-free. To be connected with your local authorized Kaeser representative, please call (877) 586-2691.

TECHNOLOGY PICKS

New Gardner Denver EnviroAire S Air Compressors

With the launch of the EnviroAire S scroll air compressor range, Gardner Denver has further extended its PureAir range of oil-free air compressors, now catering to application requirements in the 4 kW to 15 kW range.

Air purity is crucial in a variety of industries, ranging from food production and pharmaceuticals, to electronics and biotechnology. With its compact design and low noise operation, the EnviroAire S series of air compressors is ideally suited to ensure full protection from contamination and meet the demands of sensitive environments such as laboratories and hospitals.

Compact, Modular and Application-Oriented

The EnviroAire S series provides continuous, reliable, low-maintenance operation to meet a variety of flexible compressed air demands. Available in a range of kW sizes, starting at 4 kW for Simplex units, and 7 kW for Duplex units, the EnviroAire S series is capable of delivering a volume flow between 23.6 to 106 m³/hr at 8 bar, and 21.2 to 82.6 m³/hr at 10 bar.

Control and Monitoring at Your Fingertips

The EnviroAire S series can also be installed with the optional Deluxe HMI control panel. With an intuitive and easy-to-use graphical user interface the Deluxe HMI control panel provides users with real-time information such as system runtime meters, maintenance timers, and discharge pressure/temperature statistics. An integrated web server utilizes Modbus TCP over Ethernet, allowing users to monitor EnviroAire S units from any internet-connected computer, smartphone or mobile device.

About the Gardener Denver Industrials Group

Gardner Denver Industrials Group delivers the broadest range of air compressors and vacuum products, in a wide array of technologies, to end-user and OEM customers worldwide in the industries it serves. The Group provides reliable and energy-efficient equipment meant for work in a multitude of manufacturing and process applications. Products, ranging from versatile low- to high-pressure air compressors to customized blowers and vacuum pumps, serve industries including general manufacturing, automotive, and wastewater treatment, as well as food & beverage, plastics and power generation. The group's global offering also includes a comprehensive suite of aftermarket services to complement its products.

The EnviroAire S series Duplex units are available in a range of sizes, starting at 7kW.

Gardner Denver Industrials Group, part of Gardner Denver, Inc., is headquartered in Milwaukee, WI. Gardner Denver was founded in 1859 and today has approximately 7,000 employees in more than 30 countries. For further information, please visit www.gardnerdenver.com.

BOGE C-2 Series of Oil-Lubricated Screw Air Compressors

BOGE Kompressoren is developing a new, oil-lubricated screw air compressor in the performance class of up to 22 kW. The C 22-2 LFR air compressor will be available with and without a receiver as well as with the option of an attached compressed air dryer. Further development will focus on easy maintenance, noise reduction and efficiency across the entire C series. One of these developments is a new, optimized airend for the 7.5 to 11 kW range. The market launch of the new C-2 series should be completed in 2018.

"The performance segment from 2.2 to 22 kW accounts for approximately 2/3 of the market volume worldwide," said Markus Henkel, Product-Market Manager at BOGE. "With the C-2 series, we continue to develop our well-established C series, taking into account customer and distributor requests." Machines on receivers

RESOURCES FOR ENERGY ENGINEERS

TECHNOLOGY PICKS

and those with dryers have a large share in this performance segment. Thus, in its redesigned version of the series of air compressors up to 22 kW, the Bielefeld-based family enterprise gives highest priority to the technological development of the C-2 machines. These are suitable for receiver and floor assembly and will be available with an optional dryer. Easy setup of a complete compressed air station will be possible in the smallest of spaces. The control system can be mounted variably, at the top or at the front for floor or receiver installation, respectively.

In the frequency-controlled C-2 screw air compressors, BOGE is replacing the belt drive with a direct drive in order to improve system features and meet increasing efficiency standards. For further energy savings, the company also offers an optional frequency-controlled fan and IE4 motors. As a result, sound level and power consumption are reduced. Thanks to a new component arrangement, annual maintenance can be conducted easily from one side of the machine. Additionally, a variable cooling air outlet enables flexible connection to the exhaust air duct for use of discharged heat.

BOGE is devoting special attention to its performance range of 7.5 to 11 kW. As a result, it has specially created a new airend satisfying the highest efficiency requirements, providing a respectable free air delivery-efficiency ratio. Further goals are improved performance, quiet running and reduced power consumption. This airend, like many other C-2 models, will also be eligible for BAFA incentives.

About BOGE

With more than 100 years of experience, BOGE Kompressoren Otto Boge GmbH & Co. KG is one of the oldest manufacturers of air compressors and compressed air systems in Germany. It is also one of the market leaders. Whether for High Speed Turbo air compressors, screw air compressors, piston air compressors, scroll air compressors, complete systems or individual devices, BOGE meets the most diverse requirements and highest standard. The family, operating internationally, has a workforce of 750 employees, approximately 450 of whom work at the headquarters in Bielefeld, and is managed by Wolf D. Meier-Scheuven and Thorsten Meier. With its numerous sales offices and subsidiaries, BOGE is available to its international customers at a local level and supplies products and systems in more than 120 countries worldwide. For more information visit www.boge.com/us.

New Kahn Easidew 2-Wire Dewpoint Transmitter

Kahn Instruments, based in Wethersfield, CT, is a leading manufacturer of advanced moisture-measurement instrumentation. Kahn announced the upgrading of the Easidew Dewpoint Transmitter. The new and improved Easidew 2-Wire Transmitter is a low cost, rugged dewpoint transmitter for continuous measurement of compressed air or process gas.

The new Easidew 2-Wire Dewpoint Transmitter has a dewpoint measurement range of -148˚F to +68˚F.

New and improved features include:

- The ability to be connected in a 2-wire, loop powered configuration, while maintaining complete backward compatibility with all existing 3-wire installations
- An output configurable in PPMv moisture content (0-100, 0-1000 and 0-3000 PPMv ranges)
- A new 10 micron HDPE sensor guard designed to show contamination for service ease
- Improved software and firmware to protect calibration from the most severe levels of EMI

The Easidew Transmitter has a dewpoint measurement range of -148˚F to +68˚F and an accuracy of ±3.6˚F. The instrument also features a field adjustable 4-20 mA linear analog output, resettable failure modes for Over Range, Under Range and Sensor Fault conditions and temperature compensation.

The Easidew Transmitter is economical to purchase, install and maintain. Volume manufacturing allows Kahn to keep the price low. Installation costs are minimal, because of the transmitter's ruggedness and simplicity. Ongoing operating costs are low, because the Easidew Transmitter is reliable and durable. Only periodic re-certification is required to maintain calibration accuracy. Kahn even offers an exchange program so a customer's process is never out of operation.

For more information contact Kahn Instruments, Inc., email: hygros@kahn.com or visit www.kahn.com.

TECHNOLOGY PICKS

Festo E2M Module Now Compatible with PROFINET

First introduced in 2015, the MSE6-E2M (E2M) intelligent service unit is now compatible with Ethernet/IP and PROFINET communication protocols – significantly expanding potential applications in North America. E2M units can pay for themselves in less than a year with the energy savings accrued.

The E2M automatically shuts off the air supply to a machine when in standby mode, reducing energy consumption. E2M performs typical monitoring functions, making system pressure and flow information available in real time. This enables faster response to compressed air leaks.

The E2M features a solenoid valve integrated with a pressure and a flow sensor in one compact package. These units flow up to 5,000 liters of compressed air per minute. The units are easily programmed and can quickly connect to Festo MS series air preparation units.

Automatic Standby Mode to Save Energy

Based on user-defined parameters, the E2M module detects when a machine is idle and automatically shuts off the air supply. When the unit receives a startup signal from an operator, the E2M resupplies compressed air. In the case of a particularly complex production process, automatic standby detection can be deactivated in favor of manual operation.

Automatic Leakage Detection

The E2M unit detects when there is a pressure drop greater than a predefined value and sends an alert about a possible leak. Higher than anticipated air flow during production also indicates possible leakage and triggers an alert. Eliminating leaks not only saves energy, it also brings the compressed air system back to specification, ensuring quality operation of the machine, optimum throughput and higher overall equipment effectiveness (OEE).

A Wealth of Data and Industry 4.0 (IoT)

Festo's MSE6-E2M module automatically monitors compressed air consumption and can alert plant personnel to system leaks.

The E2M actively monitors the condition of the pneumatic system in real time. This feature gives plant operations personnel access to up-to-the-minute process-related data as well as comparative data over time. Values for flow rate, air consumption and pressure are continuously available. Data can help personnel determine historical trends on consumption, the amount of air consumed per product batch, and pressure and flow at the time of a malfunction or bad batch of product. Two common themed areas of Industry 4.0 and the Internet of Things (IoT) are condition monitoring and energy efficiency; the Festo E2M addresses both. The E2M module is suitable for new machines and as an easy retrofit to existing machines.

About Festo

Festo is a leading manufacturer of pneumatic and electromechanical systems, components and controls for process and industrial automation. For more than 40 years, Festo Corporation has continuously elevated the state of manufacturing with innovations and optimized motion control solutions delivering higher performing, more profitable automated manufacturing and processing equipment. For more information visit https://www.festo.com/cms/en-us_us/index.htm.

RESOURCES FOR ENERGY ENGINEERS

TECHNOLOGY PICKS

New WebServer for Airleader Master Controller

Airleader is a leading German manufacturer of the award winning air compressor Master Controller Professional. The demand logic is second to none delivering higher energy savings as OEM offered controllers or sequencers. The Airleader WebServer comes as a part of the master controller because we believe without a monitoring system it is impossible to keep your compressed air system tuned.

The new and improved Airleader WebServer makes it easier to chart and view data from compressed air systems.

Our transparent WebServer viewing just got better. The load cycling and specific power (kW/100 CFM) information is permanently shown on the left and right of the chart. All other measured data can be accessed at the bottom of the chart with a single click.

Data is monitored based on historical average and actuals to allow easy detection of reduction of system specific performances. With the click any of the metered parameters the data gets charted:

- Absolute power (kW)
- Flow (m^3/min or CFM)
- Dew point (˚C / ˚F)
- Pressure (bar/psi)
- Performance (daily/weekly/monthly)
- Air quality data

The Master Controller functions also as a continuous data logger. Data is stored for years to come and can be downloaded as required for verification, for example, in custom utility incentive projects. The OPC Server is available to transfer any data point into a third-party monitoring system.

For more information, please visit our website at www.airleader.us.

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Sustainable Energy Savings with Compressed Air Best Practices®

Compressed Air Best Practices® is a technical magazine dedicated to discovering **Energy Savings** in compressed air systems — estimated by the U.S. Department of Energy to represent 30% of industrial energy use. Each edition outlines **Best Practice System Assessments** for industrial compressed air users — particularly those **managing energy costs in multi-factory companies.**

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– Uli Schildt, Energy Engineer, Darigold Dairies
(feature article in April 2016 Issue)

"Compressed air is our lifeline. Everything here runs on compressed air."

– Curtis Wood, Facilities Team Supervisor, HAECO Americas
(feature article in June 2016 Issue).

"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, storage, measurement and pneumatic control technology.**

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"Compressed air optimization measures reduced consumption by 31% resulting in 3.8 million kWh and $255,000 in annual savings."

– Abdul Mohideen, Electrical Energy Manager,
PROTON Automotive, Malaysia

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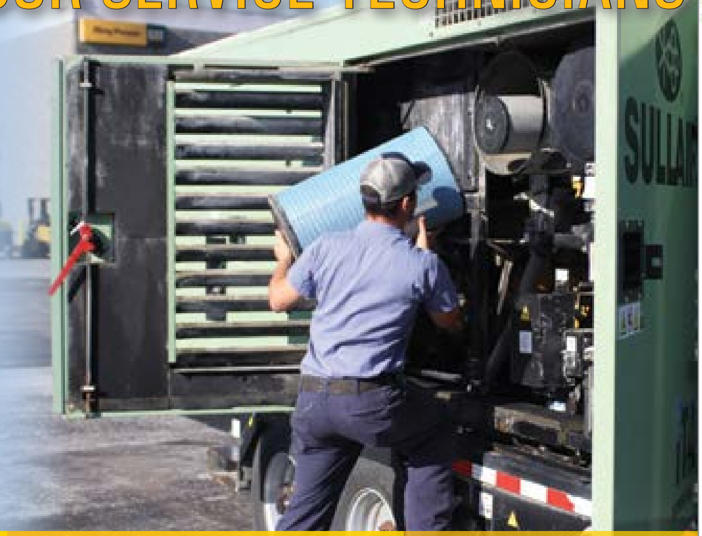

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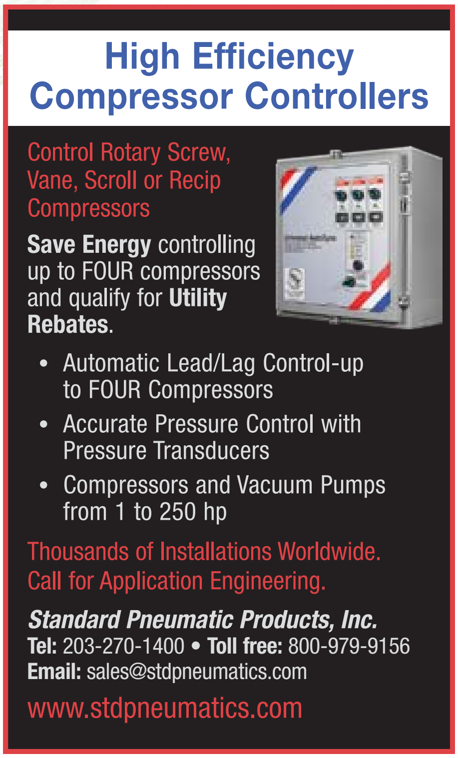


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Customer Success Story

KAESER COMPRESSORS
Built for a lifetime.™

Sweet Savings!

A compressed air audit opens a world of savings opportunities

PROBLEM: One of the world's leading candy and gum manufacturers had no idea how much their compressed air system was costing them. Four compressors (totaling 290 hp) supplied the air needed for pneumatic controls, packaging, and wax line extrusion applications. Excessive water in the compressed air lines, steep maintenance costs, and high noise levels had them looking for a new solution.

SOLUTION: A comprehensive Air Demand Analysis (ADA) established a demand profile for the plant and showed how they were using compressed air throughout the week. It also identified areas of waste and inefficiency. By installing a 100 hp variable frequency drive compressor and two 75 hp fixed speed compressors, they would have all the air needed—with one of the fixed speeds acting as a back-up. This split system solution would bring energy—and noise levels—well under control. A Sigma Air Manager 4.0 master controller could provide on demand energy reports so they would always know how their system was performing and what it was costing.

RESULT: In just over 9.5 months, the project has paid for itself. Annual energy costs have been cut by more than 800,000 kWh. Part of these savings came from reducing the plant pressure from 125 psi to 100 psi. Additionally, the new energy efficient dryers installed have taken care of the moisture concerns. Needless to say, these savings couldn't get any sweeter.

Specific Power of Previous System:	47.16 kW/100 cfm
Specific Power of New System:	17.77 kW/100 cfm
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TOTAL ANNUAL ENERGY SAVINGS:	**$80,235**
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