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April 2015

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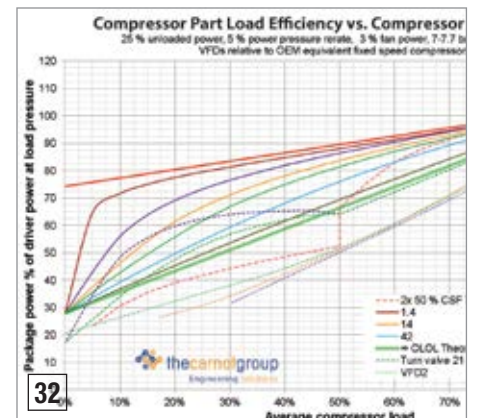
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FROM THE EDITOR

Biogas Purification



Thanks to our friends at Xebec and Parker, this issue inched my knowledge forward a bit on biogas purification by clarifying the process differences between raw gas purification and upgrading to biomethane. I hope it does the same for some of our readers. These systems use blowers, vacuum pumps, chillers, dryers and compressors – all of the technologies we cover. It made me wonder if the gas utilities in the U.S. might increase the practice of incentivizing factories to purchase renewable biogas?

Steven Scott, from Parker's FAF Division, provides us with an excellent article reviewing different kinds of raw biogas purification steps potentially required, depending upon the site, before "upgrading" to biomethane can occur. His article reviews raw biogas particulate prefiltration, dehumidification, and the removal of hydrogen sulfide (H_2S), siloxanes and volatile organic compounds.

A true entrepreneur, Kurt Sorschak from Xebec, got up at 5 AM in Shanghai to cheerfully conduct a Skype interview with me on their new membrane/PSA hybrid systems for biogas upgrading, hydrogen purification and helium recovery. The article contains some important news for the Canadian compressed air industry (how's that for a teaser) and also a very educational description of the six stages in a typical large-scale biogas upgrading system.

Compressed air industry veteran, Ron Nordby, shares his thoughts in an interesting article reviewing "Managing Change in the Industrial Air Compressor Industry." Focusing on distributors and their views, Ron walks through three steps in a process he believes can help distributors be proactive in managing the forces of change that confront them.

Murray Nottle is an Engineer with The Carnot Group in Australia. His article proposes a compressed air system parameter he calls the "CSF Compressor System Factor." He defines CSF as the percentage of a compressor's capacity per minute stored and released by the system volume during each load/unload cycle.

An underestimated challenge, to optimal compressed air system design, is the fact that the demands placed upon them are always changing! Ron Marshall, on behalf of the Compressed Air Challenge®, writes about a rapidly expanding factory and how a poor sizing decision was made when selecting an additional air compressor. The compressor horsepower size selected created a control gap difficult to overcome.

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

ROD SMITH

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*April 2015 Cover Photo supplied
courtesy of Parker FAF Division.

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INDUSTRY NEWS

Xebec Adsorption Introduces Membrane Gas Purification Solutions

Xebec Adsorption Inc., a provider of gas purification and filtration solutions for the natural gas, field gas, biogas, helium, and hydrogen markets, announced, it will be integrating high efficiency membranes into its gas purification and separation solutions.

Xebec has historically been offering gas purification and conditioning solutions solely based on adsorption technology. After an in-depth evaluation of membrane technologies, Xebec will now offer standalone membrane solutions, as well as hybrid (membrane + adsorption) solutions, which are able to achieve recovery rates and purity levels so far unobtainable with adsorption technology alone.

For biogas upgrading applications, Xebec membrane systems will achieve recovery rates of up to 99.8%, while meeting stringent product gas specifications. For biogas or landfill gas applications containing nitrogen (N₂) and oxygen (O₂), Xebec offers advanced fast cycle kinetic pressure swing adsorption (kPSA) solutions that can handle nitrogen levels of up to 30% with excellent recovery rates.

For hydrogen applications, Xebec now integrates membranes into its overall system design, which results in significantly higher overall recovery rates, while still being able to meet extremely stringent product gas specifications of up to 99.9999% pure hydrogen.

Xebec has been designing advanced Helium (He) recovery systems for several years, but has just recently developed a hybrid helium purification and conditioning system that will take low helium concentrations from a gas well, typically 0.6% to 2.5% of helium, and purify the gas stream to 99.999% (5 nines)

pure helium, while achieving recovery rates of up to 95+%. After the helium purification step, the product helium gas can be liquefied or compressed for further monetization. Thanks to the fast cycle PSA technology of Xebec and the utilization of high performance membranes, these helium purification systems have a relatively small footprint, and can be deployed in remote areas.

About Xebec Adsorption Inc.

Xebec Adsorption Inc. is a global provider of clean energy solutions to corporations and governments looking to reduce their carbon footprints. With more than 1,500 customers worldwide, Xebec designs, engineers and manufactures innovative products that transform raw gases into marketable sources of clean energy. Xebec's strategy is focused on establishing leadership positions in markets where demand for gas purification, natural gas dehydration, and filtration is growing. Headquartered in Montreal (QC), Xebec is a global company with two manufacturing facilities in Montreal and Shanghai, as well as a sales and distribution network in North America and Asia.

For more information visit
www.xebecinc.com

Ariel Corporation Developing New Production Facility

Ariel Corporation announced it is currently developing a new production facility in the Heath-Newark-Licking County Port Authority business complex. The 50,000 square foot building is the first phase of expansion and calls for the hiring of machinists and support personnel from the central Ohio region. The Ariel-Newark facility will increase Ariel's manufacturing capacity in the production of our reciprocating compressor product line.



“CNG is cleaner, costs less, and is made in the U.S.”

— Earl Benton, CEO and President, Champion Brands, Inc.

Established in 1966 and headquartered in Mount Vernon, Ohio, Ariel Corporation is the world's largest manufacturer of separable reciprocating gas compressors utilized by the global energy industry. As a world-class manufacturer, Ariel sets the industry standard through industry-leading research & development, expert design & manufacturing, and unmatched customer support.

*For more information visit
www.arielcorp.com*

amp Trillium Holds Grand Opening for First Public Access CNG Station in Jacksonville, FL

amp Trillium LLC, the joint venture between ampCNG and Trillium CNG, and Champion Brands Incorporated (CBI) recently celebrated the grand opening of Northeast Florida's first public access compressed natural gas (CNG) refueling station. The new station will be open 24 hours a day, seven days a week, and features Trillium

CNG's proprietary fast-fill hydraulic intensifier compressor (HY-C).

Close to 100 people gathered to celebrate and solidify Northeast Florida's leadership in the natural gas industry. Noted dignitaries in attendance included: State Representative Lake Ray (R-Jacksonville); City Councilmen Jim Love and Greg Anderson; Ted Carter, Executive Director, Office of Economic Development, City of Jacksonville (COJ); Daniel Davis, President,

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L-R: Chris Turner, Florida Natural Gas, Councilman Greg Anderson, COJ, Representative Lake Ray (R-Jacksonville), Donna Rolf, ampCNG, Earl Benton, Champion Brands, Ted Carter, OED, COJ, Bill Zobel, Trillium CNG, Alan Mosley, JaxAlliance and Jeff Sheffield, North Florida TPO, Photo Credit: Ken McCray Photography

JaxChamber; Alan Mosley, Executive Director, JaxAlliance; and Jeff Sheffield, Executive Director, North Florida TPO, to name a few.

Attendees were invited to tour the inner-workings of the new CNG station and participate in fueling demonstrations before and after the official program. Everyone left with an understanding of the importance of this project to the future of the region's economic development and natural gas infrastructure.

The opening of Northeast Florida's first public access CNG station supports the region's quest to be the transportation, logistics and natural gas hub of the Southeast — and eventually of the U.S. It also supports the Global Cities Initiative to increase exports.

Donna Rolf, President of ampCNG, said: "What comes first, the chicken or the egg? While many regions debate between purchasing CNG trucks first and then building a fueling station, or building a fueling station and then hoping trucks come, Jacksonville decided to do both at the same time."

Earl Benton, CEO and President, Champion Brands, Inc., commented: "I've been waiting four years for this. CNG is cleaner, costs less, and is made in the U.S. I'm a capitalist, don't get me wrong. If this didn't make good business sense, first and foremost, we wouldn't be here today. The bonus — I have a hand in leaving this planet in a better place. And with this sustainable snip (cutting of the ribbon) we have the first public access CNG Station in Northeast Florida."

State Representative Lake Ray added: "It begins with understanding the opportunities and setting the pathway for the future. In 100 years, I'll be lost in history, but what we accomplished today with CNG."



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The new station, which uses a public access card reader, includes two dual hose dispensers, enabling two semitrailers to fuel at the same time. This station marks an important milestone in host Champion Brands' mission to replace its entire fleet of trucks to CNG by July 2017.

For more information, visit www.ampcng.com

Ariel Compressors Installed in Ohio's Largest Public CNG Station

The City of Columbus is gearing up to open the second in a series of compressed natural gas fueling stations in Ohio's capital city.

The public station, located at 2333 Morse Road, is comprised of nine dedicated CNG

fueling pumps and will be open to the public once all testing of the facility is complete. The station was financed by a city bond package passed in November of 2013.

Columbus Mayor Michael Coleman was on hand to celebrate the station dedication, and was eager to discuss his views on bringing this alternative fuel to the city. "When I think about saving tax payers dollars, protecting our environment and cutting edge technology — I think about CNG stations in the city of Columbus," said Coleman.

Mayor Coleman and Councilwoman Priscilla Tyson praised city employees for their passion and drive to get the stations finished on time and on budget. Councilwoman Tyson also took

the time to highlight the choice of equipment for the newest station — Ariel compressors.

"By building this station we are lowering the amount of harmful pollutants in the air, reducing our dependence on foreign oil and also creating jobs in Ohio. This station represents a \$6.4 investment into this community which includes equipment made in this state — like the Ariel compressors that are made right here in Ohio," said Tyson.

Columbus opened its first CNG fueling station on the east side in 2012, and has saved taxpayers over \$600,000 in fuel costs for the city's CNG fleet. About 40 percent of the fuel pumped has been sold for private vehicles. By 2020, the city will have 440 CNG vehicles

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INDUSTRY NEWS

in this fleet, which is estimated to save the city around \$1.9 million per year in fuel costs.

The Morse Road station is the second step in a 10-year plan to promote CNG use and allow for adequate fueling sites in central Ohio. Preliminary designs for a third station, which will be located on the west side of the city, are currently underway.

“At one time there was a gas station on every corner in America. In the future, there may be a CNG station on the corner of every street in Columbus. Imagine what that would do for our economy,” said Coleman.

For more information regarding CNG, visit <https://www.arielcorp.com/cng/> or <http://www.ngvc.org/>

National Waste Associations Comment on Proposed Revision to U.S. EPA Landfill Regulations

The Solid Waste Association of North America (SWANA) and the National Waste & Recycling Association (NW&RA) have jointly provided comments to the U.S. Environmental Protection Agency on its proposed rules to update the Standards of Performance for Municipal Solid Waste Landfills. The SWANA/NW&RA joint comments are available at <http://bit.ly/NSPSCComments>.

SWANA and NW&RA represent the private and municipal (public) sectors of the waste and recycling industry in the United States and share concerns about unnecessary new regulations in EPA's proposed rule. John H. Skinner, Ph.D., SWANA executive director and

CEO, and Sharon H. Kneiss, NW&RA president and CEO, cosigned the submission to EPA.

“EPA's proposed new rule and cost analysis substantially underestimates the number of existing landfills that will be affected,” Skinner said. “Significant investments have already reduced methane emissions from existing landfills by more than 30 percent since 1996. Applying these new facility requirements to existing landfills could disrupt the progress already made and make it more difficult and expensive to achieve greater emission reductions.”

“Landfills are a critical component in the spectrum of waste management options in the United States, but the latest round of regulations proposed by the EPA create significant, undue burden that will prove harmful to continued development of renewable energy projects and efficient management of America's waste,” Kneiss said.

The joint comments express concern that the proposed rule establishes several unnecessary agency review processes and reporting redundancies that will hamper facility efficiency. These added processes and redundancies will slow operational changes, reduce efficiencies, increase costs and expose landfills to potential violations while not providing any environmental benefit.

Further, the comments note that the EPA did not consider the financial impact of its proposed rule on existing facilities that expand or make site modifications, which are the vast majority of those that will be affected, when assessing programmatic costs. EPA's cost analysis considered only the projected impact on landfills opening in 2014 or later, which is a relatively small number.

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The comments also warned that EPA's proposed treatment standards would require highly expensive additions to and maintenance of renewable energy infrastructure, potentially damaging the momentum behind repurposing America's waste as a resource. These new standards would dramatically increase costs and administrative oversight at modified waste facilities, possibly leading them to cease operations and precluding new renewable energy projects from being developed.

It is anticipated that EPA will publish the final rule early next year after issuing its proposed rule July 17 of this year.

About SWANA:

The Solid Waste Association of North America (SWANA) is a professional association with

the mission of promoting environmentally and economically sound management of municipal solid waste in North America and serves over 8,000 members from both the public and private sectors. For more than 50 years, SWANA has been the leading association in the solid waste management field. SWANA serves industry professionals with technical conferences, certifications, publications and a large offering of technical training courses.

*For more information, visit
www.SWANA.org*

About NWRA:

The National Waste & Recycling Association is the trade association that represents the private sector waste and recycling services industry. Association members conduct business in all 50 states and include

companies that collect and manage garbage, recycling and medical waste, equipment manufacturers and distributors and a variety of other service providers.

*For more information
about NW&RA, visit
www.wasterecycling.org*

Spectronics Promotes Limin Chen to VP of Manufacturing

Spectronics Corporation has announced the promotion of Limin Chen to the position of Vice President of Manufacturing and Special Projects.

Limin began his career at Spectronics in 1993 as a Mechanical Product Development Engineer, and has been the lead engineer for the Pipe Freezer, UV EPROM/Wafer Eraser and Grid Lamp products for more than 10

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years. He has also worked on fluorescent leak detection products and been involved in other areas as well.

Before joining Spectronics, Chen worked as a Product Development Engineer at the Shanghai General Machinery Corporation for 8 years. He holds an Associate's Degree in Manufacturing, a Master's Degree in Business Administration, as well as Bachelor's and Master's Degrees in Mechanical Engineering.

As part of his duties, Limin will direct and guide Spectronics' manufacturing/engineering team in establishing procedures and all required documents in the manufacturing process from start to finish. The team will also supply the production department with the proper tools, equipment and machines needed to fulfill orders on a timely basis, produce

products of the highest quality, and monitor ongoing productivity improvements.

In addition, Limin will direct and guide Spectronics' plant engineering team, which is responsible for the overall maintenance of the manufacturing facility.

Spectronics Corporation is committed to the same ideals today as when it was founded 60 years ago — to produce top-quality, competitively priced products that are on the cutting edge of today's technology.

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Limin Chen, VP of Manufacturing and Special Projects, Spectronics Corporation

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From Dehumidification to Siloxane Removal: PARKER BIOGAS PURIFICATION

By Steven Scott, Business Development Manager —
Alternative Energies, Parker Hiross Zander Filtration Division



A Parker Regenerative Siloxane Removal System

► Biogas Production and Utilization

Biogas is an extremely valuable energy source. Originating from biomass, sewage, plants and landfill sites, it is gaining ever-increasing worldwide recognition as a premium source of renewable energy. It is also making a major contribution to the global energy supply mix by replacing existing fossil-fuel sources such as coal, oil and conventional natural gas.

In biogas production plants, anaerobic digestion is a process that occurs when microorganisms decompose the organic content of the feedstock in the absence of oxygen to generate raw biogas. The principle constituents of raw biogas are methane and carbon dioxide, with other trace gases also present in differing amounts depending on the feedstock and digestion process.

The characteristics of biogas are comparable to natural gas in that the methane concentration defines the energy content of the gas — the higher the methane content, the higher the calorific energy value of the gas.

The most common method of using biogas for energy production is through combustion in a gas engine or turbine to generate a combination of heat and electrical power (CHP). Biogas can also be upgraded, which essentially entails the removal of CO₂, to produce biomethane (also known as renewable natural gas), which is equivalent to conventional natural gas (CNG) and can be injected into the gas grid or used as a vehicle fuel.

Raw Biogas Treatment

Most of today's digestion processes produce biogas that is saturated with water vapor and contains varying degrees of other impurities. These impurities may cause corrosion, deposits and damage to equipment, and they should be removed before biogas is used to produce energy.

Gaseous constituents that should be removed (or reduced) along with water vapor include hydrogen sulphide, halogen compounds (chlorides, fluorides), ammonia, siloxanes and volatile organic compounds (VOCs). Biogas also contains dust and dirt particles, which should also be removed as part of the raw biogas treatment process.

The selection of an effective biogas treatment is therefore particularly important, especially for optimizing the cogeneration of electrical and thermal energy, making the most of the available renewable energy, reducing energy consumption, and keeping operating costs to a minimum.



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Particulate prefilters can prevent pipescale from fouling heat exchangers

Biogas Particulate Prefiltration

Biogas produced in anaerobic digesters and landfills contain foams, small solid particles in suspension, greases, particulates and other contaminants that must be removed from the gas by filtration prior to any downstream equipment or pipework. Failure to remove these impurities may lead to a malfunction of devices and processes downstream.

It is beneficial for all biogas production systems to install a coarse particulate filter (around 25 micron is optimal) as a first line of protection for all downstream equipment.

A well designed particulate filter for raw biogas should combine particle retention efficiency with extremely low pressure-drop to produce clean, ready-to-use biogas, while minimizing service costs. It is also imperative that the materials of construction, principally the housing and the filter element, are resistant to the aggressive contaminants in the gas.

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Biogas Dehumidification

It is generally accepted that a reduction in water content is beneficial to the CHP system, however, traditional methods, such as condensate traps and underground pipework, cannot achieve low dew points, consequently reducing the benefit of removing water. For underground pipework alone to have any real cooling effect, long runs of pipe are necessary, which is often impractical, expensive, and difficult to maintain and service.

It is also common to use “air conditioning” type chillers for biogas cooling, but these units are not designed to produce low-temperature water. They either result in higher gas dew points or end up operating well outside of their design limits, resulting in higher energy consumption and reduced service life.

It is therefore essential to use a cooling system, such as those in the Parker BioEnergy range, specifically designed to produce low dew points and operate in aggressive ambient conditions, such as those experienced in biogas applications.

The 4 Major Benefits of Dehumidifying Biogas

There are four major benefits of dehumidifying biogas. It will increase the energy content of gas, prevent the corrosion of pipework and system components, partially removes or reduces concentrations of specific gases, and complies with instructions from major gas engine suppliers.

1. Increases Energy Content of Gas

Raw biogas usually has a very high water vapor content (between 30 and 100 g water per m³ gas), which equates to between 4 and 8 percent of the total gas composition and reduces the calorific value of the gas. Drying biogas to a dew point of 5 °C reduces the moisture content

to 1 percent, thus increasing the methane content by around 5 percent. This, in turn, increases the calorific value of the gas.

2. Prevents Corrosion of Pipework and System Components

When ambient temperature drops, the gas cools, causing water vapor to condense in the pipeline. Condensate can combine with CO₂, hydrogen sulfide (H₂S), etc. to form an acidic compound that causes the accelerated corrosion of machines, gas scrubbers, pipelines, buffer vessels, sensors and instruments. The combination of H₂S and water produces sulphuric acid and/or ionic hydrogen, and the combination of CO₂ and water produces carbonic acid. The resulting acidic condensate is highly corrosive and will cause a rapid drop in the alkalinity of the engine oil. Drying the gas to a low dew point ensures that water vapor

does not condense, thereby preventing the production of these corrosive acids.

3. Partially Removes H₂S, Ammonia, Siloxanes and Other Water-Soluble Gases

With efficient dehumidification, it is possible not only to remove the water vapor, but also to reduce the concentration of components, such as H₂S, siloxanes, ammonia and halogen compounds, each of which dissolves in the condensed water. The partial or complete removal of these contaminants improves the efficiency of the whole plant and greatly reduces maintenance costs and plant downtime.

4. Complies with Technical Instruction of Major Gas Engine Suppliers

Unlike petrol and diesel fuels, gaseous fuels generally do not have to comply with strict quality specifications. For this reason, the



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FROM DEHUMIDIFICATION TO SILOXANE REMOVAL: PARKER BIOGAS PURIFICATION



A Biogas dehumidification system

manufacturers of cogeneration engines issue technical instructions to ensure the fuel gas is of sufficient quality to prevent any negative effects on engine performance and service life.

In terms of water content, all of the major engine manufacturers are clear in stating that water condensate in the fuel gas pipes or engine is NOT acceptable.

Installing a cooling system to dry the gas to a low dew point will ensure that water vapor does not condense in the gas pipe, which helps meet the technical instructions of the major gas engine suppliers.

Hydrogen Sulfide (H₂S) Removal

Desulphurization of biogas is necessary to prevent corrosion, avoid high toxicity levels, reduce the frequency of engine oil changes, and prevent problems in the combustion process. Depending on the feedstock, H₂S levels can vary considerably, with typical concentrations ranging from 100 to 3000 ppm.

There are various processes available for the desulphurization of biogas, the most common being:

1. Biological Oxidation (Bioscrubber)

The simplest of the three processes uses air directly injected into the

fermenter and/or a bioscrubber to absorb the sulphur into the washing liquid. This process is often used for the bulk removal of H₂S.

2. Chemical Adsorption

Based on chemical reaction of H₂S with iron oxide or iron salts, this process can reduce high concentrations of H₂S to low levels, but a balance against operating costs needs to be achieved.

3. Physical Adsorption

The most common example of this method is the use of activated carbon, which can be untreated, impregnated or doped to improve efficiency. The high replacement costs make this process more suitable for fine desulphurization or polishing after a biological system.

Siloxanes and VOC Removal

Recent years have seen a marked increase in the use of siloxane-containing products, a substantial amount passing through to waste products both in sewage and landfill sites.

As the gas produced from these sites is used to power biogas-to-energy units, a substantial increase in the effects of the siloxane contamination will be seen in the form of crystalline silicon dioxide (quartz/sand) building up on the combustion surfaces inside generating engines — if the process is left untreated. In addition to damaged engine components, affected engines run inefficiently



“In terms of water content, all of the major engine manufacturers are clear in stating that water condensate in the fuel gas pipes or engine is NOT acceptable.”

— Steven Scott, Parker Hiross Zander Filtration Division

and produce excessive emissions, particularly carbon monoxide and mono-nitrogen oxides (NOx).

The result is increased operating costs, decreased electricity production and increased pollutants.

There are various technologies commercially available for the removal of siloxanes from biogas. The most common are adsorption-based systems that use media that can be regenerative or non-regenerative.

For lower concentrations of siloxanes, activated carbon is often used as an adsorption media. Activated carbon can remove siloxanes to very low levels, but this method has high operation costs due to the need for the frequent replacement and disposal of hazardous spent media.

For medium to high concentrations of siloxanes, the higher capital investment of a regenerative system is often justified. Regenerative systems can reduce siloxanes to low levels with adsorption media lasting much longer than carbon-based systems. For example, the PpTek BGAK Siloxane Removal System manufactured by Parker (Refer to Figure 4) can guarantee media life of 5 years, during which time siloxane concentrations will remain below 10 mg/m³.

“Upgrading” Biogas

Raw biogas can be “upgraded” to biomethane, which essentially means it is refined to natural gas quality and can be injected into a gas grid or used as vehicle fuel. To reach pipeline quality, the gas must be upgraded to the correct composition for the gas distribution network to accept.

Prior to upgrading, the gas should be conditioned (see Raw Biogas Treatment)

and, in the case of landfill and sewage gas applications, siloxanes and VOCs should be removed (see Siloxane and VOC Removal). The efficient removal of VOCs, such as limonene and other terpenes, is particularly important, as they can mask the odorants added to the upgraded gas as a safety requirement.

The Benefits of Purifying Biogas

The cleaning or purification of biogas involves a complex mix of filtration and separation technologies, but even the most basic of installations can benefit from the advantages of clean, dry gas. For power generation, gas engines are a significant investment in terms of capital and operating costs, making the investment in effective

and efficient biogas purification an even more important consideration. This applies even more so for biogas upgrading applications where the processing plants need a high degree of protection from contaminants, and the gas grid specifications strictly insist on clean, dry biomethane before injection can be permitted. **BP**

For more information, please contact Kevin Ray, Business Development Manager BioEnergy, Parker Hannifin Corporation, Finite Airtex Division, by phone at (716) 686-6582 or by email at kevin.ray@parker.com. Or, you can visit www.parker.com/hzd or www.parker.com/dhfn.

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XEBEC MEMBRANE/PSA HYBRID SYSTEMS FOR BIOGAS

By Rod Smith, Compressed Air Best Practices® Magazine

The Malaysian government passed a law requiring every palm oil plantation to operate a digester by the year 2020.

Compressed Air Best Practices® Magazine spoke with Xebec Inc. President, Mr. Kurt Sorschak.

► **Good afternoon, or actually good morning to you. How are things in China?!**

Good morning to you! Yes, I am visiting our factory in Shanghai and China continues to amaze me. Did you know that in rural China,

approximately 30 million households receive cooking fuel from super-small anaerobic underground digesters? China is just starting to look at industrial biogas upgrading in a serious manner. The market is in its' infancy but we believe in five years it will be the biggest biogas market in the world. Incineration is not popular as it requires a lot of energy. Here we have many manure-based issues. Soil and water contamination in densely populated areas can lead towards anaerobic digester

projects. Today there are very few projects although we are doing one right now in northern China.

Are infrastructure investments in China slowing down? Have they peaked?

I can't comment on whether they've peaked or not. Depending upon the topic, I can tell you the scale of infrastructure investments is still astounding. China currently is building six thousand (6,000) wastewater treatment plants. Yes, six thousand! Compare this to the total of 16,000 wastewater treatment plants in the U.S.

Last week we flew to a city in northern China with 6.5 million inhabitants. We then took a 1 ½ hour train ride to another city with four million people. We had to take the train because they don't have an airport there. This city is roughly the same size as the greater Montreal metropolitan area and has no airport! China currently has plans to build twenty major airports. We also believe biogas is part of the next investment chapter for China.

Can you define landfill gas and digester gas for us?

Landfill gas (LFG) and Digester Gas (DG), also known as Biogas (BG), are generated by microorganisms metabolizing organic materials in an anaerobic (oxygen-free) environment. The largest components of LFG and DG are methane and carbon dioxide, but smaller amounts of water vapor, hydrogen sulfide (H_2S), ammonia (NH_3) and volatile organic compounds (VOCs) can also be present in LFG and DG. Oxygen (O_2) and Nitrogen (N_2) are



sometimes found in low levels in LFG if there is in-leakage of air in the gas collection system at the landfill site.

LFG typically contains 45-55% methane (CH_4) and 45-55% carbon dioxide (CO_2), while DG typically contains 50-60% CH_4 and 30-35% CO_2 .

What kind of anaerobic digesters exist in southeast Asia?

It is clear the market is already here in southeast Asia. Here we have a very different situation with the huge palm oil plantations in countries like Malaysia and Indonesia. Some of these plantations cover hundreds of square kilometers. Palm tree fruit is pressed and the empty fruit pouches will either decompose and release harmful levels of methane and VOCs — or you put them into an anaerobic digester and produce biogas for electricity or fuel. The Malaysian government passed a law requiring every palm oil plantation to operate a digester by the year 2020.

Xebec has over 200 Biogas installations — how's the market doing?

Biogas started about 18 years ago primarily in Germany and Scandinavia. It was triggered by a U.N. protocol asking landfills and farms to cover the decomposing materials — as the methane going into the atmosphere is 21x more of a greenhouse gas than CO_2 . Landfills had flares until someone said, “lets produce electricity.” Initially the projects were almost all biogas to electricity- Germany alone has over 8,000 anaerobic digester on farms. Only two percent are upgrading methane for renewable gas, 98% are producing on-site electricity.

Today there are around 220 to 250 projects for biogas upgrading in North America and Europe. It's a small, niche market right now with five to eight companies offering equipment and technology. We are seeing more activity in North America due to a growing interest in renewable gas. Electric utility companies have the option to offer renewable-source electricity. Gas utilities are interested in being able to offer a renewable-

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source gas option. The biogas market has strong tailwinds and growth is accelerating, particularly in Asia.

Can you describe a typical large-scale biogas upgrading system?

Sure. Please keep in mind that there are many different technologies and system designs. I'll describe a typical six-stage system Xebec gets involved with. Readers can see these visually in an interactive process overview at www.xebecinc.com/biogas-plants.php

Stage 1: Feed Gas Blower Module: Raw landfill and digester gas are typically available at low pressure. A blower is used to draw the raw feed gas from the feed gas pipeline and increase its pressure in preparation for further pretreatment and compression. The feed biogas normally is saturated with moisture. A knock-

out drum, located on the low pressure side of the blower, removes entrained moisture. After passing through the blower, the heat of compression is removed in a heat exchanger. As the temperature is reduced, additional entrained moisture is formed. A coalescing filter is used to remove this moisture. The coalescing filter has a special media for the collection of free moisture, while allowing other components of the gas to pass through.

Stage 2: Hydrogen Sulfide Removal

Module: In many cases landfill and digester gas contains hydrogen sulfide at a level above acceptable limits in the product gas. Hydrogen sulfide (H_2S) is formed by microbial processes, is toxic and corrosive and can damage downstream equipment. Therefore it must be removed. There are a number of different technologies available to remove H_2S

from the feed biogas. One system uses two H_2S removal towers containing a media selectively removing H_2S to acceptable limits normally in the 2 ppmv range. After passing through the towers, the feed gas passes through a particulate filter to remove any dust carryover from the media beds.

Stage 3: Feed Gas Compression Module:

Feed gas compressors compress the feed biogas to 120-165 psia (8-11 bar) for downstream processing. A number of compressor designs can be used. Some compressor types introduce oil into the biogas stream to lubricate the compressor internals and to remove some of the heat of compression from the gas. In this case, the oil droplets are removed by a coalescing filter. The oil is collected and cooled in a heat exchanger. Once cooled, it is returned to the compressor

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oil-circulating pump and sprayed into the compressor. The compressed feed gas, now at an elevated temperature, passes through a separate heat exchanger to remove the heat of compression and through another coalescing filter to remove any entrained moisture.

Stage 4: Feed Gas Drying Module:

In some cases a feed gas drying module, upstream of the PSA drying system, is used to remove additional water vapor. A regenerative twin-tower desiccant dryer is one technology used. This drying step also removes siloxane compounds. Siloxanes are a silica based compound which can be harmful to downstream equipment and must be removed before the product gas can be injected into a natural gas pipeline or used as a vehicle fuel.

Stage 5: PSA CO₂ Removal Module:

CO₂ must be removed from LFG and DG to meet the 1-2% allowable limits for most product gas specifications. CO₂ is removed using Xebec's proprietary pressure swing adsorption (PSA) technology utilizing a 9-vessel system employing a patented rotary valve. The vessels contain a media selectively adsorbing CO₂ while allowing the methane to

pass through. In some process configurations, there can be separate 1st and 2nd stage PSA modules. Methane purity is controlled by continuously monitoring the product gas using CO₂ and specific gravity monitors. If CO₂ rises above the allowable limit, the PSA regeneration cycle is adjusted by changing the rotational speed of the rotary valve.

Stage 6: Product Gas Compression

Module: In some cases, the pressure of the product gas leaving the PSA module is below the operating pressure of the natural gas pipeline and must be further compressed prior to injection into the pipeline. Product gas flow to the compressor inlet, is compressed and then cooled in a heat exchanger. The product gas is continuously analyzed to ensure it meets the customer's required quality specification. Off-spec gas is recycled back to the beginning of the process or sent to a thermal oxidizer or enclosed ground flare. The final step is odorization. Pure methane has no odor and odorant is metered into the product gas to serve as a warning in the event of a leak.

Let's talk about your introduction of membrane technology.

Membrane technologies have made a lot of progress and are becoming better and better gas separators. For smaller flow rates, membranes are perfect as a stand-alone gas separation technology. We use membranes for flows of up to 1500 normal cubic meters and for the upgrading of biogas if there is no nitrogen and oxygen in the feed gas. We are using a special membrane polymer suited to separate CO₂ from CH₄. We use a PSA system when nitrogen and oxygen are present.

Membranes are a great bulk separator and can be used efficiently. Having both PSA and membrane technology gives us great flexibility in design systems to optimize recovery rates (the amount of methane you can capture). Let's assume a feed gas of 50% CH₄ and 50% CO₂, how much methane can we recover? Membranes can recover 99.8% of the feed gas, for PSA systems it's 96%. There is almost a 3%

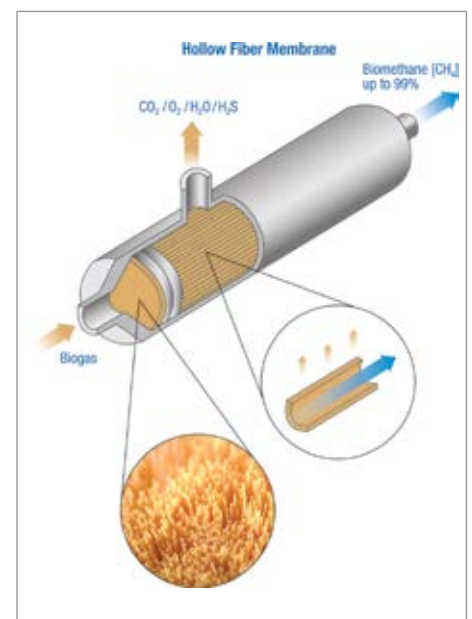
difference, which over a 20-30 year time-frame can add up.

Membranes require a pre-treatment module and then gas compression to 16-18 bar (235-265 psi). A PSA system requires 6-8 bar (88-118 psi). As far as maintenance goes, PSA's change adsorbents every 5-10 years. Every 2 ½ years an inspection is recommended. On membranes you look for degradation of performance. Normal membrane life is 7-10 years if you don't contaminate them.

How do you use membranes on hydrogen applications?

We have a great reputation in the hydrogen market. Steam methane reforming (SMR) systems produce hydrogen. SMR systems produce hydrogen quality, however, that is not good enough for applications like fuel cells. The hydrogen needs to be purified to five or six 9's (99.99999%). We do liquid projects, where our PSA systems purify hydrogen to these levels before it's liquified.

Recovery rates are very important and impact the size of the liquifier. Hydrogen recovery rates are normally between 75-85%. With



Xebec's Polymer Membrane provides High Selectivity, delivering pure biomethane with recoveries up to 99.8%

membranes, recovery rates can get to 90%. A membrane, however, can't do it alone so we've created hybrid membrane/PSA systems. Membranes are used to pre-separate hydrogen and then it goes into a smaller PSA system. The recovery rate can be improved by 7-12%. Another benefit, of these hybrid systems, is the SMR can be downsized and use less feed gas.

Please review your work with helium.

We've been purifying Helium for a long time. For a long time, helium was considered a strategic concern by the U.S. government. There was a gas field with 2-3% gas content. Helium comes out of the ground and is a finite resource. We don't make it artificially. Helium was cheap because the government made it available at a low price. One year ago the debt (for the gas field) was paid off and the law said the government had to exit the market. Prices spiked and helium rationing began. Congress extended the supply for a couple of years to allow a transition to other helium sources. The helium reserve will be depleted in 10 years. Your party balloons today are probably no longer using helium!

With the higher prices, industries using helium (glass and microchips for example) deploy helium recovery/recycling systems. We have a hybrid membrane/PSA system where we can take a low helium concentration and purify it to five 99.9999% helium purity. We can recover up to 95% of the helium.

Quickly and on a different topic, what's happening with CNG refueling stations in the U.S. Are the air compressor distributors getting involved?

The waste company, Waste Management Inc., owns 400 landfills in the U.S. They announced they would convert their 19,000 trucks to CNG, so it makes sense for them to use the gas in their landfills. As municipalities seek to change their "footprint" they are also favoring trucking companies who have made the switch to CNG fleets.

The CNG industry forecast was for a little over 200 stations to be built in the U.S. in 2015. The drop in energy prices may cause a reduction in activity, so my number is 160 new stations. More and more air compressor people are getting interested in providing technical service to the now more than 1500 compressors out there. These companies are well suited to do the maintenance — it just requires looking at a new market.

As you know from our article with you in 2013, Xebec has natural gas desiccant dryers in roughly eighty percent (80%) of the CNG refueling stations in North America. We have launched a high-pressure filter line for up to 6000 psig for these stations. This year we are launching onboard filters for vehicles. These filters are rated for 3600 psig and fit right on the engine.

Any other final news?

Yes, Xebec is going back into the business of manufacturing compressed air dryers. We have over 8,000 desiccant air dryers installed in the field and at one time had over 50% market share in Canada. We are re-launching our line of desiccant compressed air dryers because there is no Canadian dryer manufacturer and the 28% depreciation of the Canadian \$ (vs. the U.S. \$) has made things very difficult for customers importing equipment. We are also bringing out a new filter line to accompany the dryers.

Thank you for your time. ^{BP}

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Managing Change in the Industrial Air Compressor Industry Part 1: GENESIS OF CHANGE

By Ron Nordby, Contributing Editor, Nordby Consulting

► There are many distributors in the industrial air compressor industry that are very concerned about the future role of distribution — or, more specifically — if there even is a role for distribution in the new business environment. The industry has changed, and doing business in the current environment is very different from what distribution has become accustomed to. You may describe it as a “changing of the paradigm” or “moving the cheese,” but make no mistake — it has changed drastically. There are examples of progressive distributors that have succeeded in managing change and have adapted their business strategy accordingly. This, however, is the exception. For a variety of reasons, many distributors have been unsuccessful in making this transition. The reality of the situation is that for distribution to remain not only relevant, but also influential in the industrial air compressor industry, it must have the vision and commitment necessary to successfully manage change and adapt to the new business environment.

This vision and commitment must start with a process by which distributors can become proactive in managing the forces of change that confront them. The three major steps that are necessary to accomplish this include:

1. Recognition and acceptance of change
2. Understanding the genesis and catalysts for change
3. Development of business strategies to successfully manage change

The intent of this two part series of articles is to apply this process to the industrial air compressor industry. Hopefully, these concepts will provide distribution with an understanding of the current business environment and inform companies on how to align their business strategies to adapt successfully. In part one of the series, *Genesis of Change*, the recognition, acceptance and understanding of change will be examined. In the follow-up article, *Business Strategies*

to Manage Change, specific business strategies for distribution will be presented.

Recognition and Acceptance of Change

The recognition and acceptance of change is the critical first step. This recognition and acceptance does not mean that you have to agree with the direction of change; you only need to recognize that change has occurred. While this sounds very simple, this step is essential for giving distribution the ability to identify and take advantage of new opportunities, embrace new technologies, implement new business strategies, and allow for profitable growth.

Understanding the Catalyst for Change

The second step is understanding the catalyst for change. Max McKeown, a strategic business adviser specializing in innovation strategy, leadership and culture, is quoted as saying: “To make improvements, you will have to make changes. But to make successful change, you



“Distribution in the industrial air compressor industry is very aware of the fact that they have not been in alignment with the changes occurring in the industry.”

— Ron Nordby, Contributing Editor, Nordby Consulting

have to understand the nature of change, why it happens, how it starts, how it continues.”

Distribution in the industrial air compressor industry is very aware of the fact that they have not been in alignment with the changes occurring in the industry, often citing the level of conflict and distrust that currently exists within the industry as a symptom of this disconnect. Yet there seems to be a tendency for distribution to focus on these symptoms rather than, as Max McKeown stated, the nature, cause and characteristics of the change. Focusing on the symptoms of change and neglecting to gain an understanding of the reasons behind change undermines the ability of distribution to develop the strategic business plans necessary to take advantage of the changes that are occurring. This can pose a threat to their position as a major factor in the industry. Knowledge is a powerful tool, and having the ability to not only understand the nature and cause, but also the direction of change, will enable distribution to successfully control their future and be proactive in that endeavor.

What Catalyzed Change in the Compressed Air Industry?

Identifying the catalyst for change and the effect it had on distribution requires identifying both internal and external events in the industry that could have facilitated this change. While there are a number of events that have affected the industry over the last 25 years, only two have had the potential to enable this level of change.

1. Evolving industry lifecycle
2. Manufacturers' adaptation to the evolving industry lifecycle

During the process of examining the role the above catalysts played as a force of change, it became obvious that the evolving industry lifecycle was the genesis of the change. However, manufacturers' adaptation to the industry lifecycle by the development of new

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Figure 1: The Four Phases of Industry Lifecycle

business strategies also played a crucial role from the perspective of distribution. Both of these events are intimately related and need to be a part of the discussion.

When discussing the effect of the industry lifecycle as a catalyst for change, it is important to have a basic understanding of what an industry lifecycle is and how it affects an industry. While definitions vary, in simplistic terms the industry lifecycle can be defined as a business concept relating to the different stages an industry goes through during its life. Versions of the industry lifecycle differ, but most models describe four distinct phases. These are introduction, growth, maturity and decline, as illustrated in Figure 1. While there are many characteristics of an industry lifecycle, some basic traits include:

- Industry lifecycle is common to all industries.
- Each distinct phase of the industry lifecycle presents new business challenges.
- Each distinct phase of the industry lifecycle requires different business strategies.
- The industry lifecycle greatly influences a company's strategic plans.

When relating the industry lifecycle to the industrial air compressor industry, it becomes apparent that the industry has transitioned from the growth to the maturity stage of its lifecycle. This transition actually occurred somewhere in the late 1980s to early 1990s based on initial changes in the industry. Industries transitioning from growth into the maturity phase of the lifecycle face a dramatically different business environment, and it is a very stressful period for an industry. When comparing the characteristics of the growth and maturity phases of the industry lifecycle, the major changes include:

GROWTH PHASE	MATURITY PHASE
Market increasing →	Market saturation
Fast earning growth →	Slowing earning growth
Increasing sales →	Sales peak then fall
Improving profit margins →	Pressure on profit margins
Increasing profits →	Profits peak then fall

Based on the comparison of characteristics between these two phases, it is easy to understand the instability caused by this transition for both manufacturers and distribution. While the transition affected distribution in the industry, the influence was more immediate and profound for manufacturers. Manufacturers well aware of the transition from the growth to the maturity phase

of the lifecycle adjusted their business plans and instituted changes very early in the process.

The Ever-Evolving Relationship Between Manufacturers and Distributors

Although the effect of the industry lifecycle was certainly the genesis and catalyst for change within the industry, manufacturers' adaptation to the industry lifecycle was not only the catalyst, but also the channel for bringing the reality of change to distribution. Adapting to the new business environment while maintaining aggressive growth required manufacturers to restructure their strategic business plans to focus primarily on market share and profitability. All business processes and relationships both internal and external were scrutinized and altered to align with this new focus. While the impact on distribution differed, many of the changes fundamentally transformed the relationship between manufacturers and distributors. This relationship will continue to evolve.

These changes manifested themselves in the following manufacturer initiatives:

1. **Establishing greater control over their distribution channel:** Manufacturers increase pressure on distribution for total product line loyalty. This involves employing strategies such as implementation of loyalty clauses in distribution agreements and multi-product requirements in stocking, discounting and extended warranty programs.
2. **Modification of the distribution channel:** Manufacturers look to maximize their market coverage by reducing their dependence on exclusive distribution as their sole channel to market. Types of strategies include multiple levels of distribution, sub-dealer programs, factory stores and Internet sales.

GENESIS OF CHANGE

3. **Diversification of product offerings:** Manufacturers expand their product line offerings through internal development, acquisition or strategic partnering.
4. **Consolidation of competition:** Manufacturers look to increase market share and critical growth by focusing on inorganic means, such as mergers and acquisitions of competitors.
5. **Reduction in channel costs:** Strategies utilized by manufacturers include the use of more efficient channels to market (i.e. Internet sales), thereby increasing electronic processes for all channel transactions, and increasing controls on warranty programs. This helps reduce factory support personnel and shift traditional manufacturer responsibilities and costs to distribution.
6. **Reducing manufacturing costs:** Manufacturers employ cost reduction strategies, such as product standardization, parts rationalization, facility consolidation, value-added engineering of products, and moving manufacturing to less expensive labor areas.
7. **Product line rationalization:** Manufacturers focus on profitable products while eliminating or outsourcing marginal products.
8. **Diversification into new markets:** Manufacturers develop products and dedicated marketing initiatives to expand into niche markets that were ignored or underdeveloped during the growth phase of the industry lifecycle.

Certainly the list could go on, and clearly these initiatives were designed to reflect the direction of the new strategic business plans of manufacturers. While the industry can argue about the necessity and scope of the

initiatives, their implementation should come as no surprise to distributors. From a manufacturer's perspective, they are considered good business decisions tailored to meet the challenges they face. While these initiatives have increased the conflict and distrust between some manufacturers and distributors, this is the new reality the industry faces.

Can Distributors Adapt to the New Paradigm?

Whether you are a manufacturer or a distributor, there is a new a new paradigm, the cheese has been moved, and change is continuing to happen. While manufacturers accepted and adapted to the new reality, distribution is still struggling with their

response. They continue to underestimate their power, influence and importance, and they readily accept a subservient role in the industry. For distributors that adapt only to survive, the future will be very difficult and uncertain. However, for progressive distributors that embrace change and acquire the knowledge to be proactive in adapting to change, the future is very bright. Distribution has an excellent opportunity to regain control of their future. How they respond will determine their success. **BP**

For more information, please contact Ron Nordby at tel: (651) 308-2740, email: ronknordby@gmail.com.

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A VIEW FROM AUSTRALIA: Efficiency Curves, System Volumes and the Compressor System Factor



By Murray Nottle, Working Air Systems Engineer, The Carnot Group

► This article introduces a new and useful compressed air system parameter called the “Compressor System Factor,” or CSF. The CSF of a given system defines the relationship between an air compressor, its system, and how the compressor is being operated. Knowing the CSF of a system allows comparisons to be made between existing operating characteristics and the characteristics of a proposed system. Changing a system by applying energy efficiency measures like adding storage receiver capacity, changing pressure bandwidth, or switching to different compressor control modes also changes the CSF. The results of the change can be easily predicted using the CSF number.

The unit used for CSF is the percentage of a minute, making the result useful and compatible with any unit of measurement, whether it is an SI base unit or a standard unit used by North American manufacturers.

The calculation of the CSF is a simple yet powerful tool that can:

- Provide insight into the state of a compressed air system
- Help identify low capital cost projects to improve the efficiency of compressed air systems
- Help assess the merits of supply side and demand side compressed air efficiency projects

The CSF of a given system:

- Largely governs the curve shape, and therefore the efficiency, of a compressor’s power versus flow characteristics for those compressors running in load/unload (online/offline, OLOL) mode
- Can be calculated during the design of a system to help predict system efficiency for different equipment choices
- Can be easily determined for an installed compressor using a stopwatch and a simple calculation

Compressor System Factor Basics

What CSF measures is not profound, and it is not a hard concept to understand.

CSF is simply the percentage of a compressor’s capacity per minute stored and released by the system volume during each load/unload cycle.

For example, if a 1000 cfm compressor has a CSF of 10, its compressed air system will store and then release 10 percent of 1000 cfm, or 100 cubic feet of air in each load/unload cycle. A 25-cfm compressor could also have a CSF of 10, but its system would only be storing and releasing 2.5 cubic feet of air during each

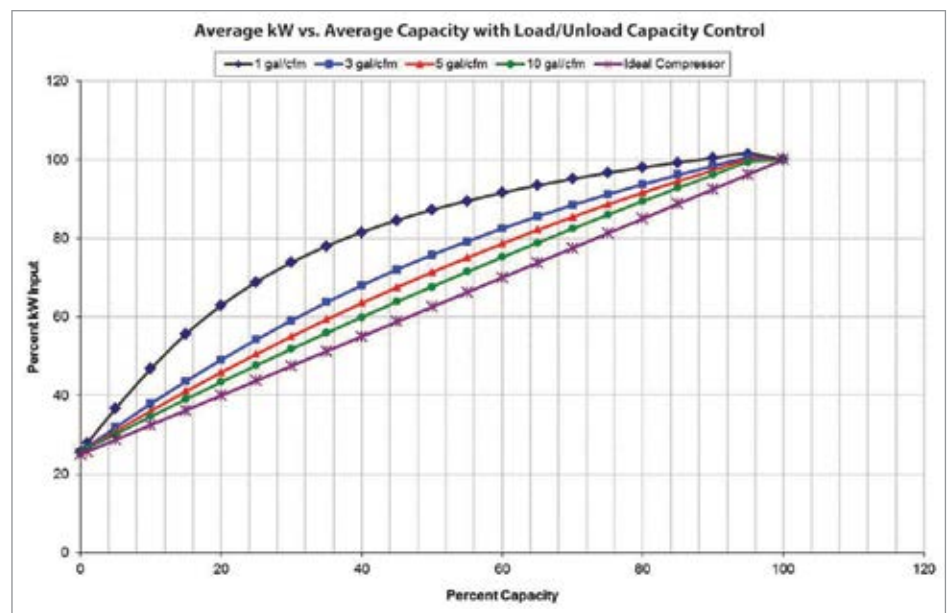


Figure 1: Typical Power vs. Flow Graph for Load/Unload Compressors

Source: Compressed Air Challenge

cycle. Compressors that have the same CSF have the same cycle characteristics, regardless of the size of the compressor. It is important to note that the amount of air stored and released in each cycle depends on the effective volume of the storage receivers **and** the width of the load/unload pressure band.

Many readers will recognize the percent power versus percent capacity curves found in the U.S. Department of Energy's guidebook "Improving Compressed Air System Performance: A Sourcebook for Industry." These curves show how changing the system volume affects the efficiency of a typical lubricated screw compressor running in load/unload mode. The curves shown in Figure 1 are generated with a fixed load/unload pressure bandwidth of 10 psi. For the graph to be correct for compressors not operating with a 10-psi pressure band, a new set of curves would have to be generated. But, if each line on the graph represented a given CSF, the curves could become valid for any combination of system storage and pressure bandwidth with about the same middle pressure.

Knowing the pressure change used to construct the original graph was 10 psi, the legend could be changed from 1, 3, 5 and 10 gal/cfm to the corresponding CSF values of 5.3, 15.9, 26.5 and 53.

How and Why Does the Volume Stored and Released for Each Cycle Affect Part Load Power?

The units of CSF are percentage of a minute (i.e. time). This provides a clue as to how it affects compressor efficiency. A large CSF means the compressor cycles are longer than those if the compressor had a small CSF. If system storage is large, or the pressure band is wide, it takes a longer time for the compressor to increase the system pressure from the load setting to the unload setting. It also takes a longer time for the demand to use up the stored air, causing the pressure to drop to the load setting. If the compressor CSF is very small, these same times would be short, and the compressor would cycle quickly. This may cause short cycling, which is known to waste power.

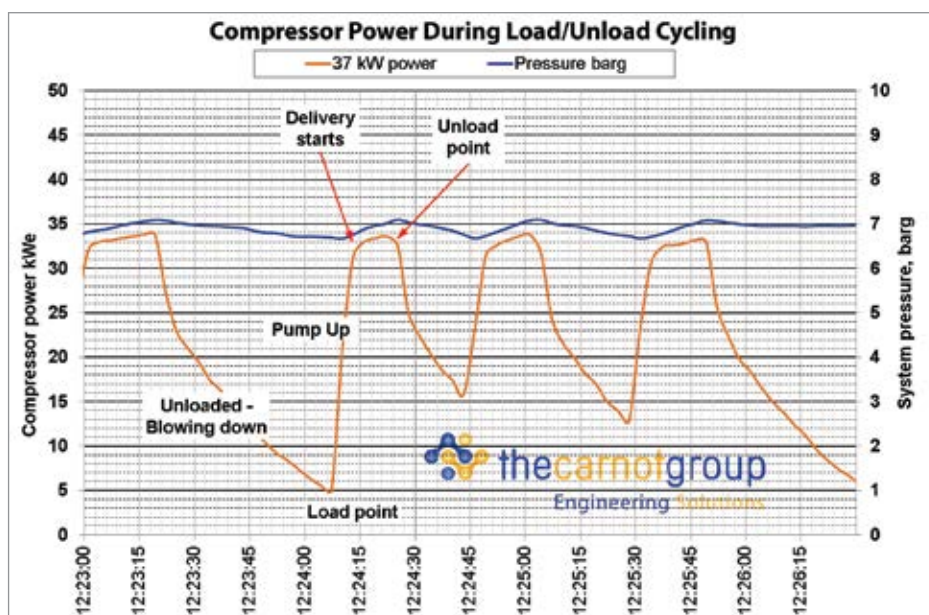


Figure 2: Example Compressor Cycles Showing Power and Pressure

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A VIEW FROM AUSTRALIA: EFFICIENCY CURVES, SYSTEM VOLUMES AND THE

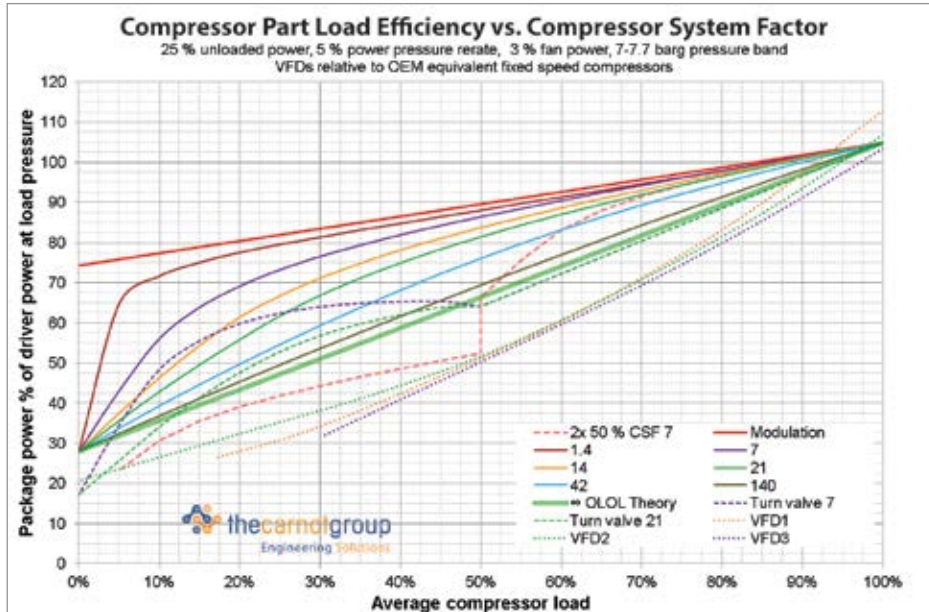


Figure 3: Comparison of Compressor Operating Modes

The next plot will help you understand why long cycle times result in lower power consumption.

Figure 2 shows the power and pressure changes during four load and unload cycles of an example 37-kW compressor. Note that during the cycles, the flow is changing, which changes the characteristics of each load/unload cycle. Observe the following from the chart:

- For some of the cycles, the compressor is unloaded for a longer time and the compressor power drops to low values, resulting in a lower average unloaded power.

- Some of the cycles are short. When this happens, the power doesn't drop as far, and the average unloaded power is higher.
- The compressor is only "online" and producing air for the peaks of the power curve (i.e. between the "delivery starts" and "unload" points). These are highlighted for one of the four cycles shown. At this time, the power and pressure both increase together.
- The power used by the compressor at any other time is wasted.

- From the unload point, the power can be seen to drop quickly (to around 24 kW) as the inlet valve closes. The compressor is now in full modulation.
- The power then drops with time as the separator tank is vented through the blow down valve. It stabilizes after 30 to 80 seconds, which varies with compressor design. Only then is the compressor fully unloaded. The compressor is never fully unloaded in this plot.
- When the compressor reloads, a delay of 2 to 5 seconds occurs as the compressor pumps up its internal volumes so air can be delivered into the system. This pump up power is wasted.

Compressors with high load/unload cycle frequencies due to a low CSF system value (small system storage, narrow pressure band) have the following characteristics compared to machines with larger CSF values:

- The unloaded power is higher.
- The power wasted doing "internal pump up" occurs more often.
- The overall power use is higher.

For example, the same compressor at 50 percent load will use less power if it's load/unload cycle times are, say, 30 seconds / 30 seconds (CSF 25) compared to times of 10



"A bigger pressure band results in increased power use by all compressors on the system and increased artificial demand."

COMPRESSOR SYSTEM FACTOR

seconds /10 seconds for lower system values (CSF 8).

At the same average load, longer cycle times due to a bigger CSF value means the compressor is unloaded for longer, the average unloaded power will be less, and the compressor more efficient than if it had a smaller CSF value.

Figure 3 below shows typical percent power/flow curves for the following:

- Fixed-speed load/unload compressors for different CSF values, including a curve for the same system but with two half-sized compressors (2 x 50 percent x CSF 7)
- Variable geometry-controlled compressors with different CSF values (Note that for capacities below the turn valve minimum output, the compressors operate load/unload like a fixed-capacity machine. Hence CSF affects these machines.)
- Different variable speed compressors scaled to fixed-speed compressors (where possible with the same air end) from the same OEM

Many people believe that the way to make a compressor system more efficient is to make the trim compressor load/unload pressure band as narrow as possible. This is not the case, as a small pressure band will store little air per cycle, resulting in a CSF value that is very small.

This is not to say that the pressure band should be as big as possible. A bigger pressure band results in increased power use by all compressors on the system and increased artificial demand. When these factors are

considered with CSF, it is no surprise that there is an Optimal Pressure Band (OPB) for each system and its operating conditions at any time.

How Can You Use CSF To Improve Your Compressed Air System Efficiency?

CSF values can be used in many ways to improve the efficiency of a compressed air system:

- The concept of CSF provides insight on how the trimming compressor size, the operating mode, the system volume, and the wet-to-dry side pressure drop affect its part load efficiency.
- The equations used to calculate CSF from known and measured parameters can be used to find any of the parameters used in the equations. For example, CSF could be found from measured
- The CSF value for a compressor can be used directly with efficiency curve data to estimate the power consumption of the compressor at a specific percentage load. This assists in the modelling of new or changed compressed system power consumption based on a known (measured or assumed) load profile.
- It allows the development of the Per Unit Power and savings Yield (PUP-Y) chart (Figure 4 shown below).

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A VIEW FROM AUSTRALIA: EFFICIENCY CURVES, SYSTEM VOLUMES AND THE

Calculating CSF From Known Parameters

CSF can be calculated from the known parameters of compressor capacity, system volume, load pressure setting and unload pressure setting.

Value	Imperial units, cfm, psi	Metric Units, m ³ /min, bar
V _{st} , Volume stored per cycle	$= \frac{V_{\text{wv}} \times (P_u - P_L)}{14.5}$	$= V_{\text{wv}} \times (P_u - P_L)$
V _{wv} , System (water) volume	Cubic feet	Cubic metres
P _u , Unload pressure setting	psig	barg = kPag /100
P _L , Load pressure setting	psig	barg = kPag /100
CSF	$= 100 \times \frac{V_{\text{st}}}{q}$	$= 100 \times \frac{V_{\text{st}}}{q}$
q, Compressor flow rate	cfm	m ³ /min

Note that V_{st} is the effective system volume at the compressor outlet:

- For a wet system or a system where the dry side volume is much smaller than the wet side volume, the wet system volume can be used for V_{st}.
- Where there is a large dry side volume, the volume stored per cycle for each side of the system must be calculated.
- For the wet side calculation, the equation in the table can be used directly. Note that the value of V_{wv} to use is for the wet side volumes only.
- For the dry side calculation, V_{wv} must be for the dry side volumes only. The pressures to use are the dry side pressures when the compressor loads and when it unloads. Note that the downstream pressure will increase slightly after the compressor unloads as the pressure drop across the air treatment will drop slightly, and the wet side will transfer air to the dry side as well as supplying some of the demand. Hence the pressure to use is at the moment the compressor unloads.

Calculating CSF From Measured Values

The CSF value for a compressor can be calculated from measured values. The unit of CSF is the percentage of a minute. It is not ft³ per cfm, m³ per m³/min, or l per l/sec. Therefore, it doesn't matter what volume units are used, since the units of CSF are a universal, time-based value.

As the units of CSF are time-based, the value for a given compressor and its system can be found using a watch and a simple calculation.

$$\text{CSF} = \frac{100 \times (\text{Td} \times \text{Tu})}{60 \times (\text{Td} + \text{Tu})}$$

Where:

- CSF is Compressor System Factor.
- Td is the time the compressor is delivering air in seconds. This is roughly the time from hearing the compressor load to hearing it unload (but this does include the 2 to 3 seconds of pump up time).
- Tu is the time spent unloaded (including pump up and blow down).

Note that CSF can change with load as air treatment pressure drop (which varies with load) alters the air stored in the dry side during each cycle.

COMPRESSOR SYSTEM FACTOR

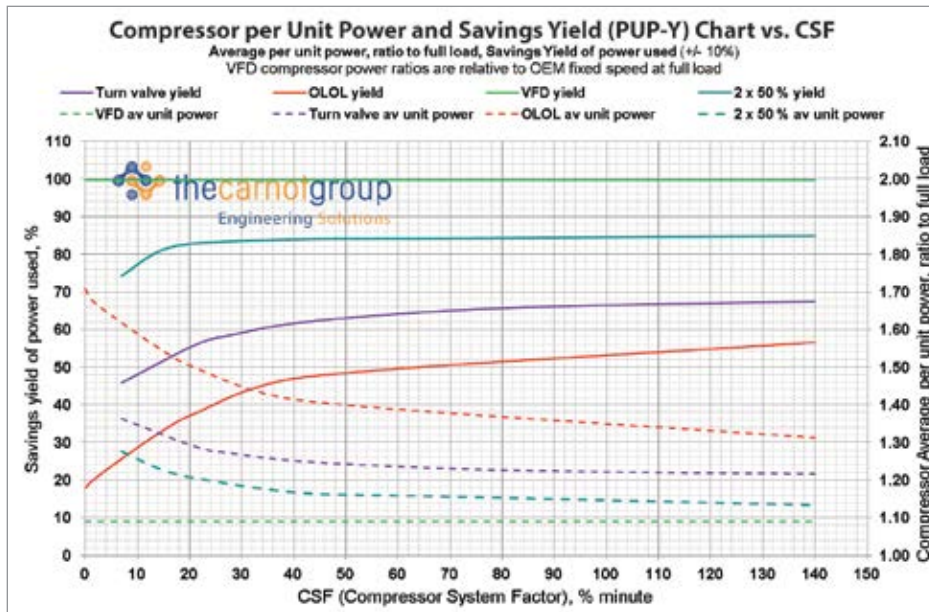


Figure 4: Compressor PUP-Y Chart

The PUP-Y chart displays average Per Unit Power and savings Yield for different CSF values. The PUP trends are based on averaging power values at specific loads (20, 40, 60 and 80 percent) for a CSF value. These power values are compared to the power value at 100 percent load. Hence, the PUP curve provides a means of estimating the average power consumption of a trimming compressor.

The Yield trend of the chart is based on the average slope between points on the percent power/flow curve (80 to 60 percent, 80 to 40 percent, 80 to 20 percent) for different CSF values. It is a ratio between the change in percentage load of a compressor to the change in average power use.

For example, based on the PUP-Y chart, a compressor with CSF 10 will:

- Have an average specific power consumption 1.59 x that of its full-load specific power
- Have a Yield of 30 percent: For example, an average compressor

load reduction (e.g. from leak repairs) from 60 to 40 percent will result in a 6 percent reduction in average power use (i.e. 30 percent of $60 - 40 = 6$).

- If the effective system volume is increased so that the resulting CSF is now 20:
- The trimming compressor average specific power becomes 1.5 x the full-load value, resulting in a 5.6 percent saving.
- The Yield becomes 38 percent, making the same load reduction from the previous example larger (60 to 40 percent now saves 7.6 percent in power).

Together the PUP-Y trends allow a quick estimate of power consumption and savings.

Some other comments:

- The PUP-Y chart is based on the compressor spending equal time at all loads between 20 and 80 percent. This will not be the case

for all trimming compressors. Hence, the PUP-Y chart is only a guide to allow a quick estimate in a few minutes instead of hours of detailed modelling. If highly accurate values are required, then detailed modelling should be done.

- The PUP-Y chart shows that there are diminishing returns from increasing the CSF value.
- The PUP-Y chart allows modelling work to find the Optimal Pressure Band (i.e. the best choice of pressure bandwidth) when relative compressor sizes, leak and artificial demand loads, and the system volume are considered.

This article has introduced the compressor system parameter CSF. It has shown how to find the CSF value for a compressor in its system. It has also shown how CSF can be a powerful tool in improving the efficiency of compressor systems and in evaluating compressed air efficiency-related projects.

Future articles will further explore the application of CSF. For example, by affecting CSF value, one can find the Optimal Pressure Band for a compressor and evaluate how air treatment pressure drop affects power use. **BP**

Author Bio

Murray Nottle is a university-qualified mechanical engineer based in Melbourne, Australia. He has worked in the compressed air industry for well over 15 years. Some of this time has been with pneumatics companies, however, most was with compressor companies. This included establishing the energy auditing abilities of one organization. Murray consults on compressed air productivity and efficiency with The Carnot Group. He can be contacted via email at mnottle@carnot.com.au or visit www.carnot.com.au

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GROWING FACTORY EXPERIENCES AIR COMPRESSOR CONTROL-GAP ISSUES

By Ron Marshall for the
Compressed Air Challenge®



► A factory expanded their production facilities in response to a new product line being introduced in their plant. The plant was to run as a separate entity with its own utility services. Because this company is very conscientious about their energy consumption, they specified top-of-the-line compressed air production equipment to keep their costs low while maintaining the very clean air quality required by their product. This equipment should have worked wonderfully. Unfortunately, events transpired, and poor decisions were made that pushed their system out of control, resulting in unexpected inefficient compressor operation and higher-than-desired energy consumption.

Initial Design

Like many systems, this installation was to be designed from scratch with nothing but the production machine specifications to go on for sizing the compressed air equipment. Based on engineering design calculations, it was determined that the site needed two 75-hp compressors. The air dryers selected

were required to be desiccant-style to maintain adequate dew point in cool areas of the plant where the ambient temperatures were maintained near 40 °F.

To ensure excellent efficiency, the plant selected two 75-hp variable speed drive (VSD) compressors, dew point-controlled heatless desiccant dryers, oversized mist eliminator-style filtering, large storage receiver capacity, and a pressure/flow controller to maintain constant lower regulated pressure in the plant. Two VSD compressors were selected so the compressor hours could be balanced by alternating the operation, with one compressor expected to run at a time, while the remaining unit was to remain in standby duty.

An air compressor controller was installed to orchestrate the compressor changeover, while keeping compressor discharge pressures low and saving power. This sizing was adequate for the original production equipment that was planned to operate in the plant, but plans changed. By the time the final construction

was completed, additional plant production equipment was installed that exceeded the capacity of one compressor, so two units had to run during peak periods. In fact, the load grew so much from the planned levels that peak flows were nearing the full capacity of both compressors. This worried the plant manager because if one compressor failed, there wasn't any backup capacity available to carry over his daytime production levels.

Poor Sizing Decision

The concerned plant manager had to purchase more air compressor and dryer capacity in order to protect himself from production shutdown if a compressor went down. Since two 75-hp compressors were on the edge of not being able to supply plant peaks, he decided he needed a new compressor that was larger than 75 hp. The next size larger was chosen, but because project budgets were stretched, and a VSD compressor was significantly more expensive, he chose a fixed-speed compressor.

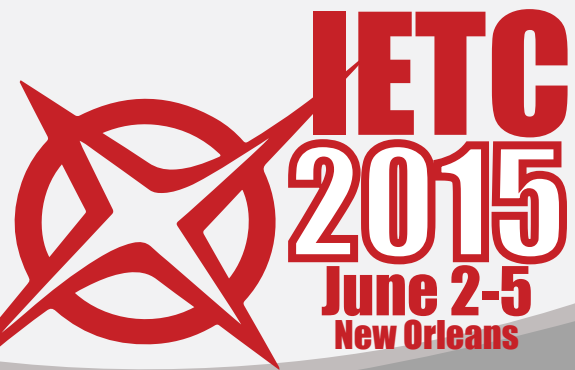
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GROWING FACTORY EXPERIENCES AIR COMPRESSOR CONTROL-GAP ISSUES

In choosing this size, the plant manager inadvertently broke a sizing rule when mixing VSD compressors with fixed-speed variety. The VSD compressor's variable capacity must be equal to or larger than the fixed-speed base compressor's capacity, or a control gap problem is created. A control gap happens whenever the plant flow falls between the capacity of the undersized VSD compressor and the oversized base compressor. In this case, whenever there was a compressed air flow equivalent between 75 hp, the size of the VSD compressors, and 100 hp, the base unit size, there was a problem. As we will learn, this wasn't the only issue.

As a result, the initial state of the system had all three compressors normally running during production times, with the VSD compressors running at low average capacity, their most inefficient point, and the fixed-speed compressor loading and unloading, its most inefficient mode of operation (Chart 1). And because all three compressors were

normally running, all three heatless desiccant dryers were also active, consuming more than necessary purge flow for the actual compressed air demand.

Sophisticated Controller System Falls Short

As part of the initial installation, a sophisticated compressor controller was installed that was capable of controlling multiple VSDs and base compressors. Since two 75-hp VSDs add up to more capacity than a 100-hp compressor, the problem with control gap could be prevented — if the VSD compressors were controlled properly. This control was put into service, and it was immediately obvious that the operation of the system was even worse. The control response time, which could not be adjusted due to control limitations, wasn't fast enough to prevent all the compressors from rapidly cycling. And the control introduced an inherent delay to the control loop and caused very sluggish VSD response to pressure changes.

As is typical with central controllers, the pressure to be controlled is sensed downstream of the air dryers and filters, not at the compressor discharge. This normally produces a nice stable air pressure, free from the pressure sag caused by the restriction to flow in the clean-up equipment. But in this installation, there existed a large mist eliminator filter and a heatless desiccant air dryer for each compressor, representing significant storage volume.

Each air dryer contained a check valve that prevented the air from flowing from the system back to the compressor discharge if the compressor was turned off. Whenever the associated compressor turned off, the pressure in the mist eliminator and air dryer would drain away due to the dryer purge. Then, when the controller sensed low pressure and the compressor was called to start, there would be a delay of up to 60 seconds while the compressor filled up the filter and dryer volume to system pressure. By the time this

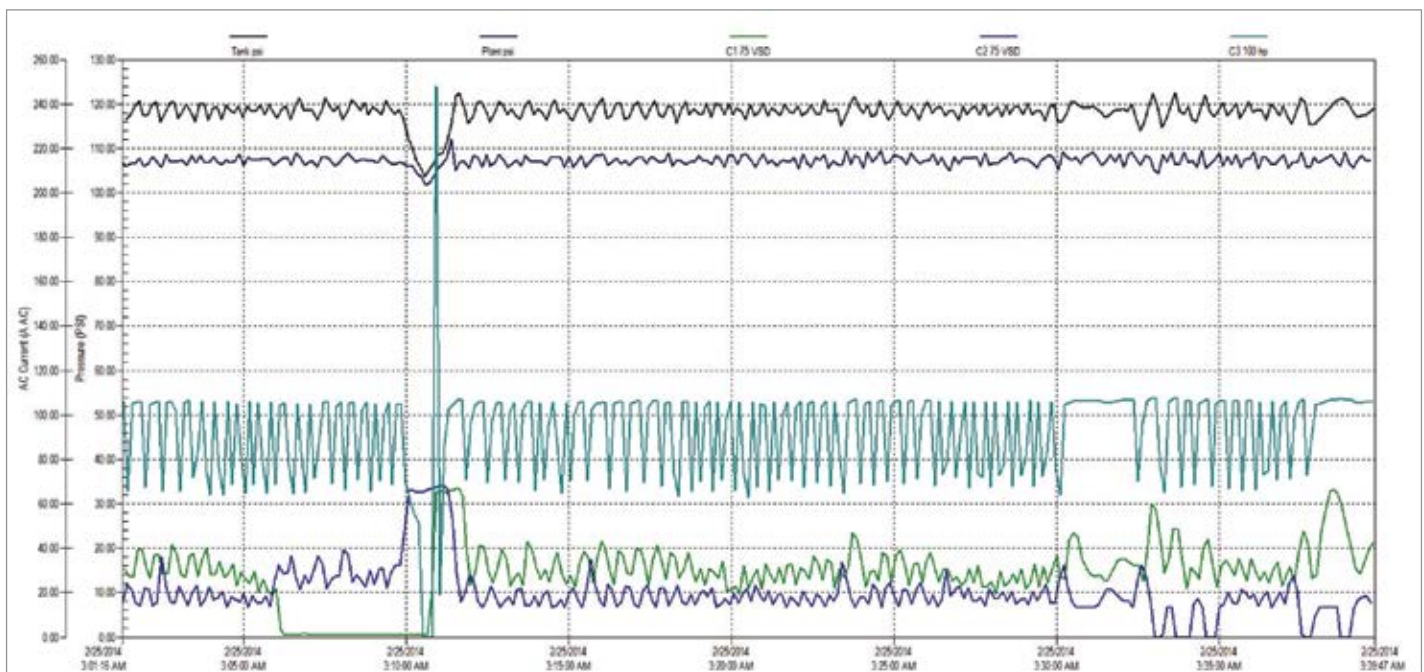
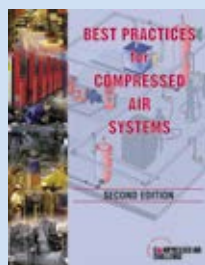


Chart 1: As found, data logging showed undesirable loading and unloading of the base compressor.

capacity filled up, the compressor sequencer would call on another compressor to start, resulting in too much running capacity. This additional capacity caused the pressure to rise at a very fast rate — too fast for the controller to handle — and the system would overshoot, causing an algorithm inside the controller to unload the base compressor. Once this happened, the system would go out of control, with the base compressor loading and unloading at the same time that the VSDs would be speeding up to full speed or slowing down to minimum speed (Chart 2).

To eliminate this delay due to the empty mist eliminator and dryer storage capacity, balancing lines were installed to allow a small amount of dry compressed air back past the check valve to keep the dryer and mist eliminator charged, but this was not enough to improve the system. The control still introduced an undesirable delay in VSD response time, which allowed the pressure to swing above and below desirable limits.

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Solving the Problem with Coordinated Compressor Set Points

The only way this problem could be prevented was to take the compressors off the controller and precisely coordinate the local compressor controls manually. After some experimentation, the local compressor controls were adjusted so that the whole capacity of both VSD compressors was utilized before the fixed-

speed base compressor was called to start. Similarly, when unloading compressors, the coordination was adjusted to ensure the total VSD capacity was removed from the system before the 100-hp base compressor was unloaded. This was done by “bracketing” the base compressor’s load and unload settings above and below the set points of the two VSDs. Care was taken to ensure the VSD set

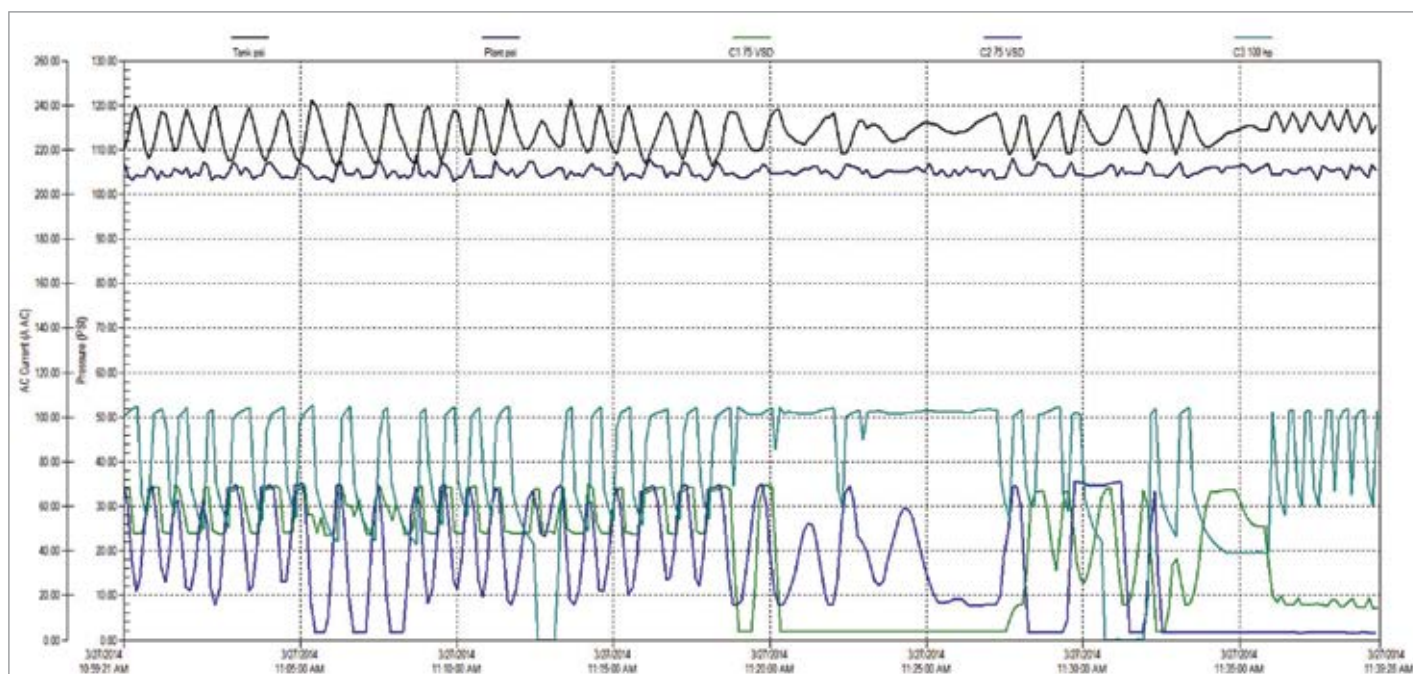


Chart 2: Activating the compressor sequencing controller put the system out of control, making matters worse.

GROWING FACTORY EXPERIENCES AIR COMPRESSOR CONTROL-GAP ISSUES

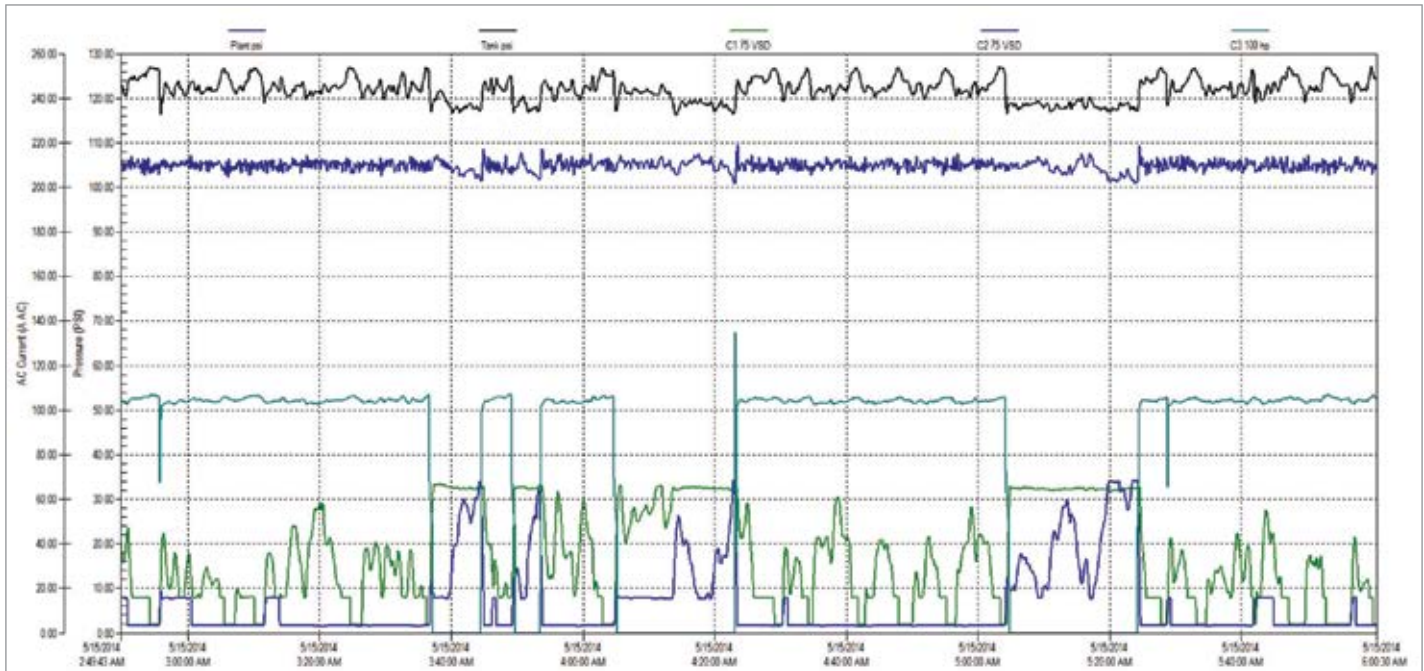


Chart 3: Non-standard local pressure band settings were used to improve compressor control, and the controller was shut down.

points were offset within the base control band, so the two VSD compressors would not run at minimum speed at the same time, which is an undesirable condition. The resulting pressure setup (Chart 3) is not a standard arrangement, but it finally provided some nice efficient compressor control and stopped the base compressor from rapidly loading and unloading.

What Went Wrong?

This case study illustrates the importance of verifying the installation after the installation by monitoring the system with data loggers. Sometimes, even with the best intentions, the conditions that exist and the limitations of the control system can cause the system to run inefficiently. The customer had no idea that the premium system they had just purchased was not running efficiently. They weren't aware of the sizing rule for base compressors. And, why should they be? Their expertise was producing their food product, not compressing air. The

sizing rule was something that the supplier should have told them about. However, when questioned about this, the supplier sheepishly replied that they simply supplied what the customer had requested and felt it was not their place to ask questions, especially if it might involve losing a sale.

The marketing literature of the compressor controller promised efficient operation, but due to its limitations (it was a low-end unit) in this unique case, the controller was inadequate for the job. As it turned out, this large, multi-national supplier admitted they had no controller that could do the job. Monitoring and troubleshooting was used to identify and correct poor system operation.

Future Improvements to the Compressed Air System

The plant is planning further changes to the system to improve operation. Upgrades to the inlet filters of the air dryers will reduce

pressure differential, giving the compressors more pressure band to use to improve compressor control response, and reducing the required compressor discharge pressure. Also, additional storage receiver capacity is currently under consideration to slow down pressure changes in the system, again to improve compressor control.

After the control was improved, the system operation became much more efficient. The system improvements were enough to trigger a significant energy efficiency incentive from their local power utility to help pay for the original equipment and the required improvements. **BP**

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Festo recently introduced the new VS series of piston-spool solenoid and pneumatic valves and valve manifolds. This new generation of individually wired valves is designed to give years of dependable service while helping OEMs lower the costs of acquisition, assembly and inventory.

The high-flow rate VS series is ideal for simple clamping and locking operations in semiautomatic assembly, end-of-line packaging, conveying, painting, open-pit mining, woodworking and other applications. The valves can be applied in explosive environments and can be modified to meet the IP67 standard for dust and immersion resistance.

The VS series comprises VUVS solenoid valves, VUWS pneumatic valves, and the VTUS valve manifolds. VS series flow rate ranges from 700 l/min to 2,000 l/min. Pressure ranges from 0 to 10 bar and from 2.5 to 10 bar for internally piloted valves. Valve types include 3/2, 5/2, and 5/3. Valve widths range from .79 inches (20 mm) to 1.2 inches (30 mm).

The extensive range of accessories, including a selection of DC and AC voltage coils, contributes to lower inventory requirements and greater flexibility. Rather than having to inventory a large selection of separate valve/coil combinations, for example, OEMs can mount DC or AC coils themselves or order valves pre-assembled. In addition to coils, other accessories include seal kit for the IP67 standard, supply manifold, compact and standard manifold rails, blanking plates, check valves for manifold rails with exhaust air ducting, wall mounting plate,



foot mounting bracket, and ATEX variants. G and NPT port styles are available in 1/8, 1/4, and 3/8 sizes respectively.

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

Leak Detection Kit From Spectronics Ideal for Finding Leaks in Oil-Based Fluid Systems

The OPK-441 Industrial Leak Detection Kit from Spectronics Corporation is a starter kit designed to effectively pinpoint the exact source of all leaks in hydraulic equipment, compressors, engines, gearboxes and fuel systems.

The kit features the OPTIMAX 400 violet light LED flashlight, a compact, high-intensity unit that quickly reveals all leaks in small-to medium-sized industrial systems — even in cramped areas that are inaccessible to larger lamps.



RESOURCES FOR ENERGY ENGINEERS

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Also included is an 8-oz (237 ml) twin-neck bottle of patented OIL-GLO 44 concentrated fluorescent oil dye, which is compatible with all synthetic and petroleum-based fluids. When a leaking system is scanned with the OPTIMAX 400 flashlight, the dye glows a bright yellow/green at all leak sources to reveal the precise location of each and every leak.

Rounding out the kit is an 8-oz (237 ml) spray bottle of GLO-AWAY dye cleaner, dye treatment tags, and fluorescence-enhancing glasses. All components are packed in a rugged carrying case.

For more information, visit www.spectroline.com.

KROHNE Announces New Vortex Flowmeter for Advanced Energy Measurement

KROHNE recently announced the availability of the new OPTISWIRL 4200 vortex flowmeter, ideal for advanced energy management systems. Used to measure both conducting and non-conducting liquids, gases and steam, the new OPTISWIRL 4200 vortex flowmeter can be used for internal monitoring of energy flows for saturated and superheated steam or hot water, and heat metering applications. It is also a perfect choice for such applications as steam boiler monitoring, burner consumption measurement, and compressed air network monitoring, including free air delivery (FAD) applications.

Equipped with comprehensive communication options, and designed in accordance with international IEC 61508 functional safety

standards, the OPTISWIRL 4200 is a major update to the original OPTISWIRL 4070. With one temperature sensor integrated as standard, the device can be installed as a heat meter in the feed line directly connected with an external temperature sensor in the return line. The gross and net heat calculation can be fed into a distributed control system (DCS) to support advanced energy management.

The all-in-one solution features integrated pressure and temperature compensation, and can perform both gross heat calculations for steam and net heat calculation for steam and condensate. The OPTISWIRL 4200 is available in a remote version equipped with a field housing converter with a connection cable up to 164 feet (50 meters). Temperature and pressure compensation options are also available, which enable calculation of standard flow volume under fluctuating pressures and temperatures. By measurement of flow, temperature, and pressure in one 2-wire device, the line has to be opened only once for installation.



In addition to the standard sensor range, another available option features an integrated reduction of nominal diameter up to two sizes, ideal for space-saving installations and large measuring spans. A dual version with two independent sensors and two signal converters is also available for multiproduct pipelines, redundant measurement, or increased safety demands.

The OPTISWIRL 4200 also includes a variety of electronics enhancements. The device is now equipped with a new advanced vortex frequency detection (AVFD) function, as well as a newly developed signal converter (VFC 200), with advanced signal processing and filtering that suppresses interferences and disturbances in the pick-up signal and filters out signals other than the relevant frequency band. Redundant data management prevents loss of calibration and configuration data when changing electronics or display.

For more information, visit www.us.krohne.com.

TECHNOLOGY PICKS

New Oxygen Analyzer From Michell Instruments Provides Cost Savings

Michell Instruments' new XZR400BM oxygen analyzer is a small and light transportable instrument capable of taking readings of both trace and percentage oxygen levels. It has been introduced to meet the demands of companies that wish to take routine readings from multiple sample points, and is a highly cost-effective solution. The instrument is capable of taking readings on a low flow rate — just 2 l/h — which means less waste of the sample gas from the process.

Based on Michell's MSRS Zirconia oxygen sensor, the XZR400BM gives fast readings — 11 seconds for T90 — saving the operator working time when collecting field readings. As with all Michell's XZR range, the instrument is highly stable, giving reliable results over a long time. A key benefit of the instrument is its low cost of ownership. Unlike electro-chemical sensors, which require regular replacement, the MSRS sensor of the XZR400BM should last in excess of 7 years. Calibration is not needed as frequently either (every 3 to 6 months), and can be carried out with just one calibration gas, saving time and money.

The instrument also features an intuitive touch-screen interface to enable fast and easy operation without the need to invest in extensive training. This is useful when multiple operators work with the instrument. It also has a switch-mode power supply, operating from mains power between 90 and 264 V AC with an IEC cable. At just 13 lbs, and with a small footprint, the XZR400BM is easy-to-move and takes up minimal bench space.

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



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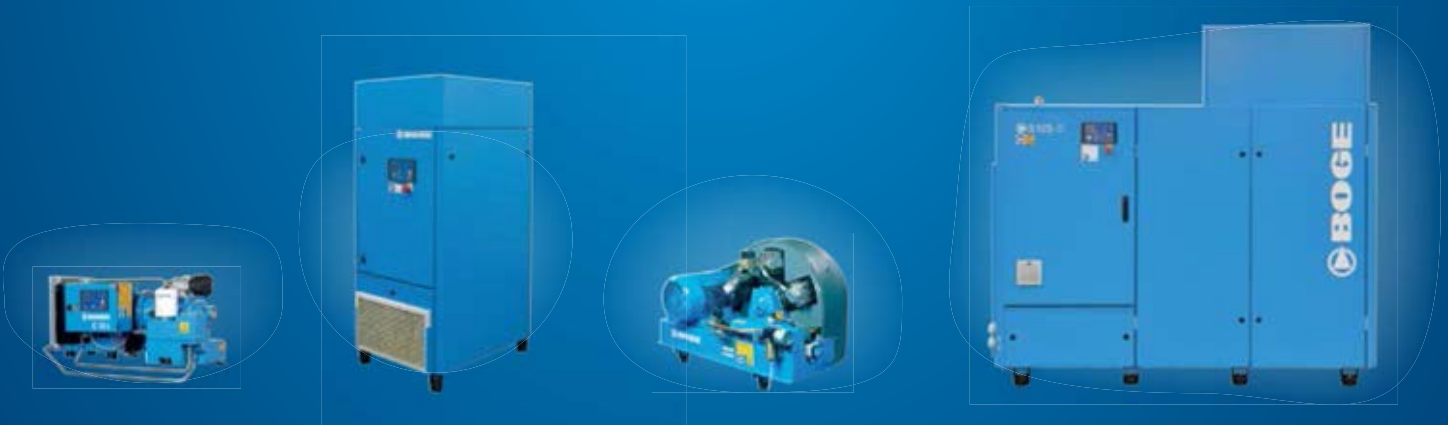
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