The Magazine for ENERGY EFFICIENCY in Compressed Air Systems

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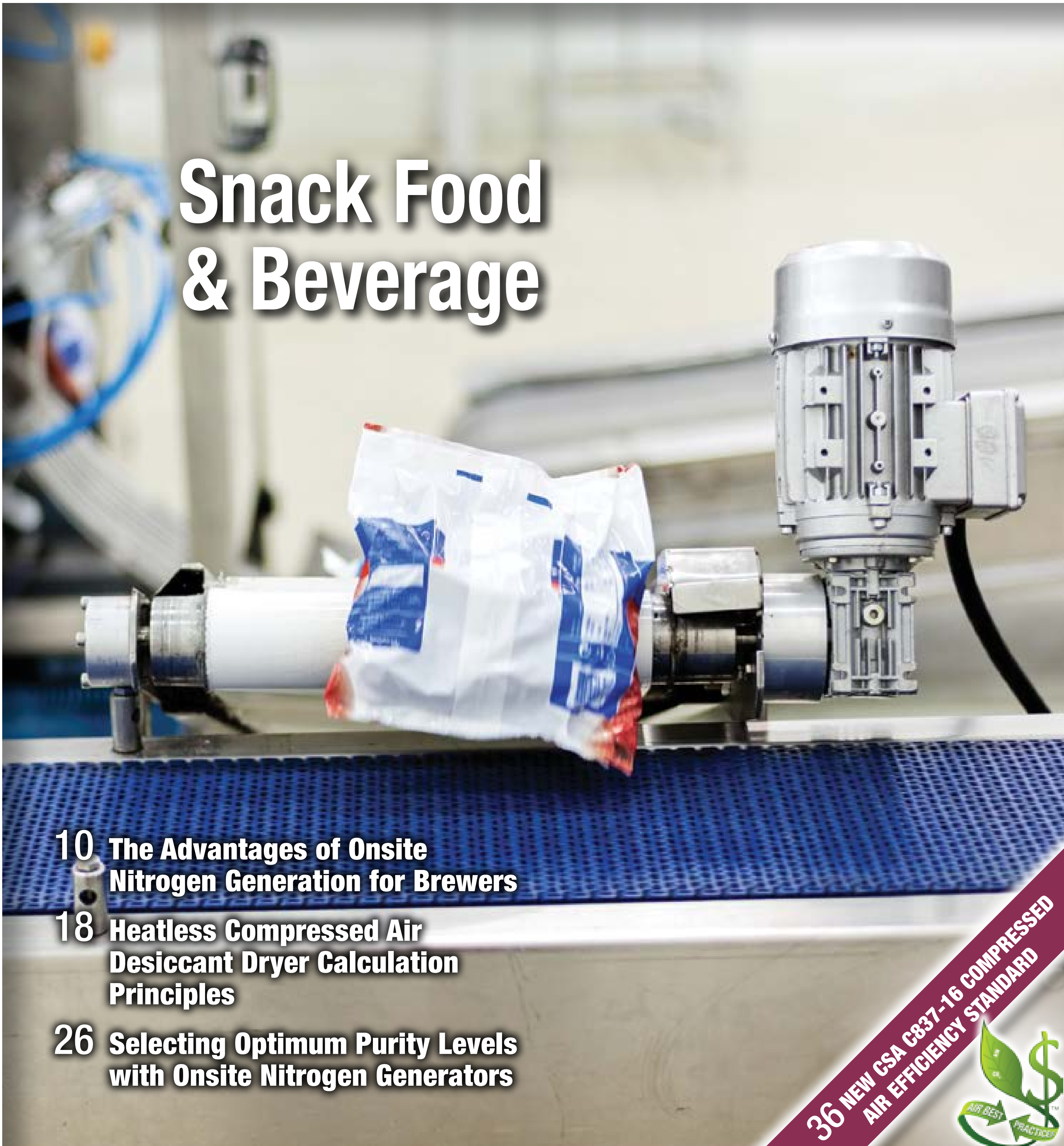
October 2016



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FROM THE EDITOR | Snack Food & Beverage

Onsite nitrogen generation continues to gather momentum. The benefits of onsite (vs. commercially supplied nitrogen) to the environment and to profitability are well established. Mike Robinson, from Atlas Copco Compressors, kicks off the issue writing about brewery applications. “Producing nitrogen onsite offers microbrewers three key benefits over ordering bulk nitrogen: less production time is lost, no gas waste and lower costs.”

David Connaughton, from Parker’s Gas Separation and Filtration Division, provides another article focusing on nitrogen purity specifications by application. “Although onsite nitrogen generation can produce N_2 purities of up to 99.999%, users can realize significant financial and energy savings if they match the purity of the nitrogen to the purity required by the application. Indeed, for many applications, a purity of 99.9% or above is not required.” His article provides a very useful review of typical N_2 purities by application.

Compressed air purity is critical to the snack food industry. Pressure dew points of -40 °F (-40 °C) are often required. Heatless desiccant compressed air dryers are often the technology of choice to get the job done. Donald White, from Aircel, provides us with a very interesting article which is both a history and an engineering lesson - on how and where the calculations came from to properly design a heatless desiccant air dryer.

Our Canadian neighbors up north have come up with a new standard for compressed air efficiency, CSA C837-16. Ron Marshall provides us with an overview of the standard he helped create!

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

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INDUSTRY NEWS

Nano-purification Solutions Establishes Joint Venture for Refrigeration Products

Purification Solutions LLC (nano) of Charlotte, NC USA and CTA SAS of Chaponost, France have announced a joint venture for the North American market. The JV will be owned by both CTA and Purification Solutions and the new business will be managed locally by the nano team. Don Joyce, Director of Sales & Marketing for CTA-North America will be a key member of the management team and remain focused on building the CTA-NA process cooling business established in April 2016.

David Peters, Purification Solutions Managing Member commented, "We are extremely pleased to have reached this agreement with CTA. We considered several options prior to making this commitment since we wanted to ensure it was the right decision for our business as well as our customers. After visiting CTA, we quickly realized their commitment to quality products and excellent customer service was critical to their success and, that really stood out for us. Customers come to nano for several reasons and, of course, quality products and features are important to them. However, we believe the key to our success is the service and support we provide before, during and after the sale. As we spoke to CTA about our experience, customer service, philosophy, we found they operated CTA with similar principles and didn't simply treat customer service as a buzz phrase. We knew from that meeting we found someone we wanted to partner with and it was only down to crafting an agreement that met both our needs. The joint venture approach works perfectly for us both. A JV not only meets the needs of our existing customer base but, it protects our business and the value we create. Additionally, it positions CTA in the market directly rather

David Peters, Celine Perez, Emmanuel Perez, Adrien Perez and Don Joyce (left to right).

"As we spoke to CTA about our experience, customer service, philosophy, we found they operated CTA with similar principles and didn't simply treat customer service as a buzz phrase."

— David Peters, Purification Solutions Managing Member than through an importer or wholesale distribution outlet which is important to CTA as they continue to build their brand globally."

The CTA brand will be reserved for the core process chiller product offering and the CTA-NA team will predominately target OEM opportunities. nano will continue to focus on the air compressor distribution network with an improved (NXC) thermal mass and new (NDX) direct expansion refrigeration dryer line to round out nano's complete range of compressed air treatment and air separation products. The CTA chillers will also be branded for nano's distributors (NCS) since the chiller market presents a large growth opportunity for nano's existing customers. Both entities will operate out of the same facility and share many internal technical and customer service resources.

CTA's product offering includes a 24-model standard range of completely packaged process chillers through 105 Ton capacity and Don Joyce's experience allows the group to provide process cooling solutions to meet our customers' engineered project requirements. nano's refrigerated dryer product offering will continue to include true energy-saving, thermal mass cycling refrigerated dryers from 20 scfm to 2000 scfm and adds non-cycling refrigerated dryers from 15 scfm to 4,750 scfm to the lineup, as well. nano continue to provide engineered products for larger flow and higher pressure applications.

Purification Solutions is also proud to announce, starting in October 2016, our businesses will operate and ship directly from a new, larger office and warehouse facility in Charlotte, NC.

For further information, contact Purification Solutions LLC, tel: 704.897.2182, email: marketing@n-psi.com

Bristol-Myers Squibb Recognized as a ENERGY STAR® Partner of the Year-Energy Management

Bristol-Myers Squibb is a global BioPharma company focused on discovering, developing, and delivering innovative medicines that help patients prevail over serious diseases. The company has built a robust energy management program by utilizing ENERGY STAR® energy management tools and actively participates in the ENERGY STAR partnership.

Bristol-Myers Squibb is receiving ENERGY STAR Partner of the Year recognition for furthering its commitment to the environment and its energy management program over the past year. Key 2015 accomplishments include:

- Achieving an absolute energy use reduction of 14 percent and greenhouse gas emissions reduction of 17 percent from a baseline year of 2009.
- Implementing 50 new major energy projects in 2015, bringing the total number of projects implemented since 2009 to 275. These projects generate an annual average savings of $14.5 million from an investment of $35.1 million.
- Earning ENERGY STAR certification for three buildings.
- Engaging over 200 employees, vendors and industry peers through Energy Treasure Hunts that identified plant-wide energy savings opportunities averaging 15 percent with total cost savings potential of over $7.5 million.
- Actively participating in the ENERGY STAR Focus on Energy Efficiency in Pharmaceutical Manufacturing and Industrial Partnership.

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INDUSTRY NEWS

- Promoting energy efficiency and building capacity for better energy management among employees through numerous energy fairs, lighting fairs, and Earth Day observances.

Building a culture of continuous improvement through employee engagement using ENERGY STAR resources as the keystone of the energy program.

Bristol-Myers Squibb

For more information, visit www.bms.com/sustainability or www.energystar.gov

MCAA Publishes 2016 Process Instrumentation Market Forecast

The Measurement, Control & Automation Association (MCAA) has published its Annual Market Forecast for 2016. The report focuses on the Process Instrumentation and Automation (PI&A) markets in both the United States and Canada. Twelve industry segments and product categories are examined in-depth, with a forecast timeline extending to the year 2020.

The PI&A market in the United States did experience growth in 2015, however that growth was minimal. At $11.6 billion, the increase was 0.3 percent above the 2014 level of $11.1 billion.

Lack of growth was attributed to a decline in oil prices as well as a downturn in mining and mineral spending due to falling commodity prices. Another factor is surplus capacity in the metals, cement, and pulp & paper sectors that is suppressing demand for those products. A strong dollar and weaker economies in China, Russia, and Brazil have also reduced U.S. domestic demand for PI&A products and services.

Five industries within the U.S. are expected to experience above average growth for the period 2015-2020: electric utilities, pharmaceuticals, chemicals, refining, and food & beverage. These industries will account for $7.8 billion in 2015, expanding to $9.4 billion in 2020.

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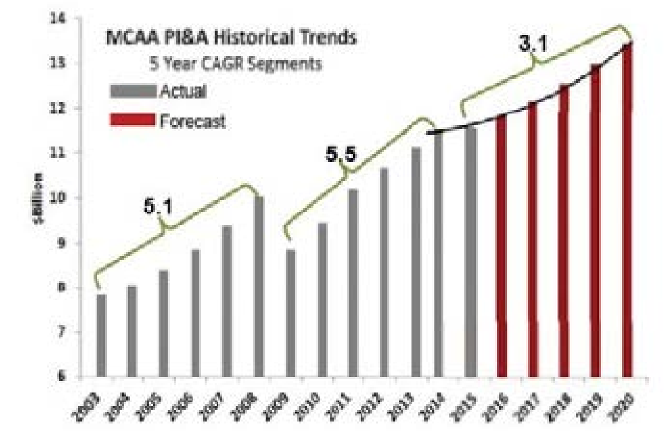
In Canada, process industries will grow slightly slower than in the United States. Mining and oil production comprise nearly 20 percent of the Canadian economy. The drop in oil & gas and mining & minerals spending resulted in a 4 percentage-point drop in the PI&A growth rate for 2015.

Canadian process industries are positioned for growth over the forecast period. Metals, cement, water/wastewater, and chemicals are all expected to profit from increased government spending on infrastructure.

MCAA exists to help the management teams of process and factory automation product and solution providers run and grow successful businesses by offering timely, unique and highly specialized resources acquired from shared management benchmarks where proprietary company information is secure.

This report is included in annual membership but can be purchased by non-members for a fee. Please contact MCAA for purchase details at tel: (757) 258-3100, mcaa@measure.org, www.measure.org



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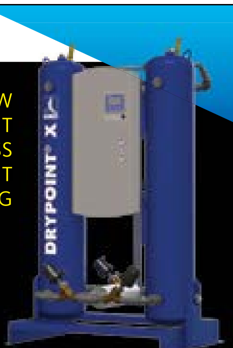

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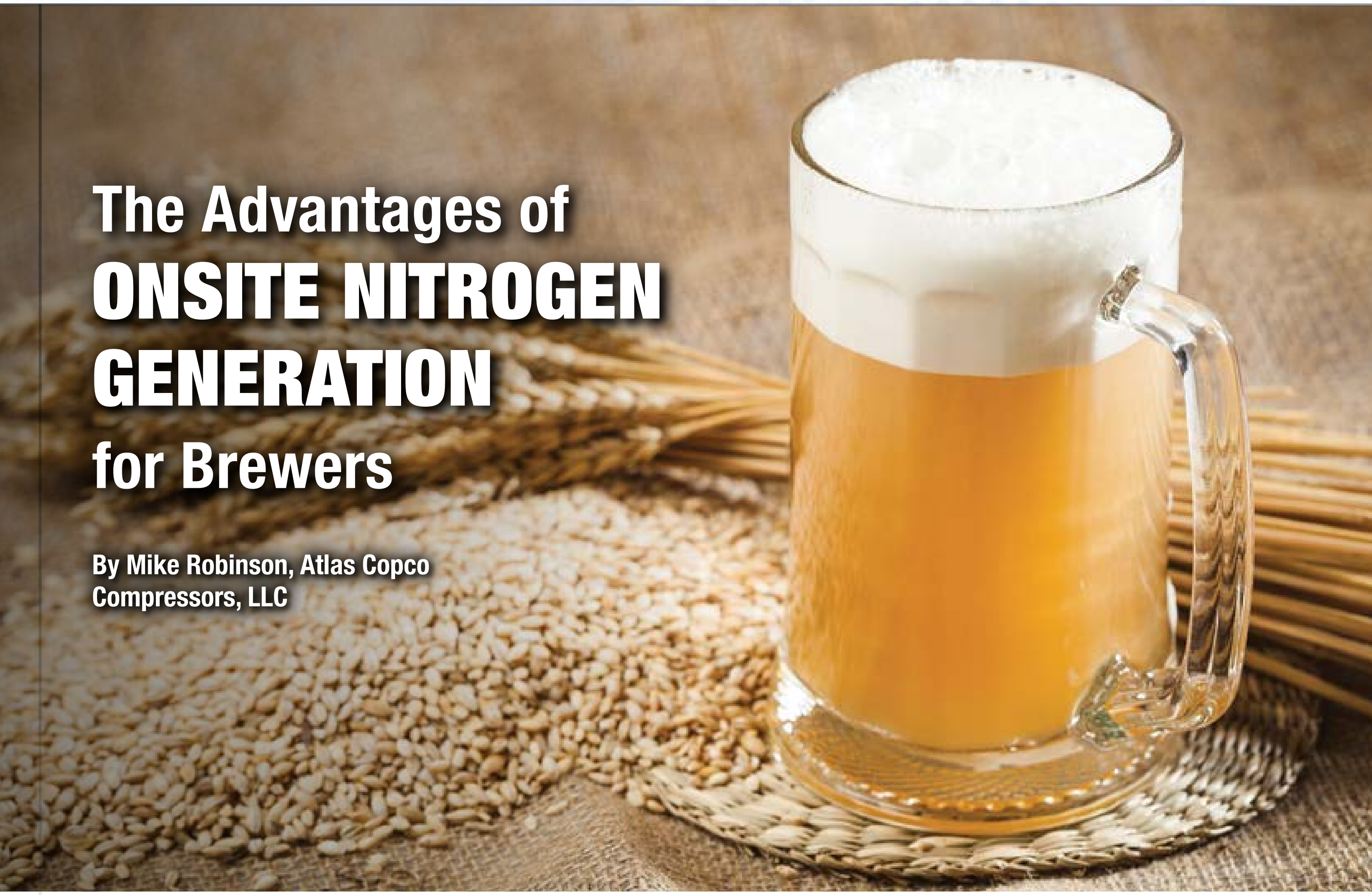

The Advantages of ONSITE NITROGEN GENERATION for Brewers

By Mike Robinson, Atlas Copco Compressors, LLC

Made from various combinations of hops, grain, yeast and water, beer is a drink that has been produced for centuries. But while the ingredients are simple, the chemical processes behind the drink are anything but. Through various reactions, barley becomes fermentable sugars that are then digested by the active yeast to produce carbonation and alcohol. Although the basic principles behind brewing are little changed since their advent, the technological aspects are much improved. Today, large stainless steel tanks are used for fermentation and wort aeration, and complex, automated systems help with everything from temperature regulation to bottling. A price tag comes with these high-tech systems, and it's not insignificant. By using onsite nitrogen generation, brewers can save significant amounts of money throughout the life of their operation.

The Brewing Process

To produce alcohol of any kind, sugars must be separated from a grain. This could be corn, wheat, barley or rye. In beer production, the yeast digests the sugars to create alcohol and carbon dioxide. The brewing

> "By using onsite nitrogen generation, brewers can save significant amounts of money throughout the life of their operation."
>
> — Mike Robinson, Atlas Copco Compressors, LLC

process is broken down into four discrete steps: malting, mashing, boiling and fermentation.

First, the grain must be malted, or heated, dried and cracked to make certain necessary enzymes available. During mashing, the grain is steeped in hot water to break down the enzymes released by malting. The mash is then strained to remove leftover particulate. The resulting sugary liquid is called wort. In the boiling phase, bitter hops are added to mitigate the overly-sweet taste of the wort. Hops also act as a preservative. At this stage, other flavors can also be added. The wort is boiled, cooled and strained again. The wort can also be aerated, or injected with small air bubbles. This assists in the last step in the process, fermentation. Yeast is added to the wort. Fueled by oxygen, the yeast digests the sugars and release alcohol and carbon dioxide. The duration and temperature of fermentation depends on the type of beer being made. Each of these steps takes place in large tanks dedicated to different phases of the brewing process.

Stainless steel tanks are used to store mash, aerate wort and ferment beer.

THE ADVANTAGES OF ONSITE NITROGEN GENERATION FOR BREWERS

Brewery equipment using nitrogen generated onsite from the compressed air system.

Nitrogen uses in brewery applications

Nitrogen or other compressed gases are used in various phases of the brewing process. Brewers use nitrogen to purge tanks between uses, ensuring residual mash, wort or beer doesn't oxidize and pollute the next batch with harsh or sour flavors. It can be used to displace oxygen and carbon dioxide in tanks and to push beer from one tank to another. Nitrogen is also injected into kegs to pressurize them prior to shipment, storage and use.

Benefits of onsite nitrogen generation

Producing nitrogen onsite offers microbrewers three key benefits beyond ordering bulk nitrogen: less production time is lost, no gas waste and lower costs.

1. **Less time lost**

   When brewers produce nitrogen onsite, their operations aren't at the mercy of a supplier's delivery schedule. Even if it's just for a few days, production may have to be

How does a nitrogen generator work?

The air around us is composed of about 78 percent nitrogen and 21 percent oxygen. Nitrogen generators remove the oxygen molecules. This is accomplished through two methods: pressure swing adsorption and membrane nitrogen generation.

Pressure swing adsorption (PSA) separates molecules with a carbon molecular sieve (CMS). The media has pores the same size as oxygen molecules across its surface, allowing the passing oxygen molecules to adsorb to the sieve. Nitrogen molecules are larger than oxygen, so they bypass the CMS and continue on to the tank. PSA generators have two chambers: one that is adsorbing oxygen and another that swings to a low pressure for desorption. These generators can produce nitrogen with a 10 parts per million remaining oxygen content or a purity level of 99.999%.

Membrane nitrogen generation operates differently than PSA nitrogen generation. Instead of adsorption, this process utilizes a bundle of small, hollow polymer fibers to remove oxygen from the gas stream. The fibers have small surface holes large enough for oxygen to pass through, but nitrogen is too large to fit. This method can produce up to 99.5 percent purity level nitrogen.

halted, leading to less uptime and potential product losses. Once the compressed gas does arrive, it needs to be brought in, attached to the current system, and the old canisters need to be removed. Having nitrogen on hand reduces time lost waiting for these steps to occur and removes some of the work on the operators end, freeing up more time for other functional tasks.

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THE ADVANTAGES OF ONSITE NITROGEN GENERATION FOR BREWERS

Nitrogen is used to push contents from one tank to another.

2. **No gas waste**

Typically, breweries do not measure compressed gas usage. However, you don't need exact measurements to know gas gets wasted. When bulk liquid nitrogen is purchased, it's not used all at once. While it sits idle in tanks, the ambient heat causes it to expand. If this pressure isn't released, the tanks can explode. To prevent this from happening, the tanks must be opened and the gas released back into the atmosphere. While this is certainly a good safety practice, it wastes product – and money. Onsite nitrogen generation allows brewers to use only what they need, when they need it, reducing the costs associated with wasted or unused pressurized gas.

3. **Lower costs**

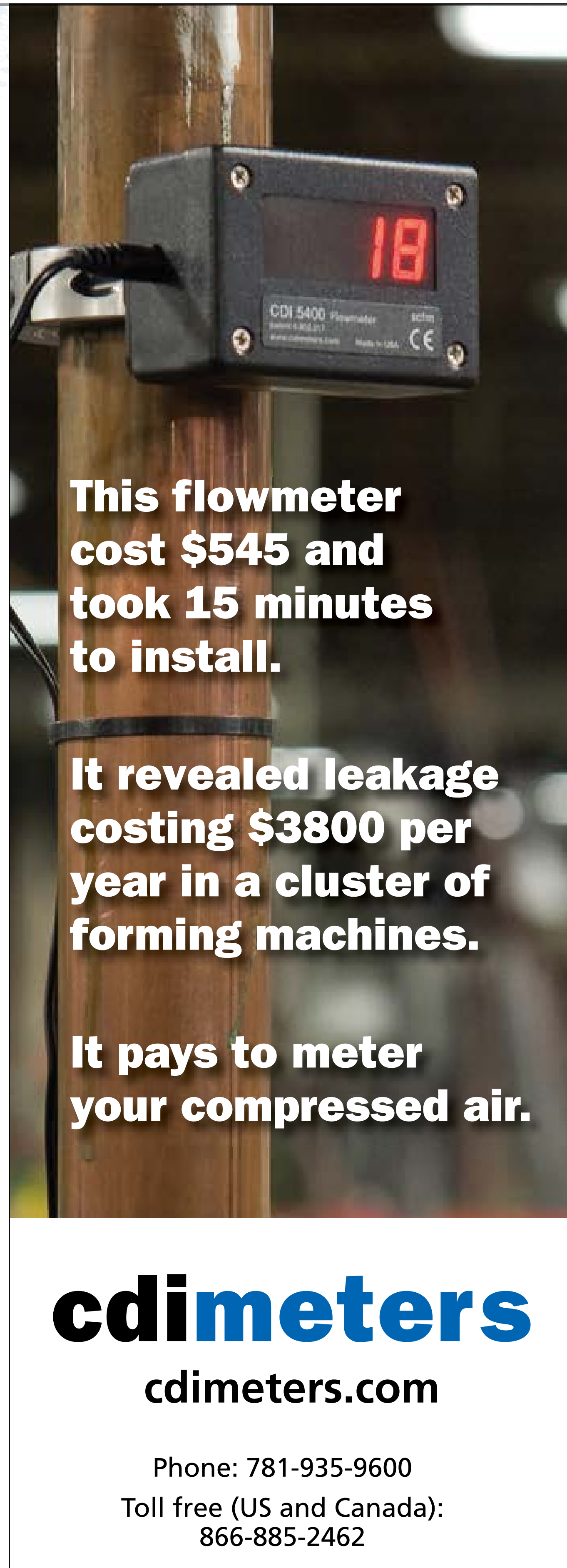
   In addition to costs incurred from lost production time and wasted compressed gas, onsite nitrogen generation is cheaper than purchasing carbon dioxide or nitrogen. Most brewers do not have a clear market awareness of how much compressed carbon dioxide and nitrogen should cost, which is understandable; prices can differ depending on how near or far the brewery is to the gas generation site. For example, while one brewery may be paying $0.25 per cubic foot, another brewer in the same city could be paying three times more.

On average, purchasing nitrogen costs between $0.25 and $0.40 per cubic foot, and carbon dioxide is typically slightly more expensive. Generating nitrogen is much cheaper than either option, costing about $0.10 to $0.15 per cubic foot. Depending on purchase and delivery costs in an area, brewers can realize savings of 40 to 75 percent by choosing to use onsite nitrogen generation.

Initial purchase and life cycle costs

The upfront cost of a nitrogen generator may be a deterrent for some brewers, but looking past the initial purchase price reveals the true value. Using the above data, it's easy to understand the daily savings an onsite nitrogen generator provides. These savings quickly compound and, depending on usage, many brewers break even within the first two years of installation.

Nitrogen generators use either pressure-swing adsorption (PSA) or membrane technology.



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THE ADVANTAGES OF ONSITE NITROGEN GENERATION FOR BREWERS

Nitrogen generation and oil-free air

To generate nitrogen you first need a source of compressed air. While some small nitrogen generation systems include an internal compressor, these would not generate the capacity needed to support a brewery. Oil-free compressors are well-suited to this task.

Breweries that use oil-free compressors alongside nitrogen generators can use the same compressor to power other functions throughout the facility such as control air for valves and filling equipment. This can help breweries lower their energy costs associated with compressed air, potentially offsetting the initial price of the nitrogen generator.

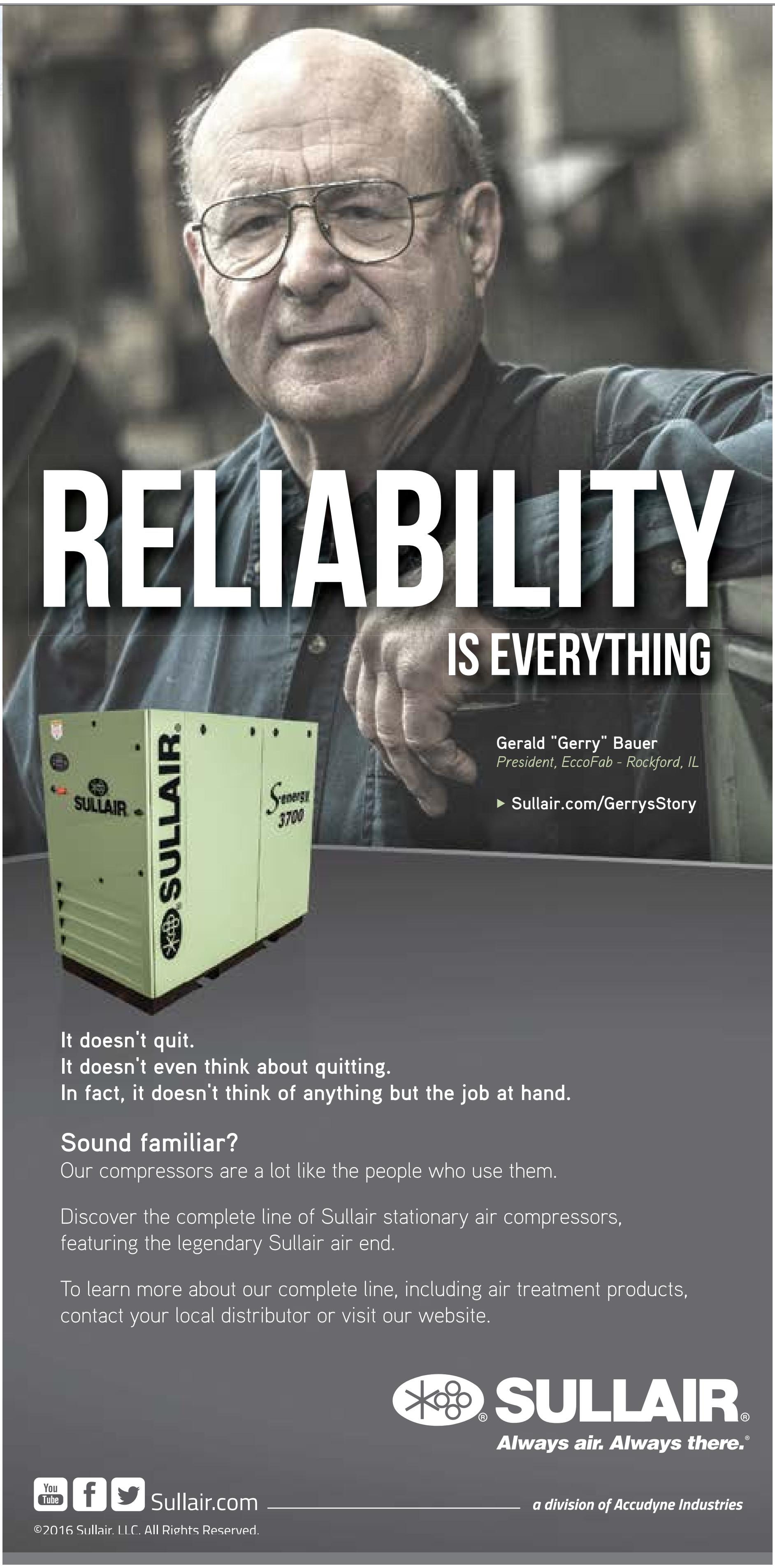
Oil-free compressors are the best choice when selecting a compressor to power a brewery with an onsite nitrogen generator. Since they are not lubricated by oil, there is no risk of contaminating the beer at any stage during production. This also reduces the cost of maintaining and replacing filters in the nitrogen generator.

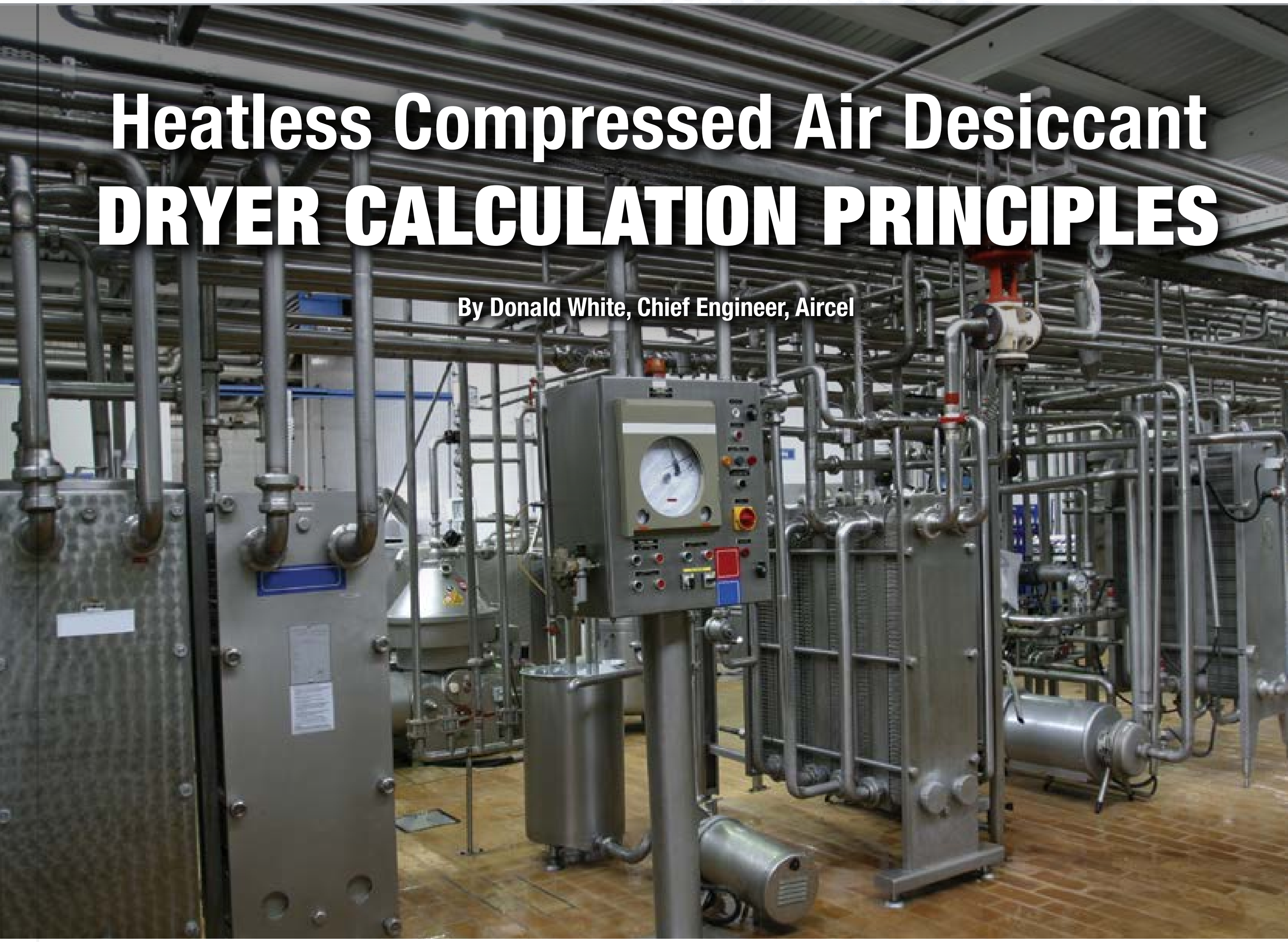
Conclusion

The various benefits of onsite nitrogen generation all boil down to one common theme: savings. From lower gas expenses to less gas waste to no delivery and installation wait time, nitrogen generators are a clear boon to brewers. Brewers can gain further savings by pairing nitrogen generation with oil-free VSD compressors, mitigating costs to bolster their bottom line. BP

For more information, please contact Mike Robinson, Atlas Copco Compressors, LLC, tel: (803) 817-7340, email: mike.robinson@us.atlascopco.com, www.atlascopco.us

To read more ***Nitrogen Generation Technology*** articles, please visit http://www.airbestpractices.com/technology/air-treatment





Heatless Compressed Air Desiccant DRYER CALCULATION PRINCIPLES

By Donald White, Chief Engineer, Aircel

Compressed air is provided to power pneumatic valve actuators, drive air motors, convey raw material and products, activate analytical instrumentation, and for cooling services. To be effective, compressed air must be dried to remove moisture, and other contaminants, which contaminate and corrode critical components. Purity levels recommended for various services are given in Fig. 1.

Adsorption devices are commonly installed in compressed air systems to remove moisture. Heatless compressed air dyers are the most common type furnished to meet the requirement for -40˚F dew point "commercially dry" air, especially in systems of less than 1,000 standard cubic feet per minute (scfm). Heatless air dryers are pressure swing adsorbers designed to retain

> "With diligence and attention to design principles, the heatless dryer can be constructed to fulfill very stringent service specifications."
>
> — Donald White, Chief Engineer, Aircel

the heat of adsorption within the desiccant beds during the drying process.

The stored heat of adsorption is consumed during the regeneration process to remove moisture from the desiccant to provide continuous service. If the heat is lost prematurely, such as by excessive flow rates, the heatless dryer cannot regenerate and the system fails requiring priming at minimal flow for an extended period of time before continuing. The dryer is heater-less, but it relies on the retention of the heat of adsorption evolved during the drying process to provide continuous service.

The Inventor: Dr. Charles W. Skarstrom

The heatless dryer process was born out of necessity by Dr. Charles W. Skarstrom in 1956 at the Esso refinery in Bayway, New Jersey[1]. Dr. Skarstrom, who had worked on the Manhattan Project during World War II,

Dr. Charles W. Skarstrom, Inventor

	DEW POINT AT PRESSURE	ISO 8573.1 PURITY CLASS
Air Motors	-20˚F / -29˚C	2.3.2
Pneumatic Actuators	-20˚F / -29˚C	2.3.2
Manufacturing Services	-20˚F / -29˚C	2.3.2
Spray Painting	-20˚F / -29˚C	2.3.2
Sand Blasting	-20˚F / -29˚C	2.3.2
Breathing Air	-40˚F / -40˚C	2.2.2
Drying Processes	-40˚F / -40˚C	2.2.2
Wind Tunnels	-40˚F / -40˚C	2.2.2
Pneumatic Controls	-40˚F / -40˚C	1.2.1
Electronics	-40˚F / -40˚C	1.2.1
Pneumatic Conveyors	-40˚F / -40˚C	1.2.1
Plastic Mold Blowing	-40˚F / -40˚C	1.2.1
Cryogenic Services	-100˚F / -74˚C	1.1.1
Optical Lenses	-100˚F / -74˚C	1.1.1
Instrumentation	-100˚F / -74˚C	1.1.1

Fig. 1 – Recommended Compressed Air Dryness Levels

HEATLESS COMPRESSED AIR DESICCANT DRYER CALCULATION PRINCIPLES

was developing an automatic gas analyzer for his laboratory when the plant's desiccant air dryer failed. The dryer's regeneration heater burned out. Acting on the theory of heater-less regeneration, Dr. Skarstrom solicited the assistance of Virgil Mannion and Robert C. Axt, adsorption system engineers, and together they shortened the dryer cycle time sufficiently to conserve the heat of adsorption and continue the drying process without an external heat source. Based on the successful operation, the process was patented[2]. Dr. Skarstrom's laboratory observations are preserved in his patent issued in 1960, and in the 1972 CRC Press publication[3]. He discovered that to dry compressed air, the following principles must be applied for the process to continue.

- Principle #1: Short cycles and low throughput per cycle are required to conserve the heat of adsorption
- Principle #2: Regeneration at low pressure using some of the purified product for countercurrent purge
- Principle #3: Actual purge flow rate (acfm) must equal or exceed the throughput flow rate (acfm). The third principle can be restated in terms of standard cubic feet per minute (scfm): Purge (scfm) ≥ Feed (scfm) x (Regeneration Pressure, psig + 14.7) / (Inlet Pressure, psig + 14.7)

Microporous Desiccant Material

The desiccant in a heatless air dryer is a microporous mineral rather than a chemical reagent, and moisture is removed from the air by adsorption, a physical phenomenon, rather than by chemical reaction. Desiccants are rigid, nanoporous, sponge-like granules that provide a large active internal surface in angstrom size channels for attracting and retaining fluid molecules.

The physical attraction is the result of van der Waal forces and electrostatic interactions. These forces, explored by Johann Dietrich van der Waal (1838-1923) and Linus Carl Pauling (1901-1994) include polar attraction, London forces, and gravitational dispersion among other forces. The adsorption phenomenon was studied extensively by many researchers including Stephen Brunauer and Paul Emmett, who later developed the method for separating U-235 from U-238, and Edward Teller who led in the development of the hydrogen bomb. They devised the B.E.T. method of measuring the internal surface area of adsorbent granules[4]. Recently research has shown that adsorbed water molecules are retained in a state differing from either a vapor or a liquid. Upon entry into the nanocavities, the atoms of the water molecules delocalize and adhere to the solid surfaces in a "quantum tunneling state". The discovery was made by neutron scattering and ab initio simulations at the Department of Energy's Oak Ridge National Laboratory (ORNL) in 2016[5].

Knowledge Developments in Heat of Adsorption and Adsorption Isotherms

Experimentation revealed that the heat released during the adsorption process is exothermic in accordance with J.W. Gibbs' law. The atoms from the water molecules lose

Calculation Notations

c_o = influent concentration of water vapor, lb_m of water vapor per lb_m of dry air

c_p = specific heat of air at constant pressure, btu/lb_m-°F

G = Gibbs Free Energy, btu/lb_m

H = enthalpy, btu/lb_m

M = adsorbent equivalent capacity, lb_m water vapor/lb_m of adsorbent

N = number of mass transfer units, dimensionless

p_2 = effluent system pressure, psia

p_3 = purge exhaust pressure, psia

P = influent system pressure, psig

P_r = excess purge ratio, actual purge / minimum purge

S = entropy, btu/lb_m-°R

t = parametric time constant, (1.8 minutes)

ta = drying time, minutes

T = absolute temperature, °R

T = throughput parameter, dimensionless

V = volume of water vapor adsorbed, cu.ft./lbm of adsorbent

W = humidity ratio, mass of water vapor per mass of dry air

W_d = mass of desiccant, lb_m

X = effluent concentration of water vapor, lb_m water vapor per lb_m air

ρ_0 = standard density of air, lb_m per cubic foot (0.075 lb_m/cu. ft.)

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HEATLESS COMPRESSED AIR DESICCANT DRYER CALCULATION PRINCIPLES

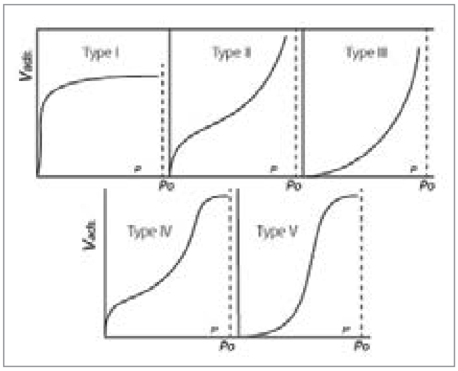

Fig. 2 - The Five Types of van der Waals Adsorption Isotherms

a degree of freedom during the adsorption process and the adsorption process is accompanied by a reduction in entropy (S) and Gibbs free energy (G):

$$\Delta H = \Delta G + T\,\Delta S$$

This phenomenon is observed when liquid water is added to a flask of dry desiccant. The heat released is sufficient to produce steam shown rising from a beaker of molecular sieve desiccant.

The released heat is absorbed into the compressed air stream by convection resulting in an elevation of the air temperature, ΔT_a. The temperature rise is directly proportional to the heat of adsorption and to the change in specific humidity in the air, ΔW, divided by the specific heat of air, c_p[6].

$$\Delta T_a = \Delta H \times \Delta W / c_p$$

The three common industrial desiccants are activated alumina commercialized by Pechiney in France in the 1950's based on the Bayer process[7], synthetic silica gel developed by Walter Albert Patrick in 1918 (Grace Davison), and synthetic molecular sieve invented by R.M. Milton of Union Carbide (Linde) in 1959[8]. The B.E.T. surface area of commercial activated alumina is about 350 square meters per gram, silica gel has a B.E.T. internal surface area of about 650 square meters per gram, and molecular sieves have an internal B.E.T. surface area of approximately 800 square meters per gram.

At partial pressures below saturation, the adsorption capacity for water vapor decreases, but not linearly. Stephen Brunauer, Lola S. Deming, W. Edwards Deming and Edward Teller studied the various isothermal adsorption capacity curves and published the five characteristic forms:[9]

Dual Chambers and Fluidization

Desiccant is installed inside two chambers and the compressed air is directed into one chamber while the other is being regenerated. As recommended by Dr. Skarstrom, the flow through the regenerating chamber is countercurrent to the direction of flow through the chamber that is drying the compressed air[3]. The wet air can be admitted into either the top or the bottom of the drying chamber. Depressurization of the chamber at the start of regeneration must be opposite to the direction of the drying flow. It is most practical to flow upward during drying so that the chamber will be depressurized downward to initiate regeneration. This causes the least disturbance in the desiccant bed and minimal adsorbent abrasion.

The compressed air is subject to energy losses and pressure reduction as it flows through a chamber filled with desiccant. This loss should never be so severe as to fluidize the desiccant granules or cause them to oscillate violently resulting in granular attrition. The energy losses in a fluid stream passing through a granule bed are expressed by Daniel Bernoulli's law of hydrodynamic pressure, and more recently by Sabri Ergun[10]. The vessel flow area must be sufficiently large to prevent the fluid velocity from reaching fluidization. To protect the desiccant granules, the upward flow rate is limited to approximately 70% of fluidization. The down flow fluidization limit is twice the up flow limit as the granules tend to nestle and retain stable positions as the flow presses downward. The catastrophic effects of excessive velocities through packed beds have been reported by Theodore von Kármán, Frederick A. Zenz, and Edward Ledoux.

As the flow passes through the bed of desiccant granules, hydraulic energy is reduced, and mass transfer and heat transfer waves are established. Water vapor is not adsorbed evenly throughout the bed, but rather starts at the inlet end and quickly forms a mass transfer wave that permeates gradually through the bed. As the water vapor is adsorbed, heat of adsorption is liberated forming a thermal front that advances through the bed at a much faster rate than the mass transfer front. The shape of the heat and mass transfer fronts and their rates of propagation have been defined mathematically by A. Anzelius[11] in 1926, and by Albert Einstein[12] in 1937. The solution was simplified for linear-equilibrium isotherms by an approximation offered by Adrian Klinkenberg[13] in 1948 as given by the following equation:

$$X = \tfrac{1}{2}\left[\,1 - \mathrm{erf}\left(\sqrt{N} - \sqrt{\mathbf{NT}}\right)\right]$$

For Type I Langmuir type adsorption isotherms such as for molecular sieve desiccants, the following solution offers improved accuracy[14].

$$X = \tfrac{1}{2}\left[\,1 - \mathrm{erf}\left(\sqrt{N - \mathbf{NT}}\right)\right]$$

The effluent water vapor concentration is determined from an analysis of the mass transfer front which is distorted by the short cycle time required to contain the heat of adsorption. The NEMA cycle time is normally 10 minutes, 5 minutes per desiccant chamber, to provide a -40˚F pressure dew point. The time is shortened to lower the effluent dew point or to reduce the size of the dryer chambers. To provide a -100˚F pressure dew point, the cycle time is typically shortened to 5 minutes, 2.5 minutes per desiccant chamber. Cycle times as short as 24 seconds have been used to reduce the size of a desiccant heatless dryer to a fraction of the standard size. The effluent water vapor concentration from a heatless dryer is determined from the following equation[6].

$$X = (t_a{}^3/t^2)\ (c_o)^2\ (\text{scfm x } \rho_0)\ /\ \{M\ N\ W_d\ (P_r)^2\ [1 - (p_3/p_2)]\ \}\ \text{lb}_m \text{ water vapor per lb}_m \text{ air}$$

A lower effluent concentration can be achieved by decreasing the cycle time, $\tau_a{}^3$, decreasing the inlet moisture content, $c_o{}^2$, increasing the excess purge flow ratio, $P_r{}^{-2}$, or by increasing the desiccant mass, $W_d{}^{-2}$ (Note: W_d is also included in "N").

HEATLESS COMPRESSED AIR DESICCANT DRYER CALCULATION PRINCIPLES

Heatless Compressed Air Dryer Observations

The heatless air dryer offers a design that is based on the most advanced scientific principles. Through the years, estimating methods have been developed to provide first approximations for designing, operating and maintaining heatless air dryers. Some of the observations are listed below:

- Inlet moisture content doubles approximately with every 20˚F increase in inlet air temperature.
- Compressed air temperature increases 20˚F to 25˚F when adsorbing moisture at 100˚F and 100 psig.
- The inlet pressure must be at least 40 psig, preferably 60 psig, to prevent excessive temperatures.
- Pressure loss through the dryer including prefilter and after filter should not exceed 5 psi.
- The regenerated vessel should be pressurized to at least 95% of line pressure before switch-over.
- Purge flow is increased by approximately 15% to account for heat losses from the chamber.
- Minimum purge is about 15% of the inlet flow rate based on operating at 100˚F inlet and 100 psig.

The Heatless Compressed Air Dryer Assembly (Courtesy Aircel LLC)

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- Rob Thomson's rule: outlet dew point changes about 1˚F with each 1˚F change in inlet temperature.
- Depressurization air loss is approximately 10% of the purge loss, and the two losses are additive.
- Harry Cordes equation: Minimum contact time (10 Min. NEMA) = 0.75 + [0.0345 x (P, psig)] seconds.
- Required mass of desiccant to retain the heat of adsorption is approximately 600 pounds of adsorbent per 1,000 scfm of air at 100˚F and 100 psig operating on a 10 minute NEMA cycle.
- Desiccants: activated alumina (Type II isotherm) is standard, silica gel (Type IV) is used for lower dew points, and molecular sieve (Type I) for the lowest dew points and for inlet temperatures over 100˚F.
- The chambers are filled with desiccant to the knuckle in the top head creating a distribution plenum.
- Upflow drying and downflow depressurization result in minimum desiccant abrasion and attrition.
- Moisture and temperature switch-over spikes, prevalent in heat regenerated dryers, are not present.
- Desiccant chamber safety valves, one per chamber, should be set approximately 10% over the maximum system operating pressure to prevent valve plug simmering or chattering.
- Thermal safety valves on the desiccant chambers are sized to relieve excess pressure resulting from the expansion of trapped air in a closed vessel caused by an external conflagration.
- Pneumatic control air tubing can be stainless steel, Teflon®, copper, and for indoor service, nylon.

With diligence and attention to design principles, the heatless dryer can be constructed to fulfill very stringent service specifications. Testing of the finished product at the design operating conditions before shipment is advisable to confirm expected performance. A properly designed, fabricated, and tested heatless desiccant compressed air dryer is assured to satisfy the application requirements. BP

By Donald White, Chief Engineer, Aircel, email: don.white@airceldryers.com, tel: 865-268-1011, www.Airceldryers.com

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Selecting Purity Levels WITH ONSITE NITROGEN GENERATORS

By David Connaughton, Product Sales Manager, Parker Hannifin, Gas Separation and Filtration Division

The useful and various properties of nitrogen (N_2) in industrial applications rank it as one of the most specified gases in industry. For the manufacturer, nitrogen options exist in the choice of delivery system, compliance with clean air standards, safety and purity[1]. In researching these choices, manufacturers can accurately select the optimum nitrogen supply required, often at a considerable savings. Selecting purity levels of 99.99% or higher in many industries and applications ads a variety of costs, both financial and efficiency, which may be needlessly incurred.

Commercially Supplied Nitrogen: The Process and the Costs

Liquid air separation plants provide nitrogen generated by using cooled air to separate out the oxygen and nitrogen as they become liquid. Cryogenic distillation accounts for approximately >95% of the total nitrogen production. Generating nitrogen using this method is energy-intensive because the process entails condensing ambient air into liquid air by cooling and compressing it in a refrigeration cycle that utilizes the Joule-Thompson effect.

After N_2 is separated from the air, additional energy is needed to purify it to requirements and fill the appropriate transport container.

> "On-site nitrogen generators are safer and easier to handle than high-pressure cylinders and offer speed of delivery advantages over liquid nitrogen evaporation from dewars and tankers."
>
> — David Connaughton, Product Sales Manager, Parker Hannifin, Gas Separation and Filtration Division

Since this process is performed continuously on a large scale, its power usage generates hundreds or thousands of tons of greenhouse gases every day.

Nitrogen produced through this process can attain a purity of 99.99% or higher. This process is completed at a higher cost for a purity level offering no added benefit for most applications. Purchased nitrogen from a commercial gas company is the most expensive option. Costs are slightly lower for liquid nitrogen in a Dewar or bulk tank. In cylinders, the cost rises.

The cost of transport of nitrogen via delivery tankers from a fractional distillery facility to and from an end users plant is factored into the price. Delivery of nitrogen uses a lot of energy and significantly contributes to the amount of CO_2 generated in the process of delivering nitrogen to end users. Obviously, the amount of energy required to transport the nitrogen depends on the distance between the facility and the end user's plant, but the environmental impact of trucking nitrogen is significant. For example, a tractor trailer traveling around 100,000 miles per year generates about 360,000 pounds of carbon dioxide during that time period. The highly pressurized and heavy cylinders require proper handling and can lead to back injuries or catastrophic damage and injuries if the valve were to shear off.

On-site Nitrogen Generators: The Process and Benefits

On-site nitrogen generators are safer and easier to handle than high-pressure cylinders and offer speed of delivery advantages over liquid nitrogen evaporation from dewars and tankers. On-demand gaseous nitrogen generation uses one of two alternative methods. They include Pressure Swing Absorption (PSA) and membrane system technologies. The choice of generator largely depends on the purity of nitrogen needed. In both cases, the level of O_2 can be controlled to just the required purity level.

Applications that need nitrogen of 95 to 98 percent purity (5% to 2% oxygen), such as fire and explosion prevention, can use membrane generators. Applications such as the blanketing of oxygen sensitive compounds, specialty chemicals and pharmaceutical processing need a high purity stream and require the use of PSA generators.

PSA systems take compressed air and filter the air using high quality coalescing filters to remove 99.99% of 0.01 micron particles. The system then separates nitrogen from oxygen based on the preferential adsorption and desorption of oxygen, water vapor and other contaminants on a Carbon Molecular Sieve (CMS) bed. PSA nitrogen generators have two bed columns: one with fresh CMS for the current adsorption process and another that swings to low pressure to desorb oxygen from saturated CMS. One column provides nitrogen while the other column is being regenerated. These column beds are cycled back and forth to generate and regenerate the beds. The resulting high purity nitrogen then feeds a buffer tank to allow for a continuous high-pressure output. The high purity nitrogen stream passes through a final filter to ensure the delivery of pure, sterile nitrogen.

The hollow fiber membrane system uses compressed air that is directed through the bore of a membrane tube. The smaller and more soluble oxygen and water molecules pass through the wall of the polymeric membrane tube thus enriching the nitrogen in the air stream. Membranes produce nitrogen


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SELECTING PURITY LEVELS WITH ONSITE NITROGEN GENERATORS

in a continuous process assuring constant downstream purity. Like the PSA system, the nitrogen-enriched gas stream passes through a final filter to ensure the delivery of pure, sterile nitrogen.

Purity Specified in Industrial Applications

Although on site nitrogen generation can produce N_2 purities of up to 99.999%, users can realize significant financial and energy savings if they match the purity of the nitrogen to the purity required by the application. Indeed, for many applications, a purity of 99.9% or above is not required.

Nitrogen serves to extend shelf life and preserve flavor, color and aroma in **food and beverage** products ranging from snack food packaging, coffee packaging and wine bottling. A purity level between 98-99.5% is specified for most products. Packaging of many products is filled with nitrogen, an odorless and tasteless addition. Products can undergo longer shipping distances without a loss of flavor when the oxygen is replaced with nitrogen in the packaging. Nitrogen is occasionally mixed with CO_2 or small amounts of O_2 to create a modified atmosphere packaging to inhibit specific bacterial growth in meats, fish or poultry. Other products, such as edible oils are blanketed with nitrogen to prevent oxygen from inducing rancidity. In wine production, nitrogen is used both in the blanketing of the fermenting stock and in bottling. Bottles are purged with nitrogen, filled with wine and topped with more nitrogen before corked.

The **metals** industry values nitrogen for a wide variety of purposes. In aluminum degassing, the molten metal is sparged with nitrogen, pushing out hydrogen which can cause gaseous occlusions. In aluminum extrusion, the inert nitrogen prevents the formation of oxides. Laser cutting employs nitrogen to blow off dross and minimize oxidation at the cut, while

Parker dh Multibank Nitrogen Generators at a Coffee Packager a laser bellow is purged so the dust is removed from the mirrors and H_2O and CO_2 is cleared, preventing the absorption of laser energy and blurring the cut. Heat treating metal needs an inert atmosphere such as nitrogen. Purities range from 97% for aluminum degassing to 99.5% or higher for heat treating and aluminum extrusion. For laser cutting, purities of nitrogen can be as low as 99.95% or lower depending on the material and thickness being cut.

Oil and gas and the petrochemical industries face safety concerns, well served by the inert properties of nitrogen. Levels of purity in these industries are usually between 95-99%. Fire prevention and explosion blanketing successfully removes the oxygen with the introduction of nitrogen. Chemical tanks are often blanketed with nitrogen to prevent fire or explosion. In upstream and midstream areas of the oil and gas industry there are multiple uses, from the cleaning and inspection of pipes to the pressurization of riser tensioners, used to maintain stability in a floating or tethered rig. Within a pipeline, gas seal turbines are often sealed using a cushion of nitrogen. The nitrogen prevents natural gas leakage and suppresses the risk of fire should any slight leak occur.

The **pharmaceutical** industry relies on the inert properties of nitrogen to assure safety and sterility in the chemicals and packaging, with an average purity level of 97-99.99%. In product transfer, nitrogen is used to purge receptacles to eliminate contamination. Chemical blanketing, with nitrogen, assists with the stability of the final pharmaceutical product. Sealed packaging is infused with nitrogen to maintain freshness of the drugs. Deionized water, used throughout pharmaceutical processes, is blanketed to assure a constant pH by preventing exposure to CO_2.

The development of **plastics** requires both the low dewpoint drying and inert properties of nitrogen for molding and extrusion processes. Nitrogen purities range from 95-99.5% in this industry. In injection molding, purging of the pellet hoppers and the prevention of carburization on the screw is achieved with nitrogen introduction. In gas-assist injection molding, pressurized nitrogen assists in packing out the part and eliminates shrinkage. Blown film extrusion uses nitrogen for both purging and spray drying products.

The Power generation industry is highly safety and maintenance conscious. Nitrogen assists in removing oxygen and preventing corrosion. During boiler cycling, the proper layup of the Heat Recovery Steam Generator (HRSG) includes nitrogen to avoid corrosion and pitting of the boiler, following ASME guidelines. A boiler that has been powered down is both blanketed and sparged with nitrogen to prevent corrosion. Nitrogen is often used to blanket and sparge demineralized water tanks to prevent CO_2 contamination of demineralized water. Purging natural gas lines with nitrogen allows repairs or valve installations without fire concerns. Across the field of power generation, nitrogen purity is usually between 95-98%, with up to 99.6% in boiler layup.

In the **Electronics Assembly** industry, nitrogen is used to keep solder clean and soot free especially in the selective solder and wave solder processes. Purities in this industry can be as high as 99.999%

Other applications for nitrogen use are in diverse fields where its inert properties and purging of oxygen is needed. Coal or other mines can be partitioned off and filled with nitrogen to purge oxygen and prevent explosions. Automotive paint blanketing

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SELECTING PURITY LEVELS WITH ONSITE NITROGEN GENERATORS

Typical Nitrogen Purity Levels by Industry

The following is a list of common applications and typical purities based on over 50,000 generators deployed worldwide:[2]

Electronic Assembly

Application	Purity (N_2)
Lead free solder processes	(99.999 to 99.99% N_2)
Wave soldering	(99.999 to 99.99% N_2)
Reflow soldering	(99.999 to 99.99% N_2)
Selective solder	(99.999 to 99.99% N_2)
Dry box storage	(95-99%)
De-ionized water storage	(98-99%)
Burn-in ovens	(97-99.99%)
Parts cleaning	(95-98%)
Adhesive blanketing	(99.5%)

Food & Beverage

On average, this application uses a nitrogen purity of 98-99.5%.

- Snack food packaging
- Salad and fruit packaging
- Coffee packaging
- Edible oil blanketing
- Flavorings blanketing
- Dairy Packaging
- Wine blanketing, transfer and bottling
- Modified atmosphere packaging

Metal Industry

Application	Purity (N_2)	Use
Aluminum degassing	97-99%	Remove H_2
Aluminum extrusion	99-99.5%	Prevent carburization
Laser cutting	99-99.999%	Blow off dross and minimize oxidation at the cut
Laser bellows purge	97-99%	Purge bellows so the dust stays off mirrors, H_2O, C_2O absorb laser energy and blur the laser
Heat treating	95-99%	Inert atmosphere
Additive manufacturing	97-98%	Inert atmosphere
Can welding	99%	Inert atmosphere

Oil, Gas and Petrochemical

Application	Purity (N_2)
Fire/explosion prevention	95-99%
Inert blanketing	95-99%
Paint blanketing	98%
Inert transfer in enhanced oil recovery	98%
Pressurizing Riser Tensioners	98%
Gas Seals	95-97%

Pharmaceutical Industry

Application	Purity (N_2)
Chemical product transfer	97-99.99%
Chemical blanketing	97-99.99%
Product packaging	97-99.99%
DI water blanketing	97-99.99%

Plastics

Application	Purity (N_2)	Use
Injection molding	98-99%	Prevent carburization of the screw
Injection molding	95%	Purging the pellet hoppers
Gas assist injection molding	99.5%	Pack out parts and eliminate shrinkage
Blown film extrusion	98-99.5%	Purging, spray dry products

Power Generation

Purging mechanical gas seals	95-98%
Boiler layup	99.6%
Purging natural gas lines	95-98%
Demineralized water blanketing	95-98%

Others

Mine inerting	95-99%
Automotive paint blanketing/spray	95-98%
Gold refining	99.99%
Museum/artifact preservation	95%

[1] Nitrogen concentration or purity is defined in a percentage. The percentage represents 100% minus the oxygen content. The specified nitrogen is the inert gas content and will include Argon. For example, 98% nitrogen represents 2 % oxygen and the balance inert gases, i.e. nitrogen and argon.

[2] Based on observed industry averages and customer information feedback from Parker Hannifin Corporation Filtration and Separation Division installations worldwide in the listed industrial applications. Each customer should determine the nitrogen purity which best suits their applications.

Parker NITROSource nitrogen generators

and paint spraying with nitrogen speeds drying and improves product finish. Museum artifacts and antiquities are often stored in a nitrogen atmosphere to preserve and protect their surfaces.

Conclusion

In the majority of industrial applications, a nitrogen purity of 99.9% or above is not needed to achieve the benefits nitrogen provides. Specifying a purity of that level may unnecessarily add to the cost of production, and the amount of energy needed to create and transport the nitrogen which impacts CO_2 emissions. In the purchase of bulk nitrogen, manufacturers must consider safety in handling cylinders, the potential of delivery delays, additional truck traffic to and from the manufacturing site, as well as the environmental impact.

On-site PSA and membrane systems are energy efficient and cost effective, requiring only enough energy to power the air compressor that supplies air to the system. Gas industry sources indicate that an air separation plant uses 1976 kJ of electricity per kilogram of nitrogen at 99.9% purities. At a purity of 98 percent, the energy required for in-house nitrogen consumes 62 percent less energy. Even for those applications requiring 99.9% purity, generating nitrogen in-house on-demand with a PSA system will use 28 percent less electrically compared to third-party supplied bulk nitrogen.

The elevated and constant use of electricity in air separation plants and trucking to end user customers adds more greenhouse gases to the atmosphere than on-demand nitrogen generation. By eliminating the need for a third party facility to generate nitrogen, and transport it to a user's site, the entire carbon footprint required to supply nitrogen to the plant is reduced. BP

For more information contact David Connaughton, Product Sales Manager, Parker Hannifin, Gas Separation and Filtration Division, email: dconnaughton@parker.com, tel: 978-478-2760

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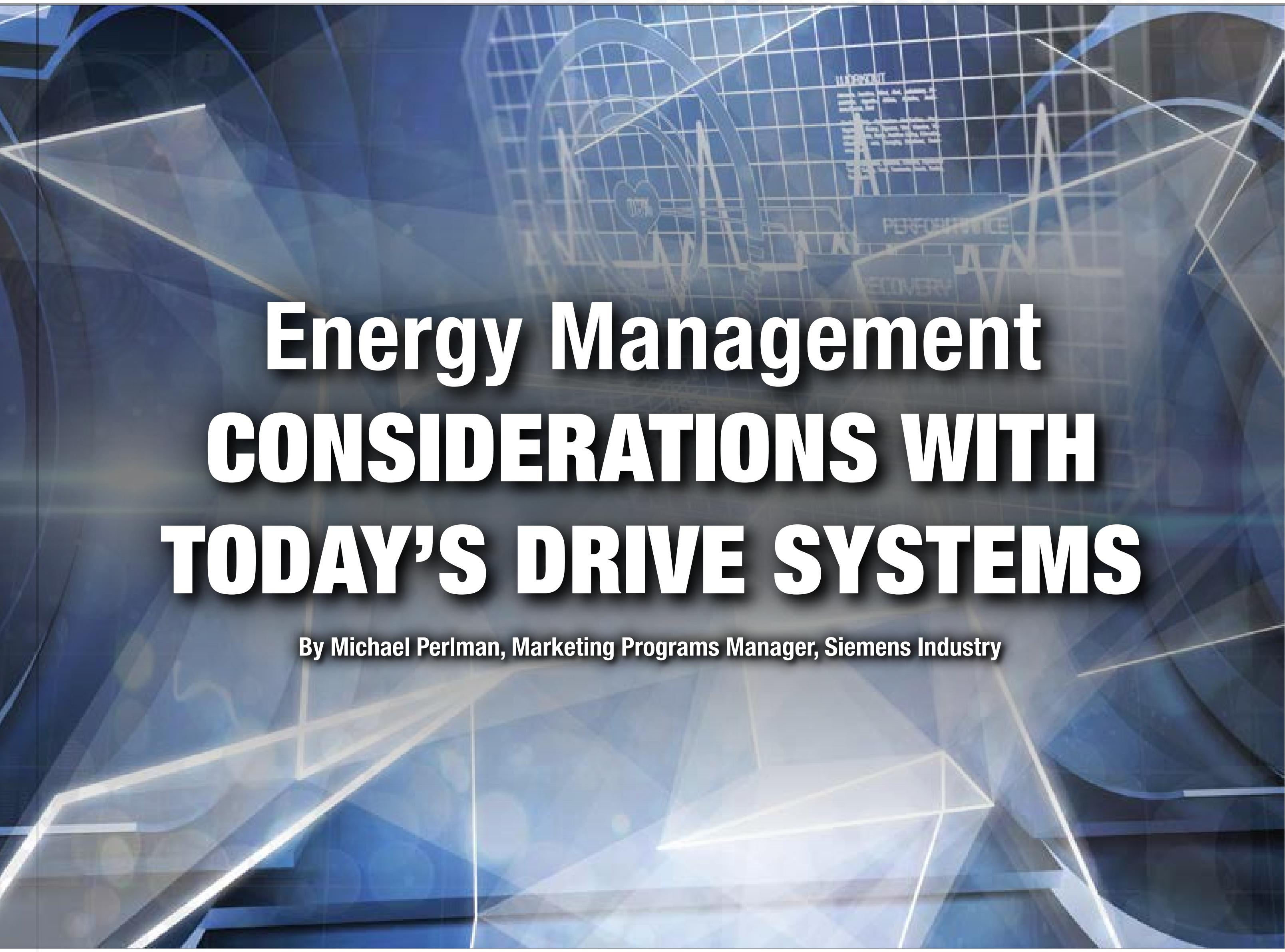


Energy Management CONSIDERATIONS WITH TODAY'S DRIVE SYSTEMS

By Michael Perlman, Marketing Programs Manager, Siemens Industry

Introduction

While it is valid to state that energy efficiency is defined as the same level of production being achieved at an overall lower energy cost, it is equally important for today's machine builders and automation engineers alike to remember than an energy-efficient system can actually translate into higher productivity. This is achievable through a comprehensive approach to energy management.

It is a fact that most of the energy loss in a system occurs in three areas, namely, the generation, distribution and conversion of energy into useful work, the last being accomplished through heat exchangers,

> "An energy-efficient system can actually translate into higher productivity. This is achievable through a comprehensive approach to energy management."
>
> — Michael Perlman, Marketing Programs Manager, Siemens Industry

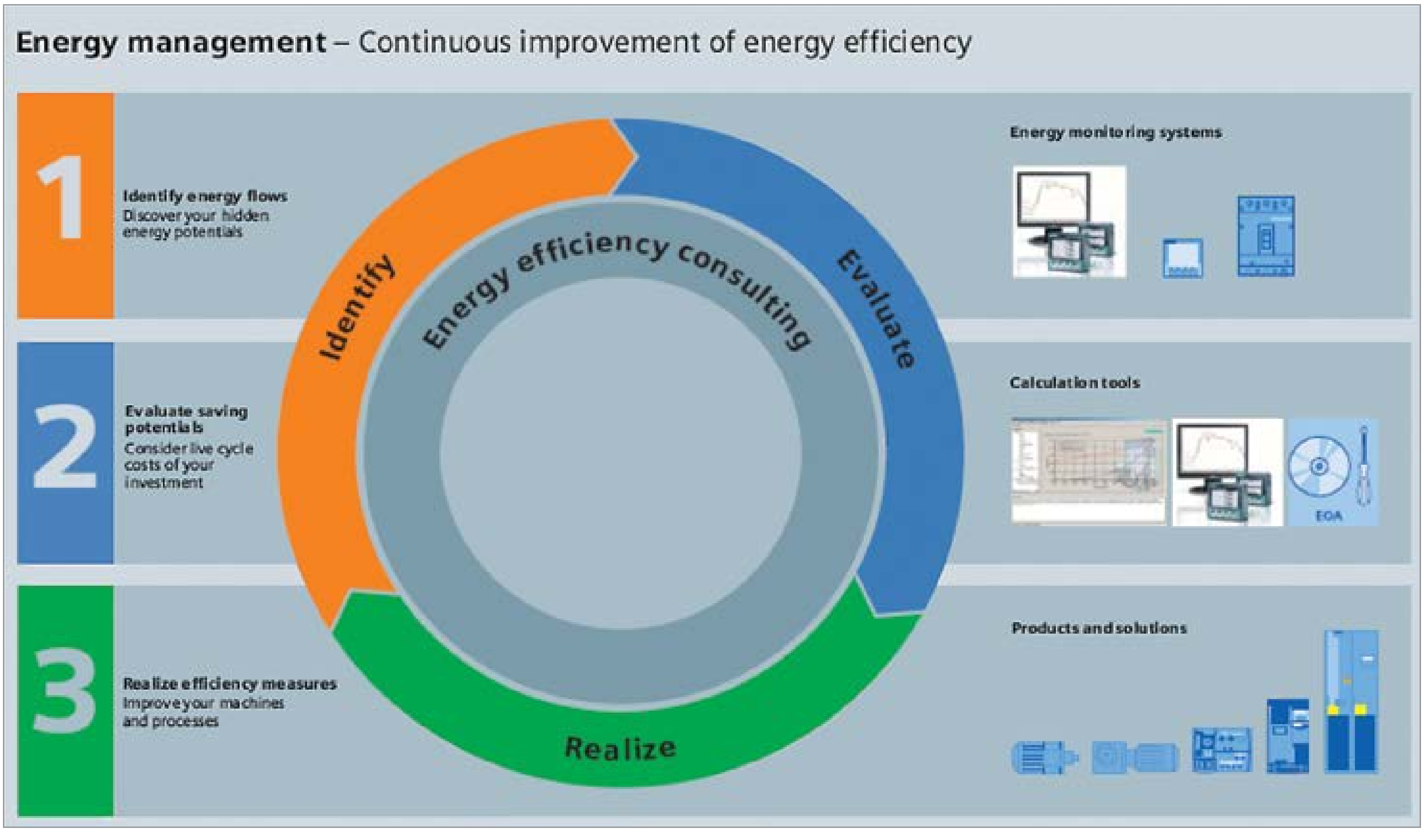
pumps, motors and drives. This paper will concentrate on the last product group.

Energy Management is a Process

Energy management is a process, rather than a product or series of products installed on a machine, or inline, to achieve a basic energy saving of kW hour consumption. This process must be ongoing and perpetual, meaning that any defined goal should be viewed as a momentary metric of achievement, rather than a final end. While any vendor, including our company, can supply the right products and support services to hit a target mark of energy savings, the mindset of the customer is key in keeping the process recurrent. This ensures a continual increase in the productivity levels achieved, defined as a factor of the energy consumed. In many ways, it can be viewed in the same manner as an ongoing, effective but constantly evolving quality management system at your company.

Three essential elements are the basis of such a process

First, energy monitoring systems must be in place to effectively determine the current consumption. These can include, but are certainly not limited to, energy consumption displays, infeed/supply monitoring devices, power factor meters and more. Next, the proper calculation tools are needed to properly evaluate the life cycle costs of any investment. These tools can be as simple as a motor sizing chart or the software programs used to parameterize drives. However, a more formal mechatronics protocol may be beneficial to your operation. In this scenario, a thorough evaluation of both mechanical and electrical/electronic influences on your system, be it a machine or a process line, is conducted. The results can often open the eyes of machine designers, process engineers and system integrators alike. To realize the benefits this analysis the proper products and system solutions must be implemented.



Optimum energy monitoring and management are not products, they're a process, according to Siemens Digital Factory — Motion Control.

ENERGY MANAGEMENT CONSIDERATIONS WITH TODAY'S DRIVE SYSTEMS

This is where a competent supplier can be an effective partner for your operation. For example, the solution you need might involve a vector drive that utilizes an energy optimization function to enhance the efficiency of the motor during partial load operations. In a system with multiple motors, energy savings might be realized to a substantial degree by the use of a drive unit with a common DC bus. The designer can also select the most appropriate infeed solution for the machine, pump or process operation, given the particulars of performance and required output. This may include an appropriately sized infeed unit with regenerative capability, the ability to put unused or braking energy back on the incoming power line.

Some applications may allow the use of high efficiency standard induction motors and, in the process, realize a potential savings of 1-3%. The use of frequency converters (VFD) for speed control might raise this to an 8-10% savings.

Optimizing your entire system through mechatronic analysis of the machine or process design, can result in a potential savings of 15-20% by the avoidance of over dimensioning of motors, plus partial load optimization by means of energy-related flow control. This analysis may also point to the ability to use controlled energy infeed and recovery.

In order to determine the true efficiency of any drive system, it is necessary to demonstrate the amount of energy required by its power components and a corresponding examination of how the system uses energy. How different drive concepts used on the same system under identical power load must also be considered. This latter exercise

might look into partial load efficiencies with various motor and drive combinations, straight comparisons between synchronous servo vs. asynchronous induction motors or direct drive vs. motor/gearbox combinations, drives with braking components vs. regenerative drive technology, as well as solutions with single vs. multi-drive, common DC bus solutions.

A corollary to this discussion should also include a review of potential hydraulic/pneumatic component change outs in certain applications where replacement with an integrated package of motion control and PLC technology might better resolve closed loop pressure control of axes, for example. Fewer components and their related power consumption can lead to overall system productivity improvements, as well as ongoing enhanced energy efficiencies. Reduced programming, diagnostic and commissioning times can also flow from such an approach, providing even more opportunities for overall machine or process improvements. Tracking the energy efficiency of such a system may seem problematic at first, but here again today's sophisticated mechatronic and virtual production protocols can be utilized to validate the real-world performance characteristics of such designs, far in advance of their implementation.

As the emergence of new technologies has impacted many of the products used in energy-efficient systems, it is equally important to take a more holistic look at operational sequences and the overall integration scheme when designing, retrofitting or rebuilding for improved energy utilization.

For more information contact Michael Perlman, Marketing Programs Manager, Motion Control Business, Siemens Industry, Inc., Email: michael.perlman@siemens.com

Website: http://www.usa.siemens.com/motioncontrol

Michael Perlman – Bio

Michael Perlman is the Marketing Programs Manager for the Motion Control business of Siemens Industry, Inc. In this role, he oversees the technical marketing for products including SINAMICS intelligent drives and SIMOTION motion controllers. Michael has over 20 years of experience in plant and corporate automation engineering at a number of Fortune 100 manufacturers including Kraft Foods, General Mills and Masterfoods (Mars). He received a Bachelors of Electrical Engineering from the Georgia Institute of Technology and an MBA from SUNY Buffalo.

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Tom Jenkins has over 30 years of experience with aeration blowers and blower controls.

According to the U.S. Environmental Protection Agency (EPA), wastewater treatment plants consume 56 billion kWh totaling nearly $3 billion per year -equal to almost 3 percent of total power usage in the United States. Aeration blowers, in a typical biological wastewater treatment plant, can account for 50 to 70 percent of the facility's energy use. This webinar will explain the rationale behind the 8 to 1 turndown design target and provide aeration blower system design calculation examples.

Our **Sponsor Speaker** is Stephen Horne, Blower Product Manager from Kaeser Compressors, whose presentation is titled, ***Evaluating Blower Flow and Specific Power Performance.*** This presentation will cover how total package data is needed to understand a blower's true efficiency and review testing standards for evaluating blower performance.

Stephen Horne is the Blower Product Manager for Kaeser Compressors.

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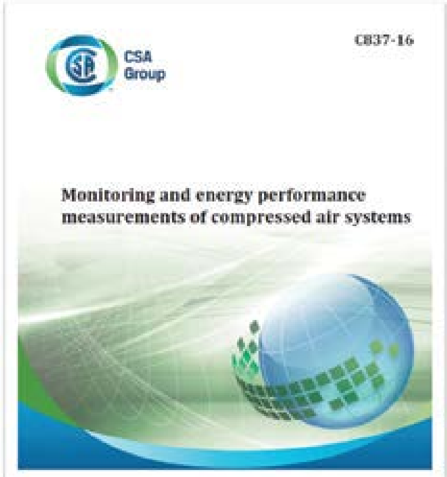
NEW CSA C837-16 COMPRESSED AIR EFFICIENCY STANDARD

By Ron Marshall for the Compressed Air Challenge®

Introduction

After almost three and a half years of development work the Canadian Standards Association C837-16 document "Monitoring and Energy Performance of Compressed Air Systems" has finally been published and is available for download. The work in writing the document was done by a CSA Technical Subcommittee made up of personnel from power utilities and government organizations, compressed air manufacturers and end users from both USA and Canada, with the committee activities facilitated and coordinated by the CSA Group (see list of committee members).



The project was started and championed by Quebec Hydro, a Canadian power utility as a result of challenges being faced in the compressed air industry with regard to performance measurement. Problems were being encountered with inconsistency of reporting of system energy readings. The utility requested CSA Technical Committee T402 (Technical Committee on Industrial Equipment) to initiate work to solve these challenges. Therefore, a new subcommittee was created to work on a standard starting in the Fall of 2012.

What is the standard all about?

The introduction of the standard defines the reason it was developed and its subject matter (used with permission):

> *"Historically, there has been a lack of consistency in the methods used to determine the energy performance of compressed air systems. This often makes it difficult for stakeholders to make informed decisions concerning energy efficiency. This lack of consistent information complicates the task of ensuring any existing, new, or optimized system is operating efficiently.*
>
> *This Standard specifies which information is to be gathered and how system parameters like power, energy, flow, pressure, and production output are to be measured or calculated using transparent, uniform, validated, repeatable, and consistent methods of measurement.*
>
> *This standard provides guidance in defining methodologies for establishing energy performance indicators (EnPIs) and energy baselines (EnBs) to be used as part of an overall energy management system (EnMS) or other related purposes. For compressed air systems, specific requirements outlining a consistent methodology for measuring, estimating, and reporting the energy performance are provided.*
>
> *The intent of this Standard is to align with the requirements of ISO 50006, Energy management systems — Measuring energy performance using energy baselines (EnB) and energy*

Fundamentals of Compressed Air Systems WE (web-edition)

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If you have additional questions about the new web-based training or other CAC training opportunities, please contact the CAC at info@compressedairchallenge.org

performance indicators (EnPI) — General principles and guidance, adapted for compressed air system.

This Standard is not intended as a replacement for a compressed air system energy efficiency assessment (audit) as defined by other Standards, such as ISO 11011, nor does it specify measures that can be used to improve the energy efficiency of a compressed air system.

Scope
1.1 Inclusions
This Standard is intended to be used for compressed air systems with the following characteristics:

a) electrically driven three-phase air compressors equal to or greater than 5 horsepower;

b) positive displacement stationary air compressors and associated equipment;

c) operating pressures between 2.5 and 17 bar(g) (36 and 250 psi(g)); and

d) industrial and commercial applications of compressed air.

1.2 Exclusions
The Standard is not intended to be used for the following purposes or systems:

a) electrically driven single phase compressors;

b) bench testing, measurement, or certification of the performance of an air compressor;

c) measurement of heat recovery;"

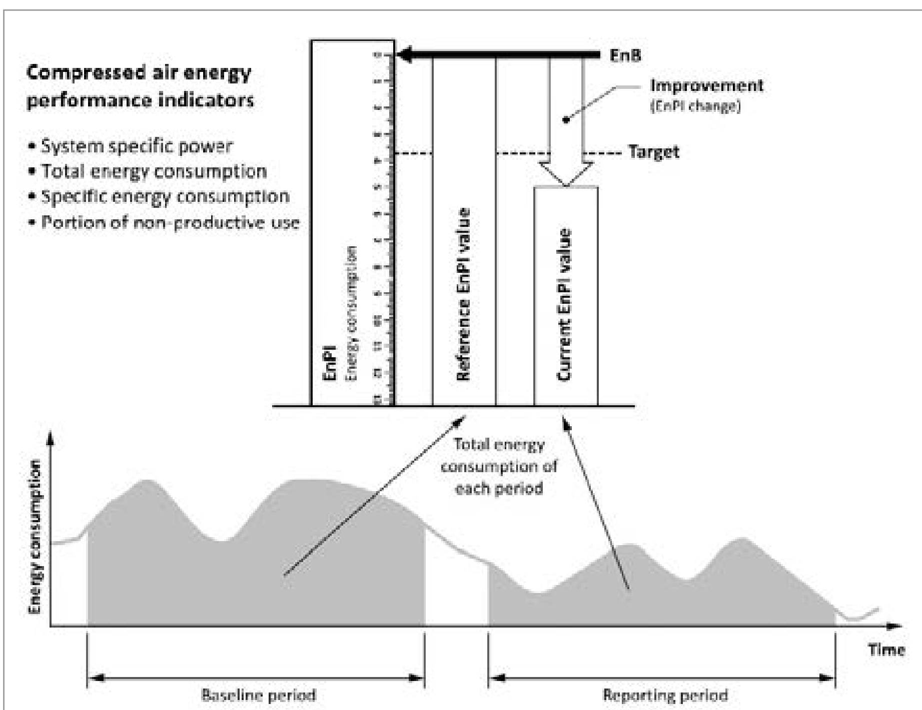
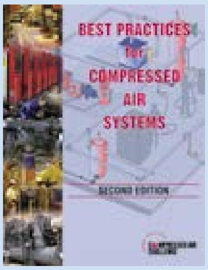


Figure 1: The standard defines a number of Energy Performance Indicators (EnPI's) and guides the reader how to compare a specified baseline period with any reporting period (Source CSA C837-16).

NEW CSA C837-16 COMPRESSED AIR EFFICIENCY STANDARD

Best Practices for Compressed Air Systems Second Edition



Learn more about optimizing compressed air systems

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

Content of the Standard

The standard has a list of reference publications for the guidance of the reader and provides definitions used to clarify important terms and phrases mentioned in the body of the work. General explanation of how to measure and quantify Energy Performance by defining Indicators (EnPIs) and Energy Baselines (EnBs) pertaining to compressed air systems are described (Figure 1). A process flow is defined (Figure 2) to guide the reader in the general steps to take to perform the required measurements, calculations and comparisons. Key to the process is creating an energy baseline as a starting point to be used to compare subsequent measurement periods in which the system may have changed. Changes to the energy performance indicators can, for example, show changes to the system as a result of energy efficiency projects. These measurements can be used by the user, perhaps a power utility energy program or a plant manager, to quantify the improvement to the energy performance of the system. This might feed into the overall performance totals of an energy program. Important to this process is the ongoing continuous consistent measurement and comparison of the system to ensure energy savings are sustained and that the system is operating normally.

With any measurement there must be a defined measurement boundary so the energy baseline and additional measurement periods can be apples-to-apples comparisons. In any complex system there are a number of choices for measurement, often these are dictated by what is physically possible or economical to undertake. Once the boundary is defined all the energy inputs are identified for measurement, as well as the compressed air outputs.

Some static factors are identified that are important to the measurement process but do not routinely change over time. These could be product type in an industrial plant, the number of shifts per day, the floor area of the plant, the typical system pressure and other factors. Some conditions are identified that might change these static factors into relevant variables, such as changing the operating hours of a plant.

Guidance is given to the reader in determining a suitable baseline and reporting periods for the comparison process. General discussion is included about the data collection, such as how to measure, data collection frequency, data quality, and the calculation and comparison of energy baselines. Some discussion is given to normalizing the data, this would be necessary if something has changed between the time the baseline has been captured and the recent measurements are done. For example, a factory might change their production process and/or start a third shift. In this case the energy performance indicators might need to be normalized (adjusted) for a fair comparison.

The standard recognizes the fact that the size of the system and the comparison of the total system energy consumption to the total facility consumption might determine the complexity of the methods used to measure and calculate EnPIs. Thus simple and inexpensive Level 1 measurement methods might be used for small systems that make up a small percentage of the total load. If a system is large and consumes a significant portion of the total load then it may be worthwhile to

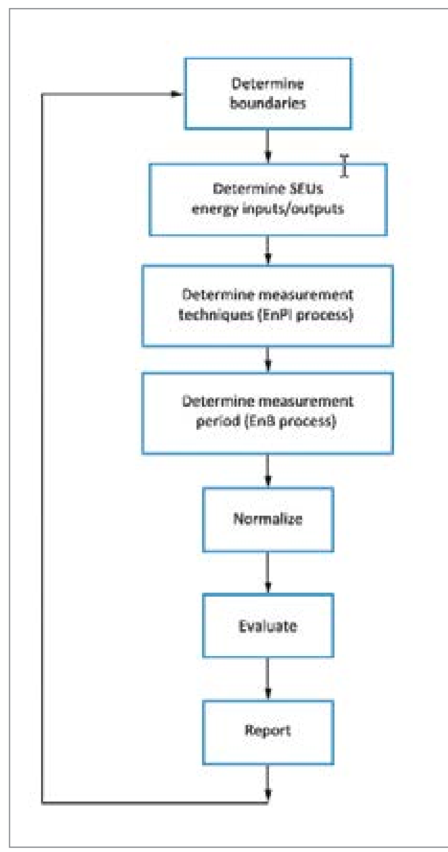


Figure 2: The standard provides definitions and recommended actions on how to determine an energy baseline. (Source CSA C837-16)

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fully instrument the system and continuously monitor the EnPIs with Level 3 accuracy.

Energy Performance Indicators

The standard defines two EnPIs as mandatory in development of any baseline. These are system specific power (SSP) and total energy consumption (TEC). Optional indicators are specific energy consumption (SEC) and portion of non-productive usage (PNPU). These are defined as follows:

- SSP – Average kW sent into the measurement boundary divided by average flow coming out x 100, during the measurement period. An output of this might be average kW per 100 cfm. This is an indicator of how efficiently the compressed air is being produced.
- TEC – Total kWh consumed within the measurement boundary in the specific measurement period. This can be an indicator of compressor efficiency and also how much air is being produced.
- SEC – Total kWh consumed divided by a user defined and specified production unit. Often this is could be the number of product units produced or the weight of a product. This tracks how the system energy consumption varies with product output.
- PNPU – An estimate of the percentage of non-productive compressed air flow crossing the measurement boundary compared to the average flow measured within the measurement period. In some plants this might be readily measured during regular production downtime during weekends. In others some special testing might be required. In the majority of the plants this would be an indicator of leakage and system waste.

These energy performance indicators are dependent on system pressure, therefore the standard dictates pressure should always be measured at the same time.

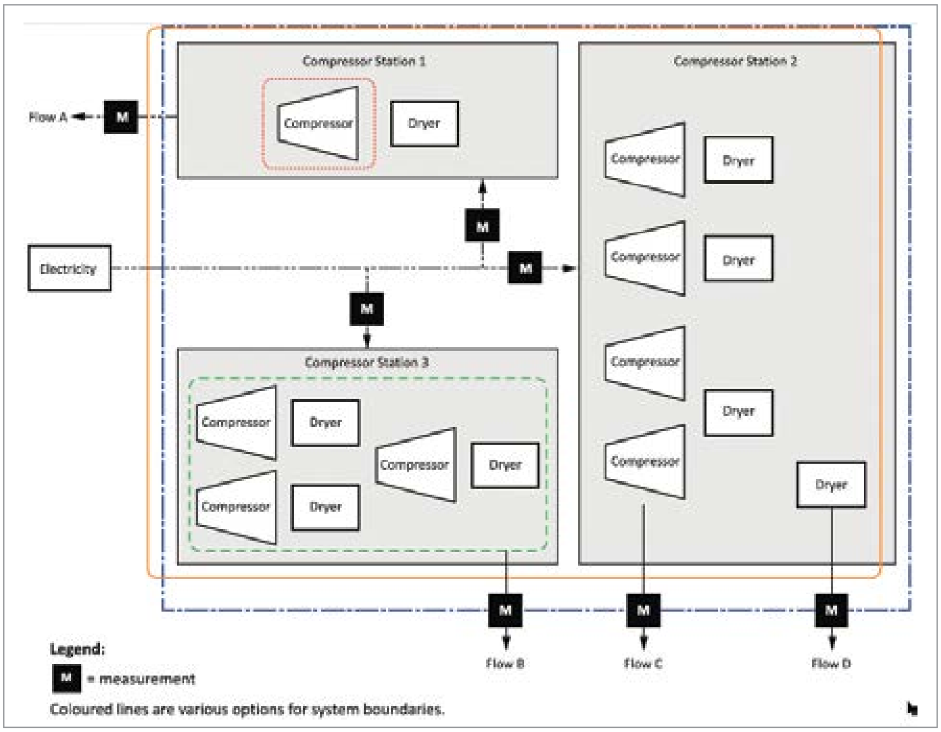

Figure 3: For this sample system a number of system boundaries could be selected depending on the needs of the user (Source CSA C837-16).

Parameters to be Measured

The standard identifies five parameters to be measured or estimated in various specified ways as inputs to the EnPIs. These measurements would be taken on all equipment inside the measurement boundary:

- Power
- Flow
- Pressure
- Energy
- Production output

The standard recognizes that measuring these parameters is sometimes costly and impractical, especially if the system is a small part of the total plant load, so three different measurement levels are identified. Level 1 might be the simplest spot check measurements, Level 2 more complex estimates based on defined more complicated measurement and calculation methods, or Level 3 more complex and expensive direct measurements of the parameters using accurate meters designed for that purpose. The standard discusses various ways of determining these parameters for guidance of the user, depending on the characteristics of their system and what is possible. Some examples might be calculating flow using a stopwatch test of a load/unload compressor at various intervals throughout the day, this might be at level 1 accuracy. The parameters might also be estimated based on the output of each system controller and the rated power and flow of the compressors, such as done when using runtime hour meters. Or actual flow meters and kWh meters might be installed either on a temporary basis or permanently to measure the parameters at Level 3.

A discussion of various methods of measurement and calculation is provided in the standard. These include calculating three

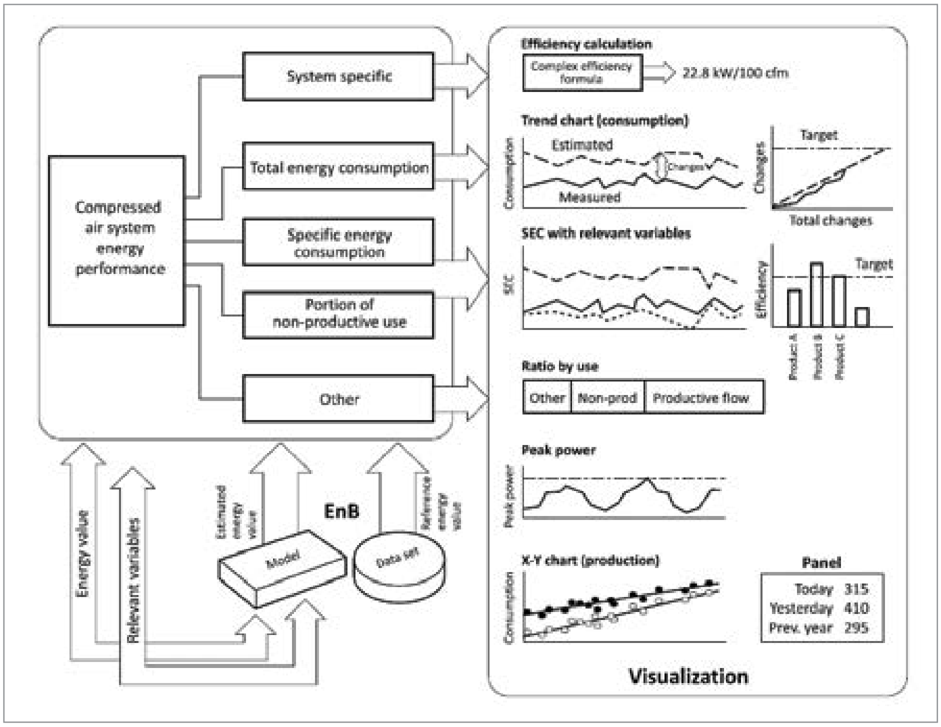

Figure 4: Conceptualized diagram of what a continuous monitoring system could report f or a compressed air system (Source CSA C837-16).

phase power consumption using amps, voltage and power factor estimates, and the adjustment of power factor for lightly loaded compressors. The use of data from system controllers is discussed and is allowed as a method of input for the calculations. The use of CAGI sheets for aid in estimating is also discussed. Some suggested system data collection of nameplate information and developing reports is discussed.

At the end of the standard there are three fully illustrative examples of the three levels of measurement (L1 to L3) and calculation of the EnPIs for three different example systems for the guidance of the reader.

It is hoped the standard will serve a useful purpose in the industry and help standardize the collection of data for reporting to energy programs and to customers considering implementing efficiency improvement projects. Already there is one example of the use of this standard in support of a new energy program at BC Hydro in Canada. As part of a new initiative large customers with systems 1,000 hp and up may be 100 percent funded at levels up to $40,000 if they perform system baseline monitoring, have an energy audit done on their systems, and initiate low cost/ no cost energy measures. Key to this program is the installation of permanent monitoring that conforms to CSA C837-16. It is hoped that more organizations will adopt this standard for guidance of energy performance measurement of compressed air systems.

The standard is available at the CSA Group website at www.csagroup.com BP

For more information about the Compressed Air Challenge, contact Ron Marshall, email: info@compressedairchallenge.org or visit www.compressedairchallenge.org

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The chairman of the Committee thanks all participants for their most valuable contributions and the considerable time spent on this standard development.

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Sustainable Energy Savings with Compressed Air Best Practices®

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

"We're in 75 to 80 locations. We've done literally hundreds of compressed air modifications, changes, upgrades and audits."

– William Gerald, CEM, Chief Energy Engineer, CalPortland (feature article in August 2015 Issue)

"Compressed air is essential to any manufacturing process, particularly in the automotive industry, and it accounts for about 23 percent of total energy costs at our powertrain facility."

– Mike Clemmer, Director/Plant Manager-Paint & Plastics, Nissan North America (feature article in October 2015 Issue)

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

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

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

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

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RESOURCES FOR ENERGY ENGINEERS

TECHNOLOGY PICKS

Sullair Introduces New OFS Series Oil Free Air Compressor Line

Sullair has launched a new line of OFS Series Oil Free Air Compressors, which consists of models in two frame sizes: 100-200 hp and 250-350 hp. All Sullair OFS Series compressors are ISO 8573-1 Class 0 certified to ensure oil-free operation and all are available with Integrated Variable Speed Drive. A variable speed drive can offer up to 60% turn down from full load to improve operating efficiency in the right application.

The new OFS Series Oil Free Compressors' air ends feature rotors with a high-efficiency asymmetrical profile that are coated with an FDA-approved food grade PTFE corrosion resistant coating, offering 100% oil free air. The air end design features anti-friction bearings with an L10 design life of more than 100,000 hours.

The new OFS line also incorporates a robust controller, featuring a Sullair WS Input/Output module paired with a new user interface panel. The controller accurately monitors and controls the compressor; offers built-in sequencing capabilities for automatic load sharing; and constantly displays essential functions and applicable alarms on a large back-lit LCD screen. All of these features and improvements come with a smaller footprint compared to previous Sullair oil free units.

The new Sullair OFS Series Oil Free Air Compressor range has models from 100 to 350 hp

About Sullair

Since 1965, Sullair has developed and manufactured air compressors with proven reliability and wear-free durability. Sullair is globally recognized as a leading manufacturer of portable air compressors, contractors' air tools, stationary air compressors, compressed air treatment equipment and vacuum systems. Additionally, Sullair provides customers with a full line of aftermarket parts, fluids and services. Sullair has manufacturing capabilities in Michigan City, Indiana; Shenzhen and Suzhou, China; Mahindra World City, India; as well as a JV (IHI-Sullair) based in Suzhou. For more information, visit www.sullair.com.

About Accudyne

Accudyne Industries is the parent company of Sullair, and a global provider of precision-engineered, process-critical and technologically advanced flow control systems and industrial compressors that deliver consistently high performance and give confidence to the mission of its customers in the most important industries and harshest environments around the world. Today, Accudyne is powered by ~3,000 employees at 15 manufacturing facilities, supporting a broad range of industries in more than 150 countries. For more information, visit www.accudyneindustries.com.

RESOURCES FOR ENERGY ENGINEERS

TECHNOLOGY PICKS

Atlas Copco Improves Three GA Series Rotary Screw Air Compressor Models

Atlas Copco has enhanced three air compressors in its popular GA series. The improved GA 30+, 37 and 45 compressors offer better performance, lower noise and a smaller footprint. The updated oil-injected rotary screw compressors are now available worldwide.

The free air delivery (FAD) and specific energy requirement (SER) of the GA 30+, 37 and 45 have both been improved by 1 percent. Each model now offers low noise levels down to 65 dB(a) for extremely quiet operation. The new GA 30+, 37 and 45 provide 30 percent smaller footprints than previous editions; the 60 hp version has a footprint as small as 52 inches long and 35 inches wide. The low noise levels and reduced size make it possible to install units on the work floor, sharply reducing the energy consumption of transporting compressed air to the point of use.

"At Atlas Copco, we are always finding new ways to further advance our world-class products," said Alfred Piccolo, vice president of sales and marketing with Atlas Copco Compressors. "The updated GA 30+, 37 and 45 represent our commitment to bringing customers the best technology to support their applications."

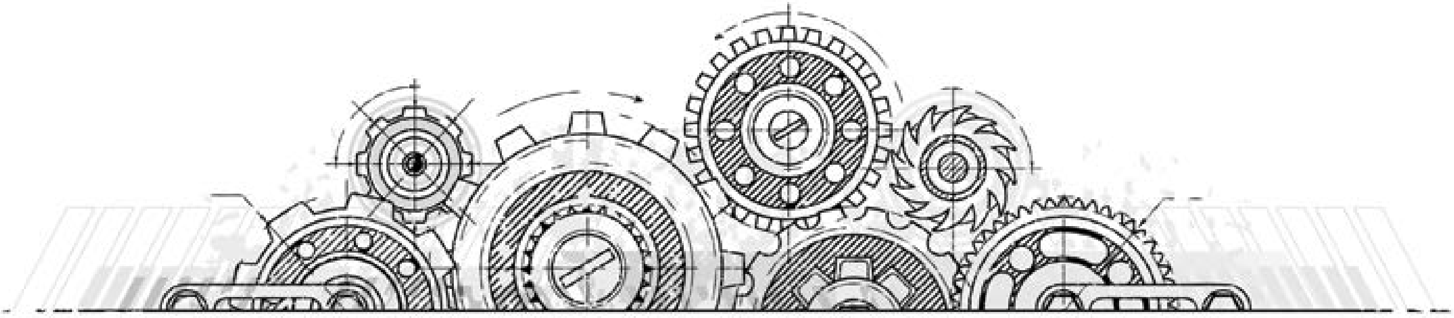
The GA30+, 37, and 45 are integrated packages with built-in refrigerant dryers. Each comes with an Elektronikon® controller and SMARTLINK® technology for remote monitoring. Due to their strong performance and durability, these compressors can be used in a variety of industrial applications, and in harsh environmental conditions and high ambient temperatures.

For more information, please visit http://www.atlascopco.us/usus/products/air-and-gas-compressors/product/1512842/

Atlas Copco is a world-leading provider of sustainable productivity solutions. The Group serves customers with innovative compressors, vacuum solutions and air treatment systems, construction and mining equipment, power tools and assembly systems. Atlas Copco develops products and services focused on productivity, energy efficiency, safety and ergonomics. The company was founded in 1873, is based in Stockholm, Sweden, and has a global reach spanning more than 180 countries. In 2015, Atlas Copco had revenues of BSEK 102 (BEUR 11) and more than 43,000 employees. Learn more at www.atlascopco.com

The improved GA 30+, 37 and 45 air compressors offer better performance, lower noise and a smaller footprint.

Atlas Copco Compressors LLC is part of the Compressor Technique Business Area, and its headquarters are located in Rock Hill, S.C. The company manufactures, markets, and services oil-free and oil-injected stationary air compressors, air treatment equipment, and air management systems, including



TECHNOLOGY PICKS

local manufacturing of select products. The Atlas Copco Group, which celebrated its 140th anniversary in 2013, is among the Top 100 sustainable companies in the world and a member of the Dow Jones World Sustainability Index. Atlas Copco has also been recognized by Forbes, Thomson-Reuters and Newsweek, among others, for its commitment to innovation and sustainability. Atlas Copco Compressors has major sales, manufacturing, production, and distribution facilities located in California, Illinois, Massachusetts, North Carolina, South Carolina, and Texas. www.atlascopco.us

ELGI Introduces Airmate Refrigerated Dryers

ELGI Compressors USA, Inc. has introduced their new EGRD Series Airmate refrigerated dryer line with models from 10 to 2500 cfm. Dryer units, up to 1100 cfm, are in stock for immediate deliveries from ELGI'S distribution center in Charlotte, NC. All units are supported by ELGI's UPTIME ASSURANCE warranty program.

The EGRD refrigerated dryer product line is built for reliability using UPTIME components like the unique ALU Module heat exchanger, a single cast body with cross flow technology and an integrated moisture separator to maximize efficiency package robustness. The microprocessor-based controls are on a visual LED display providing online monitoring of dryer operating conditions, including pressure dew point. Other UPTIME components include high quality integrated automatic condensate drains. EGRD600 and above units use zero air-loss drains while EGRD10-500 models use electronic drain valves controlled by the dryer's microprocessor.

A new ELGI Airmate EGRD Series refrigerated dryer for 1100 cfm.

All models use environmentally-friendly refrigerants. EGRD600 and above models use R-407C with hermetically sealed rotary scroll refrigeration compressors while EGRD10 - 500 cfm units use R134a. ELGI Product Manager Grayson Biggins said, "All units feature a robust and reliable hot gas bypass valve cycle controller designed to ensure stable pressure dew points by providing quick responses to changing inlet air temperature conditions."

To learn more about the new ELGI Airmate EGRD Series refrigerated dryers visit www.ELGI.us

New Ingersoll Rand® R-Series Rotary Screw Air Compressor Models

Ingersoll Rand®, a global leader in compression technologies and services, has introduced new models to its revolutionary line of Next Generation R-Series compressors, which incorporate the latest advancements in variable speed drive (VSD) technology to increase air flow output by up to 15 percent, reduce energy costs by up to 35 percent and increase system reliability. With the launch of the RS30n and RS37n VSD models, Ingersoll Rand engineers designed a streamlined system that maximizes the latest advancements in rotor dynamics coupled with Totally Enclosed, Fan-Cooled (TEFC) high-performance motors.

"Faced with high energy costs and an increasing focus on sustainability goals, plant managers and facility owners are under extraordinary pressure to reduce costs while improving productivity and energy efficiency," says Eric Seidel, vice president of product management for compression technologies and services at Ingersoll Rand. "Our Next-Generation R-Series line reduces customers' energy footprint. In these models, we've combined our state-of-the-art airend with a VSD to provide exemplary compressor efficiency and durability to keep plants running optimally."

At the heart of every Next Generation R-Series compressor is the airend Ingersoll Rand engineers designed to significantly improve overall system efficiency by ensuring low pressure drops. It delivers specific energy output and premier airflow capacity for each compressor application.

The compressors are designed to withstand harsh plant conditions and can run continuously in ambient temperatures of up to 115 degrees Fahrenheit. The starter panel meets NEMA 12/IP55 protection ratings to provide protection against circulating dust, falling dirt and dripping or splashing liquids.

In addition to matching output based on the demand, the RS30n and RS37n compressors also decrease energy use during start-up,

RESOURCES FOR ENERGY ENGINEERS

TECHNOLOGY PICKS

which can draw up to 800 percent of the full load current. RS30n and RS37n limit the in-rush current during start-up, minimizing peak power charges and lowering energy usage.

The new compressor models also come equipped with updated standard features to enhance reliability and durability. The following design enhancements translate to thousands of dollars in savings over the competition within the first five years of operation:

- braided PTFE hoses that increase the lifetime of the compressor and mitigate downtime;
- an integrated dryer that is ISO 1.5.1 classified, which provides higher air purity and reduces the likelihood of damage to tools powered by the compressor;
- a NEMA 12 rated enclosure and standard pre-filter allow these compressors to operate in harsh application environments;
- enhanced separators and coolers, and standard coolant that lasts twice as long as comparable models, thereby significantly reducing maintenance costs; and

The new RS30n and RS37n models include new VSD technology and TEFC motors.

- less energy required to operate, reducing energy costs over fixed speed.

"The Next Generation R-Series compressors with VSD provide customers with greater value than other products in the category,"

Contact Rod Smith for ad rates: **rod@airbestpractices.com, Tel: 412-980-9901**

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TECHNOLOGY PICKS

Seidel adds. "Ingersoll Rand is continuing to improve and expand this product line to meet the ever-increasing performance needs of customers and the sustainability goals they face."

All Next Generation R-Series air compressors are equipped with Xe-series controllers, which allow easy access to and control of the compressed air system. The Xe70 controller has customizable units of measure and built-in sequencing for up to four compressors and communicates directly to the inverter drive to determine the appropriate running speed of the airend. Backed by extensive leading global service offerings, Ingersoll Rand is dedicated to proactively maintaining customers' equipment, allowing them to do what they do best – focus on their production.

For more information on the Ingersoll Rand Next Generation R-Series VSD air compressors, visit www.IngersollRandProducts.com/NextGenRSeries or contact your local service representative.

[1]Savings vary by application, use and energy costs at point-of-use, see your local service representative for more details.

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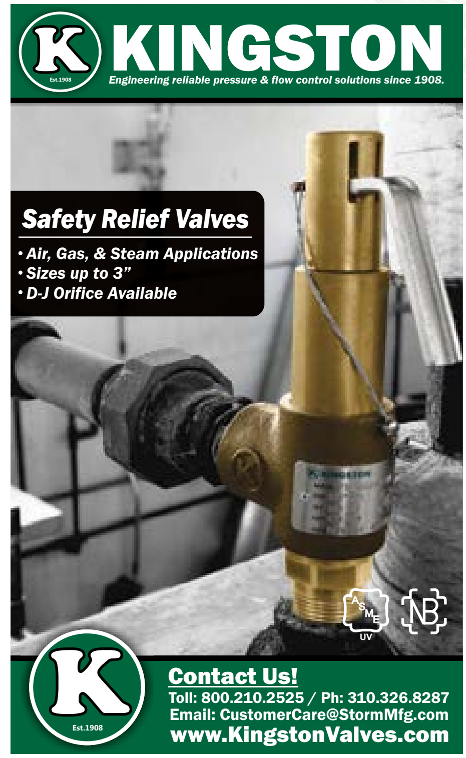
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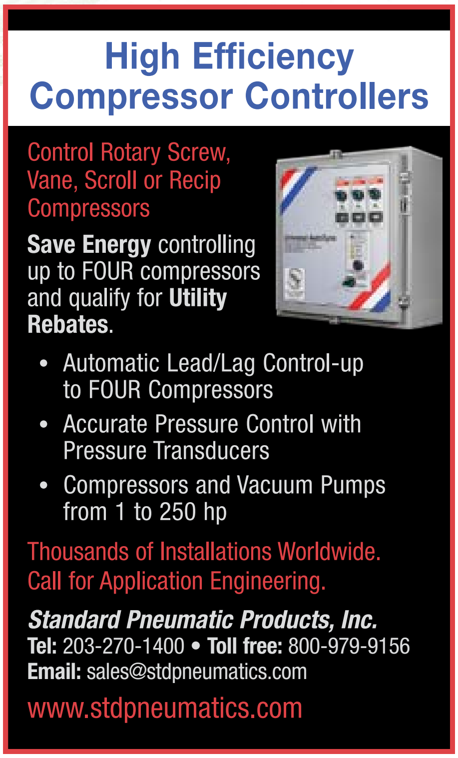

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PROBLEM:

At a plant manufacturing turbines for hydro-electric power plants, excess capacity had been a source of comfort for many years despite recommendations for system updates. Four modulating, twenty-year old compressors, two 75 hp, two 25 hp, supplied the system—without central controls—causing excessively high energy costs. When a new plant engineer came on board, he took a closer look at the energy efficiency. Having attended a Kaeser Compressed Air Seminar, he knew a systems approach could unlock significant savings.

SOLUTION:

Kaeser ran a KESS (Kaeser Energy Saving Simulation) using supply side audit data and designed a complete system solution that would dramatically reduce the specific power from 62.0 kW/100 cfm to 17.5 kW/100 cfm. New energy efficient compressors, an air receiver, as well as a system master controller were installed. The new system has the same number of compressors and total horsepower as before, but it provides even more flow.

RESULT:

The Sigma Air Manager (SAM) master controller monitors the four new compressors and selects the most efficient combination of units to meet the plant demand. With its built-in SAC *Plus* software, SAM continually tracks energy consumption so the plant benefits from having an ongoing compressed air energy audit. As a matter of fact, the specific power has been reduced more than anticipated—all the way down to 16.7 kW/100 cfm.

Annual Energy Costs of Previous System:	$59,780 per year
Reduction in Specific Power:	45.3 kW/100 cfm
Annual Energy Cost Savings:	$22,680 per year
Additional Savings in Maintenance Costs:	$7,240 per year
TOTAL ANNUAL SAVINGS:	**$29,920**
Simple Payback Period:	**14 months**

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