# CHEMICAL ENGINEERING

June 2017

ESSENTIALS FOR THE CPI PROFESSIONAL

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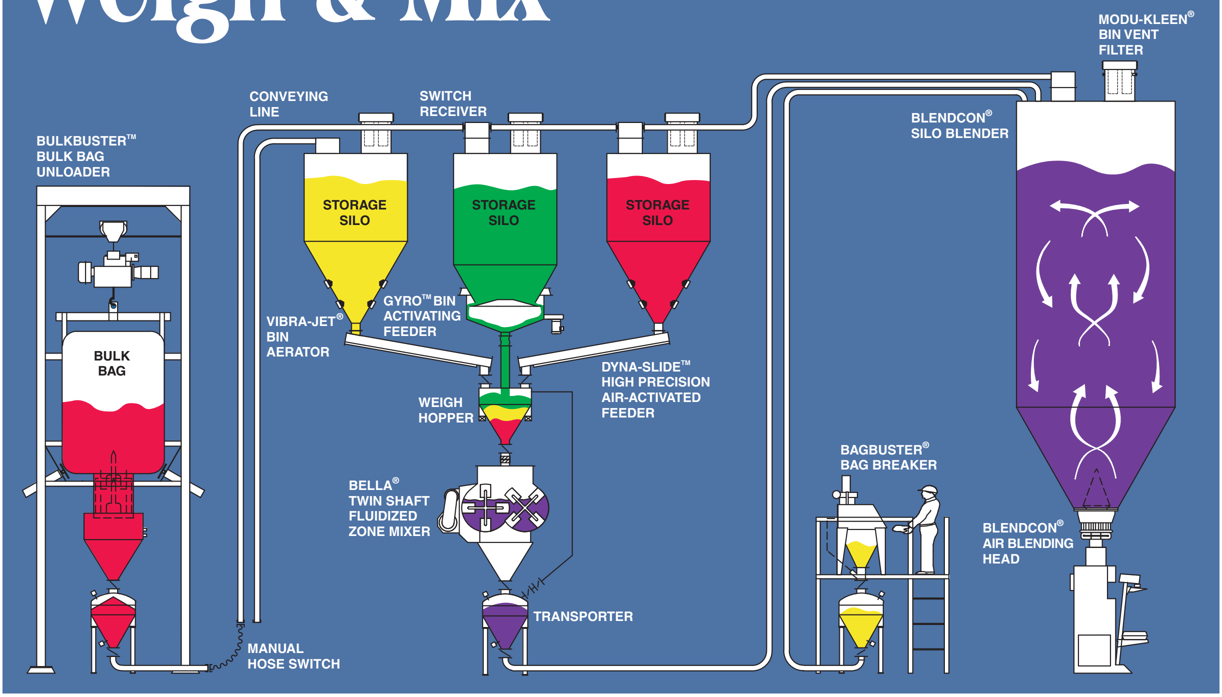


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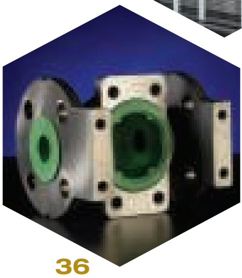

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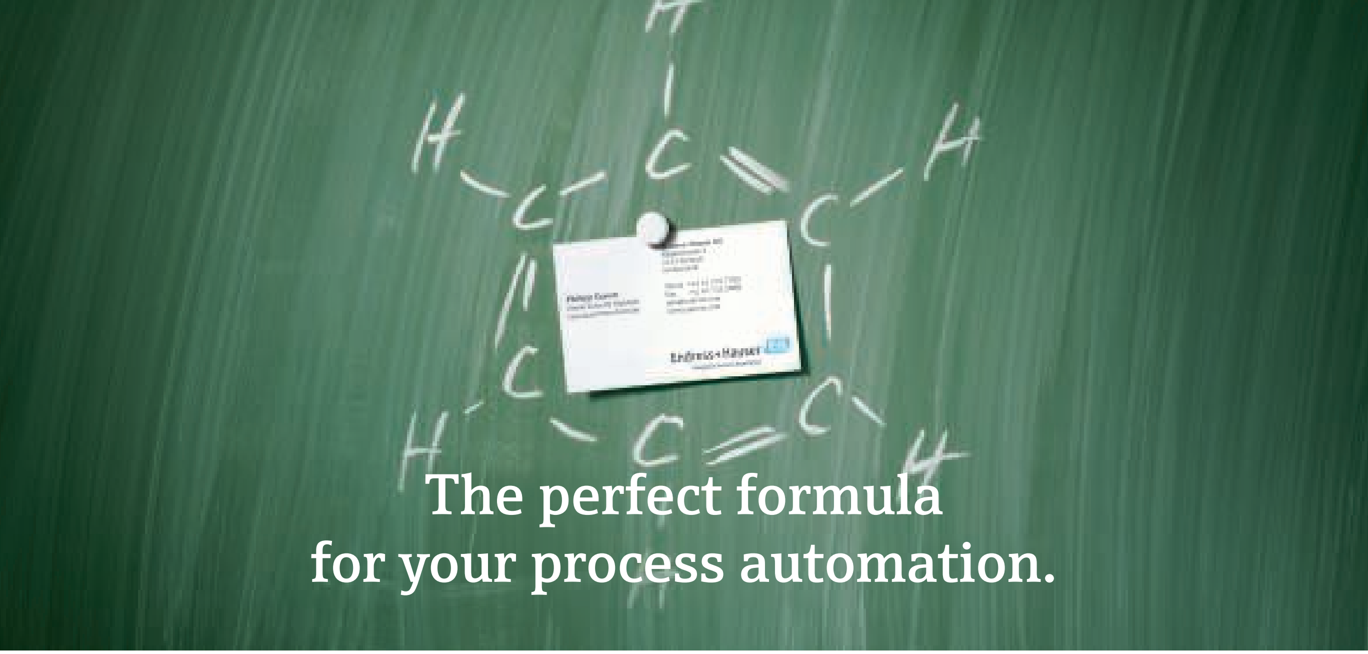


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# Editor's Page

## Achieving commercialization

Much hard work goes into developing new processes and products, and few of these developments make it to commercialization. Those innovative technologies that have been commercialized are honored by *Chemical Engineering* through the Kirkpatrick Chemical Engineering Achievement Award, which is bestowed every other year. This year, six finalists were selected from the many nominations that we received. While we at *Chemical Engineering* organize the award, the finalists are not chosen by our staff, but by heads of chemical engineering department at accredited universities. The finalists will have the opportunity to present their technologies at the Chem Show in New York City on November 1. The winner will be announced that evening. Here is a brief summary of the six technologies that made it to the finals:

***CB&I/Albemarle — Solid catalyst alkylation process.*** The AlkyClean technology eliminates the use of liquid acids for the production of motor fuel alkylate, and thus eliminates the hazards and operating issues associated with handling liquid acids. The world's first solid catalyst alkylation process was commercialized with this new catalyst and process.

***Chemetry — eShuttle technology.*** This technology eliminates chlorine generation from the traditional chlor-alkali process used to synthesize chlorinated organic compounds. In addition to eliminating the safety concerns and costs associated with chlorine handling, the technology requires less energy to operate.

***Dow Coating Materials — Canvera, Polyolefin Dispersion Technology.*** Metal food and beverage containers require an interior coating to protect the contents and the container itself. With this innovative technology, a polyethylene film can be applied to the metal, using an aqueous dispersion of polyethylene. These coatings address concerns about leaching of other materials that have been used in the past.

***Dow Coating Materials — Paraloid Edge Technology.*** Paraloid Edge technology produces urethane coatings without isocyanate or formaldehyde. The polyurethane coating is formed by a reaction between a polycarbamate and a di-aldehyde. In addition to being safer, the product is said to be superior to conventional urethanes in performance.

***Microvi — Denitrovi Biocatalytic Nitrate Removal.*** Denitrovi addresses the challenge of removing nitrates from drinking water. With this technology, organisms housed in biocatalysts degrade nitrate and convert it into nitrogen gas. One of the key achievements in this process is that no sludge is formed. The technology is also said to be more cost efficient than other technologies, such as ion-exchange.

***Praxair — Oxygen-fired combustion with thermochemical regenerators.*** The Optimelt thermochemical regenerator process is said to be the first commercial oxy-fuel glass melting process that utilizes endothermic chemical reactions for waste heat recovery. Savings of 15–18% in fuel and oxygen along with low NOx emissions have been demonstrated. ■

*Dorothy Lozowski, Editorial Director*

# Letters

## Atmospheric storage tanks

This refers to the [Engineering Practice] article "Designing Atmospheric Storage Tanks" [March 2017, pp. 77–82]. It is interesting and informative. Please convey my congratulations to the author. Some of the suggested methods may lead to expensive designs and are not needed, based on my experience in the industry.

The statement "tank heights do not exceed 1.5 times the tank diameter" may be true only for sites where land is not at premium… The API codes do not prohibit tank height versus diameter ratio.

Large diameter, low height (squatter) tanks end up with much higher dead volume as compared to tall (slim) tanks… With economics tightening, refiners seek the least dead inventory, as large dead inventories in storage tanks do not generate revenue. [Also], in the case of blanketed tanks, the inert gas inventory and consumption increases due to [a] large gas-space at [the] top for large diameter tanks.....

A tall tank may require heavy foundation. However, the cost evens out due to smaller footprint. Similarly, tank weights even out. ....

**Gopal Murti, P.E., senior consultant**
The Augustus Group, Montgomery, Texas

## Author's response

It feels great that the author [of the above letter] has taken time to go through my article and share his comments.

The exact statement as given in the article (p. 80) is "In general, tank heights do not exceed 1.5 times the tank diameter." The prefix "In general" ....sufficiently points out that no specific scenario is being spoken about. Also, no prohibitions about *L/D* [height-to-diameter ratio] nor any reference to API is suggested in this regard….

It is indeed correct that dead inventories below floating roof (known as tank heel) do not generate revenue. However, this [was] a specific example where allowances for jet mixer and floating roof add to the requirement. Lowering the minimum operating level of the floating roof increases the tank net-working capacity and reduces associated vapor emissions. The goal is to reduce the roof landing position for reduced heel operations.

[In a project involving a tank farm of a refinery in the Middle East], there was a heel pump (rotary pump) to drain out the tank with its suction pipe dipped in the tank sump to empty it out as much as possible… This heel pump transferred its contents to a re-run tank.

The reference to tank foundations is restricted only to a single sentence. ... Also it is clearly stated (p. 79) that "To obtain an economical unit, it is the tank manufacturer who will choose the number of courses and plate widths to obtain the height required for a given diameter. Hence a process or mechanical design engineer does not necessarily specify the number of shell plate courses."

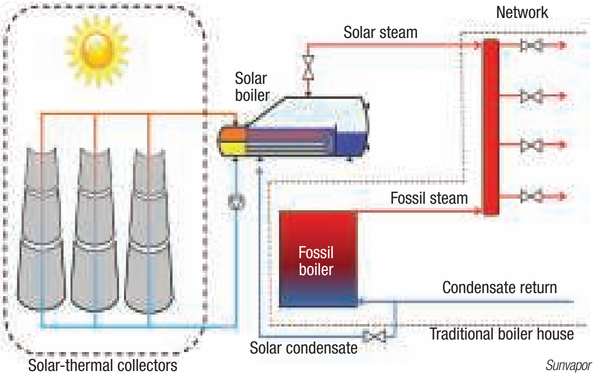
It is considered that the revision status of the datasheet is preliminary (on p. 80) and will be updated as engineering progresses....

**Prasanna Kenkre**
Jacobs Engineering

*Editor's note: The two letters above are exerpts. The full letters can be found online at www.chemengonline.com*

**Circle 27 on p. 78 or go to adlinks.chemengonline.com/66429-27**

## Low-cost solar collectors provide renewable process heat




The first pre-commercial demonstration has started for a system that can provide steam for industrial process heat using solar energy at prices lower than using natural gas. The technology uses solar thermal collectors to generate hot water, air or steam in the range of 100–300°C for a host of unit operations, including steam pasteurization, drying, cleaning, roasting and others. The low-cost solar thermal heat reduces emissions of greenhouse gases and oxides of nitrogen (NOx).

The company Sunvapor Inc. (Livermore, Calif.; www.sunvapor.net) has developed a new method for assembling and installing solar thermal collectors that cuts costs by half compared to existing solar thermal systems. "We have completely re-thought the most critical element of the solar thermal plant — the collectors," explains Philip Gleckman, president of Sunvapor. "Leveraging existing building construction techniques, Sunvapor uses forest products to support the optical elements of the parabolic trough, rather than the traditional steel," he says. In this way, the manufacturing and assembly of the collector avoids the need for precision fabricated parts and expensive labor for their assembly.

However, to use lumber rather than steel, the company had to overcome the difficult engineering challenge of achieving high levels of precision and durability for the collectors, which are composed of components that have significant variability in mechanical and geometric properties. Sunvapor has developed a proprietary alignment process that can compensate for these variations to achieve a true parabola and maintain its form even in the presence of high winds. The company uses highly accurate metrology to align a template fixture, onto which each collector module is assembled. The location of each mirror panel making up the parabola is located to sub-millimeter accuracy using the same type of three-dimensional laser technology found in modern aerospace manufacturing.

Sunvapor has partnered with California pistachio producer Horizon Nut on the initial demonstration of the system, which was funded with a cooperative award from the U.S. Dept. of Energy's SunShot program. The pre-commercial demonstration will include a single 50-kW solar collector module the size of two buses side-by-side. Using a heat-purchase model that does not require companies to outlay capital upfront, Sunvapor seeks to move beyond the food production industry into chemical and petroleum manufacturing, where the process heat could be used in distillation and other unit operations involving steam.

Edited by:
**Gerald Ondrey**

### EFFICIENT DISTILLATION

Last month, Toyo Engineering Corp. (Toyo; Chiba, www.toyo-eng.co.jp) and Koch-Glitsch, LP (Wichita, Kan.; www.koch-glitsch.com) announced a new partnership to distribute Toyo's energy-saving distillation system, SuperHIDiC, to new global markets in Europe and the Middle East.

SuperHIDiC provides energy savings of over 50% compared to conventional distillation systems in various industrial applications, says Toyo. With its enhanced heat-integrated distillation column, SuperHIDiC has been recognized as the ultimate energy-saving distillation system (for more details, see *Chem. Eng.*, January 2012, p. 10). The first commercial application of SuperHIDiC — for the production of methyl ethyl ketone (MEK) at Maruzen Petrochemical Co. — started up recently in Japan (*Chem. Eng.* April 2017, p. 9).

### NEW ADSORBENTS

Last month, Clariant's Business Unit Catalysts (Munich, Germany; www.clariant.com) introduced two new additions to its ActiSorb GP Series of adsorbent products. ActiSorb GP 108, for

(Continues on p. 10)

## A hyperstable zeolite catalyst for methanol-to-olefin conversion

The New Energy and Industrial Technology Development Organization (NEDO, Kawasaki City; Japan; www.nedo.go.jp), in partnership with Japan Technological Research Assn. of Artificial Photosynthetic Chemical Process (ARPChem) members, Mitsubishi Chemical Corp. and the Tokyo Institute of Technology, has developed a hyperstable zeolite catalyst that provides high-yield productivity for lower olefins (C2–C4) from methanol. Using methanol synthesized from $CO_2$, the researchers demonstrated the methanol-to-olefin (MTO) process using a compact, fixed-bed pilot facility installed at Mitsubishi Chemical. With the new MTO process, the researchers were also able to prevent a reduction in catalytic activity, even after steam processing at temperatures higher than 500°C.

In the new zeolite catalyst, acid sites attributable to tetra-coordinated aluminum within the zeolite framework are catalytically active for the MTO reaction. It was confirmed that these active sites are stable and maintain catalytic activity, even after high-temperature steam treatment. The new catalyst was shown to have a lifetime of 1,500 h at 500°C, which is nearly twice that of existing MTO catalyst systems, and it can endure de-coking treatment, NEDO says.

Researchers from the Tokyo Institute of Technology confirmed that the catalyst life can be prolonged by introducing aluminum atoms into specific sites, and that metal doping enhances the selectivity of the MTO reaction. They observed a 83% yield for C2–C4 olefins at a reaction temperature of 550°C.

the removal of sulfur from gas streams, is said to offer high capacity that lowers operating costs and extends cycle lengths. The product is suitable for the purification of dry and wet gas streams that contain hydrogen sulfide, traces of mercaptans and carbonyl sulfide. ActiSorb GP 418 is an adsorbent for the removal of all forms of mercury from dry gas streams, and is said to offer 2–3 times better performance than conventional, commercially-available mercury adsorbents.

### 'UP-CYCLING'

Last month, SGL Group (Wiesbaden, Germany; www.sglgroup.com) became an official up-cycling partner of Dyneon GmbH (Burgkirchen, Germany), a subsidiary of 3M Deutschland GmbH (www.3m.com), and was awarded the up-cycling signet 2017.

Dyneon, in collaboration with the University of Bayreuth and the InVerTec research institute, has developed an innovative process for the up-cycling of perfluorinated polymer residues as part of a project funded by the German Federal Foundation for the Environment (*Chem. Eng.*, May 2015, p. 16). This new waste treatment technology enables environmentally friendly and sustainable recovery of raw materials, which are then used for the production of new materials. The award means that fluoropolymers from SGL Group are now approved for use in this recycling plant.

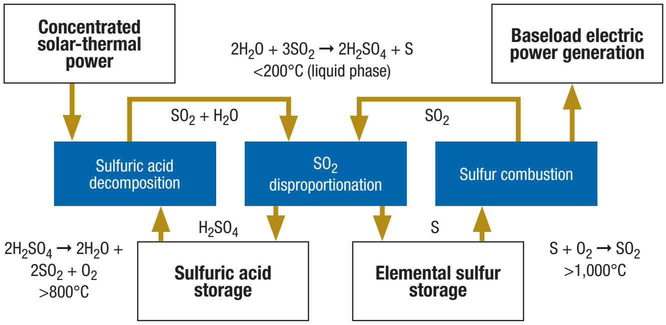
The industry's first high-temperature up-cycling facility is located in the Gendorf Industrial Park in Burgkirchen, and is based on a multi-phase pyrolysis process. Via pyrolysis, the perfluorinated "end-of-life" waste material is split back into monomers with a very high recovery rate of more than 90%. Monomers are fed into the existing distillation plant and can be reused in normal production.

### FOUR-IN-ONE CATALYST

Chemists at Brown University (Providence, R.I.; www.brown.edu) have developed a new composite catalyst that

(Continues on p. 12)

## Using sulfur to store solar energy



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An international group of researchers, coordinated by the Institute of Solar Research of the German Aerospace Center e.V. (DLR; Cologne, Germany; www.dlr.de), is developing a sulfur-based storage system for solar power. Large-scale chemical storage of solar power and its overnight use as a fuel are to be achieved by means of a closed sulfur-sulfuric acid cycle. The four-year, €4.7-million Pegasus project is being funded under the E.U.'s Horizon 2020 Framework Program. The partners are DLR, the Karlsruhe Institute of Technology (KIT; Germany) the Center for Research and Technology CERTH (Greece), Brightsource Industries Israel Ltd., Processi Innovativi S.r.l. (Italy) and Baltic Ceramics S.A. (Poland).

In the process under development (diagram), elemental sulfur is burned as fuel for a power plant, producing electricity and $SO_2$ gas. The $SO_2$ is mixed with water and converted to fresh sulfur and dilute sulfuric acid in a disproportionation reactor. Both products (S and $H_2SO_4$) can be easily stored using conventional technology. To complete the cycle, the $H_2SO_4$ is concentrated and decomposed using heat produced by a concentrated solar-thermal tower. The technology will be tested under real conditions at the Jülich Solar Power Tower Facility (STJ) in Germany.

The partners will demonstrate the feasibility of the overall process. A detailed flowsheet will be drafted and the optimized integrated process scaled to the 5-MW thermal-power level shall be analyzed. Prototypes of the key components, such as the solar absorber, sulfuric acid evaporator, sulfur trioxide decomposer, and sulfur burner will be developed and tested. In addition, the materials required for heat absorption, transfer and storage and for the catalysts of the chemical reactions will be tested for efficiency and long-term stability.

## Harvesting agricultural fertilizers from wastewater sludge

Recovery of the essential plant nutrient phosphorus from wastewater can be an effective way to reduce runoff into waterways while avoiding the need to obtain the element from mined minerals. While phosphorus recovery from wastewater effluent performs well, it is much more difficult to harvest phosphorus efficiently from sewage sludge. A new process can harvest 1.5-times the amount of phosphorus from sewage sludge than possible with conventional technologies, while producing a valuable P-containing mineral, known as brushite, for agricultural fertilizer.

In May 2017, Nutrient Recovery and Upcycling LLC (NRU; Madison, Wis.; www.nrutech.com) started up an optimized version of its pilot plant in a new partnership with CNP/Centirsys, a municipal wastewater treatment company. In the patented process, sewage sludge first enters a short-retention anaerobic acidogenic digester, where bacteria break down the biopolymers into organic acids and release phosphorus into solution. The low-phosphorus solids are centrifuged and separated.

"For the process to work, we need to separate the acidogenic portion of the process from methanogenesis portion, in which methanogens convert organic acids to methane and $CO_2$," says Menachem Tabanpour, NRU president.

The separation of the processes allows NRU to manipulate the pH of the P-containing solution by adding calcium hydroxide to raise the pH and precipitate the brushite ($CaHPO_4 \cdot 2H_2O$) from solution. In addition to obtaining the solid fertilizer product, the process also benefits downstream processing by preventing buildup of P-containing struvite species on pipes.

The pilot, located at a municipal water treatment plant, processes 10 gal/min, and the company envisions eventually scaling up the process to work with plants larger than 10 million gal/d wastewater, as well as farms.

NRU is also set to pilot a membrane-based, nitrogen-recovery process that works by using electric fields to separate ammonium compounds.


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can perform four separate, sequential reactions in a single reactor to produce pharmaceutical precursors. The new catalyst — described in a recent issue of *JACS* — is made by growing silver-palladium nanoparticles on the surface of nanorods made of oxygen-deficient tungsten-oxide. The researchers showed that it could catalyze the series of reactions needed to convert formic acid, nitrobenzene and an aldehyde into a benzoxazole, which can be used to make antibacterials, antifungals and NSAID painkillers. The catalyst could also be used to make quinazoline, which is used in a variety of anti-cancer drugs.

Experiments showed that the catalyst could perform the four reactions with a nearly quantitative yield, a lower temperature, in a shorter amount of time and using solvents that are more environmentally friendly than those normally used for these reactions, says Brown. The new catalyst could be used up to five times with little drop-off in reaction yield.

### BIOBUTADIENE

A team of researchers from the Universities of Delaware (www.udel.edu), Minnesota (www.twin-cities.umn.edu) and Massachusetts (www.umass.edu) has found a new route for making butadiene from sugars derived from biomass, such as wood, grass or corn. The authors of the study — described in a recent issue of *Sustainable Chemistry and Engineering* — are all affiliated with the Catalysis Center for Energy Innovation (CCEI) based at the University of Delaware. CCEI is an Energy Frontier Research Center funded by the U.S. Dept. of Energy (Washington, D.C.; www.energy.gov).

Using technology developed within CCEI, the team first converted sugars to a ring compound called furfural, which is then transformed into tetrahydrofuran (THF). In the third step, THF is directly converted into butadiene with better than 95% yield, via a "dehydra-decyclization" reaction using a new catalyst called "phosphorus all-silica zeolite," developed within the center.

"Our team combined a catalyst we recently discovered with new and exciting chemistry to find the first high-yield, low-cost method of manufacturing butadiene," says CCEI director Dionisios Vlachos, the Allan and Myra Ferguson Professor of Chemical and Biomolecular Engineering at the University of Delaware.

Butadiene is used for making rubbers (styrene-butadiene rubber, nitrile butadiene rubber) and plastics (acrylonitrile-butadiene-styrene).

(Continues on p. 14)

## Plasma oxidation for making carbon fibers

Carbon fibers, an increasingly essential component for lightweight materials, are typically made from polyacrylonitrile (PAN) in a three-step process consisting of oxidation/stabilization, carbonization and surface treatment/sizing. 4M Industrial Oxidation, LLC (Knoxville, Tenn.; www.4mio.com) intends to commercialize a technology to produce carbon fibers that accelerates the oxidation step and uses significantly less energy than traditional techniques by replacing massive convection ovens with smaller plasma-oxidation ovens.

"Our proprietary plasma technology is the cornerstone of the process," explains Truman Bonds, chief technology officer of 4M. "Plasma oxidation only requires air and electricity, the same as conventional oxidation. Our plasma technology creates special chemistry from air that oxidizes the fiber three times faster on average than conventional oxidation," says Bonds. 4M anticipates that the faster processing speed will allow for three times as much material to be produced in the same plant footprint as traditional oxidation. This is the rate-limiting factor in the carbon-fiber manufacturing process. The plasma electrodes also generate heat more efficiently than traditional heaters and contribute to better heat distribution and cooling inside the oven, so significantly less airflow is required. Additionally, 4M is currently working to optimize its plasma oxidation process for textile-grade PAN. The goal is to produce an industrial-grade carbon fiber from this low-cost material, which would further lower manufacturing costs to levels of interest to the automotive industry.

4M, along with oven manufacturer C.A. Litzler Co. (Cleveland, Ohio; www.calitzler.com), is building the world's first commercial-scale plasma-oxidation oven, and is in discussions with several carbon fiber manufacturers about building additional production lines over the next several years. "We are designing and building a 175-ton oven now, which is a typical pilot line scale for the industry," says Bonds. This design will be the basis for larger-scale units — typical carbon-fiber production scale is 1,500 tons, but 4M believes this technology can eventually enable production lines of 4,000 tons and larger.

## Scaleup for cellulose nanofiber production

Nippon Paper Industries Co. (NPI; Tokyo, Japan; www.nipponpapergroup.com) has installed the world's largest facility of its kind for the commercial production of cellulose nanofiber (CNF). Located at its Ishinomaki Works in Miyagi Prefecture, the $16-million investment has a production capacity of 500 ton/yr — significantly higher than the company's 30-ton/yr demonstration facility at the Iwakuni Mill that started up in October 2013.

At Ishinomaki, NPI is producing homogeneous and "perfectly" dispersed CNF from wood pulp, using a technique developed in 2011 by the research group of professor Akira Isogai at the University of Tokyo. The process involves the TEMPO (2,2,6,6-tetramethylpiperidine-1-oxyl radical)-mediated oxidation of pulp, followed by mild disintegration in water. The TEMPO-oxidized CNF made from wood fiber is finely defibrated to the nano-scale and completely nano-dispersed, to give uniform fiber widths (3–4 nm) and high crystallinity. The crystalline CNF is transparent, and can easily be chemically modified into functional materials.

For example, in 2015, NPI succeeded in producing CNF sheets with a large amount of metal ions on the surface, which render antimicrobial and deodorizing effects. NPI's subsidiary, Nippon Paper Crecia Co., became the first company to commercialize health-care products (for instance, adult diapers) utilizing such functionalized CNF.

NPI has since been developing a wide range of other applications for CNF, such as functionalized sheets with a thermal dimensional stability equal to that of glass fibers and high gas-barrier properties that do not allow oxygen to penetrate. Nanocomposite materials made of CNF, resin and rubber have also been developed for applications requiring low weight and added strength.

This work is being supported by New Energy and Industrial Technology Development Organization (NEDO) under the authority of Japan's Ministry of Economy, Trade and Industry (METI; Tokyo; www.meti.go.jp).

## Silk-based batteries for medical implants

Researchers from the University of Wollongong (Australia; www.uow.edu.au), led by professor Gordon Wallace and Caiyun Wang, built a battery with electrodes and a solid electrolyte out of silk.

Previous attempts at making such biodegradable, dissolvable batteries used natural, biocompatible materials for the electrodes and electrolytes. The electrolytes were usually solutions of various salts in water. However, liquid electrolytes can leak out and degrade battery electrodes, and they make batteries relatively bulky.

The solid electrolyte enables thinner, flatter and more flexible and robust batteries. Among other applications, the silk battery is ideal for temporary medical implants because it can be made into thin films, is biocompatible and is designed to harmlessly dissolve in the body in a few weeks, once its work has been done.

Thin films are made by dissolving fibroin (a fibrous silk protein derived from silkworm cocoons) in water. The solution is then spread in a mold. After the water evaporates, ultrathin films of silk can be peeled off. The electrolyte is made by infusing a piece of silk membrane with an ionic liquid (choline nitrate). The anode is made by depositing a biocompatible magnesium alloy onto a piece of the silk film, and the cathode is made by depositing gold onto another piece of silk film. The electrolyte is then sandwiched between the two electrode films, and the assembly fused together at the uncoated edges with a sticky, amorphous silk film. The postage-stamp-sized, 170-μm-thick device generates 0.87 V with a power density of 8.7 $\mu W/cm^2$, which is enough to power an implantable medical sensor.

The device decomposed almost completely after 45 days in a saline buffer solution, leaving behind inert gold nanoparticles, which would be cleared by the body.

## Enhanced perovskites

Researchers from the Ulsan National Institute of Science and Technology (Ulsan; www.unist.ac.kr) have found a new way to increase the energy efficiency of metal-air batteries — which are next-generation energy devices — by adding the conducting polymer polypyrrole (pPy). According to the researchers, when either a perovskite or pPy are used alone, their catalytic activity cannot match that of platinum, but when used together, however, their catalytic effect matched that of platinum.

Nitrogen-containing electrocatalysts, such as metal-nitrogen-carbon composites and nitrogen-doped carbons, are known to exhibit high activity for an oxygen-reduction reaction. However, a strong electronic interaction between nitrogen and active sites has been found in these composites. The researchers demonstrated a case in which nitrogen improves the electroactivity, but in the absence of a strong interaction with other components.

The researchers thus found a way of increasing the catalytic activity of perovskite oxide catalysts for the oxygen-reduction reaction (ORR) or oxygen-evolution reaction (OER) in rechargeable metal-air batteries and fuel cells.

## ANIMAL FEED

Last month, The Perstorp Group (Malmö, Sweden; www.perstorp.com) introduced ProPhorce Valerins — a new organic acid for animal feed. ProPhorce Valerins are glycerol esters of valeric acid, and have been shown to reduce the negative impact of *Clostridium perfringens*, says the company.

Since 2010, Perstorp has been working on ways to reduce the usage of antibiotics in animal husbandry, focusing on how short-chain fatty acids (SCFAs) drive gut health and performance. Research has been conducted by specialists in Perstorp's innovation laboratories together with the Universities of Ghent and Lund and the Southern Poultry Research Group (Athens, Ga.). The research conducted included an extensive screening of all the SCFAs available. ProPhorce Valerins showed remarkable results, especially in broiler chicken diets in the presence of a *Clostridium perfringens* challenge.

The commercial introduction of ProPhorce Valerins will commence immediately in selected markets. Perstorp says this is the first new organic acid to be introduced into animal feed in decades, and that it is now producing both the product ProPhorce Valerins, and its main precursors, valeric acid and glycerol. ❑

# Nanorod arrays as photocatalysts

Many $ZnO@TiO_2$ core-shell nanorod arrays (the notation means ZnO is the core inside the $TiO_2$ shell) with good photocatalytic activity have been designed and synthesized. There has been an increasing interest in the design and synthesis of those arrays to improve the quantum efficiency of dye-sensitized solar cells, to produce highly transparent self-cleaning coatings for LEDs, and to use as photocatalysts for the decomposition of organic pollutants in wastewater.

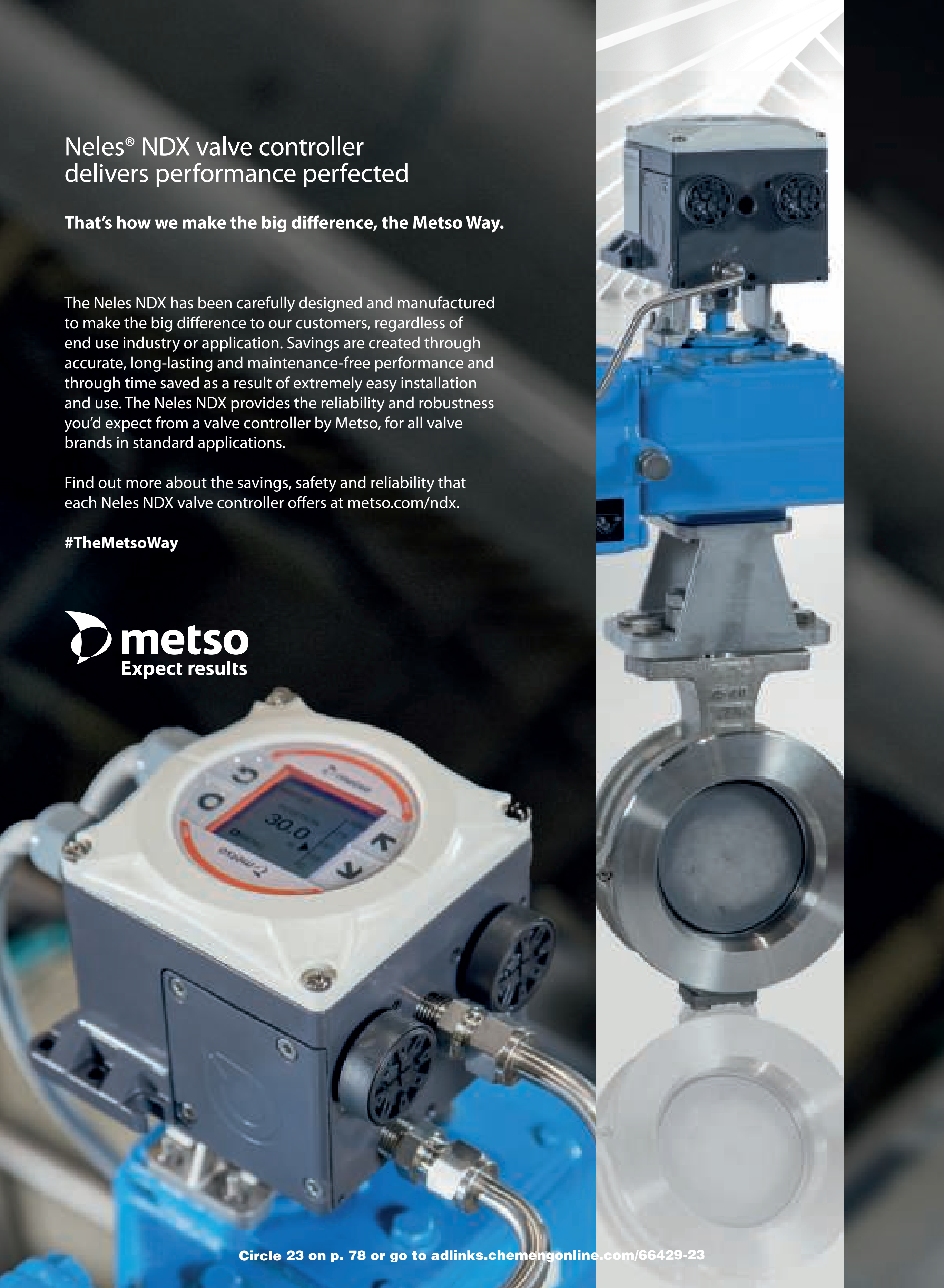
However, it is still necessary to develop a low-temperature, low-cost and environmentally friendly way to prepare those arrays over a large area for future device applications.

Now a team from Huaibei Normal University (Huaibei, China; www.hbcnc.edu.cn), has reported a facile, green and efficient route for the preparation of $ZnO@TiO_2$ nanorod arrays with a highly uniform core-shell structure over a large area on a Zn wafer. The team uses a vapor-thermal method at relatively low temperature.

The team said the photocatalytic decomposition of methylene blue revealed that the arrays have excellent photocatalytic activity compared with the performance of the ZnO nanorod arrays. According to the team, the superior photocatalytic performance could be attributed to the fact that the large binding energy of ZnO and the high reactivity of $TiO_2$ can significantly increase the process of electron and hole transfer between the corresponding conduction and valence bands. Thus, compared with photoanode materials or single metal-oxide catalysts, a better separation of photogenerated carriers can be obtained in $ZnO@TiO_2$ core-shell structures.

Also, the team says, it is very easy to separate or recover $ZnO@TiO_2$-array catalysts when they are used in water purification processes.

Recycling of a photocatalyst in nanometer scale is important in practical applications, the team says. "Thus, our proposed route to prepare $ZnO@TiO_2$ core-shell structure catalysts represents a very important advance for environmental remediation applications." ■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## Plant Watch

### Dow plans for significant U.S. growth with five-year investment strategy

May 11, 2017 — The Dow Chemical Co. (Midland, Mich.; www.dow.com) announced a five-year investment plan that includes expansion of Dow's new TX-9 ethylene cracker through the addition of two furnaces, bringing the facility's total ethylene capacity to 2 million metric tons per year (m.t./yr). Dow also plans to construct a 600,000-m.t./yr polyethylene unit on the U.S. Gulf Coast and conduct global debottleneck projects to deliver 350,000 m.t. of additional polyethylene.

### Kraton opens new HSBC plant in Taiwan

May 10, 2017 — Kraton Corp. (Houston; www.kraton.com) announced the opening of its new hydrogenated styrenic block copolymer (HSBC) plant in Mailiao, Taiwan. The plant has capacity to produce 30,000 m.t./yr of HSBC. The new plant is owned and operated by Kraton Formosa Polymers Co., a joint venture (JV) between Kraton and Formosa Petrochemical Corp. (Mailiao; www.fpcc.com)

### Showa Denko to increase production of high-purity aluminum

May 10, 2017 — Showa Denko K.K. (SDK; Tokyo, Japan; www.sdk.co.jp) will increase its capacity in China to produce high-purity aluminum foil, which is a major material for aluminum electrolytic capacitors. SDK's subsidiary Showa Denko Aluminum (Nantong) Ltd. (SDAN) will extend capacity to produce high-purity aluminum foil from 600 to 800 m.t./month, and start operation of the expanded plant in November 2017.

### Formosa awards contract to CB&I for Ningbo phenol and cumene plant

May 8, 2017 — CB&I (The Woodlands, Tex.; www.cbi.com) was awarded a contract by Formosa for the license and engineering design of a cumene and phenol plant expansion in Ningbo, China. The original plant was licensed in 2010 by CB&I, and will now be re-engineered to achieve higher capacity.

### Ineos Styrolution to boost capacities for ASA and ABS in Mexico and the U.S.

April 28, 2017 — Ineos Styrolution (Frankfurt, Germany; www.ineos-styrolution.com) plans to expand capacity for ABS (acrylonitrile butadiene styrene) and ASA (acrylonitrile styrene acrylate) in the Americas. The plans include constructing a new ASA plant in Bayport, Tex. with a capacity of 100,000 m.t./yr and increasing the ABS capacity at Ineos' plant in Altamira, Mexico. The new ASA plant in Bayport is expected to be operational by the end of 2020.

### Arkema inaugurates molecular sieve production lines in France

April 27, 2017 — Arkema (Colombes, France; www.arkema.com), inaugurated new specialty molecular sieve capacity at its plant in Honfleur, France. Representing an investment of around €60 million, this capacity expansion marks the doubling of capacity for Arkema's specialty molecular sieves dedicated to aromatics separation, in particular xylenes separation.

### Wacker expands its integrated ketene production in Burghausen

April 25, 2017 — Wacker Group (Munich, Germany; www.wacker.com) is expanding the integrated ketene production capacity at its Burghausen, Germany site by building an additional reactor for the manufacture of isopropenyl acetate (IPA). The new unit will produce 2,500 m.t./yr of IPA, an important starting material for acetylacetone. Capital expenditures of almost €2 million are budgeted for the capacity increase.

### Messer to build the largest industrial-gas facility in Vietnam

April 21, 2017 — Messer (Bad Soden/Frankfurt, Germany; www.messergroup.com) will construct two plants in Dung Quat, Vietnam for the supply of industrial gases to Hoa Phat Steel. Both plants are expected to start operation in November 2018. Total production capacity amounts to 80,000 $Nm^3/h$ of oxygen and 160,000 $Nm^3/h$ of nitrogen, making it the largest production facility for industrial gases in Vietnam. Messer is investing over $90 million in the project.

### WorleyParsons wins FEED contract from Biosynthetic Technologies

April 20, 2017 — WorleyParsons Ltd. (North Sydney, Australia; www.worleyparsons.com) won a contract to perform front-end engineering design (FEED) services for a new synthetic base-oil facility that will commercialize Biosynthetic Technologies' process technology to convert natural oils into performance base stocks. The plant will be constructed on the Texas Gulf Coast.

## Mergers & Acquisitions

### ExxonMobil to acquire aromatics plant in Singapore

May 11, 2017 — ExxonMobil Chemical Co. (Houston; www.exxonmobilchemical.com) announced that its Singapore affiliate has reached an agreement with Jurong Aromatics Corp. to acquire its plant located on Jurong Island in Singapore. With a production capacity of 1.4 million m.t./yr, the plant is said to be one of the largest in the world. The company expects to complete the transaction in the second half of 2017.

### Pentair to split into two companies

May 10, 2017 — The Board of Directors of Pentair plc (London; www.pentair.com) has approved a plan to separate into two independent, publicly traded companies focused on the water and electrical sectors, respectively. Pentair expects to complete the separation in the second quarter of 2018. The water-focused business will retain the Pentair name, and the electrical business will be named at a later date.

### Siemens and Chromalloy form turbine-blade joint venture

May 10, 2017 — Siemens AG (Munich, Germany; www.siemens.com) and Chromalloy Gas Turbine LLC (Palm Beach Gardens, Fla.; www.chromalloy.com) have entered a partnership to form a new JV called Advanced Airfoil Components. The primary scope of the company will be turbine blade and vane cast components. Both partners are investing approximately $130 million to create a new production facility in the U.S., which is scheduled for completion in the fall of 2018.

### Huntsman announces separation of Venator Materials subsidiary

May 8, 2017 — Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com) announced that its wholly owned subsidiary Venator Materials has publicly filed a registration statement for a proposed initial public offering. Once separated from Huntsman, Venator will own Huntsman's Titanium Dioxide and Performance Additives businesses. The offering is expected to commence in 2017.

### BP to sell interest in SECCO to Sinopec

April 27, 2017 — BP plc (London; www.bp.com) has agreed to sell its 50% stake in the Shanghai SECCO Petrochemical Co. (SECCO) to Gaoqiao Petrochemical Co., a wholly owned subsidiary of China Petroleum & Chemical Corp. (Sinopec), BP's JV partner, for $1.68 billion. SECCO is currently owned by BP (50%), Sinopec (30%) and Sinopec Shanghai Petrochemical Co. (20%).

### AkzoNobel plans to separate Specialty Chemicals business unit

April 19, 2017 — AkzoNobel N.V. (Amsterdam, the Netherlands; www.akzonobel.com) outlined a new strategy to create two separate companies — Paints and Coatings and Specialty Chemicals. The separation of Specialty Chemicals is to take place within 12 months. AkzoNobel anticipates €50 million in cost savings related to the separation of the Specialty Chemicals business.

### Chevron to sell Canadian downstream assets to Parkland

April 19, 2017 — Parkland Fuel Corp. (Calgary, Alta., Canada; www.parkland.ca) announced that it has entered into an agreement with Chevron Canada Ltd. (CCL) to acquire all of the shares of Chevron Canada R&M ULC, which operates its Canadian integrated downstream fuel business. The acquisition includes a petroleum refinery in Burnaby that produces 55,000 bbl/d. Parkland will pay approximately $1.1 billion for the acquired business. ■

*Mary Page Bailey*

# The Digital Transformation in the CPI

**An overview of how the chemical process industries are looking to the IIoT to help form new business models in a competitive environment**

## IN BRIEF

WHAT IS THE DIGITAL TRANSFORMATION?

INSIGHTS FROM INDUSTRY LEADERS

TECHNOLOGICAL ADVANCES

CONVERGENCE OF IT, OT AND ET

Today, technological advances are being made and implemented at an accelerated pace that is quickly changing the way we live and work. In our day-to-day environments we encounter "smart" objects, including our phones, cars and devices throughout our homes. And, these devices are being connected to each other. This trend is also taking place in industry, and while perhaps not as rapidly as with our personal devices, changes are occurring quickly.

### What is the digital transformation?

More and more, smart sensors and equipment that contain smart diagnostic features are being used in industry to generate large volumes of data. Advanced computing technologies are allowing these devices to be connected to each other, and to use the data in a variety of ways. This growing interconnectedness of industrial operations is what is meant by the now familiar term, the Industrial Internet of Things (IIoT). As Marcelo Carugo, senior director Chemical and Refining Solutions, Emerson Automation Solutions (St. Louis, Mo.; www.emerson.com) states, "IIoT is partly about how we make data accessible and then get the right data to the right person, in the right format, at the right time — to make a decision. It's about transferring digital data into digital intelligence by using the thousands of touch and sensing points in your plant and advanced analytics to help you recognize patterns and make decisions based on patterns instead of individual measurements."

Industry 4.0 is another familiar term, perhaps more so in Europe than elsewhere, because it has its origins in Germany. The term refers to this interconnectedness and related concepts in the digital transformation as a fourth industrial revolution, with the first three including mechanization, mass production and automation. Digitization, digitalization and "smart industry" are additional terms associated with the current movement toward the implementation of IIoT and the newest digital technologies. These terms are used

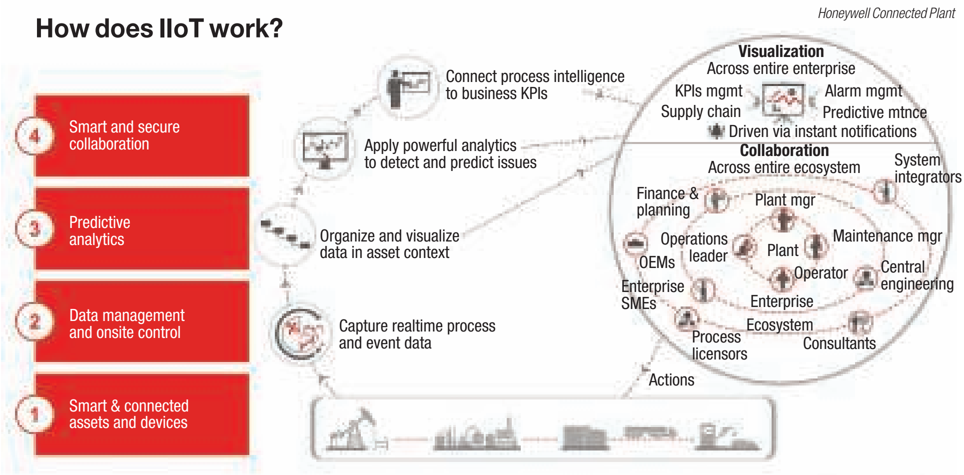


**FIGURE 1.** The Industrial Internet of Things (IIoT) can connect assets across a company to create a powerful interconnected enterprise as depicted in this graphic

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**FIGURE 2.** Rainer Gimbel (left) and Jeff Landau (right) are digital strategists in Evonik's newly formed digitalization subsidiary, Evonik Digital GmbH

interchangeably by some, and defined more rigorously by others, but in general they all refer to the same trend that goes beyond connecting things, and often refers, in a broader sense, to connecting the process to the business as well (Figure 1).

Advances in sensors, data analytics, computing networks (the "cloud"), software, additive manufacturing, unmanned aerial vehicles (UAVs or drones) and more, are enabling this fourth industrial revolution. While the chemical process industries (CPI) may be slower to adopt some of these technologies than the consumer market, the CPI are very familiar with the use of sensors and automation and are well poised to take advantage of the newer technologies. As Billy Bardin, Global Operations Technology Center director for The Dow Chemical Company (Midland, Michigan; www.dow.com) states, "In general, the process industries have been slower to adopt these new technologies than the consumer and service sectors, but the process industries do have an advantage with the installed instrumentation base that has been a mainstay of our technology for decades. We have significant amounts of data from our instrumentation and process sensors to use with the new analytics and deep-learning technologies."

## Insights from industry leaders

A key driver for the digital transformation in the CPI is maintaining a competitive edge. Global competition, immediate communications and technological advances are creating an environment where businesses need to respond with increasing speed. Aligning production and business through the tools available with digitalization offers new possibilities for business models.

John Cate, commercial director for Surface Chemistry at Akzo Nobel N.V. (Amsterdam, the Netherlands; www.akzonobel.com) says, "We've been driving digitalization across our entire business. It's all about efficiency and optimization. The digital world delivers more comprehensible and actionable data than we have ever had before. By replacing gut-feeling with comprehensive, realtime data, we are able to make better decisions. Whether this is about plant utilization, selecting R&D projects to fund, or sales accounts to focus on, we now have data work for us instead of the other way around." He further explains that IIoT can help combine supply and demand intelligence and that it is essential in today's environment, "Forget about getting ahead — just to ensure survival in today's chemical industry, this [IIoT] should be high up on top management's agenda. And the earlier you start understanding the IIoT and implementing digitalization, the more effective you'll be in execution over time."

Dow's Bardin also expects digitalization to affect all aspects of business and production. "We are connecting data streams from R&D, marketing, supply chain and manufacturing to better serve our markets," he says. And he also sees applications in safety and sustainability, "We can use robotics, augmented reality, big data, the digital twins and other aspects of Industry 4.0 to help achieve Dow's 2025 sustainability goals and to continue to improve our safety performance. Safety, as well as cybersecurity, remain paramount as our industry continues to evolve."

Earlier this year, Evonik Industries AG (Essen, Germany; www.evonik.com) confirmed its commitment to the digital transformation by establishing a digitalization subsidiary, Evonik Digital GmbH (Figure 2). The group is building digital expertise and developing digital business models under the guidance of Henrik Hahn, who holds the newly created position of chief digital officer (CDO). Evonik is also the first chemical company to join the Industrial Internet Consortium (IIC; www.iiconsortium.com), which is a global organization formed to promote the growth of the IIoT. Hahn says that it will become more and more common to realize truly personalized customer experiences, and in the future, there may be more competition between business models rather than between products or process technology. "Therefore we believe strategy, not technology, drives digital transformation," he says.

## Technological advances

Technology, however, is an enabler for digital transformation. There is much going on in this area, and new developments are occurring quickly. Several key developing areas are the following:

***Sensors*** have been ubiquitous in the CPI for decades. In recent years, however, advances in smart sensor technology and implementation have helped to make sensors one of the powerful enablers of the IIoT. Automation vendors, such as Siemens AG (Munich, Germany; www.siemens.com), Endress+Hauser (Greenwood, Ind.; www.us.endress.com), Honeywell Process Solutions (HPS; Houston; www.honeywellprocess.com), Emerson and many others offer a wide variety of sensors. Regarding sensors, Jeroen Pul, marketing manager and digital lead for AkzoNobel Surface Chemistry says, "More sensors equals more data. More data equals better decisions. In general, and at AkzoNobel, we're employing more creative use of sensors to measure all aspects that impact our business."

In addition to developing new sensors, research is also going on to optimize placement of sensors — where do you best locate them in a plant? Stephen E. Zitney, at the Research & Innovation Center, U.S. Dept. of Energy, National Energy Technology Laboratory (NETL; www.netl.doe.gov) is studying underlying technologies for optimal sensor network design in a digitalization framework. Four key applications for optimization-based sensor placement technology include: better disturbance rejection in plants; better state estimation (using data from other sensors to estimate process variables that are not directly measurable, perhaps due to harsh operating environments); condition monitoring (the "health" of equipment); and fault diagnosis.

***Augmented and virtual reality*** are familiar to some from the gaming industry. Advances in virtual reality software and more readily available hardware are enabling the use of these techniques in the CPI. Two of the targeted application areas are training and asset management.

One example of a dynamic simulator enhanced by a 3-D virtual plant is one that was developed and deployed at the Advanced Virtual Energy Simulation Training and Research (AVESTAR) Center at West Virginia University (Morgantown; www.wvu.edu) in collaboration with the NETL. The simulator is for an IGCC (integrated gasification combined cycle) system with carbon dioxide capture (Figure 3). NETL's Zitney, who led the project, explains that it provides a very realistic, immersive training system for operators, engineers and students. It is currently being used at the university to educate chemical engineering students in process dynamics, operations and control. Vendors, such as Schneider Electric (Rueil-Malmaison, France; www.schneider-electric.com) and others, offer software for augmented and virtual reality simulations.

Another application where 3-D reality modeling has great potential is in asset management. Bentley Systems, Inc. (Exton, Pa.; www.bentley.com), for example, offers software that can combine photos taken from the ground, from drones and from laser scans to create 3-D reconstructions of facilities. These reality models can be used for planning maintenance, construction, training and more.



**FIGURE 3.** This virtual reality environment for an IGCC plant offers realistic training opportunities

***Process modeling and simulation*** capabilities are increasing as software becomes more advanced and more readily available (see A New Mentality in Process Modeling, pp. 22–25). One of the areas gaining momentum is in moving from steady-state process optimization that is run periodically, to continuous dynamics optimization and control. So called "digital twins" are realtime dynamic models that run alongside a functioning plant. These dynamic models can use data from sensors installed in the plant to match its realtime status and condition, and to carry out offline dynamic studies to help optimize its performance. These digital twins can also be used to train operators. Vendors such as Honeywell Process Solutions and others offer digital twin technology (also see Refineries Explore IIoT Tools to Maximize Profits, *Chem. Eng.* May, pp. 16–20).

## Convergence of IT, OT and ET

To draw the full benefits of the digital transformation, cultural changes are needed in addition to technological ones. A better working relationship between operational technology (OT), information technology (IT) and engineering technology (ET) has been cited as an important step. Greg Gorbach, vice president of the ARC Advisory Group (Dedham, Mass.; www.arcweb.com) says, "Chemical companies are revisiting their own business processes and technology approaches as competitors and partners start to employ 'digitalized' business processes and exploit the increasing convergence between OT and IT on the plant floor, to connect the enterprise as a whole to the extended supply chain and throughout the ecosystem."

One of the areas where this convergence is most needed is in cybersecurity. While cybersecurity on enterprise IT has been well defined with firewalls, routers, anti-virus software and more, the needs on the OT side are less well defined. Eddie Habibi, CEO and founder of PAS Inc. (Houston, www.pas.com) says "Operational technology used to be thought of as 'cyber-immune,' but we've come to know that OT is also vulnerable." Because "we cannot know what the cyber hackers are thinking or will be doing next," Habibi sees cybersecurity as a compelling need for IIoT. On the OT side, he says that there are a tremendous number of assets that are unprotected, and part of the problem is that owners are often not aware of what cyber assets they have. Taking an inventory is a first step that he recommends. And on the cultural side, training employees in cybersecurity — even the most basic steps — is much needed.

The new technologies and advanced computing that are now available with the dawn of the digital transformation offer amazing possibilities. To put it into perspective, Dow's Bardin offers the following insight: "A key in this environment is to determine what makes sense for your business, develop a concise strategy that will achieve the desired objectives, and stick to the principles of that strategy to screen out the hype in order to find the nuggets of technology that can provide true, long-term benefit." ■

*Dorothy Lozowski*

# A New Mentality in Process Modeling

## Predictive process models enable more efficient operations and higher-value products

**IN BRIEF**

MODELING PRODUCT PERFORMANCE

VISUALIZING COMPLEX SCENARIOS

LOOKING TO THE NEXT GENERATION

When they hear the words "process modeling," some may envision an engineer sitting in front of a laptop waiting for a distillation column flowsheet to converge. While flowsheet simulations are still an invaluable step for engineering design, process modeling is becoming an overarching part of operations as a whole, serving various purposes throughout the entire operational chain — from conceptual design to continuous process improvements to end-use product applications.

### Modeling product performance

At Optimize 2017, the users' conference for Aspen Technology, Inc. (Bedford, Mass.; www.aspentech.com), David Kolesar, senior engineering leader from the Dow Chemical Co. (Midland, Mich.; www.dow.com) presented an example where process modeling at the molecular level allowed Dow to fine-tune polymer products to meet the requirements of various application tests while also decreasing batch cycle times. When certain products began failing application tests, and a root-cause analysis indicated no issues with raw-material quality, the team turned to process modeling to evaluate the polymers' intrinsic properties, focusing on the molecular weight. However, it was determined that the batches were indeed achieving the target molecular weight, so another factor had to be the culprit.

Through extensive modeling using Aspen Polymers and Aspen Dynamics, the team determined that the polymers were rearranging and branching, impacting the structure and ultimate application properties of the polymer. These structural changes were deemed to be the source of the failures. The team was able to model the relationship between the polymers' intrinsic properties, structure and application requirements to "reverse engineer" the best polymer structure for the application tests. This modeling capability allowed Dow to "work backwards from customer needs," explained Kolesar, listing adhesive stickiness and noise creation among the important application properties being evaluated for these polymers. Kolesar highlighted model-guided experimentation — completing modeling activities prior to plant trials and pilot work — as a major driver in expediting process advancement and reducing the time to market for new products.

Solenis

**FIGURE 1.** Engineers run water-quality models using a cooling-tower pilot plant to determine the effectiveness of treatment chemicals

With its Bonfire property predictor tool, NOVA Chemicals Corp. (Calgary, Canada; www.novachem.com) brings the ability to model product applications straight to its customers. Bonfire was developed to help NOVA's resin customers evaluate different structures of multilayer films by modeling key properties, such as secant modulus, moisture barrier and bending stiffness. For instance, users can predict how employing a new polyethylene resin will impact film properties before conducting physical trials. "Running these simulations can eliminate some film structure designs that would not be expected to meet property targets and identify structures that are more promising," says Dan Ward, senior technical service specialist and developer of the Bonfire tool. A new release of the tool introduced a larger resin database, and work is currently underway to incorporate machine direction tear and penetration energy, as well as a blown film calculator, into the model. "Longer term, we are also evaluating new calculations for film creep, tensile and impact strength and optical properties, as well as accounting for end-use environmental factors, such as storage temperature and relative humidity," explains Ward. "We believe that Bonfire is the only integrated model that calculates many film properties simultaneously and allows the user to estimate property tradeoffs when developing a multilayer film or making a change," he says.

At a recently opened technology center in São Paulo, Brazil, scientists from Solenis (Wilmington, Del.; www.solenis.com) develop models for a cooling-tower pilot plant (Figure 1) to simulate various treatment processes for water samples from customers' cooling towers. "Simulating customer processes in a laboratory setting allows us to investigate a wide variety of problem-solving scenarios in a controlled environment," says Edmir Carone Jr., technology and development manager at Solenis. These efforts have not only aided in the selection of appropriate cooling-water treatment options for specific processes, but have also allowed users to reduce their consumption of water and treatment chemicals. Furthermore, the cooling-tower models have accelerated the development of new cooling-water treatment chemistries, according to Carone. Among the important parameters simulated in the cooling-tower models are water temperature, skin temperature, pH, oxidation-reduction potential (ORP), conductivity and scale, and well as information from online corrosion monitoring.

## Visualizing complex scenarios

An incident involving the accidental release of chemicals, whether via explosion, fire or toxic dispersion, is an extremely complex situation that holds a number of potentially dire consequences. "Conducting a modeling analysis to determine the potential impacts from a hazardous toxic release is important in order to understand the effects it could have on personnel, nearby communities and equipment," says Tiffany Stefanescu, senior product specialist and meteorologist for Breeze Software, a division of Trinity Consultants (Dallas, Tex.; www.breeze-software.com). Incident Analyst, a program offered by Breeze Software, models the consequences of accidental chemical releases (Figure 2), and provides practical information for emergency response planning, facility design, realtime assessment of hazards and reconstruction of past incidents. The software is also set up so that users can conduct U.S. Environmental Protection Agency (EPA; www.epa.gov) Risk Management Program Offsite analyses, adds Stefanescu.

With numerous mathematical models included and a database consisting of over 180 chemicals and mixtures, Incident Analyst can assess the potential consequences for a release event, taking into account site meteorological conditions and levels of concern (LOC), the threshold values above which a hazard might exist. "For each LOC modeled, Incident Analyst will estimate a hazard zone where the chemical concentration, overpressure and thermal radiation values are predicted to exceed that LOC at some time after

Breeze Software

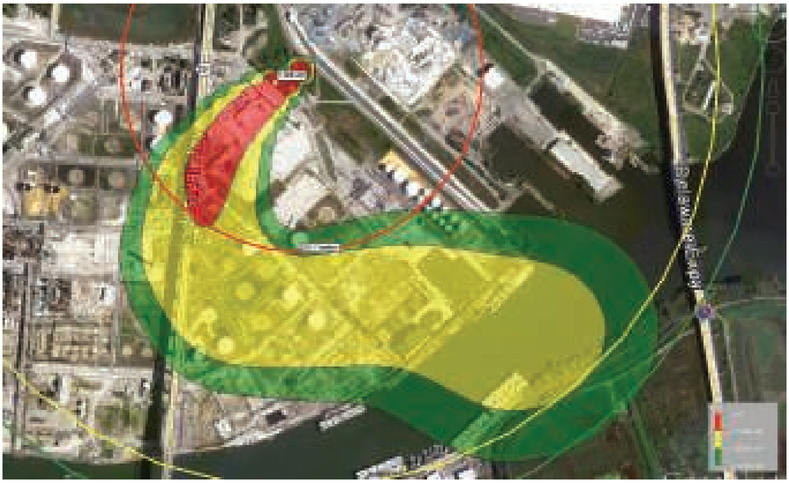

**FIGURE 2.** Many factors go into accurately modeling an accidental chemical release incident, including the local climate and geography

a release begins," says Stefanescu. The modeling capabilities in Incident Analyst also allow Breeze to develop custom realtime modeling systems that read onsite meteorological and monitored process data, and then automatically run the models within Incident Analyst using predetermined scenarios to produce realtime concentrations. "This realtime modeling capability is becoming increasingly popular and even mandatory for certain facilities, since it allows companies to make better operational decisions and address public concerns based on realistic conditions," comments Stefanescu.

For some extremely complex or sensitive process anomalies, combining several pillars of modeling, such as fluid dynamics and structural stress analysis, can be helpful in gaining a full evaluation of the process. One such example of a complicated scenario that requires "co-simulation" is the investigation of the acoustics of flow-induced pipeline vibrations. Acoustic data are useful for evaluating the extent that a damaged pipeline will affect fluid flow, and also to estimate the damaged pipe's suitability for continued operation. Typically, these types of assessments are first approached using industry design codes and empirical data. For instance, the U.K.'s Energy Institute (London; www.energyinst.org) provides guidelines and calculations to determine the likelihood of failure due to vibration, but doesn't necessarily provide methods for assessing or mitigating the vibrations, explains Matt Straw, managing director of Norton Straw Consultants (Derby, U.K.; www.nortonstraw.com). This is where the detailed analysis facilitated by co-simulation becomes critical. If these initial evaluations indicate the presence of a problem, a rigorous model that couples computational fluid dynamics (CFD) and structural analysis tools (Figure 3), and ultimately, fatigue analysis, is required, says Straw. This allows operators to ascertain the timeline for making modifications and also how the vibration may impact process integrity. "The work that we've done has often involved assessing the fluid dynamics of the system to see if the energy content of the system or the turbulence generated by the flow could cause any resonance in the structure. Then you can couple that with analysis of the structure itself to see how it responds," says Straw.

Site survey data can be used to recreate the geometry of the system, and if damaged, this will show any piping irregularity, which is input into the model. From there, simulation is used to produce the time history of the pressure generated inside the pipe from the fluid flow and translate that into the effects on the structural behavior using finite element analysis (FEA). Finally, the modelling data are used in a fatigue assessment that will determine if the design life is threatened or if mitigation is required.

Straw emphasizes that traditional process simulator software is not designed to do these sorts of analyses, and that is why using multiple platforms like CFD and FEA is necessary to ensure a robust model of both the process system and the mechanical structure. He has also used co-simulation for selecting materials of construction for piping and equipment that may experience very low temperatures due to Joule-Thompson cooling.

Underlining the importance of integrating multiple simulation and modeling pillars, Siemens Product Lifecycle Management Software (PLM; www.siemens.com/plm) launched its SimCenter platform in 2016, which brings together a number of software and analysis tools. "Essentially what is designed using process simulation can be analyzed using CFD and DEM [discrete element modeling]. That analysis tells how you can actually employ your design before it is implemented," says Ravi Aglave, director of Siemens PLM Software's Chemical & Process Industry division.

A key facet of SimCenter is the ability to produce digital twins — virtual, sensor-enabled representations of an individual equipment component or process that allow engineers to predict the effect of process changes or upsets. "If you can know how equipment will perform under different conditions by using a digital twin, then you have a predictive ability that can be used to control that equipment," explains Aglave. Modeling with a digital twin may pinpoint specific process variables that should be measured to better predict process behavior. "Based on those expectations, you can modify the control algorithm to achieve the optimum for

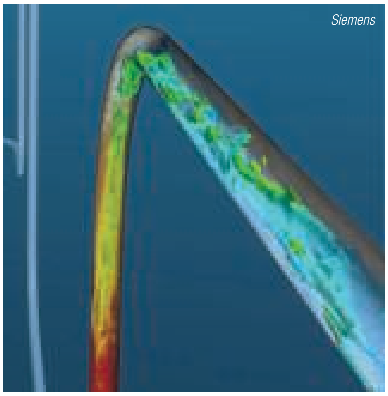


**FIGURE 3.** Anomalies in pipelines, such as dents and bends, can affect fluid flow and cause acoustic excitations that may result in pipe damage or loss of production integrity

that new condition," he continues. This enables a quicker response to changes in operating conditions or product distribution demands.

## Looking to the next generation

Because modeling and monitoring capabilities have matured in recent years, engineers have unprecedented amounts of data at their disposal, but the best ways to utilize so-called big data are not always clear. "Many engineers do not understand what the meaning of 'big data' is, let alone the application of it to the chemical process industries [CPI]. Ask ten engineers and you would be at risk of getting ten or more different versions," comments Andy Howell, chief executive officer of KBC Advanced Technologies Ltd. (Surrey, U.K.; www.kbcat.com). In short, says Howell, big data and the availability of smart devices and mature process models — ones that go beyond traditional engineering design to incorporate operations, planning and logistics via cloud-based infrastructures — are driving the emergence of predictive, rather than reactive, analytics. "The process simulator has graduated from the design system of the past to the operations system of the future," says Howell. He suggests that a marriage of thermodynamic simulation with equipment degradation modeling (considering erosion, corrosion or other types of damage) is essential for predictive analytics to become the CPI norm. Furthermore, energy management is another sphere where process modeling is helping CPI facilities maximize production. "Recent innovations in process simulation now model the gas turbines and power-generating equipment within the flowsheet, including the fuel and air quality from the process. This means an operator can optimize production versus power and can reduce energy costs," explains Howell.

At AspenTech's Optimize 2017 event, a panel of experts discussed some trends in modeling that are moving the industry forward, including big data and the push toward predictive analytics. A common thread among the panelists was that big data is not only changing how facilities operate, but also how engineers think. The panelists agreed that this shift in mindset should begin with undergraduate chemical engineering education, as data science and statistics become more intertwined with traditional engineering tasks. "A wide spectrum of expertise is required from engineers. Statistics and data analysis courses are crucial in chemical engineering education," emphasized John MacGregor, distinguished professor emeritus at McMaster University (Hamilton, Ont., Canada; www.mcmaster.ca).

Kai Dadhe, head of the Computer Aided Process Engineering and Automation division of Evonik Industries (Essen, Germany; www.evonik.com), commented: "Digitalization and big data are about breaking silos, with respect to both data and disciplines." Ultimately, this holistic mentality will ensure that engineers are well equipped for the most demanding process modeling tasks in the CPI. ■

*Mary Page Bailey*

# Benefits of Sophisticated Motor & Drive Technologies

## New motors and drives provide energy efficiency and reliability in chemical applications

### IN BRIEF

DESIGNED FOR RELIABILITY AND EFFICIENCY

IMPROVING THROUGH INTEGRATION

Leeson Electric

**FIGURE 1. The Extreme Duck Ultra offers a motor design that ensures that liquids don't penetrate the motor in any mounting position via a new encapsulation process with better materials to ensure complete filling of the motors and curing of the epoxy encapsulation**

Always on the lookout for ways to reduce downtime and energy costs, chemical processors are turning to advanced motors and drives to help achieve these goals. Sometimes as integrated systems, sometimes not, new motors designed for premium efficiency and reliability and more sophisticated drives are helping processors increase availability and lower cost of ownership. Fortunately, motor and drive suppliers are working hard to provide top-notch equipment with modern features that can withstand the demanding applications found in the chemical processing environment.

"Producers are very aware of energy consumption and seek ways to minimize energy consumption through new information-enabled technologies," says Sergio Gama, market development director for power control business with Rockwell Automation (Milwaukee, Wis.; www.rockwellautomation.com). "Reliability and plant availability are also important to them. They want to keep the plant running 24/7 and maximize asset utilization, so they want to minimize unplanned downtime by reducing mean time to repair, allowing a quick return to full capacity."

George Weihrauch, product manager for LV NEMA Motors with Baldor, a member of the ABB Group (Fort Smith, Ark.; www.baldor.com) agrees that these are priorities. "When it comes to motors, processors are beginning to look at the total cost of ownership, which includes reliability and efficiency," Weihrauch says. "Selecting motors based upon the lowest price is not something chemical processors do anymore. Instead, they look for proven technologies, so as manufacturers, we look at how to make designs more reliable and efficient. We study modes of failure that affect motor life, such as operating temperatures, vibration and things that affect motors like power supply and inverter operation, and look for new materials, design improvements and features that can reduce the modes of failure so the motor will last longer and run more efficiently."

Drives, too, are being improved to increase reliability and efficiency. "There are typically two reasons to purchase a drive: to reduce energy consumption or improve process control," says Matti Paaso, Chemical, Oil and Gas segment manager with ABB Group

The ABB Group

**FIGURE 2. The ABB Ability Smart Sensor provides remote condition monitoring for low-voltage motors. It attaches to the frame of the motor, without wires, and picks up data on vibration, temperature and other parameters**

(Cary, N.C.; www.abb.com). "So, processors are starting to realize the value of more efficient motor control methods like vector control over traditional volts-per-hertz control."

He continues: "And, because chemical plants are typically a high-dollar-value investment, which need to operate 24/7, reliability is important, as a failed drive can shut down a plant's essential processes and restart time can be days. Availability of the drive system has become a more prominent concern, as are reduced maintenance intervals and quick and safe recovery from failure situations."

## Designed for reliability & efficiency

As such, providers of equipment wish to incorporate improvements, such as more cost-efficient computational power to improve motor control methods, additional programming features and more intelligence in the drives. Motor designs have also improved to include new materials and encapsulation methods. Further, motor types that were not previously cost effective, such as permanent-magnet motors and synchronous-reluctance motors, are being redesigned and gaining more acceptance in the chemical process industries (CPI) due to energy efficiency benefits and reduced cost of ownership.

Because the chemical industry presents many challenging applications, motor manufacturers are working to design motors that can better withstand the environment, says Chris Medinger, product marketing specialist with Leeson Electric (Grafton, Wis.; www.leeson.com). "Reliability of motors is a great need, for the downtime costs in chemical applications are very expensive. Because processors can't afford to have downtime in their applications, they need a motor that can stand up to chemicals and washdowns," he says. So, Leeson went to work and re-engineered their design to provide a liquid-proof motor, called the Extreme Duck Ultra (Figure 1). The motor's design ensures that liquids don't penetrate the motor in any mounting position via a new encapsulation process with better materials to ensure complete filling of the motors and curing of the epoxy encapsulation.

Another way motor manufacturers are adding reliability is by adding more sophistication. For example, ABB offers an add-on device, the ABB Ability Smart Sensor, says Weihrauch. The device provides remote condition monitoring for low-voltage motors. It attaches to the frame of the motor, without wires, and picks up data on vibration, temperature and other parameters (Figure 2). It uses on-board algorithms and relays information about the motor's health via a smartphone or over the Internet to a secure server. Weihrauch says this can help reduce motor downtime by up to 70%, extend lifetime by as much as 30% and lower energy use by up to 10%.

"The device has the ability to look at how the motor is used and provide meaningful information on motor condition and performance," he says. "This enables users to plan maintenance according to actual needs rather than on the basis of time intervals or operating hours and allows them to see changes in motor performance that indicate a problem and address it before shut down, thus enhancing reliability."

Drives, too, are receiving updates. For example, ABB's ACS880 drive is an all-compatible, low-voltage drive that uses Direct Torque Control, which is capable of controlling induction, synchronous and synchronous reluctance motors, and helps simplify operation, provide better control of the process and optimize energy efficiency. Its "common drives architecture" features the same control panel, parameter menu structure, universal accessories and engineering tools. The control panel is equipped with an intuitive control display, enabling easy navigation. Flexible data visualizations including bar charts, histograms and trend graphs help users analyze processes, says Paaso. "This drive allows operators to learn one drive and use it multiple times, while controlling motors more accurately to reduce energy consumption, and it is compatible with higher efficiency motor technologies such as synchronized and synchronous reluctance motors."

Rockwell Automation

**FIGURE 4.** PowerFlex 755T drives provide harmonic mitigation, regeneration and common bus solutions to reduce energy costs, add flexibility and increase productivity. The drives feature predictive diagnostics and maintenance settings that monitor drive and motor operating conditions to help analyze system health



## Improving through integration

Offerings of integrated systems are another way equipment providers are helping processors increase efficiency and reliability. "Since processors are looking to minimize downtime and maximize system efficiency, one of the big pushes right now is integrating motors and drives," says Patrick Hogg, application engineer-

Nidec Motor


**FIGURE 3.** This 3–10 hp electronically commutated motor with an IE4 rating integrated with a tuned variable frequency drive is part of the ACCU-Series line of variable speed products. The brushless permanent magnet motor and drive have an integrated user interface that allows for easy setup

ing manager for industrial horsepower applications with Nidec Motor Corp. (St. Louis, Mo.; www.nidecmotor.com). "Instead of having a separate motor and drive, you have a motor with a drive that's integrated and the drive is characterized to run specifically with that motor."

The benefits of this type of integration, he says, are that the motor and drive are tested and tuned together, which saves steps during installation and ensures compatibility. For example, Nidec offers its ACCU-Series product line, which allows users to match a U.S. Motors brand inverter duty motor with a Nidec drive. These products are solution driven and are designed to be used together as a system.

Often, these systems are available with advanced motor technologies to provide further efficiencies, says Hogg. For instance, a 3–10 hp electronically commutated motor with an IE4 (Super Premium efficiency) rating integrated with a tuned variable-frequency drive (VFD) is part of the ACCU-Series line of variable speed products (Figure 3). The integrated motor and drive was designed with ferrite magnets rather than rare earths for more consistent pricing and cost structure. The brushless permanent-magnet motor and drive have an integrated user interface that allows for easy setup. The product is simpler than a modular approach, and it reduces costs and lead-time by eliminating cabling between motor and separate control. It also reduces electromagnetic interference and corona, which can result in power loss and interfere with performance.

Similarly, Rich Mintz, low voltage motors and drives marketing manager with Siemens (Alpharetta, Ga.; www.siemens.com), says Siemens uses advanced manufacturing and design to provide a synchronous reluctance motor that uses less material, provides better efficiencies and was designed to be integrated with a drive. "Synchronous reluctance technology allows the motor to be lighter and have better efficiency, and combining it with a VFD makes it more efficient than the advanced design alone," says Mintz.

The company's Simotics reluctance motors are precisely harmonized and coordinated with Sinamics converters to create a Siemens integrated synchronous-reluctance drive system. It offers the advantages of

well-proven standard platforms and links these with energy-efficient synchronous-reluctance motor technology, he says. "The transition from an induction motor with converter to a synchronous-reluctance drive system represents a small step, however, the impact is enormous: The high efficiency ensures minimum operating costs and high productivity."

Taking it a step further, Rockwell Automation's Gama says the ability to integrate not just the motor and drive, but all the motor control and sensing devices into the control system, allows users to collect and use diagnostic information from all of these devices. "We are coming to the point where processors realize there is a lot of data they haven't been using. So, many are interested in taking a holistic approach and using analytical tools to look at the data from the process, the plant and even data from other plants within the enterprise to draw correlations between performance in one plant and another in an effort to understand what's working well and what's not and then using that information to achieve better overall performance throughout the enterprise," he says. "We call this the 'Connected Enterprise Approach'."

Gordon Bordelon, chemical industry leader with Rockwell Automation, continues: "Processors increase reliability by being able to get data and do predictive maintenance before there's a potential process upset, so it comes down to getting enabled devices — the smarts on the motor control centers, the smarts of the drives — and sharing that data, along with process data, to infer knowledge about the process and make decisions in the most efficient manner."

One of the ways to begin deploying this type of holistic approach, he says, is to bring smart devices, particularly those centered around drives and motor controls, back to the distributed control system (DCS). Rockwell's PowerFlex 755T drives were designed to help with this (Figure 4). The drives, which provide harmonic mitigation, regeneration and common bus solutions, can reduce energy costs, add flexibility and increase productivity. The drives feature predictive diagnostics and maintenance settings that monitor drive and motor operating conditions to help analyze system health. Gama says they also offer adaptive control to accommodate changes in load and to compensate for those changes so there's no impact on availability. "When there's an issue, the drive is sophisticated enough to adjust to the unfavorable conditions, but it also provides communication that it is working under stressful conditions so that something can be done to avoid plant downtime. Users can make decisions based upon this intelligence and information."

Clearly motors and drives are adapting to the demands of the chemical industry via improved designs and more sophistication, which will help increase reliability and efficiency, ultimately providing lower lifetime equipment costs and better bottom lines. ■

*Joy LePree*


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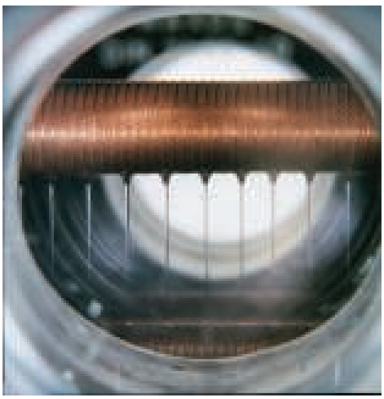
# Heating and Cooling Systems

Alfa Laval

Edwards



The Wieland Group

## Guard against gasket wear in plate heat exchangers

Gaskets used in plate heat exchangers (photo) wear over time, due to natural aging, and the effect of temperature, pressure and stress that results from natural operating conditions. Getting the best performance from a plate heat exchanger and minimizing the risk of unplanned downtime requires regular preventive maintenance, especially when the unit is used for hygienic applications within the food, beverage, pharmaceutical and personal care industries. Particular focus is needed to ensure the integrity and performance of the heat transfer and sealing efficiencies of the plates and gaskets. This company's HX Advisor is an easy-to-use tool that provides advice and support during selection of heat exchangers and auxiliaries. — *Alfa Laval, Richmond, Va.*
**www.alfalaval.us**

## This compact heat exchanger has no moving parts

The ACT-HP-AAXH heat pipe air-to-air heat exchangers can be fitted to new or existing HVAC systems. The AAXH is a counterflow heat exchanger and energy-recovery system that is based on the company's high-performance heat pipes. The system is used to pre-cool or pre-heat incoming building supply air, and is designed to ensure indoor air quality while preventing cross-contamination between isolated airstreams. The system provides savings related to heating and cooling costs that typically allow for a payback period of one to two years, says the company. — *Advanced Cooling Technologies, Lancaster, Pa.*
**www.1-act.com**

## Reduce chemical condensation in semiconductor operations

The Smart Thermal Management System (TMS) is designed for process operators carrying out chemical vapor deposition (CVD), epitaxy, oxide etch and poly etch processes, which have the potential for chemical vapors to condense and deposit in exhaust lines. The system maintains desired gas temperatures in vacuum pump inlet and exhaust lines. Unheated lines are susceptible to both clogging by condensed process materials and byproducts and potential corrosion resulting from such unwanted deposition. The Smart TMS includes temperature monitoring within the heating elements, enabling feedback control to accurately maintain exhaust temperature at a specified setpoint. This is said to reduce downtime and risks to service personnel, who are tasked with cleaning out these often hazardous materials, says the company. — *Edwards, Burgess Hill, U.K.*
**www.edwardsvacuum.com**

## This partnership provides a stronger offering of tubes

This company manufactures semi-finished products in copper and copper alloys, such as strip, sheet, tubes, rods, wires and sections, including finned tubes and heat exchangers, slide bearings and components (photo). It recently acquired Wolverine Tube (Decatur, Ill.), which produces integrally finned and enhanced surface tubes from copper, copper alloys and steel alloys. — *The Wieland Group, Ulm, Germany*
**www.wieland.de**

## Heat transfer fluids target solar and geothermal applications

Three new heat-transfer liquids, which are part of the company's Antifrogen and Protectogen product family, are specially developed for use in solar thermal energy systems and geothermal systems, especially flat-plate collectors and heat-pipe systems. Antifrogen Solar is a propylene-glycol-based aqueous product that is designed to protect metal components against corrosion. It maintains its fluidity at low temperatures, virtually eliminating the risk of bursts, says the manufacturer. It has a frost resistance of –28°C and a maximum permanent use temperature of 150°C.

Note: For more information, circle the 3-digit number on p. 78, or use the website designation.

Antifrogen Solar is also available as a concentrate. Antifrogen Geo (monoethylene glycol) is specifically designed to meet the requirements of heat transfer fluids in shallow geothermal energy applications, where fluid choice is critical to safe operation. ProtectogenN Eco is a multi-purpose heat transfer fluid based on monoethylene glycol containing an effective combination of inhibitors for long-lasting protection against frost and corrosion in many different systems. Permanent usage temperatures range from –50 to 100°C. — *Clariant, Muttenz, Switzerland*
**www.clariant.com**

### Boost safety by removing coke buildup in furnaces

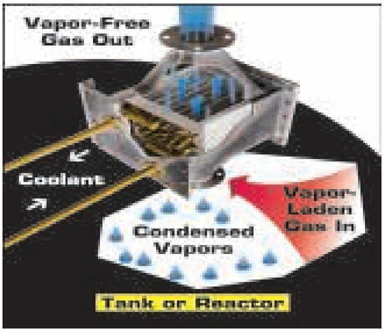
The efficiency and reliability of furnaces and process heaters depends on keeping the inner walls of furnace coils free of excessive coke deposits that can accumulate during normal operation. Without regular cleaning and maintenance, coke buildup inside the tubes continually increases in thickness, reducing the flow of process fluid and raising pressure within the unit to dangerous levels. The coke layer also makes heat-exchange less efficient and more costly for the customer. This company offers advanced, in-situ pigging and decoking services that increase flow, restore heat exchange efficiency and reduce differential pressure. This mechanical cleaning service removes hydrocarbon coke and inorganic contamination without degrading tube walls. Optional inspection services to assess the condition of tube also is also available. Every project is custom-engineered, says the company. — *DeBusk Services Group, LLC, Pasadena, Tex.*
**www.debusksg.com**

### This immersion heat exchanger is designed to resist hot spots

This Immersion Coil Heat Exchangers have been proven worldwide in a vast range of applications. These heat exchangers have corrosion resistance that is second only to diamond, says the company, and benefit from the inherently non-stick characteristics of the fluoropolymer materials of construction that are used. These include polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), perfluoroakoxy (PFA) and others, which help to resist fouling, scale buildup and clogging. These heat exchangers do not have a single tubing weld joint (which can be susceptible to failure over time). This helps to maintain optimal heat transfer efficiency over the entire lifecycle of the system and ensure uniform heat transfer between steam and acid, according to the manufacturer. — *Fluorotherm, Parsippany, N.J.*
**www.fluorotherm.com**

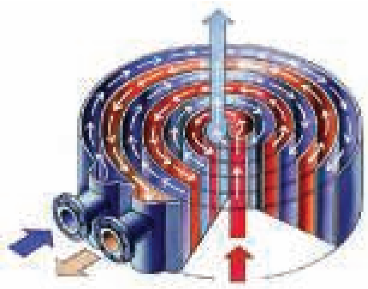
### Stainless-steel heat exchangers offer several design options

The ability to minimize waste heat emitted to the environment has a direct impact on the energy efficiency of a manufacturing or industrial process. By implementing the Kelvion Air-to-Air stainless steel heat exchanger, in conjunction with smart energy-management practices, operating companies can significantly reduce operating costs, Xchanger




Kobe Steel

Komax Systems



Sondex A/S

says the company. This manufacturer offers many models, designed for application ranges from –20° to 180°C. The glued tube-to-tubesheet design (using a silicone-free glue) assures relatively low weight and costs. For higher-temperature applications (up to 1,000°C), the tubes are welded to the tubesheets, providing greater mechanical strength. — *Kelvion Holding GmbH (formerly GEA Heat Exchangers), Bochum, Germany*
**www.kelvion.com**

## Computer modeling optimizes exchangers for condensation

The TV Series heat exchangers (photo) are available to condense vapors from low-pressure gas streams and can prevent discharge to the atmosphere of up to 85% of vapors from vents on storage tanks and reactors, and can help operators to reclaim condensate. Models are available for flows to 5,000 std. $ft^3$/min or more and for pressure to 15 psig. Fluids can be water, refrigerants, glycol or cryogenic fluids. The fins on the fin-tube core are rectangular plates with a matrix of die-extruded tube collars. A sheet-metal casing provides rigidity to the fin-tube assembly prior to tube expansion. This allows for a gap-free connection, maximizing heat transfer and structural integrity. The fluid circuit consists of parallel tubes that are joined at the inlet and outlet headers. — *Xchanger, Hopkins, Minn.*
**www.xchanger.com**

## Novel heat exchanger supports hydrogen-refueling stations

The HyAC mini-A is a compact, all-in-one compressor package that is designed for hydrogen refueling stations in the U.S. (photo). The unit combines a high-pressure hydrogen compressor and a refrigerator that are packaged with a high-pressure storage tank and dispenser. The system includes compact micro-channel, diffusion-bonded heat exchangers. To meet the U.S. fueling protocol (a U.S. standard for temperature and pressure when fueling fuel-cell vehicles), the filling pressure of the HyAC mini-A was recently raised to 87.5 MPa. The system is also equipped with a remote monitoring system. — *Kobe Steel Ltd., Tokyo, Japan*
**www.kobelco.com**

## Carry out slurry heating with greater energy efficiency

The Komax Klean-Wall Heat Exchanger (photo) is designed to enhance energy efficiency, producing as much as a300% increase over standard slurry heaters and tube-and-shell exchangers, according to the company. This heat exchanger is typically installed in a circulation loop for large digester heaters, helping to reduce retention time by up to 50%. This system is designed to minimize clogging, by allowing debris that measures up to 50% of the diameter of the pipe — even stringy debris — to flow without plugging. Meanwhile, the system is designed to provide a high level of turbulence at the boundary walls. This is said to provide constant scavenging of the wall surface to eliminate buildup. — *Komax Systems, Inc., Huntington Beach, Calif.*
**www.komax.com**

## Cart- and trailer-mounted cooling systems do the job

For outdoor industrial sites that lack foundational infrastructure, and high-temperature hazardous locations, staying cool is a top priority. This company's industrial air chiller carts are portable, and can be deployed anywhere without supporting HVAC systems. Several air chiller tower units on carts are available to cool hard-to-reach outdoor locations, up to 12 ft high. The systems are scalable, with larger-scale units mounted on trailers. — *Larson Electronics LLC, Kemp, Tex.*
**www.larsonelectronics.com**

## Cleaning system protects finned exchangers and coolers

The automated JetMaster cleaning system provides gentle intensive cleaning of sensitive fin surfaces that can become coated with industrial and atmospheric particulate buildup during operation. Such buildup on fins and other surfaces can reduce energy efficiency and increase the cost of power, maintenance and service, and potential corrosion can reduce the service life of such systems. The JetMaster uses high-power nozzles that bring compressed air and small quantities of pretreated water (but no chemicals) to supersonic speeds at low pressure, dislodging

buildup without damaging fragile fins and other sensitive surfaces (such as graphite, soft coatings, glass films and more). — *Mycon GmbH, Bielefeld, Germany*
**www.mycon.info**

## Self-cleaning heat exchangers provide improved reliability

This company has teamed up with Bronswerk Heat Transfer B.V. (Nijkerk, The Netherlands) to offer heat exchangers based on its self-cleaning heat exchanger technology. Bronswerk's particular expertise is in the design and thermodynamic, mechanical and economic optimization of heat-transfer and fluid-flow systems. When equipped with this self-cleaning heat-exchanger technology, a fluidized bed of solid particles provides a scouring effect at the tube side, where the fouling liquid flows through. This design enables heat exchangers to have zero-fouling operation, according to these manufacturers. The ability to carry out continuous cleaning in place can help to reduce process downtime, which can translate to increased yield, says the company. — *Klaren International B.V., Barneveld, The Netherlands*
**www.klarenbv.com**

## Compact spiral heat exchangers ease maintenance

This company's Spiral Heat Exchangers are circular heat exchangers with two spiral channels, each in one closed chamber. The flow of the two products is countercurrent, which makes it possible to have a close temperature approach between the two medias being treated in the heat exchanger. They are designed for demanding fluids with very high viscosity. Welded spacer studs to increase the turbulence and heat transmission. They are said to offer an alternative to plate and tubular heat exchangers for handling dirty media. — *Sondex A/S, Sondex, Denmark*
**www.sondex.dk** ■

*Suzanne Shelley*




Hoyer

Gala Industries

WIKA Alexander Wiegand

Volkmann

## This tank-container fleet is becoming smarter

This logistics company has begun fitting a new telematic system to its tank container fleet (photo), enabling seamless monitoring of goods transported in tank containers at any defined point in time. This includes monitoring not only position, as in the general cargo sector, but also the status of the transported goods with regard to their pressure, temperature, filling level and density parameters. A non-invasive filling-level measuring system solves a large number of technical challenges. Full ATEX certification for all the components completes the range of services offered. Users have access to these data, together with the transport order data, on a web platform that includes automatic monitoring and an alert if there are any discrepancies. Of the 37,000 tank containers in the company's fleet, 5,000 have already been upgraded, and around 8,000 tank containers per year will follow in each of the next few years. — *Hoyer GmbH, Hamburg, Germany*

**www.hoyer-group.com**

## A high-capacity centrifugal pellet dryer

This company has engineered a centrifugal dryer with the highest known capacity for drying polyolefin pellets. High-capacity resin producers, engineering companies and equipment manufacturers require a single dryer for virgin resins. This company has successfully increased the drying capacity of its Model 100 dryer (photo) to 150 ton/h, processing high-density polyethylene (HDPE) with lentoid pellet geometry and melt flow index of 0.35, with moisture below 500 parts per million (ppm). Future plans include a number of new concepts that will be evolving over the next 12 months, says the company. — *Gala Industries, a Maag company, Eagle Rock, Va.*

**www.gala-industries.com**

## This pressure gage covers an extreme pressure range

The CPG1500 precision digital pressure gage (photo) can measure pressures up to 10,000 bars. Furthermore, a new smartphone app is available for the CPG1500. The high-pressure version of the digital pressure gage works with an accuracy of 0.5% full scale. The measured value registration has been adapted in a rupture-proof way for this version — the thin-film cell is not welded, but rather it is inserted solidly into a conical pressure channel. Versions of the new app (iOS and Android operating systems) can be downloaded for free. The app enables a mobile parameterization of the instrument and also the reading and evaluation of the information from the data logger, which can record up to 50 measured values per second. — *WIKA Alexander Wiegand SE & Co. KG, Klingenberg, Germany*

**www.wika.com**

## A material handling system for additive manufacturing

The Additive Manufacturing Material Handling System (photo) is designed specifically to enhance additive manufacturing (3-D printing) technology when handling metal powders or toxic materials. The system consists of three elements to recover any unused material, screen it and finally return the material to the machine or a container for future use. It is available as a mobile unit or a fixed floor-mounted assembly. Developed with the company's pneumatic vacuum technology, it offers contained transfer of material from pick-up locations to the manufacturing unit, and then through the capture, integrated screening and return-to-use stations. It has been used in operations with a variety of materials, including tungsten, cobalt, silver powder, iron, stainless steel, alumina, nickel chrome, copper and carbide dust, with bulk densities ranging from 93 to 341 lb/$ft^3$. The unit works in both a normal air environment and under an inert gas. — *Volkmann, Inc., Bristol, Pa.*

**www.volkmannusa.com**

## A non-intrusive system for temperature measurement

Last month, this company introduced a new platform for its Rosemount X-well Technology surface-sensing temperature measurement solution (photo, p. 37). The new offering extends this non-intrusive temperature sensing technology to users in con-

ventional wired I/O environments for potential applications in facilities where wired networks are already installed, or where WirelessHART has not yet been deployed. Other users have found X-well to be a useful replacement for difficult thermowell installations, which often have a wired connection already available and can be reused with the wired version of X-well, says the manufacturer. X-well Technology works by measuring the pipe surface temperature and ambient temperature, and combining this information with the thermal conductivity properties of the installation and process piping to produce a process temperature measurement. This measurement technique requires no intrusions or penetrations into the process, allowing for simpler installation and maintenance. Users do not have to design, size or maintain thermowells. Wake frequency calculations are eliminated, as well as time spent determining material compatibility, the right insertion length and the necessary profile. — *Emerson Automation Solutions, St. Louis, Mo.*
**www.emerson.com**

## These AODD pumps handle high head pressures

The TC-X800 Series air-operated double-diaphragm (AODD) pump (photo) features a heavy-duty body design and can operate at variable air pressures. The pumps can also handle high head pressures and long discharge lines. With a maximum flowrate of 800 L/min and a maximum discharge head of 280 ft (85 m), the 3-in. AODD pumps are suitable for the safe transfer of a broad variety of liquids, including corrosive chemicals, liquid slurries, abrasive particle slurries, viscous liquids, fuel, oils, glues, inks and flammable liquids. TC-X800 pumps are available in stainless steel, aluminum, polypropylene and cast iron. — *Iwaki America Inc., Holliston, Mass.*
**www.iwakiair.com**

## Reliable insulation from the field to the network

The Mini Analog Pro signal conditioners (photo), featuring bus and network connection, combine the benefits of safe electrical isolation with those of digital communication. Up to eight field signals can be transmitted to industrial networks without error on less than 50-mm overall width. Signal-specific input cards are no longer required. The highly compact modules (6.2-mm width) provide all conventional signal-transmission functions: analog, temperature, frequency or switch signals are processed safely and transmitted to output signals. The new plug-in gateways digitize this output data and send it directly from the interface level to the control system or PLC via a serial communication protocol, such as Modbus or Profibus. — *Phoenix Contact GmbH & Co. KG, Blomberg, Germany*
**www.phoenixcontact.com**

## This booster increases flows by up to 500%

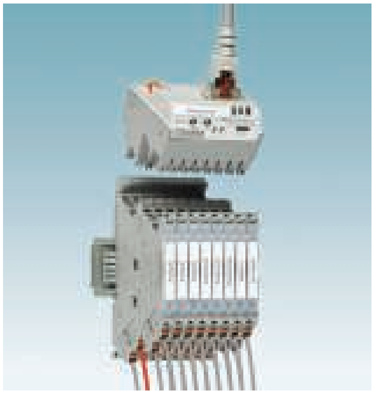
This patented volume and filter booster range in 316L stainless steel provides up to 500% higher flow than the market equivalents, says the manufacturer. By removing all elements from the main flow line, including regulators and filters, the effective *Cv* of the booster is multiplied, resulting in significantly reduced tubing sizes. Where safety is critical, the range of boosters is SIL 3 third-party certified to IEC 61508 Parts 1 & 2. In applications where a fast response time on modulating service, in combination with a fast shutdown time, is required, the device also eliminates the need for an additional poppet or quick exhaust valve to achieve the required closing speeds. This results in reduced material and labor costs and simplifies positioned setup and control. The range functions with a working pressure range of 2 to 10 barg, with maximum inlet pressure of 20 barg, and operates at a working temperature of –55 to 180°C. — *Bifold Fluidpower Ltd., Manchester, U.K.*
**www.bifold.co.uk**

## This feeder simplifies the addition of activated carbon

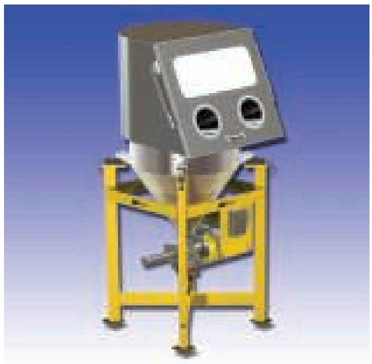
The new VMF-28/CP feeder with carbon package (photo) is a precision loss-in-weight measurement system designed specifically to provide accuracy in adding activated carbon (AC) in water-treatment operations. The new unit features an integrated scale for accurate feeding plus a bag-loading box that

*Emerson Automation Solutions*

*Iwaki America*



*Phoenix Contact*



*Scaletron Industries*

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Siemens Process Indsutries and Drives

simplifies the addition of carbon to the system, and also enhances employee safety by containing carbon dust. Designed to accept 50-lb carbon bags, a bag-loading box is positioned above the VMF-28/CP hopper. To add AC, or other materials, the operator places the bag in the loading box and closes the door, which is equipped with a scratch-resistant plexiglass window with static control. Below the window are through-door glove ports. With the door closed, using the gloves, the operator opens the bag using the built-in bag break in the loading box. This releases the carbon material into the system and all dust is contained inside the machine. Hopper capacity is to 5.0 $ft^3$. The VMF-28/CP Feeder uses a heavy-duty, gear-driven auger to continually feed material into the built-in, stainless-steel hopper at rates from 0.2 to 35.4 $ft^3$/h. — *Scaletron Industries Ltd., Plumsteadville, Pa.*
**www.scaletronscales.com**

## These rotary screw compressors provide energy savings

The new DSD series of rotary screw compressors (photo) is now available for flowrates from 14 to 25 $m^3$/min. Featuring new airends with high-efficiency Sigma Profile rotors and IE4 motors, they deliver improved specific power of up to 9%, as well as up to 6% higher flowrates than previous models, says the company. These improvements, together with other enhancements, result in significantly reduced energy costs. For example, the new IE4 motor is said to be the most efficient currently available, which enables peripheral losses in compressed-air production to be reduced even further. Moreover, the Electronic Thermo Management (ETM) system regulates oil temperature to ensure a safe and consistent differential from the dewpoint temperature. This strategy also prevents unnecessarily high airend discharge temperatures and provides additional energy savings. — *Kaeser Kompressoren SE, Coburg, Germany*
**www.kaeser.com**

## Store laboratory acids safely with these cabinets

The Acid Storage Cabinet (photo) is specifically designed for the storage of corrosive chemicals, and is available in widths of 12, 18, 24, 30, 36, 42 and 48 in. The standard size is 35-in. high and 22-in. deep. The molded one-piece fiberglass liner inserts directly into the cabinet and is sealed on all edges for ease of cleaning. The interior features a containment lip, on the front bottom edge to hold spills. The front access doors have air inlet vents, are lined and the edges are sealed. No metal is exposed to corrosive vapors. The shelf is removable for smaller container storage. — *Hemco Corp., Independence, Mo.*
**www.hemcocorp.com**

## Recent updates to this open-network control system

This company has released an updated version of the Stardom network-based control system (photo). With the addition of Windows 10 support and other new features, this release includes functionality for the onsite management of data that reduces the amount of communications traffic between central monitoring rooms and facilities distributed over a wide area. The Stardom high-speed central processing unit module comes with a new function that enables Java applications to run on a Stardom controller. Thanks to this function, the controller can be used to manage files and transmit data. This simplifies the overall system configuration by eliminating the need for a PC. In addition, an oil flowrate calculation function based on American Petroleum Institute (API) guidelines has been added. — *Yokogawa Corp. of America, Sugar Land, Tex.*
**www.yokogawa.com/us**

## A digital ultrasonic flow system with low noise

The new Sitrans FS230 clamp-on ultrasonic flow system (photo) is a combination of the Sitrans FST030 transmitter and Sitrans FSS200 clamp-on sensors. The Sitrans FST030 transmitter includes a digital sensor link that digitizes the signal at the earliest stage of measurement, resulting in an optimal signal-to-noise ratio. Due to its 100-Hz data update rate and integrated PerformancePlus algorithm, the transmitter detects

even the smallest changes in flow for consistently high accuracy of 0.5 to 1% of flowrate and a very stable zero point, says the company. Its patented pipe configuration menu allows the user to select various upstream pipe anomalies and automatically adjusts for flow-profile disorders stemming from unfavorable upstream conditions. The Sitrans FST030 also offers comprehensive diagnostics that detect changes in aeration, signal quality, sonic speed, temperature and fluid type, providing a valuable window into the process and facilitating preventative maintenance. Common architecture between digital platforms reduces training and spare part requirements. — *Siemens Process Industries and Drives, Spring House, Pa.*
**usa.siemens.com/industry**

## Onboard microprocessing for custom-configured controllers

The MGC Series (photo) is a new microprocessor-based, fully regenerative SCR (silicon-controlled rectifier) control. An onboard microprocessor allows the MCG to be preconfigured for a user's specific application. Furthermore, users can select various modes of operation out of the box, including torque, linear torque, independent speed/torque, cycling via limit switches, cycling via feedback, and positioning. The MGC eliminates the need for additional items, such as relays, switches and PLCs, thereby reducing setup and installation time. A new current-limiting algorithm prevents overshoot, extending brush life and reducing demagnetization, which extends motor life. The controller is rated for a maximum current of 11 A and a maximum temperature of 50°C. — *American Control Electronics (ACE), South Beloit, Ill.*
**www.americancontrolelectronics.com**

## Accommodate bulk material from multiple sources

This company's new flexible screw conveyor comes with a trough hopper (photo), and can receive material from multiple outlets of feeders, grinders, blenders and other process equipment. The hopper features an extended-length charging adapter that exposes 45 in. of the flexible screw rotating within an inclined U-shaped trough to charge material entering the hopper at any point. The rugged inner screw is the only moving part that contacts material, and is offered in numerous designs to handle both free- and non-free-flowing media. As it rotates, the flexible screw self-centers within the tube, providing ample clearance between the screw and tube wall to eliminate or minimize degradation. Material exits the conveyor below the drive point, precluding contact with bearings or seals. The hopper is equipped with a stainless-steel grate for worker safety, and to prevent oversized particles from entering the conveyor. — *Flexicon Corp., Bethlehem, Pa.*
**www.flexicon.com**

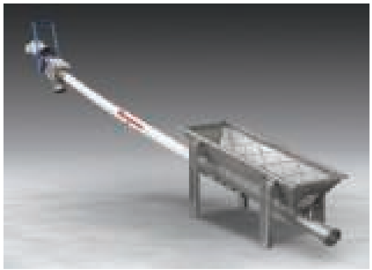
## Realtime level measurements in dusty conditions

RadarRight is a non-contact continuous level sensor (photo) that provides realtime level measurement of powders, bulk solids and liquids, even in dusty conditions. The instrument uses proven microwave-pulse technology and has a small beam angle to concentrate energy for high accuracy and reliability. The sensor has no moving parts to wear, which leads to longer operational life and lower maintenance requirements. Analog or RS-485/Modbus versions are offered. RadarRight devices are suitable for various metal or nonmetal storage vessels. — *Monitor Technologies LLC, Elburn, Ill.*
**www.monitortech.com**

## PFA resins with numerous processing options

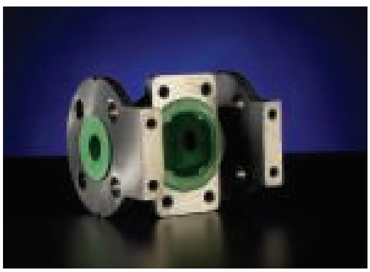
Fluon perfluoroalkoxy (PFA) resins can be used over a wide range of temperatures (–200 to 260°C) and exhibit resistance to heat, chemicals, weather and aging. With an oxygen index of 95% or better, the noncombustible resins' dielectric properties and nonstick characteristics make them suitable for numerous applications, including: valves, fittings and housings (photo); tubing and pipes; film and sheets; wire and cable; and blow-molded bottles. Fluon PFA is a melt-processible copolymer of tetrafluoroethylene and a perfluorinated vinyl ether. Fluon PFA has chemical, electrical and thermal properties al-

*American Control Electronics (ACE)*



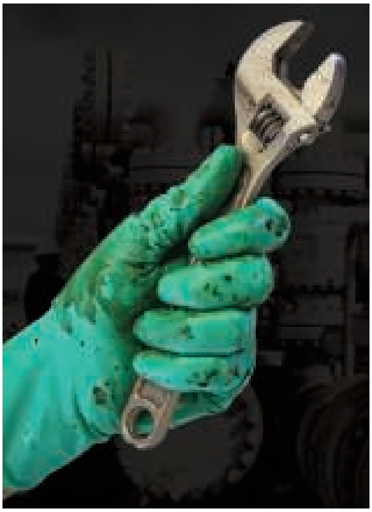
*Flexicon*

*Monitor Technologies*



*AGC Chemicals Americas*

SW Safety Solutions



Wanner Engineering

Sensorex

most identical to polytetrafluoroethylene (PTFE). However, Fluon PFA can be processed by conventional extrusion, injection molding, blow molding, compression molding, transfer molding and rotolining or molding techniques, says the manufacturer. — *AGC Chemicals Americas Inc., Exton, Pa.*
**www.agcchem.com**

## Heavy-duty single-use gloves with a robust grip design

Powerform S8+ single-use nitrile workplace gloves (photo) feature the patent-pending TracTek high density-grip pattern for 200% more tactile grip on wet and oily surfaces to significantly reduce slippage-related damage and injury, according to the manufacturer. The product offers improved safety and chemical protection due to its longer cuff and an irritant-free manufacturing process. TracTek grip technology is the result of extensive research into how a gloved hand interacts with slippery surfaces, resulting in a CAD-engineered traction pattern that prioritizes fluid evacuation while sustaining the largest surface-to-surface contact area via an embossed micro-pyramid grip pattern. This maximizes points of contact and maintains multidirectional flow channels to expel liquid in wet and oily conditions. The Powerform S8+ is designed with two layers of polymer in contrasting exterior and interior colors, boosting glove durability to ANSI Level 2 puncture resistance and making potential glove damage and breaches immediately visually detectable.— *SW Safety Solutions, Inc., Union City, Calif.*
**www.swsafety.com**

## Two new models of medium-pressure sealless pumps

The new medium-pressure Q155 Series Quintuplex sealless pumps (photo) are designed for a variety of applications, including reverse osmosis in water and wastewater treatment, mine dewatering, saltwater disposal or injection, bulk transfer, hydraulic lift and steam generation. The Q155 medium-pressure product line includes two models: Q155K, which has a maximum flowrate of 295 L/min and a maximum discharge pressure of 3,000 psi; and Q155M, which has a maximum flowrate of 246 L/min and a maximum discharge pressure of 3,500 psi. The patented sealless pumps employ hydraulically balanced diaphragms that enable the pump to handle high pressures with low stress and pump hot, abrasive fluids. The sealless design eliminates the environmental concerns of packed plunger pumps, and the multiple-diaphragm design provides virtually pulse-free, linear flow, says the company. — *Wanner Engineering, Inc., Minneapolis, Minn.*
**www.hydra-cell.com**

## High-throughput filter mesh with minimal pressure loss

New developments to this company's Optimized Dutch Weave (ODW) meshes allow for improved throughput rate, better retention rate and longer filter-media life in water or wastewater filtration facilities. The flow-optimized ODW meshes combine reliable filtration rates in the microfiltration range with almost three-times higher throughput rates than other recently available products, says the manufacturer. Other performance factors include high permeability, low pressure-loss coefficient, low clogging tendency and simplified cleaning. The special weave of the ODW mesh creates a slot-shaped pore geometry on the mesh surface, where the openings are smaller than the pores inside the mesh. With this design, particles above the specified separation limit are retained on the mesh surface. — *GKD-USA, Inc., Cambridge, Md.*
**www.gkdusa.com**

## Mercury-free handheld UV transmittance monitors

The UVT-LED-H handheld ultraviolet (UV) transmittance monitor (photo) delivers UV transmittance readings in applications employing UV disinfection, and its compact size makes it also well-suited for field measurements, laboratory use and calibration verification of online analyzers. The UVT-LED-H is said to be the only handheld, portable UV-transmittance monitor that is currently available. The device verifies UV dosing and efficient operation of UV disinfection systems

in municipal drinking water, wastewater and other industrial water-quality applications, such as food-and-beverage process water, as well as in quality-testing laboratories associated with those applications. The instrument's highly efficient UV-C LED lamps are more stable, improving accuracy when compared to instruments with traditional mercury light sources, says the manufacturer. Furthermore, the mercury-free light source also significantly lowers operating expenses related to UV transmittance monitoring by eliminating field-serviceable parts and disposal of lamps containing mercury. — *Sensorex, Garden Grove, Calif.*
**www.sensorex.com**

## An operator-friendly workstation for use in harsh environments

The VisuNet XT operator workstation features a high-bright LED-backlit LCD panel display with an optically bonded, glove-friendly and sunlight-readable 15- or 19-in. touchscreen for clear resolution in all lighting conditions. The workstation can operate in harsh environments in temperatures ranging from –40 to 65°C. VisuNet XT features North American Class I, Division 2, Class I, Zone 2, ATEX and IEC-Ex Zone 2 certifications from third-party agencies, with additional certifications and approvals underway, says the company. With a polyester-powder-coated, lightweight, cast aluminum housing, the IP66-rated VisuNet XT features a front panel with user-configurable function keys, brightness control down to zero illumination, monitor-off button and a touchscreen-disable button to enable the touchscreen to be cleaned without unintentionally activating random control functions. Users will also benefit from flexible networking options that include redundant LAN ports, a multi-mode fiber-optic LAN connection and wireless Ethernet. — *Pepperl+Fuchs GmbH, Mannheim, Germany*
**www.pepperl-fuchs.com**

## This process gas chromatograph is fast

A relatively small shift in the cut point (the threshold temperature for good product) for any petroleum-refinery product can cost refiners millions of dollars in profits. In the absence of fast, accurate and reproducible boiling point data, refinery product yields are not optimized and profits are lost. The PGC5009 "Fast" process gas chromatograph, which was launched last month, provides process analytics for simulated distillation analysis using fast temperature-programmed process chromatography. With a patented resistively heated column design and rapid cooling system, the PGC5009 provides the retention times and weight percentage measurements required for boiling-point curves, enabling optimized process controls, says the company. — *ABB Measurement & Analytics, Lewisburg, W.V.*
**www.abb.com/measurement** ■

*Mary Page Bailey and Gerald Ondrey*

## Alarm Management

*Department Editor: Scott Jenkins*

Modern control systems for chemical processes can generate frequent alarms. This one-page reference provides information on common alarm-management metrics, which can foster focused remedial actions and ultimately lead to a safer, better-performing plant.

### Alarm frequency

As alarm frequency increases, an operator's ability to respond correctly and in time to avoid the ultimate consequence of inaction decreases. If the rate is excessively high, some alarms will likely be missed altogether or be ignored by the operators. Alarm rates that exceed thousands per day are common in the chemical process industries (CPI), a level that is far greater than humans can handle successfully.

Response to alarm rates of 10 alarms per 10 minutes can possibly be achieved for short periods of time — but only if the alarms are simple ones. And this does not mean such a rate can be sustained for many 10-minute periods in a row. An alarm flood can be defined as a 10-minute period with more than 10 new alarms, continuing through subsequent 10-minute intervals until reaching a 10-minute interval with fewer than five new alarms.

The peak number of alarms within a 10-minute period is a straightforward measure of the degree of difficulty of the worst-case alarm flood for the operator. In poorly performing alarm systems, it is common to see peak alarm counts in a 10-minute period that exceed 250. During flood periods, operators are likely to miss important alarms.

### Average alarm rate

Average alarm rate is a straightforward measure of the frequency with which new alarms are presented to the operator, expressed as an average count per day, per hour or per 10-minute interval. Averages can be misleading, however, because they provide no sense of the peaks in the alarm rate, making it difficult to distinguish alarm floods from steady-state "normal" operation. Consequently, it becomes valuable to supplement this basic value with a timeline view or separate calculation of alarm rates for both the times when operation is normal and for times of an alarm flood.

An example of the timeline view is shown in Figure 1. If the overall average alarm rate (16.5 alarms/h in the example) is lower than the action limit of 18/h, it may not appear to be a point of immediate concern. However, the timeline view shows that there are significant periods of time where the performance is unacceptable.

Two metrics — the percentage of 10-minute periods with more than 10 alarms, and the percentage of time spent in an "alarm flood" state — are often used to help quantify how much of an operator's time is spent within the situation where more alarms occur than can be managed effectively. Pie charts like the one in Figure 2 illustrate how much time is spent within certain alarm-rate ranges.

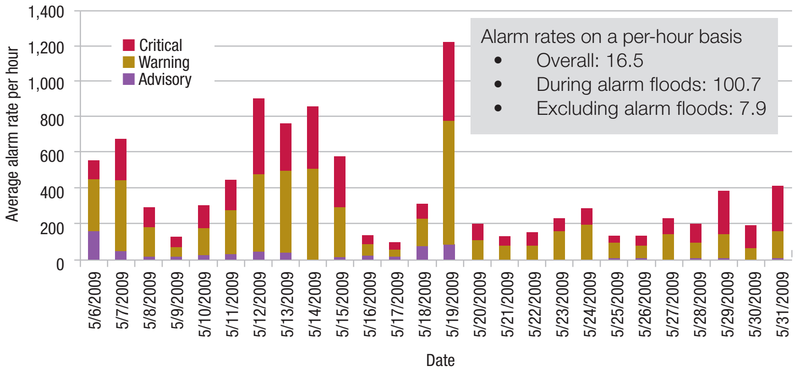



**FIGURE 1.** Timeline views of the data can reveal periods where alarm performance is not acceptable

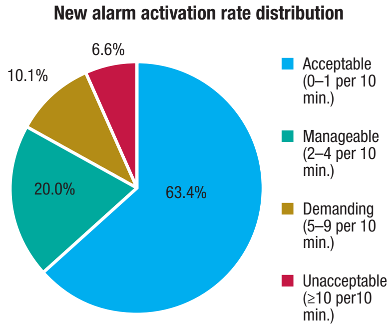



**FIGURE 2.** Pie charts can give information on how much time is spent in the acceptable range

### Causes of high alarm rates

Common contributors to excessively high alarm rates include the following:

- The alarm system is used to notify the operator of events that do not constitute actual alarms, such as communicating informational messages, reminders or alerts, rather than an equipment malfunction or process deviation
- Chattering or frequently occurring nuisance alarms are present. These often originate from non-process alarm sources of marginal interest. Chattering alarms can also indicate an incorrect alarm limit or deadband
- Redundant alarms, where multiple alarms occur for a single abnormal situation. For example, when a pump is shut down unexpectedly, it can generate a pump fail alarm in addition to alarms for low outlet flow and discharge pressure
- A problem with the metric calculation is occurring. A correct calculation only counts new alarms presented to the particular operator or operating position for which the metric is intended
- Cascading alarms happen when sudden equipment shutdowns trigger automated actions of the control system, which in turn, triggers more alarms
- When routine transitions between process states occur, the alarm system can therefore falsely indicate abnormal conditions ■

### References

1. VanCamp, K., Alarm Management By the Numbers, *Chem. Eng.*, March 2016, pp. 50–55.
2. Hollifield, B., Understand and Cure High Alarm Rates, *Chem. Eng.*, March 2016, pp. 56–60.

# Hydrogen Peroxide Production

*By Intratec Solutions*

Hydrogen peroxide ($H_2O_2$) is the simplest peroxide (defined as molecules with two oxygen atoms covalently bonded to one another). It is mainly used as a bleaching agent and as an oxidizing agent in the pulp-and-paper, cosmetic, pharmaceutical, chemical, electronics, and textile industries. The use of $H_2O_2$ as a raw material in the production of propylene oxide has significantly increased in recent years.

## The process

The process described in the following paragraphs is a conventional anthraquinone autoxidation (AO) process. In this process, 2-ethyl anthraquinone (EAQ) is sequentially hydrogenated and oxidized, generating hydrogen peroxide (Figure 1).

***Hydrogenation.*** Initially, EAQ is dissolved in a polar/non-polar solvent mix to form a solution (known as the working solution). The working solution feeds the hydrogenation reactor, where the EAQ is reduced to 2-ethyl anthrahydroquinone (EAHQ) by hydrogen gas in the presence of a catalyst. The product from the hydrogenation passes through a filtration step to recover the hydrogenation catalyst, which is returned to the hydrogenation reactor (not show in the diagram).

***Oxidation.*** During the oxidation, EAHQ is oxidized back to EAQ, while simultaneously producing $H_2O_2$. Oxygen from ambient air is used in the oxidation, and the reaction is not catalyzed (that is, autoxidation). The working solution obtained from the oxidation is directed to the concentration and purification area located downstream.

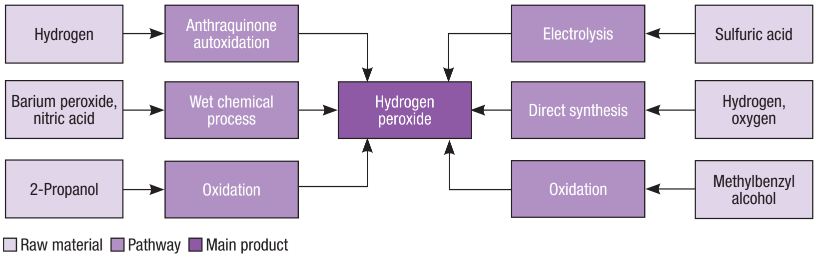



**FIGURE 2. Several production pathways exist for hydrogen peroxide**

***Concentration and purification.*** The hydrogen peroxide is separated from the working solution effluent (from the oxidation reaction) by means of countercurrent extraction with demineralized water. The aqueous-phase product from the extraction, which contains entrained organic compounds from the working solution, is then treated by contacting it with an adsorbent resin. After purification, the hydrogen peroxide solution is fed to a vacuum distillation column, where it is concentrated to 70 wt.%.

***Working solution recovery.*** The working solution leaving the extraction area is passed through a drying step to adjust the water content before being recycled back to the hydrogenation unit. Subsequently, part of the working solution is passed over an activated alumina bed for reverting unwanted quinone-related species to active quinones and removing the irreversibly degraded products. These degraded products are formed in side reactions in the hydrogenation/oxidation cycle.

## $H_2O_2$ production pathways

Hydrogen peroxide was first produced on an industrial scale using the reaction of barium peroxide with nitric acid. Since the 1950s, the largest portion of $H_2O_2$ production has been based on the autoxidation of 2-alkylanthrahydroquinones. Other pathways include: oxidation of alcohols; electrochemical process; and direct synthesis from oxygen and hydrogen. Figure 2 shows different pathways by which $H_2O_2$ is produced (in some of them, other chemicals are also produced, but are not shown in the diagram).

## Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce $H_2O_2$ is about \$630 per ton of $H_2O_2$ (on a 100%-$H_2O_2$ basis). The analysis is based on data from the second quarter of 2013 and applies to a plant with the capacity to produce 100,000 metric ton per year of $H_2O_2$ (on a 100%-$H_2O_2$ basis).

This column is based on "Hydrogen Peroxide Production Process Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/hydrogen-peroxide-production-cost. ■

*Edited by Scott Jenkins*

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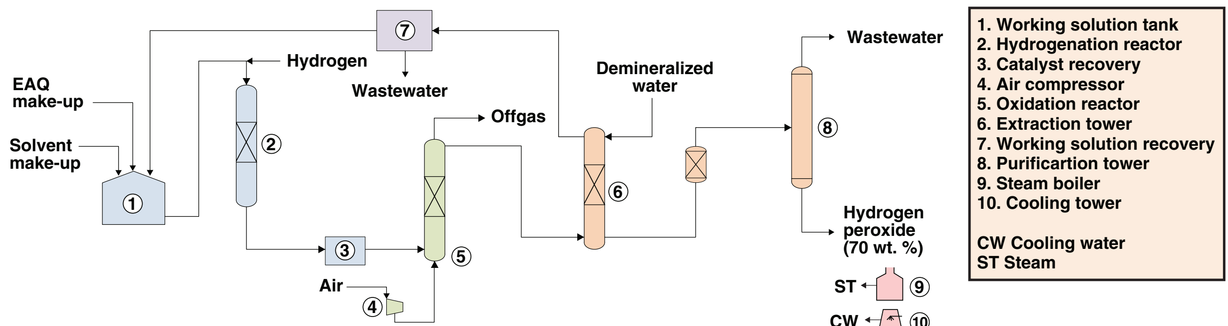



**FIGURE 1. The diagram shows a conventional anthraquinone autoxidation process for hydrogen peroxide production**

# Practical Solutions to Modular Project Execution

## Follow this guidance to improve results on capital projects

**Susan Halford**
and
**Tony Kretzschmar**
Fluor Corp.

IN BRIEF

- MODULAR ENGINEERING
- MODULE DESIGNS
- PROCUREMENT AND FABRICATION
- LOGISTICS
- ASSEMBLY AND INSTALLATION
- PRE-COMMISSIONING AND SITE COMMISSIONING

The opportunities for modularizing industrial and chemical projects are growing at an amazing pace. Once considered a mitigation strategy only for projects in remote areas with harsh climatic conditions or a shortage of skilled labor, modular execution is now prevalent across the chemical process industries (CPI). Even developing countries that have ample local labor, good site access and have previously executed "stick-built" execution are moving toward modular execution. Why? Because of the opportunity to yield improved overall project results.

**FIGURE 1.** Modularization, the pre-assembly of structures away from the primary construction site, has many benefits, including improved labor productivity and reduced HSE risks

Modularization, which involves the preassembly of structures away from the primary construction site (Figure 1), has been popular since the 1970s. Modules come in various sizes and shapes, from very large modules that are transported by barge, to smaller, truckable modules that may fit in a sea freight container. Modular execution provides many benefits, including improved labor productivity and quality, due to better controlled working conditions, and reduced health, safety and environmental (HSE) risks that arise when the need to work at elevation is reduced.

Modular projects, executed appropriately, can save time and money. A well-developed modular-execution strategy should create an integrated solution — as opposed to a hodgepodge of project scopes that are broadly planned but broken into separate engineering, procurement, fabrication and construction packages. Often, project managers do not consider that the additional interfaces are required between various organizations raise the potential for more disconnects, with no single organization having overall end-to-end accountability for the project. Integrated, innovative solutions are key for a modular execution outcome to be sucessful.

### Modular engineering

Engineering efforts associated with modularization can simplistically be separated into two main aspects. First, engineering must be technically sound and achieve the requirements that are expected for a facility to operate safely, deliver the specified product and achieve the target production. Second, engineering must support the project's downstream execution aspects, and engineering must consider the construction phase as its client; that is, to design a facility in a way that makes it easy for the construction group to build that design in the field.

This approach entails clearly identifying and procuring the right materials to be delivered at the right time to the right location, and providing timely responses to all queries. This latter aspect is typically not emphasized, but is a prime opportunity to enhance and influence a project's successful outcome.

One key aspect of successful modularization is to adhere to the concept that modularization drives layout — rather than layout driving modularization. Technically, this concept creates huge challenges and often dissuades clients and project managers from embracing modularization, but it can deliver significant project benefits.

Some of the radically different design approaches are not well known. These design approaches include plug-and-play technology (where modules go through significant pre-commissioning and testing at a fabrication yard and are then nearly ready for operations after being set into place) and elimination of pipe racks between process areas of a facility.

While some projects claim success with piperack modularization, they miss the recent step-change improvement in modularization where elimination of pipe racks is the goal (rather than just modularizing pipe racks). Such radical plot-plan reorganization by process blocks requires all engineering disciplines to be re-focused and aligned to support this goal. Some key considerations include the following:

- The establishment of a proper work-breakdown structure (WBS), which has all designs and materials coded for correct destination and installation scope. The WBS delineates the module assembly yard versus the jobsite. It avoids the use of the term "field," which can be misleading or unclear as to whether work is taking place at a module-assembly yard or at the ultimate jobsite
- The use of an accurate, continuously updated and accessible module index and dashboard that provides realtime information on design status and material availability
- The ability to obtain early reliable vendor data, particularly with respect to instrumentation and controls
- Additional management of pre-packaged equipment and the detailed integration of those components into the overall project's material-identification and numbering system
- Adherence by all engineering disciplines to an advanced (early) schedule
- Careful weight management to control module size and minimize any shipping and installation surprises
- Modular-fabrication plans that maximize installation, pre-commissioning and testing prior to shipment of completed modules to the jobsite (using a plug-and-play approach)
- A construction sequence that is defined early and does not change

**FIGURE 2.** Input from operations and maintenance teams is required early on in the design process to ensure that modularized facilities can be easily maintained

## Module designs

Module designs can vary extensively and many factors come into play. The module-design team needs to be fully aligned to the execution strategy, to finish the design and provide inputs to other disciplines early in the process. The design effort can only be successful if every discipline supports the execution schedule.

Important design aspects include efforts to ensure the following:

- Appropriate safety distances and spacing between equipment and process blocks
- Unobstructed emergency-escape routes
- Efforts to address permanent maintenance requirements (monorails, lifting beams and more)
- Efforts to incorporate ergonomic considerations for operation, with consistency and standardization in design
- Establishment of underground utility routings and pile and foundation locations

The use of advanced modular design concepts has demonstrated a reduction in facility footprints of 30%, with associated savings in some material quantities. However, advanced modularization also results in an increase in other areas, such as the need for additional structural steel for the framing and bracing of modules during transport. Steel, however, is relatively inexpensive and the additional costs are easily offset through a reduction in installed quantities of more expensive items, such as the following:

- Excavation and piling: 35% reduction is typical
- Concrete: 60% reduction
- Piping: 20% reduction

• Electrical: 30% reduction

Using a modular approach also requires unique considerations when it comes to managing design changes. In particular, late design changes in engineering adversely affect a module program more than stick-built projects, because stick-built projects typically have more work, at more areas, going on concurrently at a jobsite.

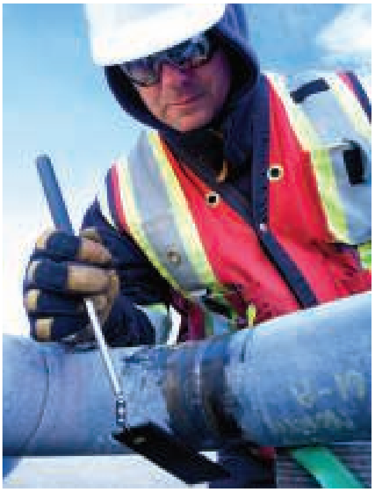
These multiple work fronts enable labor to be shifted in case of a change in one area. In contrast, modular assembly is similar to assembly-line work in manufacturing, where progress halted in one part of the assembly line slows down the whole line.

Modularization can move a significantly high percentage of the total construction work to the module assembly yard. Modules for a project are assembled at a module-assembly yard, rather than at the jobsite, thus transferring work that would have taken place at the construction site to the module assembly site. Accordingly, engineering support at the yard needs to be greater in numbers than at the site. Answers to requests for information from the module assembler should be answered the same day, if possible, to prevent delays.

When it comes to modularization efforts, successful engineering is carried out with the end in mind. The construction department's early, continuous and unchanging involvement in the design phase eliminates surprises when the time comes to build the modules and execute the remaining work at the site.

Construction and operations teams should provide input related to the ability to construct a design, as well as access and how construction will progress through the jobsite. These plans must be diligently followed through execution, as changes create untimely rework and yield unnecessary challenges. Items on modules that are not secured into place are often overlooked during engineering and planning. The items not physically secured to the module get tricky to manage and often get lost in the assembly, completion and shipment work process.

**FIGURE 3.** Projects should have a quality presence, as well as a advanced quality program, in the fabrication yards



Many modularization projects also benefit from reduced material, equipment and fabrication costs through increased use of global sourcing. While some project teams have been hesitant to work with overseas vendors, the past decade of successes (and a few highly publicized failures) has fine-tuned the global supply chain and created numerous successes on projects. Critical to this success is engineering's understanding of the fabricators' local conditions to manage the fabrication and achieve a win-win solution.

## Procurement and fabrication

Procurement used to be fairly straightforward on projects. Buyers bought the items that the engineering department requisitioned and had the items delivered to the jobsite. This is no longer the case.

End-to-end materials management has become a complex, international endeavor. Low-cost global supply and fabrication create a capital efficiency that allows many projects to be sanctioned that otherwise would not have been able to move forward. If global supply and fabrication are implemented as part of a project's execution plan, several key items should be addressed.

To mitigate quality concerns, projects should have appropriate quality personnel and resources in the module-assembly yard and at the global supplier locations. While this is a good first step, an additional valuable step is to implement an advanced quality program at the fabricators, as materials, such as pipe, steel and vessels, are also sourced from other global suppliers. Aspects of such a program include training the supplier's workers in the quality requirements and providing a physical sample of pieces of work, such as welded pipe, to clearly demonstrate the level of quality expected.

Modular fabrication and assembly facilities often have space limitations that can impact the material-delivery aspects of the procurement plan. With the "module-in-a-box" delivery concept, all materials necessary to fabricate a module are shipped to the module-fabrication yard at the same time.

This approach is widely considered mandatory when delivering materials and equipment to a module-assembly yard. Driven by the assembly-line manufacturing concept, having 100% of the materials on hand prior to starting a module's assembly is the norm. If a module is taking up yard space and cannot be finished on time, it potentially prevents another module from having the space available to be started. This sequencing is a key factor in the procurement, logistics and fabrication planning effort.

Material delivery to a module assembler can either be direct from vendors or via an intermediary marshalling yard that is set up to receive and stage materials and equipment. If a module assembler has a robust receiving and warehousing program, a project can consider having deliveries come directly from vendors. However, it is more likely that module assemblers are more focused on fabrication and thus allocate the majority of their yard to standing and building modules, instead of storing and staging materials.

Delivery using the module-in-a-box scenario requires an intermediate marshalling yard be set up to receive, separate, organize and report upcoming deliveries. This clear line-of-sight to the project team enables proper decisions to be made on when module assembly starts, and allows a project to change sequencing when one module is trending late. It serves as a risk-mitigation technique, allowing work to easily be moved from one module assembler to another, in case of schedule slippage.

If a module's material has already been delivered to one module assembler, it is very difficult to retrieve it to give it to someone else. A marshalling yard also allows for the segregation of bulk materials by module, since many vendors are not set up for (and typically charge extra for) sorting and separating items prior to shipment.

A typical oversight is the integration of pre-packaged equipment into the overall module-execution program. Careful cross-referencing of equipment

**FIGURE 4.** Transport of modules by ocean or barge requires different design considerations than modules that will be transported via truck

**FIGURE 5.** A module is prepared for transport to the project site

tags and material commodity codes from the pre-packaged equipment vendor, as well as proper identification of interfaces with the rest of the design, is imperative.

Some module assemblers may use poor integration of pre-packaged vendors into the overall project as an excuse for delays and schedule extension requests. Rather than forcing the pre-packaged equipment vendor to comply with a project's WBS or numbering system, instead focus on building a concise and comprehensive cross-referencing system and interface matrix to give the module assembler the information needed to install the equipment package in the various modules.

Finally, a module-fabrication program requires a robust material-management software tool and work processes that will ensure that data are kept up to date and the information accessible. Many hours can be wasted trying to resolve data inconsistencies between systems that report different material-availability and forecast-delivery dates. There are significant advantages to using a program-wide system that an integrated solution provider can bring to the table.

## Logistics

Logistics is an area often overlooked as a critical function in modular project execution, particularly when sourcing and fabricating globally. The logistics functionality plays a part in both the timely delivery of materials and equipment to the module assembler, and the transport of the completed module to the final installation location. Even with the additional challenges related to the logistics of transporting goods that are sourced globally and the schedule considerations of buying items earlier due to increased shipping timeframes, the net cost savings to a project can be surprising.

One of the most critical early decisions to be made on the project is the maximum size of the modules. Often this task is left entirely to the engineering group to plan, without due consideration to finished module shipping envelopes and potential road, rail and sea transport weight limitations.

Developing a route survey from the module assembler to the final installation location is critical at the very early stages of the project. There have been cases where the importance of these decisions has not been properly understood, and this has led to unwanted surprises that require drastic changes to modules far too late in the project.

Ocean-going transport should use the services of a qualified and experienced marine surveyor early in the project. Specifically, this input is required at the initial engineering stages to help design temporary (removable) shipment-related bracing and supports.

Even land-based module transportation requires careful coordination. For example, ensuring that a module is assembled at a proper height above grade for ease of loading may be overlooked. It is best to integrate the shipping beams into the module design, instead of utilizing third-party rented shipping beams and trying to recycle them in time for the next module shipment.

Global sourcing also brings considerations related to import and export compliance and anti-dumping laws. Special expertise is needed in this area to avoid surprises related to the disposition of surplus materials and moving materials in and out of special economic-exemption zones. An entire article can be written just about this one area, but the best strategy to avoid surprises is to use a person with proven expertise.

## Assembly and installation

Module assembly, when performed by a qualified company, can support critical schedules and produce the expected safety, quality and productivity that results when such assembly is carried out in a controlled environment. The schedule improvements are significant when parallel construction activities can be conducted in both the module yard and the construction jobsite. Using advanced work packaging, a modular program is typically broken into smaller, manageable and discrete packages with opportunities to separate this work into multiple locations or companies. Module yards are capable of simultaneously working on multiple modules at any given time, meeting the needs of small or large projects. The increased work fronts reduce risk to the construction schedule, increasing access and reducing the overall time to market.

Business and project drivers, risks and constraints influence the decision to incorporate modular execution into a project plan. The decision to incorporate modular execution can stem from possible adverse jobsite attributes in the following areas:

- Site safety
- Site conditions, weather and remoteness
- Availability and cost of labor
- Site location, transportation and other indirect costs to support site labor
- Efficiency and productivity at the site
- Overall quality

Ensuring a safe installation of the design is paramount. The use of modularization can help to reduce risks in several ways. For instance, it may include minimized work above grade (which reduces the potential for fall-related hazards), and it would enable work in covered workshops (out of extreme conditions).

Similarly, modularization benefits from the use of a more consistent work environment. The benefits of transferring construction and labor costs from a congested jobsite to a controlled assembly environment at the module yard can be significant. The reduction in jobsite labor hours also helps to mitigate the risks associated with skilled or limited local (jobsite) labor required to support the project schedule. It also reduces peak manpower, which reduces the overall jobsite indirect requirements, such as support staff and tool rooms, and can reduce the dependency on the adverse qualities of the jobsite.

The controlled environment that is typical of a fabrication and modular assembly yard also enables improved quality control and inspection. Teams should focus on detecting design, equipment and fit-up issues at the shop with adequate time to carry out repairs before a module transfers to the construction site. Sending incomplete modules to the site will have follow-on impacts, resulting in late project completion.

Specific consideration must be accounted for in the schedule to integrate module delivery and the sequence of placing modules at the jobsite. Construction should plan for some staging of modules prior to setting, but avoid excessive storage durations in order to minimize the required extra space for modules to be stored at the jobsite prior to being set into their final places. An integrated module and equipment setting plan requires that all teams proactively communicate, as modularization is heavily dependent on proper schedule and logistics management, and thus deviations can easily appear. It is critical to identify risks related to possible scenarios in advance and be prepared to implement contingency measures, as needed.

As the modules are set into place at the jobsite, multiple work fronts start to open, including the completion of all module interconnections and terminations, and commencement of construction testing and pre-commissioning. Advances in module lifting and setting technology have enabled the use of advanced rigging systems that can be adjusted rapidly to accommodate various module sizes and configurations. Use of these systems increases the setting pace of modules, thus increasing work-front availability. Work fronts encompass available space for construction and work. For example, only after a module is set into place can further work take place to finish it, connect it and test and energize it. With advances in module lifting and technology, modules can be set faster and work fronts opened more quickly. This provides the onsite construction workforce with more available areas for work and the ability to finish the project faster. Investments in this new technology can benefit the schedule immensely.

The construction group will be the recipient of the modules and the modular design. The continued interface with the construction group during all stages of the project will enable a successful module-delivery plan.

## Pre- and site commissioning

Opportunities to improve project value continue into pre-commissioning and site commissioning. At the module yard, modules should have, to the maximum extent possible, completed testing, pre-commissioning and preservation prior to shipment to the site. When testing and pre-commissioning activities are maximized in the module yard, the project achieves a reduction in the site commissioning efforts. This approach requires alignment in the early stages of the project to assist with the planning. The stakeholders, including construction, commissioning and operations and maintenance teams, must provide input during the design phase. This input provides an avenue for the most efficient design incorporating the experience these teams bring to the overall safe operability of the end product.

This input must continue to be an iterative process through formal reviews, or by identifying and addressing issues during design development.

As module walkdowns are completed, areas such as pressure testing, electrical and equipment testing and pre-commissioning can be incorporated into the turnover strategy from the fabrication or assembly company to the jobsite. By incorporating these activities into the turnover strategy, testing and pre-commissioning can be completed in the controlled environment of the module-assembly yard.

The quality assurance of the work is monitored to ensure all modules are fabricated in accordance with specifications and standards prior to loading for transportation to the site. The systems-turnover documentation must also be completed for immediate retrieval at the site.

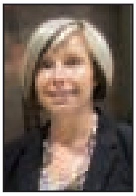
Transporting a tested and pre-commissioned component of an overall site minimizes startup timing after module delivery, as well as site installation and commissioning costs and schedule.

## Closing thoughts

The practical solutions discussed here provide an overview of modular design and execution fundamentals, and offer some recommendations on how to overcome the challenges that advanced modular execution brings. Modular execution is an integrated approach to project management, and affects every aspect of implementation, including engineering, logistics, supply chain, construction and commissioning.

The design of a module provides additional complexities that need to be effectively addressed. This approach will challenge many traditional design and execution methods. Overcoming these challenges will help all stakeholders to deliver success and overall improved project results. ■

*Edited by Suzanne Shelley*



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# Getting the Most from Severe Service Valves

Severe service valves (SSVs) differ from general purpose valves in important ways. Presented here is guidance on how to increase service life, reduce costs and improve safety and environmental performance of SSVs

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CGIS Canada

## IN BRIEF

SEVERE SERVICE CONTROL VALVES

SEVERE SERVICE ISOLATION VALVES

VALVE SELECTION DATA CHALLENGES

DIFFERENTIATING GPVS FROM SSVS

DEFINING SSVS FOR CHEMICALS

SSVS IN PULP AND PAPER

LESSONS LEARNED

FUTURE OUTLOOK

Severe service valves (SSVs) are often identified by applications that challenge the valve's ability to survive, but the term SSV can mean different things to different people. In the past, defining SSVs had little, if any, global agreement or common recognition. That is about to change as the Manufacturers Standardization Society (MSS; Vienna, Va.; www.msshq.org) has accepted an application to produce a standard practice document to define them.

Within these challenging applications, the conditions that make the service severe are being analyzed, quantified and qualified. From this effort, it is expected that objective and repeatable definitions will arise, along with guidance to improve the performance of SSVs, reduce unnecessary costs, provide longer service life and process runs, improve safety and reduce environmental issues.

This article provides information about the selection of SSVs in all chemical process industries (CPI), but focuses on metallurgical processes and applications, and offers examples to illustrate both the successful and unsuccessful use of this type of valve. The intent of the article is to raise the awareness of SSV considerations for all industry stakeholders, including suppliers and manufacturers, specifiers and users, as well as owners. The article also supplies tools to better understand where and why SSVs shoud be categorized separately from commodity, or general purpose valves (GPVs).

Flowserve

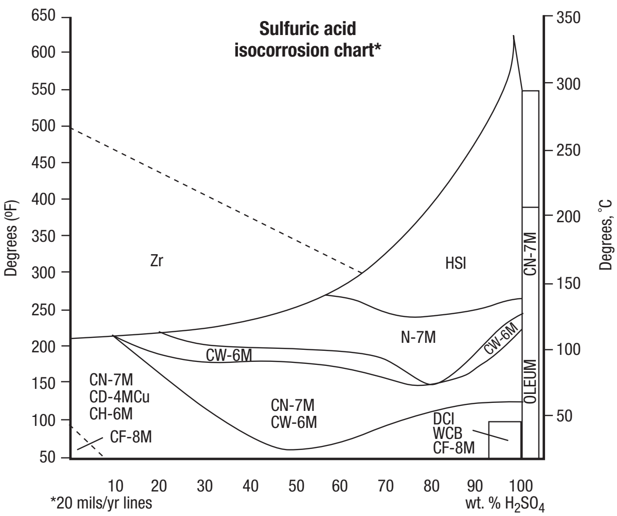


**FIGURE 1. This sulfuric acid isocorrosion chart depicts corrosion performance of several materials**

SSVs can be found throughout the CPI. However, certain industry sectors have many more SSV-related challenges than others. For example, municipal water treatment will have fewer SSV opportunities or needs than the mining or chemical industries.

In general, valves have two basic uses; they either control a process variable (like pH), or they isolate the process. No matter what type of valve — ball, butterfly, check or globe — all fit somewhere into the basic role of control or isolation.

### Severe service control valves

The dilemma facing all users of SSVs is for the valves to remain in service providing their singular functions while performing at the basic level required by the process. Severe services challenge both performance and life expectancy. SSVs must deliver a minimum performance over a minimum period of time. The valve industry does have a better understanding and agreement of what defines a *severe service control valve* (SSCV). Table 1 provides some reasonable thresholds that can be applied to any control valve situation and be used to make a reasonable determination that the application is severe and therefore requires a SSV.

**TABLE 1. DETERMINING FACTORS FOR SEVERE SERVICE CONTROL VALVES (SSCVS)**

| Condition | Formula/reference | Threshold | Notes |
|---|---|---|---|
| Cavitation | $(P_1–P_v) / (P_1–P_2)$ | $\sigma > \sigma_i$ | Cavitation index per ISA–RP75.23 |
| Choked flow | FL | $Q > Q_{choked}$ | ISA–RP75.23 |
| Erosive flow | Velocity normal flow | >8 m/s inlet | Clean liquids |
| Flashing | $P_2 / P_v$ | ≤1.0 | Liquids only |
| High-alloy metallurgy | B16.34 | >Group 3.1 | |
| High energy state | $dP(P_a) \times Q$ | >100 kW | Q is volumetric flow |
| High noise | IEC 60534-8-3&4 | | |
| | >85 dB | | |
| High turndown ratio | $Q_{max}/Q_{min}$ | >10 | |
| Scale precipitation | | >1 mm/yr | |
| Slurry | | >10% solids > 5m/s | Suspended solids |
| **Temperature** | | | |
| High normal operating | | >425°C | Or as per B16.34 |
| Low normal operating | | <–50°C | Fluid temperatures |

An example of a situation that would require an SSV would be where the fluid will likely be at or near a cavitating state. International Society of Automation (ISA) standard RP75.23 provides basic formulas that can be used to determine whether or not a fluid will cavitate in service. At a state of cavitation, fluids are accelerated and their vapor pressure is reduced in a proportional relationship. If the pressure drops below the media's vapor pressure, the fluid will separate into two or more phases — an effect known as flashing. Flashing by itself can and will be erosive to valves and other equipment, but if the downstream pressure recovery is such that the fluid is above its vapor pressure, the resultant collapse of the flashed gas creates the damaging condition of cavitation.

## Severe service isolation valves

For isolation valves, the valve industry has far less agreement and acceptance on definitions of SSVs. Table 2 provides some reasonable thresholds, although it is admitted, the valve community is still debating and discussing these thresholds, and it appears that a combination of these thresholds may need to be present in order to qualify as severe. For example, if we use the temperature threshold of 260°C — the upper useable limit of fluorocarbons — this eliminates one of the best available options for seat materials, and users would be forced into using metal valve seats, which are far more challenging to use and achieve "tight" shut-off isolation performance. "Tight" itself needs further definition and objective measurements and is in fact also being defined by MSS.

Most isolation-valve datasheets lack a clear expectation of isolation performance. For many in the CPI, the standard FCI 70.2 from the American National Standards Institute (ANSI; Washington, D.C.; www.ansi.org) is used blindly as the performance level. It is common to see Class V or Class VI listed frequently as leakage classifications. These classes offer a measurement for "allowable" leak rate. The anomaly is that the title of the standard is Allowable Leak Rate for Control Valves. Control valves can leak because they should not be used as isolation valves, and SSIVs should not leak.

The valve industry is only now catching up with the demands of the highest performance valves and is providing industry users with better tools than those that have been available in the past. For instance, currently, there is no industry standard for isolation-valve performance that does not allow some passing (seat leakage). One can reference a valve test standard, such as the American Petroleum Institute's API 598 or ISO 5208 from the International Organization for Standardization, and add a required performance statement, such as "valve seat testing to API 598 resilient seat." However, doing so eliminates metal-seated valves as options for selection, even though some metal-seated valves are capable of the tightest isolation. For now, the most common isolation valve performance standard in North America is ANSI FCI 70.2, although it has no category for zero seat leakage.

An example of a *severe service isolation valve* (SSIV) would be a situation where the process requires a degree of isolation tightness after two continuous years of installation that exceeds the tightness allowed

**TABLE 2. DETERMINING FACTORS FOR SEVERE SERVICE ISOLATION VALVES (SSIVS)**

| Condition | Formula/reference | Threshold | Notes |
|---|---|---|---|
| Available on demand | IEC 61508 &61511 | 100% | |
| ASME category M fluids | ASME B31.3 | All | |
| Cryogenic fluids | | < –150°C | |
| Fugitive emissions | ISO 15848-1 &2 | <500 ppm | VOCs (volatile organic compounds) |
| High alloy metallurgy | B16.34 | >Group 2.4 | Also all unlisted high alloys |
| High dP | $dP/P_1$ | >0.8 | |
| Solids deposition | | >1 mm/yr | |
| Slurry >10% solids | | >20 barg | |
| Tightness of closure | FCI 70.2 | >Class V | |
| Temperature | >260°C | >260°C | |

**TABLE 3. VALVE POSITION AND IN SITU HEALTH**

| Type | Position | Phase | Severity | Determining factor(s) |
|---|---|---|---|---|
| Isolation | Open fully | Steady dynamic | Medium | Pipeline flow variation |
| Isolation | Cycling closed | Accelerating dynamic | High | Number and duration of cycles |
| Isolation | Cycling open | Decelerating dynamic | High | Number and duration of cycles |
| Isolation | Closed fully | Steady static | Low | Tightness of closure |

in FCI 70.2 Class V. A typical application for this example could be a high-pressure steam boiler drain. This is because a drain valve contains the energy inside the boiler until it is time to empty the valve, and while isolating the steam, any passing (leakage) will lead to loss of efficiency, wasted resources (fuel, demineralized water), and that leakage will lead to increased seat wear and even more leakage.

## Valve selection data challenges

The focus on SSVs has uncovered a lack of data that has been responsible for making the proper selection of SSVs more challenging and therefore more prone to failures. When the datasheet of a control valve is compared to one for an isolation valve, observers will commonly discover that a fundamentally important element is missing from the isolation valve datasheet. The static conditions will be presented in the datasheet, along with maximum design temperature, pressure, pipe size, media, class, material of construction and often flowrates from minimum to maximum. For a control valve, this is all that is really needed because the control valve operates 100% of the time within the dynamic conditions that can be calculated from the data between minimum and maximum flowrates. But for an isolation valve, which is typically static for most of its service life, without knowing the number of cycles and normal operating position (normally either open or closed) engineers cannot properly consider the effects of the dynamic conditions that occur when transitioning between open and closed or vice versa (Tables 3 and 4). It is this transitional state that exposes the valve to very different conditions than those when it is at rest and when it is most vulnerable.

When isolation valves leak, passing energy in the form of differential pressure can produce a velocity increase and the media can become a destructive agent, removing mass from the seating areas. This makes the leak worse, and eventually the isolation valve is incapable of operating in its intended form.

Determining the minimum level of isolation that is required at the end of the service life of an SSIV is critical. That demands understanding what the lifecycle of the valve will be and all of the conditions that will be experienced during the valve's life. Without this full knowledge, it is extremely difficult to select the valve type, the sealing system, materials of construction and the valve bore, in addition to the operation, whether manual or automated, and special options demanded by the application.

## Differentiating SSVs from GPVs

A simple definition of a SSV is a valve that survives in a given application for a defined duration while performing a basic function (isolation or control) up to and until the agreed duration is reached. Those valves that cannot demonstrate this performance level are classified as general purpose valves (GPVs).

As indicated earlier, isolation valves have a more challenging definition than control valves. Severe services are identified by applications. If the process is such that the temperature, pressure, velocity, abrasiveness, corrosiveness or some combination of these parameters challenges the valve's ability to maintain a basic performance level, then a valve that succeeds in that application is an SSV.

SSVs are important because the consequence of a failure or degradation of performance will have a higher negative impact on the process within which it is operating than GPVs. It may be a surprise to most that not all isolation valves isolate to the same ability or tightness, nor do all types of isolation valves have similar or even close performance abilities. Tightness is relative and often misunderstood. In general, the valve industry has done a poor job of being sufficiently transparent and objective.

It is important to understand that not all isolation valves need to be perfect in the duty; the application will always dictate what is actually required and there will be applications where some through-leakage is unimportant, while for others, it will be critical. This article will shed some light on both ends of the spectrum.

As stated earlier, SSVs can be used in nearly every process and industry, but they are essential in a few. The chemical industry uses a large number of SSVs and some will be examined here. While in a technical sense, all substances are chemicals, for the purpose of this article, the examples discussed involve chemicals that, if their containment is lost, can cause great damage to personal health, property and equipment. A good example of such a chemical is hydrochloric acid (HCl).

HCl is corrosive; it will literally dissolve metals into solution, and if the integrity of the containment of the hydrochloric acid is lost, then the acid may present multiple hazards to unprepared people, equipment and ancillary processes. Corrosion is one of the key elements in the determination of SSVs — an SSV's resistance to corrosion is often of paramount importance.

## Defining SSVs for chemicals

While there are many benign chemicals (water is a chemical), many chemical manufacturing processes and the chemicals that are used and produced are dangerous. They can be toxic, explosive, aggressively reactive or corrosive. These types of chemicals need containment and management so that they are not released in areas where their properties can result in damage or where they can be lost to the downstream process for which they are designated.

For containment of hazardous chemicals, if the purpose of the valve is isolation, then resistance to corrosion from the process fluid needs to be considered carefully. Design codes like the American Society of Mechanical Engineering standard ASME B16.34 provide operating pressure and temperature limits for each pressure class at various operating temperatures for categories of materials. For example, valves of ASME Standard Class 300 for Group 2.2 materials, consisting of several grades of stainless steels including the common forged and wrought 316 and cast CF8M steels, have a working pressure by Class (in psig) at a range of temperatures. A Class 300 valve of this material operating between –29 to 38°C, has a 720-psig pressure limit, the valve's maximum allowable working pressure (MAWP).

In order to meet that working pressure, the manufacturer will produce a valve body with a minimum body-wall thickness. This wall thickness will be thicker than necessary to provide an additional safety margin. In factory testing, this extra safety is proved by pressurizing the body to 50% beyond the MAWP during its factory hydro-test.

If the corrosion begins to reduce the wall thickness either evenly or in discrete pockets or sections, the valve becomes vulnerable to loss of containment. When referring to the sulfuric acid isocorrosion chart (Figure 1), lines depicting less than or equal to 20 mpy (milli-inches, or mils, per year) corrosion. Note how alloy CF8M is only suitable for very weak or very strong acid at low temperatures and alloy CD4MCu disappears from suitability, while two others that were in the same suitable category remain for a range of higher temperatures.

Respecting the overall piping system's corrosion allowance, often expressed as *x* mpy, engineers should generally select valves with a trim (the sealing parts) that have a corrosion rating of less than 1 mpy, while the valve body would have a corrosion rating of less than 20 mpy. This practice leads to examining the body-wall thickness during the time the piping is examined. Some applications requiring SSVs would demand a lower corrosion allowance, based on the severity of an upset, the time period between maintenance turnarounds or minimum process runs.

### SSVs in pulp and paper

An example application of SSVs is in the pulp-and-paper industry, where chemicals for bleaching the pulp have evolved from chlorine ($Cl_2$) into less dangerous chlorine dioxide ($ClO_2$), sodium hypochlorite (NaOCl) or hydrogen peroxide ($H_2O_2$). For the kraft pulp process, cost efficiencies have encouraged the mills to create the necessary chemicals required on-site in a plant within a plant, known as Chem Prep. One process within this sub-plant can produce the

CGIS

**FIGURE 2. The iron disc of this seated butterfly valve was dissolved by sulfuric acid after the PVDF coating was removed by flowing acid**

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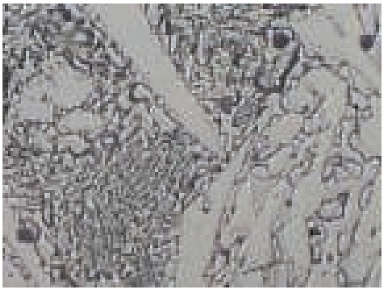

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**FIGURES 3 AND 4. Proper heat-treatment of metal valve components can have a crucial effect on valve performance. The micrograph on the left shows a non-heat-treated metal structure at 200-times magnification, while the right image shows the metal after heat-treatment (same magnification)**

bleaching agent — chlorine dioxide.

Chlorine dioxide can be made by reducing sodium chlorate in a strong acid (sulfuric or hydrochloric acid) solution and a reducing agent like methanol, hydrogen peroxide or sulfur dioxide. The basic production route is: chlorate + acid + reducing agent → chlorine dioxide + byproducts. A commercially important production route uses methanol as the reducing agent and sulfuric acid for the acidity. Advantages of not using chloride-based processes are twofold; the formation of elemental chlorine is eliminated, and sodium sulfate, a valuable chemical for the pulp mill, is a side-product.

## Lessons learned

Decades worth of experience working with SSVs in the CPI have allowed the author and other industry experts to glean many important lessons. The following are three that are helpful to consider when selecting your next valve.

***Lesson 1: Consider the whole application***. The photograph in Figure 2 is a testament to the idiom that "you get what you pay for," and it shows the importance of considering the application holistically to avoid adverse outcomes. In 1995, a new copper mine was built in Chile. It was designed to use 85 g/L of weak sulfuric acid to irrigate a heap of copper oxide ore. The acid was sprayed over a huge pile of crushed ore, which leached the copper into solution, where it was later electrowon out into pure copper cathodes. This type of mine and process plant is known as a heap leach-SXEW (solvent extraction, electro-winning).

The original process designers selected titanium as their corrosion-resistant material of construction for the valves used to direct and isolate the weak acid. These 24-in. valves cost upwards of $60,000 each originally. When a small brownfield project later arose, the local project team balked at the price and decided to investigate alternatives. They checked the corrosion charts and saw that a Buna-N (nitrile rubber) resilient seated ductile iron butterfly valve with a PVDF (polyvinylidene fluoride)-coated ductile iron disc was rated "A" for the temperature and the 85 g/L concentration of sulfuric acid. These valves cost under $6,000 each, far lower and much more attractive for the buyer.

The problem with this type of valve is that they only lasted a few months because they were not used only as full open-or-closed isolation valves. Besides being used to isolate the centrifugal pumps for maintenance, the valves were also used on the discharge of the pumps to assist the pump during startup to develop head pressure. That required them to be placed in the near closed position. Unfortunately, the velocity of the acid that was developed while nearly closed was so high that it physically removed the thin PVDF coating covering and protecting the ductile iron disc. This exposed the iron disc and the acid simply dissolved it. Of note, the originally supplied titanium valves are still in service 22 years later. Sometimes buying cheap costs more in the longterm.

***Lesson 2: Use properly processed materials***. At a recent valve conference in Düsseldorf, the global audience heard a presentation from the quality assurance (QA) manager of a major global chemical company. The QA manager identified a significant number (more than 35%) of the material test reports (MTRs) for valves and fittings purchased by his company during the year were incorrect, missing, contained obvious errors and, in some cases, were fraudulent. If this is a common occurrence, then the confidence in the valves used in severe service applications is surely mistaken.

The information in the presentation was reminiscent of a situation the author experienced at a plant in Australia in 2006. A distraught client reported a number of valve issues related to the leakage of sulfuric acid in the plant.

An investigation of the situation focused attention on the knife gate valves that had been provided by the author's company. The manufacturer used castings to make the valve bodies and wrought plate to make the blade. For the casting material, the material selected had been ASTM A890 Gr 5a, a super-duplex stainless steel well suited for the 70–80°F temperatures of the 40 wt.% sulfuric acid in the countercurrent decantation circuit of this hydrometallurgical facility.

For several years, these valves worked flawlessly. The client became very comfortable and decided to try them in an upstream, more challenging process — one in which the temperatures reached 200°F. The higher temperatures resulted in a significant problem. From the isocorrosion chart for sulfuric acid, it can be observed that this acid creates some interesting variations based upon the weight percent and temperature. At the higher temperature, the material had a lower corrosion resistance.

The investigation also exposed the potential for issues using the A890 ASTM method. The non-destructive testing is a little weaker than the more popular ASTM A995 method used today. Metallurgical testing showed that the castings were improperly heat-treated (Figures 3 and 4). While at the lower temperatures, the acid was not as aggressive at exposing the poor manufacturing, but at the higher temperature, the flaws were exposed and the valve failed to contain the acidic solution.

This situation is another case of "you don't know what you don't know" and the experience with this issue caused the author's company to re-evaluate its own QA systems, including purchasing. Key vendors were requested to provide better control of the vendor data to eliminate, or at least greatly reduce, errors that could lead to future valve issues.

Of particular interest, the gate material, which was made from plate (wrought UNS S32750 alloy) was minimally affected by either temperature. This is not to imply that wrought materials are better than cast ones, only that properly processed materials are what is really important.

***Lesson 3: Don't ignore the importance of plastics***. Metals are not the only material of construction used to fight against corrosion. Plastics and elastomers are also effective allies in the effort to protect against corrosion from a particular chemical or chemical process. The invention of fluorocarbons like Teflon (polytetrafluoroethylene) and its variants has given the valve industry a wonderful family of extremely corrosion-resistant materials.

Valves for corrosive services are often lined with one of the fluorocarbons, normally Teflon PFA, a perfluoroalkoxy copolymer which can fully isolate the valve body from the process medium. These plastic materials do not corrode like metals, but can and do allow fluids to permeate them. Thus, the quality of their manufacturing to reduce the permeability, the type of liner used, how the plastic components are anchored into the body, as well as the thickness of the lining, are all keys to preventing damage and failure of the less-noble and generally non-corrosion-resistant valve bodies that provide the application's pressure containment and retention.

Very few solid plastic valves have the strength to withstand the needs of even the lowest ASME B16.34 Class 150 pressure-retaining requirements and are typically rated to a maximum of 225 psig or lower at ambient temperatures. Lined metal-body valves are available fully rated to ASME Class 150 and up to and including Class 300, 720 psig at ambient temperatures. These alternatives to solid metallic valves often offer significantly reduced acquisition costs over high-alloy valves and can provide equivalent long-lasting service lives if selected and operated correctly. Of course, the maxim "the application dictates the valve" applies,

**TABLE 4. CORROSION ALLOWANCE DATA FOR VALVE HEALTH (MIL PER YEAR)**

| Corrosion allowance | Valve health |
|---|---|
| < 1 mpy (0.025 mm/yr) | Excellent |
| <20 mpy (0.50 mm/yr) | Good |
| <50 mpy (1.27 mm/yr) | Satisfactory |
| >50 mpy (1.27 mm/yr) | Poor |

and it is incumbent upon the valve selectors to consider all aspects of the valve requirements.

A significant challenge for plastic-lined valves has been that there are no industry standards that provide guidance on what the minimum thickness should be or on any of the other key manufacturing details that make the valve a successful piece of process equipment.

For a Teflon PFA-lined, weir-style diaphragm valve, a typical 3-mm-thick body liner is the norm and is generally sufficient to provide protection for the ductile iron body. This rigid liner is formed over the weir, which serves as the base seat for the moving diaphragm seal (Figure 5). Together, the combination provides the isolation. Due to Teflon's relatively inflexible and non-resilient properties, the diaphragm consists of a thinner layer cushioned by an elastic resilient material, such as EPDM (ethylene propylene diene monomer) or Viton.

This combination diaphragm seal must be able to flex multiple times without distortion or damage. Yet there is a line between how thin the corrosion-resistant liner should be to allow multiple flexing and how immune it is to the stress caused by the closure of the handwheel and that rotary-to-linear torque-to-thrust ratio. Too much torque will cause the PTFE to cold flow and weaken, perhaps to a point where the protective liner is compromised and the liner is torn, exposing the less resistant elastomer cushion to the process media, as well as to an uneven sealing surface that allows leakage even when the valve is fully closed.

When it is impractical or impossible to limit the closing torque's potential for damage, simply changing valve design can be the obvious solution. One approach is to convert multi-turn linear force into quarter-turn rotary action, as shown in the lined ball valve (Figure 6).

*Gemu*

**FIGURE 5.** **Plastic-lined metal diaphragm valves can offer effective solutions in severe-service applications**

Thankfully, MSS will shortly publish "Plastic-Lined Ferrous Metal Valves" as a Standard Practice. The scope covers plastic-lined ferrous metal valves intended primarily for conveying corrosive fluids. This new tool will recommend minimum liner thicknesses, grades and formulations of plastic liners including PFA, PTFE, PVDF, PP and UHMWPe, liner anchoring, inspection and testing

## Summary and future outlook

The valve industry is working to provide better information to ensure the correct selection of SSVs and the proper language to nominate the valve so that it can function in service and meet or exceed expectations. We have discovered the need for more details on the actual process dynamics, including the percentage of time spent during different dynamic conditions, as well as upsets, and to consider what those dynamic situations are doing that could damage the function of the valves, whether immediately or over time as the sum of the damage adds up.

There are many applications requiring SSVs, just as there many for GPVs, and knowing where to draw that line is essential in obtaining the best, safest and lowest-cost valve solutions. In the coming months, the industry will see better tools for identifying SSVs, including new standards for SSV testing, defining SSVs, standard practices for corrosion-resistant-lined valves and deeper knowledge that will assist in providing better valves for the most challenging applications.

*Flowserve*

**FIGURE 6.** **This ball valve uses quarter-turn rotary action to open and close, rather than multiturn linear force**

Our exposure over the last five decades to a wide range of industrial applications in all of the regions of the world has provided us with an appreciation that communication is a key aspect of success and without it, of failure. Industry's acceptance of terms like "high-performance" and "tight shut-off" gave false confidence and assurance that valves will work in difficult applications. We have begun to rid ourselves of subjective terminology and have started to bring objective and measureable performance to the task. This greatly enhances everyone's chances of success. ■

*Edited by Scott Jenkins*

## Author

**Ross Waters,** president of CGIS (558 East Kent Ave. South, Vancouver, B.C., Canada; Phone: 604-263-1671; Email: ross@cgis.ca; website: www.cgis.ca). CGIS parlayed an early focus on chemical processes and exposure to several corrosive chemicals into an eventual specialization in SSVs. The company has expertise in valves using a range of materials, including titanium, Inconels, Hastelloys and fluorocarbons such as PVDF and PTFE. Waters has been involved with industrial valves for over fifty years. Initially working in the bleached kraft pulp-and-paper industry and learning from Canadian chemical-plant-engineering company Chemetics, Waters grew his passion for supplying the highest performance valves into a life-long pursuit. Today, Waters serves on the ASTM Gaseous Oxygen Committee and the Manufacturer's Standardization Society as a task force member on C-114 Steel Valves and C-409 Knife Gates. He also chairs the task force committed to publishing a new standard on severe service valves.

# Improve Energy Efficiency using Hydraulic Power Recovery Turbines

This mature technology can be used to save energy, generate revenue and reduce emissions

**Sebastiano Giardinella, Katherine Chung and Martín Ávila**
Ecotek group of companies
**David López**
Ambitek Services, Inc.

With the Paris Agreement entering into force last November, the Parties to the Convention established their goals to implement measures to reduce the amount of greenhouse gas (GHG) emissions in order to combat climate change. The application of these measures in the chemical process industries (CPI) involves the study and employment of alternatives to improve energy efficiency and reduce emissions in an energy intensive sector.

Often in the CPI, a considerable amount of energy is wasted in pressure control valves, where high-pressure fluids must undergo a pressure reduction. Examples of this abound, such as gas sweetening (where the high-pressure rich amine stream is expanded to enter the low-pressure amine regenerator, and the lean amine is pumped back to the high-pressure absorber); gas dehydration (where the high-pressure rich glycol is expanded to enter the regenerator, and the lean glycol is pumped back); pipeline pressure-regulation stations; and others.

In these processes, a significant amount of energy can be recovered by employing hydraulic power-recovery turbines (HPRTs) where the fluid is incompressible (liquids), or expanders where the fluid is compressible (gases).

In these devices, the energy recovered in pressure reduction, which would otherwise be lost in throttling, is transformed to rotational mechanical energy, which can then be used to directly drive another rotating machine, or an electrical generator.

Even with low electricity prices, HPRT and expander technologies have advanced to a point where they represent reliable, economically feasible solutions to reduce power consumption and emissions from the CPI.

This article focuses on HPRTs — describing their main types and components, and summarizing how an operations manager, consultant or energy auditor in the CPI can assess the economic and environmental benefits of a potential HPRT installation.

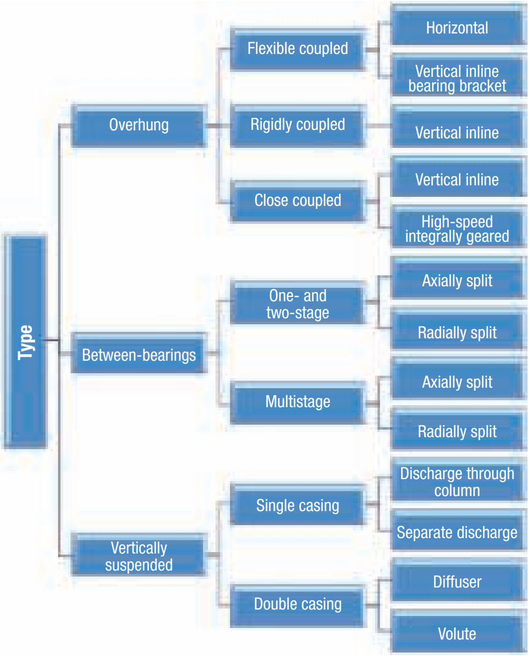


**FIGURE 1. This chart shows the classification of different types of hydraulic power-recovery turbines (HPRTs)**

## HPRT characteristics

An HPRT is a machine that transforms an incompressible fluid's hydraulic energy to mechanical energy, by reducing its pressure. The rotational mechanical energy can then be used to drive another rotating machine, or an electric generator.

In essence, an HPRT is very similar to a centrifugal pump working in reverse flow (that is, with fluid entering from the high-pressure nozzle, and being discharged from the low-pressure nozzle), and so is its mechanical design, with a runner being used instead of an impeller. In this regard, American Petroleum Institute standard API STD 610 [*1*] includes an appendix dedicated to those features for HPRTs that are different from those of a centrifugal pump.

HPRTs can be classified based on the configuration of their runners: overhung, between bearings or vertically suspended. Each type can be further classified depending on their couplings, number of stages, number of casings and geometry, as shown in Figure 1.

Performance-wise, an HPRT compares with a pump as shown in Figure 2. The HPRT efficiency curve typically follows the same behavior of a centrifugal pump, with a maximum efficiency that is similar, or slightly higher than that of the equipment being used as a pump. HPRTs typically have a minimum flowrate requirement that is slightly higher than that of a centrifugal pump, below which the HPRT begins to consume power, rather than generate it.

The HPRT efficiency curve can also vary depending on its internal geometry, as shown in Figure 3. For instance, by having a variable geometry, with guide vanes adjusting their angle depending on the flowrate, the efficiency of the HPRT is improved over the en-

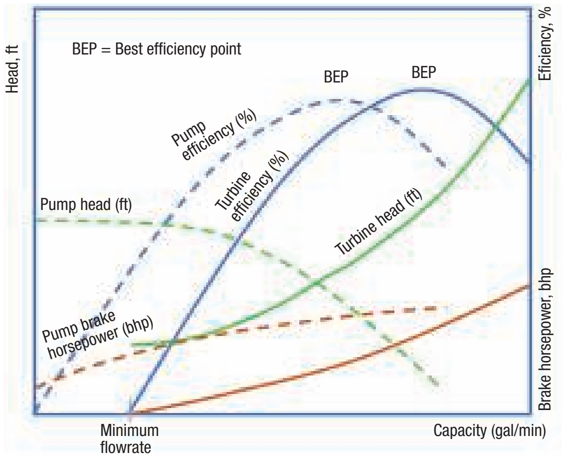


**FIGURE 2.** This graph shows the comparison of head, efficiency and horsepower curves between a pump and an HRPT

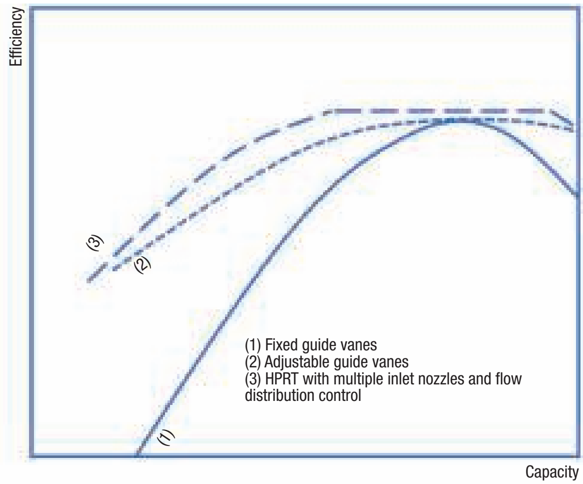


**FIGURE 3.** Shown here is the efficiency curve for three different HPRT constructions

tire capacity range when compared with a fixed-geometry HPRT. One HPRT manufacturer also offers multiple inlet nozzles with flow distribution control, which, apart from widening the operating range of the HPRT, also "flattens" its efficiency curve, creating a "best efficiency range," instead of a best efficiency point.

Fluid properties affect HPRT efficiency in the same manner as in centrifugal pumps, with higher-viscosity fluids reducing the efficiency. Some HPRTs tolerate flashing at their discharge, which greatly increases the power output.

## HPRT process arrangement

The main HPRT equipment assembly includes the HPRT coupled to a generator or a pump.

When used to drive a pump, the HPRT is typically not used as standalone driver, but rather in a train arrangement where the HPRT and a motor act as dual drivers, with the pump drive rotating at the motor speed, or at a greater than motor speed, as shown in Figures 4 and 5, respectively.

When used to drive a generator, the mechanical assembly varies when coupled to a synchronous generator (which requires a governor to maintain a continuous rotation speed, synchronizing directly to the output voltage frequency), or an asynchronous generator (where the output voltage frequency is regulated by the power system to which the generator is connected).

An asynchronous generator has significant advantages when used in HPRT applications. These include relatively low cost; slip and overload capacities; and can more easily accommodate process variations, such as changes in flowrate, inlet and outlet pressure and fluid properties.

From a process point of view, a complete HPRT installation typically includes the components shown in Figure 6. This simplified scheme depicts an HPRT coupled to an asynchronous generator, with a variable-frequency drive (VFD) adjusting the output power characteristics to match those of the grid. Important components to ensure the operability and protection of the system include the following:

***Over-speed trip.*** This protects the equipment from an excessive speed derived from unexpected process conditions that could damage the equipment.

***Throttle valve.*** The inlet flowrate is typically controlled by a throttle valve placed upstream, near the HPRT inlet, especially where gas evolution is expected, to allow for a larger power output. Some manufacturers prefer to locate the throttling valve downstream of the HPRT. Other manufacturers also offer multiple turbine inlet valves, where the flowrate added to each nozzle is controlled in order to maximize efficiency through a range of capacities.

***Bypass valve.*** A modulating bypass valve sized for full flow is installed to allow for operational flexibility, if there is a contingency with the HPRT, and when the HPRT is taken out of service (for instance, for maintenance). Normally, the control between the turbine flow valve and the bypass valve is split range. When the HPRT is installed to replace an existing throttling valve, the latter can be left as a bypass, by making the necessary control adjustments.

***Relief valve.*** A pressure safety valve (PSV) is also typically installed downstream of the HPRT to protect the low-pressure line and equipment.

***Seal flushing system.*** A seal flushing system based on API STD 682 [2] is generally recommended for an HPRT. Some manufacturers present alternative assemblies, such as seal-less HPRTs.

***Utilities.*** A typical HPRT arrangement also requires a lubricant-oil system, instrument air for pneumatic equipment, instrumentation and controls. It may also require inert gas, such as nitrogen, when handling flammable fluids.

***Instruments and controls.*** Important variables to measure include inlet and discharge pressure, flowrate, rotational speed and power output.

## HPRT process design

When preparing a request for quotation (RFQ) for an HPRT, the first step is to define and specify the service conditions to the manufacturer. These includes the following:

- Operating conditions (pumping temperature, flow, discharge pres-

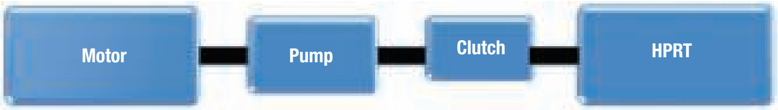


**FIGURE 4.** The arrangement of an HRPT with pump drive at motor speed is shown here


**FIGURE 5.** Shown here is the arrangement of an HPRT with pump drive at greater than motor speed

sure, suction pressure, differential pressure, differential head and hydraulic power)
- Design conditions (inlet and discharge design pressure, design temperature, rating and so on)
- Liquid properties (liquid relative density, vapor pressure, specific gravity and viscosity)
- The site and utility data (mounting location, electric area classification, site data such as elevation and atmospheric pressure, unusual conditions, and utility conditions, such as electricity, cooling water, instrument air and steam)

Also, a sketch of the installation, indicating whether the HPRT will be used to drive a rotating machine or be coupled to an electrical generator, is recommended, along with other electrical data (electrical area classification, type of generator, power output, voltage and frequency and so on).

Once the proposals have been received, the first step is to make sure that the data given to the bidders in the specification was used as input for the design.

Then, the customer can review the HPRT performance curve and predicted power output to check that the proposed equipment meets the service conditions. Ideally, an HPRT will be selected so that the operating point is near the best efficiency point (or "best efficiency range," as offered by some manufacturers).

Care must be taken to ensure that the bidder reports electrical power at the generator terminals, as opposed to only brake power. If the bidder is reporting brake power, then the purchaser must deduct other mechanical and generator losses to compare with other bidders.

Other technical considerations to be taken into account when evaluating proposals include the following:
- Does the bidder offer a turn-key package (for example, a skid-mounted unit including the HPRT, generator, plus all the piping, valves, electrical, and instrumentation components), or only the equipment (for example, HPRT and generator)?
- Does the bidder offer a warranty for the entire system, or only for the HPRT?
- Can the proposed equipment handle predicted variations in fluid conditions, flowrates and properties?
- Can it handle solids (maximum particles size), vapors, corrosive, abrasive or other foreseen contaminants in the fluid?
- Does the proposed equipment meet the area classification and other safety requirements?
- Does the bidder offer technical support? Does it have online monitoring capabilities to assess equipment performance remotely?
- What other references for previous installations can the bidder provide?
- What are the maintenance requirements (for example, replacement of parts, recommendable spare parts stock and so on)?
- Other criteria, as applicable

Finally, an economic analysis should be performed on each alternative, in order to compare the return on investment of each option. A higher initial investment can be justified by a higher equipment efficiency, which in turn translates into more savings each year.

## Economic benefits of an HPRT

The installation of an HPRT can be economically justified in many scenarios by savings in electrical power or fuel consumption, or by earnings from electricity sales to the grid. In some cases, the equipment payback period can be less than two years.

To calculate the savings (or earnings), the purchaser (or consultant) must first calculate the available hydraulic power that can be recovered in an HPRT, taking into account the fluid flowrates, properties and conditions, using the following equation:

$$W_{hyd} = Q \cdot \rho \cdot g \cdot \Delta h / 3{,}600 \quad (1)$$

Where:
$W_{hyd}$ = HPRT hydraulic power, kW
$Q$ = Flow capacity, $m^3/h$
$\rho$ = Fluid density at operating conditions, $kg/m^3$
$g$ = Acceleration due to gravity, 9.81 $m/s^2$ at sea level
$\Delta h$ = Differential head, m

Or, in U.S. customary units:

$$hp_{hyd} = Q_{gpm} \Delta P_{psi} / 1{,}715 \quad (2)$$

$$W_{hyd} = 0.7457 \cdot hp_{hyd} \quad (3)$$

Where:
$hp_{hyd}$ = HPRT hydraulic power, hp
$Q_{gpm}$ = Flow capacity, gal/min
$SG$ = Fluid specific gravity, unitless
$\Delta P_{psi}$ = Differential head, ft

Then, the hydraulic power is multiplied by the HPRT efficiency to obtain the brake power:

$$W_{brake} = W_{hyd} \cdot \eta_{HPRT} \quad (4)$$

Where:
$W_{brake}$ = HPRT brake power, kW
$\eta_{HPRT}$ = HPRT efficiency, unitless

Typical HPRT efficiencies can be higher than 80% for water, and higher than 70% for other viscous fluids, such as petroleum.

If the HPRT is used to drive another piece of rotating equipment, the total energy savings is obtained by multiplying the HPRT brake power by the efficiency of the clutch, and other mechanical devices between the HPRT and the driven equipment. Additional electrical consumption from auxiliaries (control valves, instruments, control panel and so on) is also deducted to obtain the net power savings. The total saved energy in a year is obtained by multiplying this value by the number of running hours in a year.

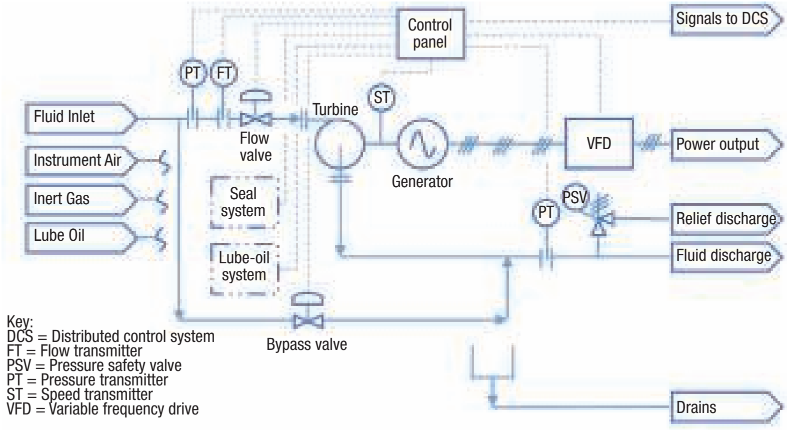


**FIGURE 6.** Shown here are the typical components used in an HPRT system (with inlet flow control)

$$E_{save,dr} = \left(W_{brake} \cdot \eta_{clutch} \cdot \eta_{coup} - W_{aux}\right) \cdot 8{,}760 \cdot A \quad (5)$$

Where:
$E_{save,dr}$ = Energy savings from HPRT as driver, kWh
$\eta_{clutch}$ = Clutch efficiency, unitless
$\eta_{coupled}$ = Coupled equipment efficiency, unitless
$W_{aux}$ = Auxiliaries power consumption, kW
$A$ = HPRT availability (Available running hours per year ÷ 8,760 hours)

If the HPRT is used to generate electricity for the grid, the power output is obtained by multiplying the HPRT brake power by the efficiency of the generator. Additional electrical consumption from auxiliaries (control valves, instruments, control panel and so on), and losses in electrical equipment (VFD, switchgear, step-up transformer, power lines and so on) are also deducted to obtain the net power output. The total energy exported in a year is obtained by multiplying this value by the number of running hours in a year.

$$E_{\exp} = \left(W_{brake} \cdot \eta_{gen} \cdot \eta_{aux} - W_{aux} - W_{loss}\right) \cdot 8{,}760 \cdot A \quad (6)$$

Where:
$E_{exp}$ = Energy exported to grid, kWh
$\eta_{gen}$ = Generator efficiency, unitless
$W_{aux}$ = Auxiliaries power consumption, kW
$W_{loss}$ = Power losses in electrical equipment and power lines, kW

Then, the savings (or revenues) can be calculated to assess the economic benefits.

When the power recovered by the HPRT is utilized at the same site (for example, in an amine regenerator, where the HPRT recovers power from the rich amine stream and drives the lean amine pump), the HPRT is economically justified by the savings in electrical consumption through the equipment life period (if the electricity is supplied by a utility or third party), or by the savings in fuel that would be burned to generate such electricity (if the facility generates its own electricity).

When the power recovered by the HPRT exceeds the local power needs (for example, in a pipeline pressure-regulation station), the excess power can be exported to the grid. In this case, the facility design would need to consider the local utility interconnection requirements, and any specific regulations and procedures applicable to cogeneration. Depending on the project specifics, the owner can then select to either feed the power to the grid in exchange for credits from the utility (as is the case with distributed generation), pay the utility a transmission and distribution charge so the power can be used at another owner's facility (for instance, a pump station), or sign a power-purchase agreement (PPA) with the utility or another power consumer. The earnings in each case vary, depending on local regulations and market conditions.

Other incentives may apply as additional earnings, from either the implementation of energy efficient measures, or by emission reduction credits in emission markets.

## An example calculation

To get an idea about the potential savings, an example calculation is provided here.

***The problem.*** An HPRT is to be installed in a natural-gas sweetening plant, to replace the pressure letdown valve at the rich amine line to the regenerator. The HPRT will be used to drive an electrical generator, and the power will be fed to the plant electrical distribution system to supply power to local loads. The HPRT will handle 500 gal/min of fluid and a pressure drop of 1,000 psi. The efficiency of the selected HPRT is 75%, whereas the efficiency of the asynchronous generator and connected VFD are 95% and 98%, respectively. The HPRT will require an additional auxiliary load of 2 kW. The distribution system losses are not taken into consideration in the analysis. The plant manager wishes to calculate the savings in electrical energy in a year, considering that the HPRT will run 95% of the time, and the local electricity cost is \$0.10/kWh.

***The solution.*** Using Equation (2), the HPRT hydraulic power is:

$hp_{hyd}$ = (500 gal/min × 1,000 psi) ÷ 1,715 = 292 hp

In kilowatts:

$W_{hyd}$ = 0.7457 × 292 hp = 217 kW

The HPRT brake power is:

$W_{brake}$ = 217 kW × 0.75 = 163 kW

The net energy output in a year is:

$E_{exp}$ = (163 kW × 0.95 × 0.98 – 2 kW) × 8,760 × 0.95 = 1,246,662 kWh

The net energy savings in a year are:

Annual energy savings = 1,246,662 kWh × \$0.10/kWh = \$124,666.

## Environmental benefits

The environmental benefits of recovering electricity include, mainly, the reduction of emissions (carbon dioxide, carbon monoxide, oxides of nitrogen and sulfur, particulate matter) that is achieved when substituting energy that would otherwise be generated through the combustion of fossil fuels.

The amount of emissions reduced each year can be calculated by multiplying the amount of annual electricity savings by the emissions factor of the main power source in the facility.

The emissions factor varies for each technology type, location and fuel. Some calculation methods assume an average emission factor for a given technology and fuel (for example, gas-fueled combustion turbine, diesel-fueled reciprocating engine or others); whereas other methods are based on calculating the amount of fuel saved, and their composition (C, H, S, N). Some of these methods can be consulted from a number of references [*3–6*].

## Concluding remarks

HPRTs are a mature technology, with several decades of application in different industries. Their principle of operation is similar to that in hydropower stations, and they can be reliable, technically and economically valuable options to reduce emissions while also securing important economic benefits for the CPI. ■

*Edited by Gerald Ondrey*

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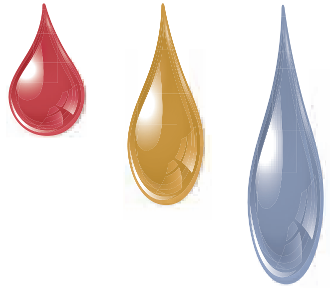





# Guarding Against Fires and Explosions Caused by Self-Heating

## The two experimental methods presented here can be used to quantify powder self-heating hazards in layer and bulk conditions in industrial processes

**Guibing Zhao**
Chilworth Technology, a DEKRA Insight company

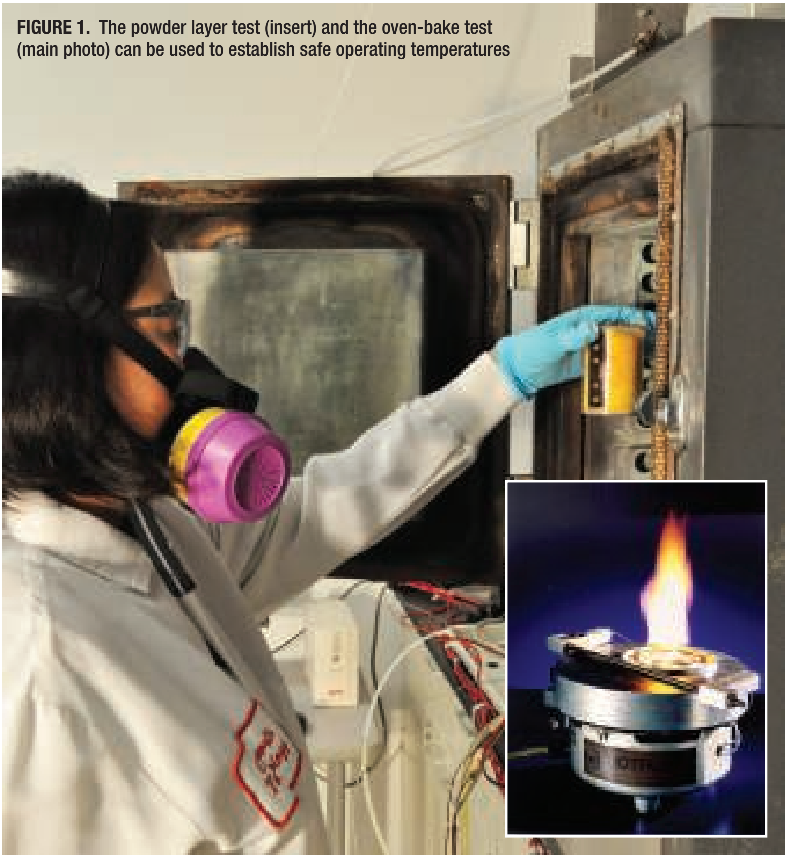

**FIGURE 1.** The powder layer test (insert) and the oven-bake test (main photo) can be used to establish safe operating temperatures

Bulk storage of heated powders and powder accumulations on hot surfaces or in heated environments can potentially lead to self-heating and spontaneous ignition. Examples of locations within processing companies where self-heating of powder accumulations may be expected include uninsulated steam pipes, inappropriately rated or selected electric motors and lighting fixtures, mechanical mills and inside surfaces of various dryers. Self-heating is a complicated phenomenon consisting of both an exothermic chemical reaction and a heat-transfer process, which can cause material smoldering and even lead to fires and dust-cloud explosions.

The parameters that affect the actual self-heating for a given material, include bulk size and shape, temperature, time and oxygen/air accessibility. Appropriate tests have been developed to predict self-heating hazard under plant-scale conditions. This article introduces the "layer powder" screening and the advanced "basket" tests (Figure 1) that may be used to deduce the reaction kinetics and therefore to extrapolate the laboratory-scale test data to the plant-scale so that the data can be used to establish safe operating limits for operating temperature, critical bulk size, and residence/exposure time.

### The dangers of self-heating

There is potential for a thermal runaway and spontaneous combustion if a material can self-heat due to decomposition or exothermic reaction with air. This article focuses on self-heating of solid materials. However, it should be noted that self-heating may also occur in gas or liquid phases.

Self-heating is a complicated phenomenon related to exothermic reaction kinetics of the material, heat transfer (sometimes including mass transfer) in both body and external surface of the bulk material, induction time, geometry and size of bulk material, and ambient temperature. Self-heating of solid materials may lead to smoldering, flaming or dust explosions, particularly when the smoldering material is disturbed and exposed to air. Self-heating reactions may also compromise product quality or produce flammable gases, which may lead to gas explosions in process vessels. Self-heating incidents in processing equipment, such as silos, dryers, dust collectors and flexible intermediate-bulk containers (FIBCs; super sacks), have caused fires and explosions in industry.

Typical materials that may experience self-heating include sawdust, coal, sewage sludge, grain and organic salts, especially those containing unsaturated bonds or peroxides, for instance.

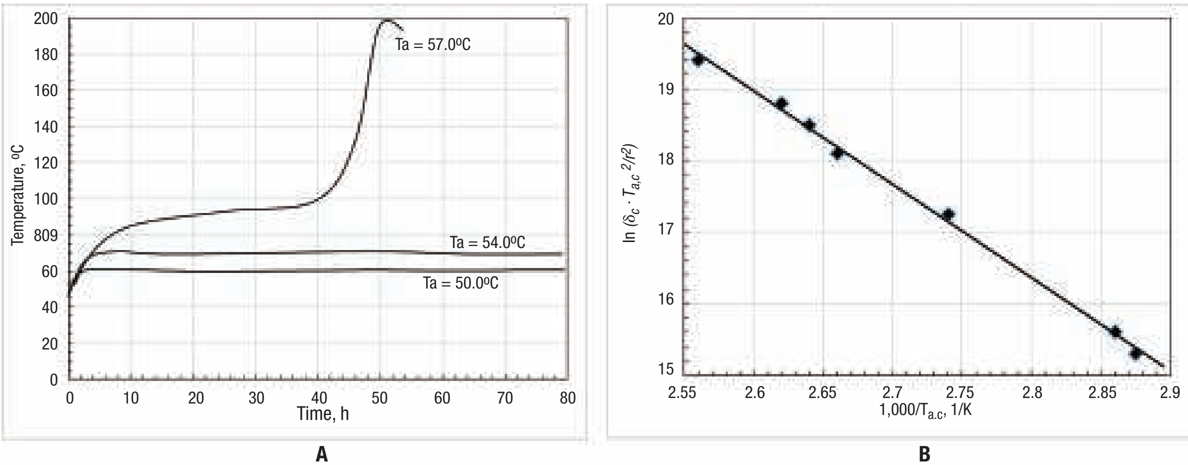


**FIGURE 2. The plot on the left shows an example of the data recorded in an oven-basket test. From this data, values for the kinetic and heat-transfer properties (*M* and *N*) of the system can be obtained from the slope (*M*) and intercept (*M*) of the plot on the right, as described in Equation (10)**

## Prediction of self-heating

Combining heat transfer and chemical reaction equations, the temperature distribution of a bulk of solid material that may experience a self-heating can be mathematically described by Equation (1) [1]:

$$\rho c \frac{\partial T}{\partial t} = \lambda \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) + q$$

(1)

where the heat generation term, $q$, is assumed to follow the Arrhenius equation:

$$q = \Delta H \cdot f(C) \cdot A_0 \cdot e^{-E/RT} \quad (2)$$

where $\rho$, $c$ and $\lambda$ are physical properties of material (density, heat capacity and thermal conductivity, respectively), $\Delta H$ is the reaction heat, $A_0$ is the pre-exponential factor, $E$ is the reaction activation energy, $R$ is the gas constant, $C$ is the concentration of reactant, $t$ is time and $T$ is temperature, which varies with the location ($x$, $y$, $z$) and time.

Solving Equation (1) needs both initial conditions (I.C.) and boundary conditions (B.C.):

$$t = 0,\ T = T_0 \quad \text{(I.C.)} \quad (3a)$$

$$-\lambda \frac{dT_s}{dx} = h(T_s - T_0) \quad \text{(B.C.)} \quad (3b)$$

where subscript $s$ and $0$ denote the surface of material and ambient condition, respectively, $h$ is the convective heat-transfer coefficient around the surface of material. The Biot number, $Bi$, is a dimensionless measure of the ratio of the resistance to heat transfer within the body to that from the surface to the surroundings, and can be defined as Equation (4):

$$Bi = \frac{rh}{\lambda} \quad (4)$$

where $r$ is the smallest physical dimension of the material body.

If only a small pile of material is present, or if access of oxygen is poor to the interior (for reactions that need oxygen) then self-heating, but not thermal runaway may occur. The material will rise in temperature above ambient, and a steady-state temperature distribution in the bulk material would be established until eventually the temperature starts going down since reactants will become depleted. Such a steady-state temperature distribution in the bulk material can be approximately solved, for example, for the geometry of a symmetric slab, as below:

$$\theta = \ln C_1 = -2 \ln\left[\cosh\left(z\sqrt{\delta C_1/2}\right)\right]$$

(5)

where $C_1$ is constant, the variable $\theta$ is a non-dimensional temperature, which is defined by Equation (6):

$$\theta = \frac{E}{RT_0^2}(T - T_0) \quad (6)$$

and $\delta$ is a non-dimensional heat generation rate, which is defined by Equation (7):

$$\delta = \frac{E}{RT_0^2} \frac{r^2 \cdot \Delta H \cdot f(C) \cdot A_0}{\lambda} e^{E/RT_0}$$

(7)

and $z$ is a non-dimensional distance:

$$z = \frac{x}{r} \quad (8)$$

where $r$ is the half thickness of the slab, and $x$ is the location. (Note that at the center of the slab, $x = 0$ and $z = 0$).

For a given material body (both size and geometry), a critical ambient temperature, $T_{a,C}$, and a corresponding critical heat-generation rate, $\delta_C$, exists such that a higher ambient temperature than the critical ambient temperature would lead to a spontaneous ignition or combustion. Physically, any bodies that have a $\delta > \delta_C$ have too little cooling at the boundaries, or they are too large, or their chemical reaction rate is too high for a stable condition. Mathematically, a solution of the conservation equation [Equation (1)] does not exist for any value $\delta > \delta_C$. In addition, for a given ambient temperature, a critical size of the self-heating material exists that a greater bulk size would lead to a spontaneous ignition or combustion. At such a critical condition, Equation (7) becomes Equation (9) as below:

$$\delta_c = \frac{E \cdot r^2 \cdot \Delta H \cdot f(C) \cdot A_0 \cdot e^{-E/RT_{a,c}}}{\lambda R T_{a,c}^2}$$

(9)

Values [2] of the critical non-dimensional heat generation rate, $\delta_C$, for different symmetrical geometries at $Bi \rightarrow \infty$ are listed in Table 1.

Rearranging Equation (9) gives the following equation:

$$\ln\left(\frac{\delta_c \cdot T_{a,c}^2}{r^2}\right) = M - \frac{N}{T_{a,c}} \qquad \textbf{(10)}$$

Where:

$$M = \frac{E \cdot \Delta H \cdot f(C) \cdot A_0}{\lambda R}$$

$$N = \frac{E}{R}$$

Thus, for a given symmetrical geometry with a size $r$, the critical ambient temperature $T_{a,c}$ can be predicted if kinetic and heat-transfer properties of the system [$M$ and $N$ in Equation (10)] are known. Similarly, for a given ambient temperature, a critical size of the bulk material that would lead to a spontaneous ignition can also be predicted by Equation (10).

## Tests for self-heating

Selection of the most appropriate test procedure depends on the type of operation and on the precision with which the critical temperature needs to be known. The widely used empirical test for preventing self-heating issues in industry is summarized in Ref. 3, while more advanced tests based on self-heating theory are summarized in Ref. 4.

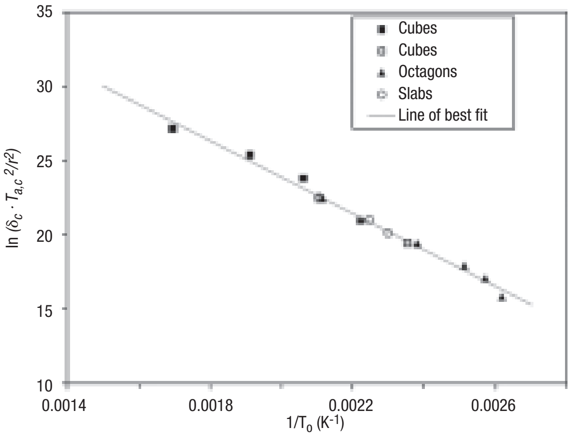


**FIGURE 3. This graph shows that the effect of basket geometries on constants *M* and *N* in Equation (10) are negligable (from Ref. 4)**

***Empirical test: Powder-layer test.*** The powder-layer test simulates the conditions in dryers, such as cross-flow, tray and band dryers, in which hot air flows above a layer of material, and also simulates the condition of deposits on the internal surfaces of all types of dryers. The objective of the test is to obtain guidance on the ignition temperature of material in a layer.

To perform the test, a layer of material is placed on a metal tray with an area of 75 mm × 40 mm and depth of 15 mm, representing the powder layer built up in a plant and

| TABLE 1. VALUES OF $\delta_c$ FOR VARIOUS GEOMETRIES AT Bi→∞ | | |
|---|---|---|
| **Geometry** | **Dimensions** | $\delta_c$ |
| Infinite plane slab | Width 2*r* | 0.878 |
| Rectangular box | Sides 2*l*, 2*r*, 2*m*; *r* < *l*, *m* | $0.873 \cdot (1 + r^2/l^2 + r^2/m^2)$ |
| Cube | Side 2*r* | 2.52 |
| Infinite cylinder | Radius *r* | 2.00 |
| Equi-cylinder | Height 2*r*, radius *r* | 2.76 |
| Sphere | Radius *r* | 3.32 |
| Infinite square rod | Side 2*r* | 1.700 |

heated by air passing around it with a velocity of 4.5 m/min. Thermocouples are used to monitor the temperature within the sample and the air. The test simulates full-scale situations well if the powder layer thickness reflects that likely to arise in the dryer. In that case, the temperature at which an exothermic reaction can progress to glowing heat can be used as the basis for defining safe drying procedures. This temperature may be considerably higher than the temperature at which exothermic activity is first detected.

An initial screening procedure, in which the temperature of the air is increased at a rate of 0.5°C/min over the temperature range of 20 to 400°C, is used to determine the approximate temperature at which exothermic activity begins. The ignition temperature is then determined by a series of extended isothermal tests. It is important to recognize that layers of material can build up on the walls of dryers and stay there for long periods of time. Eight-hour isothermal tests are mostly sufficiently long to determine the thermal ignition temperature. It is recommended that a safety margin of 20°C is used to minimize the risk of decomposition in the plant, but should not be used as the sole basis of safety.

***Advanced test: Oven-basket test.*** The most common technique for conducting bench-scale tests with an objective of predicting large-scale behavior of solid self-heating is an oven-basket test. In this technique, a representative powder sample is placed into a stainless-steel wire-gauze cubic basket. The basket is placed in an oven where the temperature can be controlled to better than ±1°C. The oven must also be equipped with a fan to keep the temperatures uniform and to provide a reasonably high convective heat transfer coefficient to the test sample so that $Bi \to \infty$.

The sample is normally prepared at room temperature, then inserted into the oven, which is at a desired test temperature. As a minimum, two thermocouples are required: one at the center of the test sample, and the second monitoring the oven air temperature. In many cases, a third thermocouple is used, located at the surface of the test sample. This third thermocouple is used to monitor whether the $Bi \to \infty$ condition is reasonably fulfilled; that is, to see if the sample surface temperature is very close to the oven air temperature. A Type K thermocouple made of 0.19- to 0.27-mm-dia. wires and having a bare junction is used. Experiments must be conducted on a number of different-sized cubes. Commonly, cubes of 25, 50, 100 and 200 mm dimensions (2*r*) are used. The sample bulk density must be controlled so that it is nearly identical for all the samples tested, and it should approximate the bulk density to which the powder is packed in the real-scale environment. The test sample must be carefully tamped or shaken in order to ensure that the packing is uniform throughout the basket.

The basic procedure is to determine the critical value of $T_{a,c}$ by a series of trials for each basket size. For any given size and oven temperature ($T_a$) setting, there are two possible results: (1) the temperature at the center of the sample rises only a modest amount over the oven temperature (if indeed it reaches it), establishes a plateau, then eventually decreases; or (2) either initially or after possibly some plateau is reached, a very sharp increase in temperature occurs and the temperature climbs way over the oven temperature. The first and second event temperatures are denoted as subcritical and supercritical, respectively.

By means of multiple trials, it is eventually possible to find a subcritical and a supercritical temperature separated by only 1 or 2°C. The critical value of $T_{a,c}$ is then deemed to be halfway in between the two. When a critical $T_{a,c}$ has been found for one basket size, experiments are repeated for the next size. A table is then compiled of *r* versus critical values of $T_{a,c}$. Since repeated testing (which may take weeks or months) may be needed for each basket size and at least three — preferably more — sizes must be studied, the procedure is rather lengthy.

## Example of an advanced test

As an example, Figure 2a shows the testing results from a cubic basket test with two subcritical and one supercritical center temperature/time traces. By testing in multiple baskets with different size *r*, the corresponding critical ambient temperatures, $T_{a,c}$, for each basket size can be obtained. Figure 2b shows that plotting $\ln(\delta_c T_{a,c}^2/r^2)$ — where $\delta_c = 2.52$, as shown in Table 1 — versus $1{,}000/T_{a,c}$ gives a straight line with a slope of *N* and an intercept of *M* as described in Equation (10). Thus, with known *N* and *M*, for a given ambient temperature, a critical size of a bulk material of the same shape that may experience spontaneous combustion can be predicted by using Equation (10). Similarly, for a given size of a bulk material, a critical ambient temperature that may experience spontaneous combustion can also be predicted.

Extensive investigations [*4*] indicated that the geometries of the basket would not affect the slope of *N* and the intercept of *M* as described in Equation (10). As shown in Figure 3, the results from different geometries (accordingly different $\delta_c$ values as shown in Table 1) of oven-test specimens fall on the same straight line. Therefore, the shapes of the test containers, provided they are reasonably compact, do not make a significant difference. Thus, the obtained *M* and *N* from a single geometry of basket tests is applicable to other geometries. Consequently, testing results of *M* and *N* from a single geometry of basket tests can be used to analyze the self-heating issues in all different actual plant conditions, such as dust accumulation layers, bulk storage in different shapes of containers, critical stacking temperature, critical ambient temperature that may lead to fire or explosion, and critical container size of different geometries that lead to spontaneous combustion, by using Equation (10).

## Final remarks

This article presents two experimental methods to quantify powder self-heating hazards in layer and bulk conditions in industrial processes. Self-heating begins at a temperature at which the rate of heat generation is greater than the rate of heat loss, and this temperature is called critical temperature that could lead to spontaneous ignition.

The occurrence of a fire or an explosion caused by self-heating presents a serious threat to some industrial processes. The temperature of combustible materials should be kept at a safe margin below the temperature for the onset of self-heating, obtained by appropriate test methods. Particular attention should be paid to this during startup and shutdown, and other periods when the evaporation load is less than normal. At such times, the heat input should be controlled to prevent the air temperature from exceeding a predetermined value. As far as possible, the design should avoid ledges, corners, crevices and so on, where powder could inadvertently build up inside process equipment. There should be no "dead" zones inside heated process equipment, such as dryers, where powder could remain or get trapped for extended periods of time. Process equipment subject to buildup of deposits of combustible material on internal surfaces should be cleaned often enough to prevent the deposit thickness from reaching a level where it can lead to self-heating. Sufficient access points should be provided to permit a thorough cleaning of all sections of the interior of the dryer and associated dust-containing equipment. ■

*Edited by Gerald Ondrey*

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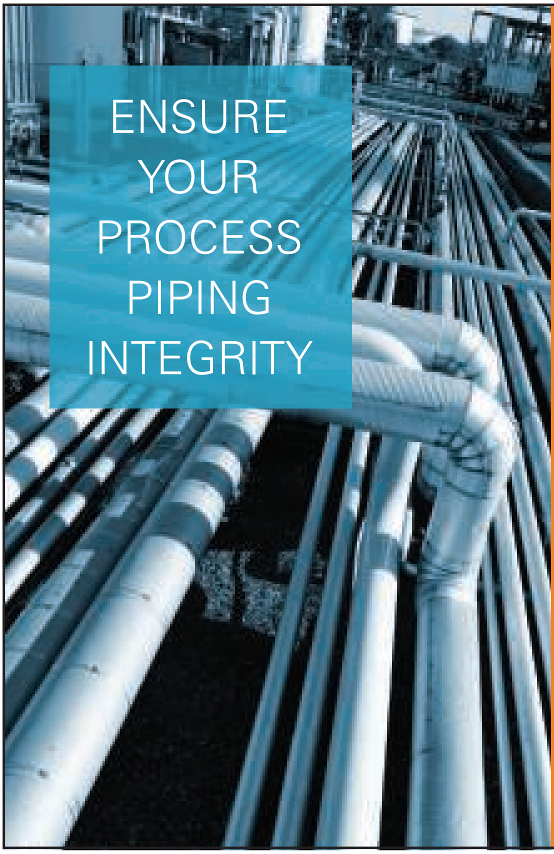

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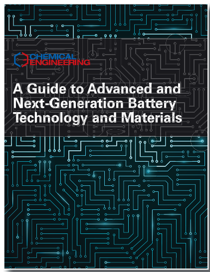
# A Guide to Advanced and Next-Generation Battery Technology and Materials




This comprehensive guidebook provides descriptions of the major battery technologies and materials in the advanced and next-generation battery markets, as well as information on many of the companies operating in the advanced and next-generation battery industries.

Included in this guidebook is a table that represents a list of selected technology-development companies in the advanced battery space, along with their areas of focus, contact information and technology status. It lists both established companies and startup companies that have made technological strides in recent years toward commercially viable battery technologies.

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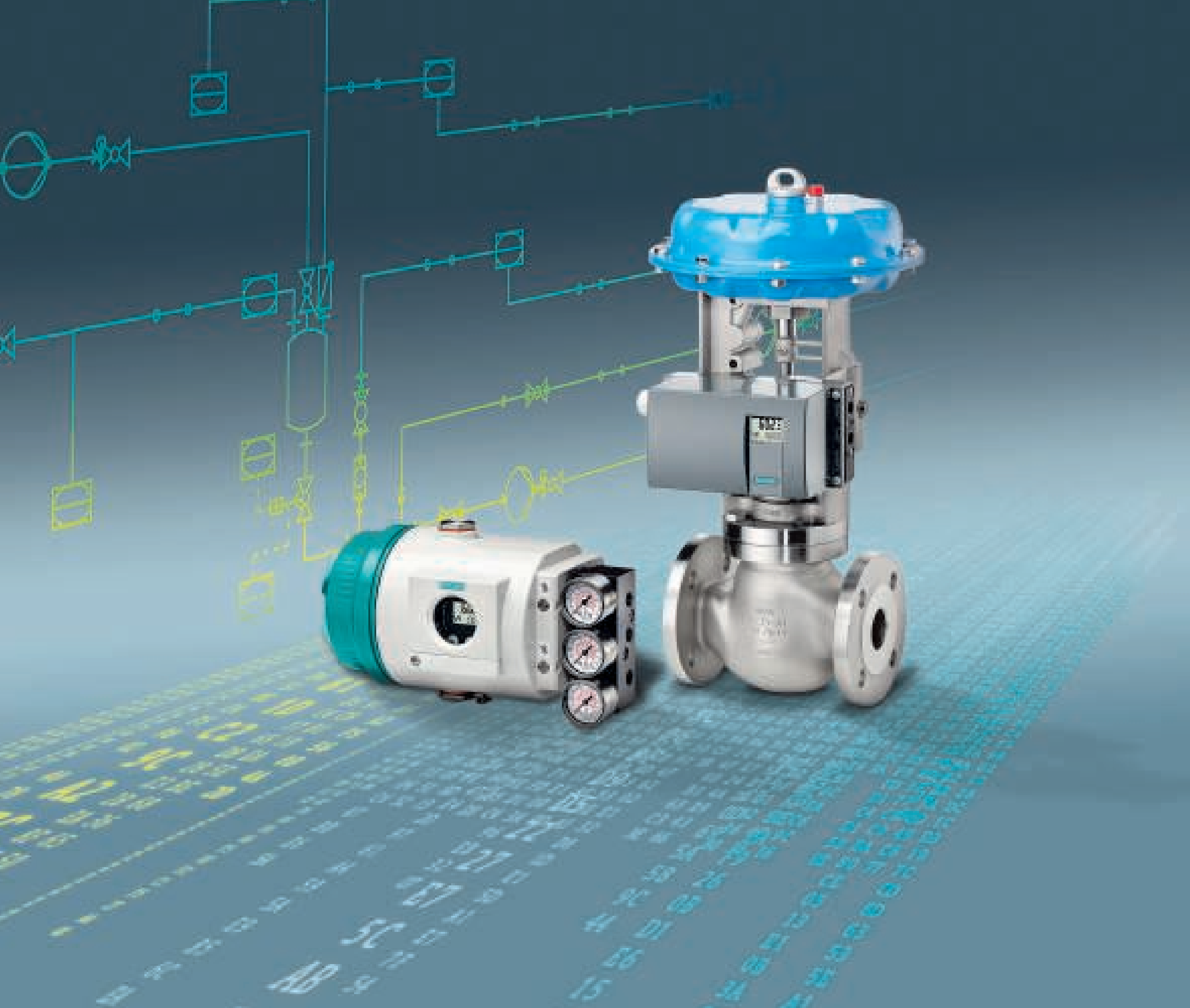

# Industrial Internet of Things

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# Optimizing processes and troubleshooting plants

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Smoother-running processes, higher profitability, and fewer breakdowns are just some of the promises of the Industrial Internet of Things (IIoT). Strictly speaking, the IIoT itself is a nuts-and-bolts network of powerful yet affordable sensors and robust – often wireless – communications technologies. What this hardware could bring to the chemical process industries (CPI), however, is change on a scale almost comparable to that of today's Internet. The term "Industry 4.0", most often heard in Germany, compares the impact to that of steam power, electricity, and computers in previous industrial revolutions.

Characteristics of this wider IIoT include systems integration that is both deep and wide; real-time process information; mobile computing; cloud computing, big data analytics, and artificial intelligence (AI); simulation; augmented reality; and robotics. Cybersecurity will become even more important than at present, while additive manufacturing (3D printing) will benefit discrete-manufacturing industries especially.

A recent article in *CE* (May 2017 p.16) shows how U.S. refineries are starting to use IIoT tools to enable predictive maintenance – an old idea that today still too often gives way to the traditional "run to failure" approach. Ubiquitous sensors, low installation costs thanks to wireless communications, and AI are the keys here.

According to IIoT proponents, however, IIoT-enabled plants can go much further. By aggregating data from multiple sources, the technology can take advantage of information that previously was either impossible or not cost-effective to collect. Big-data analytics, including pattern recognition and AI, can then turn this raw data into profitable knowledge. Examples include:

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- minimizing small efficiency losses from sources that may not have been detectable previously;
- raising operating efficiency through improved monitoring of energy usage;
- improving operations by continuous monitoring and by providing instant access to information that supports decision-making;
- maintaining the effectiveness of control loops, controllers and models over time, so the benefits of advanced process control are sustained;
- lowering overall process risk, thus improving safety; and
- reducing maintenance costs.

This special advertising section covers just a small part of the spectrum of IIoT devices and applications. On the following pages, vendors of control systems, field devices, and packaged systems explain their visions for the new connected world. ■

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An "installed base analysis" application – a web-based tool listing all the devices installed in the plant – is a simple and efficient way to bring order to asset management, especially since undocumented retrofits are not unusual in modern chemical plants. For Endress+Hauser devices, additional information displayed includes the current availability of the product and, if necessary, recommendations for substitutes. Based on the data collected, the tool can then present statistics on the installed base of devices and recommend ways to optimize it, with a view to simplifying plant operation and reducing costs.

The installed base analysis app reads data by simply scanning the device nameplate with a smartphone. Alternatively, Endress+Hauser's edge device – a smart gateway that is easy to set up – can be used with various bus systems; it automatically identifies each device and independently recognizes any changes.

**Collecting information on installed devices is the starting point for an IIoT strategy**

Data security is important in a world where networking is rapidly spreading into all areas of life. On one hand, widespread data exchange between companies brings valuable benefits. On the other hand, it is essential to protect intellectual property. To ensure maximum data security, Endress+Hauser uses the most modern safety mechanisms, including:

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*Siemens explains how its MindSphere IoT platform, aided by wireless communications, can bring solid benefits through powerful diagnostics and predictive maintenance*

To ensure high plant availability, timely maintenance of physical assets is essential, notes **Siemens**. Yet although plant owners clearly want to minimize extra costs arising from unnecessary servicing of healthy assets, maintenance today too often still follows rigid time-based schedules. So, why not use the new opportunities offered by cloud services, data and insights to reap the benefits of intelligent field device data to the fullest?

Every instrument and asset in your business holds a wealth of data. The Siemens MindSphere open IoT platform is the operating system that lets you understand it. MindSphere lets you connect your field-level assets to the digital world, and provides powerful apps and digital services that can unleash greater efficiency and productivity.

Valves, for instance, depending on their size, can represent large assets – yet insights from positioner data often remain underutilized. Imagine if your positioners could speak to you, telling you exactly when they need attention, and if you could transfer this information into predictive maintenance plans right away. The combination of smart predictions, data visualization, and collaboration tools will help to reduce maintenance effort, avoid costly unplanned shutdowns, and let maintenance operations be executed more efficiently.

But you don't always have to have your head up in the cloud. Transparency can also be implemented in the field to obtain maximum awareness of the current status of valves. One solution that guarantees a quick return on investment is to use wireless transmitters to send information directly to the DCS, without the detours implicit in a conventional wired system with decentralized I/O. The DCS aggregates all the information in a Sitrans Library faceplate that provides extensive diagnostics: setpoint, feedback signal and information from additional modules – such as alarms – are all visualized in one place. This saves you the extra engineering effort needed to integrate these device-specific functions, and lets you use the entire functional scope of your field devices. The result is a new degree of transparency for your assets, allowing easier operation and fast troubleshooting – in the cloud, or in the field. **www.siemens.com/processinstrumentation**

**MindSphere lets you connect assets, like the SIPART PS2 shown here, to the cloud**

# Product documentation available any time, worldwide

*A simple 2-D barcode lets owners of ARCA control valves retrieve essential product data by scanning equipment on the plant or in the workshop*

The problem is as old as the printed operating manual: technical documentation is never at hand when it's needed most urgently. Now, however, control valve specialist **ARCA Regler** has developed a simple yet effective solution to the problem of the missing manual.

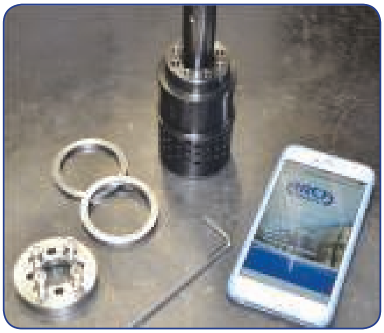

Easier to do than to explain: scan the QR code for details of this valve and actuator

The bigger the project, the more documentation it typically generates, ARCA notes. Product datasheets, operating instructions, schematics, approvals and test certificates all need to be collected and filed. With multiple requests for documentation, it's only too easy for files to go missing. Engineers and maintenance staff often cannot be certain they will be able to find the information they need – which may give rise to serious problems and high costs, especially in critical situations such as an unplanned shutdown.

ARCA's new ARCA-ONSITE software provides a perfect solution to this problem: Every control valve ordered after April 1 this year will carry an extra label bearing a QR code. Scanning the code gives service and engineering staff immediate access to all the official ARCA documentation that applies to precisely that specific valve.

ARCA-ONSITE will even trace and show later modifications to the valve – a different trim, for instance – as long as the modification parts or the technical service were ordered from ARCA with reference to the specific valve serial number. For ARCA valves, lost documentation will be a thing of the past.

The same service is also available on PCs or laptops via ARCA's website at www.arca-valve.com/Downloads. After typing in the valve order number and serial number (a unique combination that protects user privacy and ARCA know-how, like a user ID and password), engineers can download, file and print all the necessary manuals and certificates. No special software is required: everything is accessible from a web browser and PDF reader. **www.arca-valve.com**



With ARCA-ONSITE, scanning a QR code with a mobile device quickly pulls up all the original documentation associated with the sale of an individual control valve

# Actuators enhance process transparency and control

*AUMA explains how modern electric valve actuators are key elements in the IIoT, with a practical example in the form of Vienna's new real-time sewer management system*

As the Industrial Internet of Things (IIoT) gains momentum, the enhanced internetworking of physical devices is yielding cyber-physical systems with improved process state visualization, higher-level modelling and simulation capabilities, improved process control, and higher efficiency.

Electric valve actuators play a key role in these systems for several reasons, notes **AUMA**. On the one hand, they make remote process operation possible by opening and closing valves. On the other hand, powerful electronics allow electric actuators to act as information hubs for both process-related data, for example valve position feedback, and actuator-related data, based on advanced self-diagnostics. For instance, intelligent algorithms monitor actuator characteristics to indicate when maintenance should be carried out. Asset management based on device-specific data boosts plant reliability and avoids breakdowns.

While AUMA actuators can be embedded into cyber-physical systems using 4–20 mA signals or conventional fieldbus, advanced

Electric actuators from AUMA provide enhanced connectivity for IIoT applications

Industrial Ethernet-based communication standards are especially suitable. AUMA currently supports the Industrial Ethernet standard Modbus TCP/IP and Profinet.

AUMA actuators with Profinet interface provide an unprecedented connectivity and are real-time capable. Wherever they are located, even in the most remote locations, they can be easily integrated into Internet networks, using either existing Ethernet cabling or wireless LAN, without needing extra gateways. All information is directly available on the IT network and can be used for process visualization, statistics, advanced modelling, or simulation to improve process performance. AUMA actuators are fully Profinet V2.3 compatible, with device descriptions (GSD files) available.

As an application example, several hundred AUMA actuators have been successfully integrated into a real-time sewer network control system for the city of Vienna, Austria. After heavy rain, the scheme has cut combined sewer overflow by more than 50% and so reduces water pollution. Online rainfall forecasting and real-time simulation help to optimize capacity management of holdup reservoirs spread across the 220 $km^2$ of Vienna's catchment area.

The intelligent AUMA actuators provide status information on which shut-off and control valves are open and which are closed. Following the results of the real-time simulation model, the actuators are centrally controlled to optimize the combined sewer flow. **www.auma.com**

# New mobile technologies improve plant performance

*Emerson's Always Mobile technologies deliver secure, instant access to critical information by connecting personnel with digital intelligence*

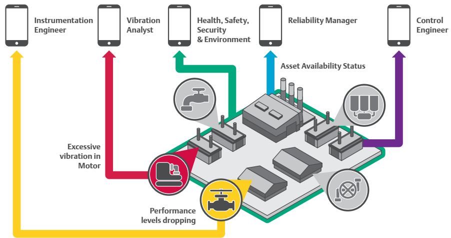
Embracing today's industrial climate requires an IIoT strategy that empowers organizations and experts with the right information wherever they are, whenever they need it. **Emerson**'s Always Mobile portfolio accomplishes that by providing workers with the digital intelligence necessary to monitor asset health and plant performance. With the right information, personnel can make timely decisions that lead to increased production, reliability, and efficiency regardless of where they work. Always Mobile solutions deliver secure, instant access to critical information in intuitive views, preparing personnel at all levels of organizations to make more effective business-critical decisions for improving plant reliability and production.

**Comprehensive control system monitoring:** With DeltaV Mobile, DeltaV distributed control system users can know the health of their plant on demand, by viewing real-time process values, trends, alarms, historians, and other key data from their mobile devices. In-app collaborative features streamline workflows by making it easier for managers and engineers to share critical information and enhance business results.

**Anywhere access to reliability dashboards:** Reliability personnel can stay on top of asset health using mobile dashboards in AMS Asset View that facilitate user collaboration to resolve issues more efficiently.

**Embedded, accessible asset prediction and protection:** Traditional protection systems deliver shutdown protection on the most critical assets, but access to data requires a visit to the control room or opening the field cabinet. Emerson's AMS 6500 ATG system delivers protection with embedded prediction capabilities that can be accessed using the ATG View mobile app from anywhere on the plant network.

**At-a-glance device health dashboards:** Personnel monitoring intelligent field devices can work smarter with device health and calibration status information available to them at any time. AMS Device View delivers device health dashboards for quick, accurate decisions on field device maintenance.




**Always Mobile technologies make for efficient business-critical decision-making**

**Always available system health monitoring:** Guardian Mobile utilizes KPI dashboards and delivers health scores for all associated systems, from anywhere.

The Always Mobile portfolio, part of Emerson's Plantweb digital ecosystem, leverages IIoT technologies to enable today's workforce to improve overall plant reliability and production and be efficient, impactful, and confident in their decisions from anywhere in their world. **www.emerson.com**

# Mobile app monitors status of entire packaging lines

*With BEUMER's new BOOM app, personnel from line operators to managers can check the status of their packaging machinery quickly, remotely, and informatively*

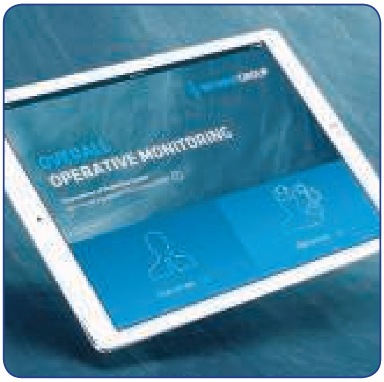
The **BEUMER Group** has developed the BEUMER Overall Operation Monitoring (BOOM) app, which enables staff to maintain an overview of all the relevant parameters of their packaging line on their mobile devices at any time. The application shows the status quo of availability, performance and quality levels as well as the consumption of energy and compressed air. This ensures efficient operation of all packaging systems at all times, the company says. The program can be adapted to customers' particular requirements.

With this development, the BEUMER Group is taking a further step towards Industry 4.0: BEUMER Overall Operation Monitoring enables users to keep a constant eye on the current status of the filling, palletizing and packaging machines connected to their system using their mobile devices. The app clearly shows all lines with their most important parameters. This gives staff important information on the effectiveness of the entire line: availability, performance and quality level of the line or individual machines, plus energy and compressed-air consumption. The customer can quickly evaluate all data and display the information in a target-performance comparison or diagram.

Users can adapt the new BEUMER Group app to their specific requirements. Parameters can be added, line constellations changed, and further dashboards added as required.

The BEUMER Group is an international leader in the manufacture of intralogistics systems for conveying, loading, palletizing, packaging, sortation, and distribution. With 4,000 employees worldwide, the Group has annual sales of about EUR 750 million. BEUMER Group and its subsidiaries and sales agencies provide their customers with high-quality system solutions and an extensive customer support network around the globe and across a wide range of industries, including bulk materials and piece goods, food/non-food, construction, mail order, mail, and airport baggage handling.

As a single-source provider, BEUMER Group supplies and installs packaging lines and adjusts them individually to the products of the customer.




**The new BEUMER app enables users to keep an eye on the current status of the machines connected to their system using their mobile devices**

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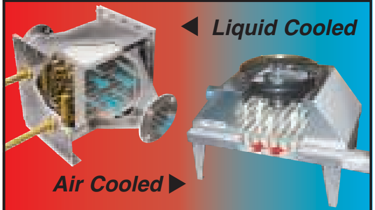


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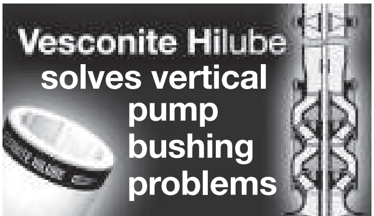

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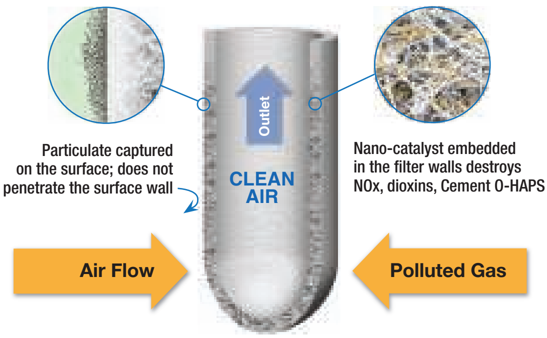


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| 2 | 17 | 32 | 47 | 62 | 77 | 92 | 107 | 122 | 137 | 152 | 167 | 182 | 197 | 212 | 227 | 242 | 257 | 272 | 287 | 302 | 317 | 332 | 347 | 362 | 377 | 392 | 407 | 422 | 437 | 452 | 467 | 482 | 497 | 512 | 527 | 542 | 557 | 572 | 587 |
| 3 | 18 | 33 | 48 | 63 | 78 | 93 | 108 | 123 | 138 | 153 | 168 | 183 | 198 | 213 | 228 | 243 | 258 | 273 | 288 | 303 | 318 | 333 | 348 | 363 | 378 | 393 | 408 | 423 | 438 | 453 | 468 | 483 | 498 | 513 | 528 | 543 | 558 | 573 | 588 |
| 4 | 19 | 34 | 49 | 64 | 79 | 94 | 109 | 124 | 139 | 154 | 169 | 184 | 199 | 214 | 229 | 244 | 259 | 274 | 289 | 304 | 319 | 334 | 349 | 364 | 379 | 394 | 409 | 424 | 439 | 454 | 469 | 484 | 499 | 514 | 529 | 544 | 559 | 574 | 589 |
| 5 | 20 | 35 | 50 | 65 | 80 | 95 | 110 | 125 | 140 | 155 | 170 | 185 | 200 | 215 | 230 | 245 | 260 | 275 | 290 | 305 | 320 | 335 | 350 | 365 | 380 | 395 | 410 | 425 | 440 | 455 | 470 | 485 | 500 | 515 | 530 | 545 | 560 | 575 | 590 |
| 6 | 21 | 36 | 51 | 66 | 81 | 96 | 111 | 126 | 141 | 156 | 171 | 186 | 201 | 216 | 231 | 246 | 261 | 276 | 291 | 306 | 321 | 336 | 351 | 366 | 381 | 396 | 411 | 426 | 441 | 456 | 471 | 486 | 501 | 516 | 531 | 546 | 561 | 576 | 591 |
| 7 | 22 | 37 | 52 | 67 | 82 | 97 | 112 | 127 | 142 | 157 | 172 | 187 | 202 | 217 | 232 | 247 | 262 | 277 | 292 | 307 | 322 | 337 | 352 | 367 | 382 | 397 | 412 | 427 | 442 | 457 | 472 | 487 | 502 | 517 | 532 | 547 | 562 | 577 | 592 |
| 8 | 23 | 38 | 53 | 68 | 83 | 98 | 113 | 128 | 143 | 158 | 173 | 188 | 203 | 218 | 233 | 248 | 263 | 278 | 293 | 308 | 323 | 338 | 353 | 368 | 383 | 398 | 413 | 428 | 443 | 458 | 473 | 488 | 503 | 518 | 533 | 548 | 563 | 578 | 593 |
| 9 | 24 | 39 | 54 | 69 | 84 | 99 | 114 | 129 | 144 | 159 | 174 | 189 | 204 | 219 | 234 | 249 | 264 | 279 | 294 | 309 | 324 | 339 | 354 | 369 | 384 | 399 | 414 | 429 | 444 | 459 | 474 | 489 | 504 | 519 | 534 | 549 | 564 | 579 | 594 |
| 10 | 25 | 40 | 55 | 70 | 85 | 100 | 115 | 130 | 145 | 160 | 175 | 190 | 205 | 220 | 235 | 250 | 265 | 280 | 295 | 310 | 325 | 340 | 355 | 370 | 385 | 400 | 415 | 430 | 445 | 460 | 475 | 490 | 505 | 520 | 535 | 550 | 565 | 580 | 595 |
| 11 | 26 | 41 | 56 | 71 | 86 | 101 | 116 | 131 | 146 | 161 | 176 | 191 | 206 | 221 | 236 | 251 | 266 | 281 | 296 | 311 | 326 | 341 | 356 | 371 | 386 | 401 | 416 | 431 | 446 | 461 | 476 | 491 | 506 | 521 | 536 | 551 | 566 | 581 | 596 |
| 12 | 27 | 42 | 57 | 72 | 87 | 102 | 117 | 132 | 147 | 162 | 177 | 192 | 207 | 222 | 237 | 252 | 267 | 282 | 297 | 312 | 327 | 342 | 357 | 372 | 387 | 402 | 417 | 432 | 447 | 462 | 477 | 492 | 507 | 522 | 537 | 552 | 567 | 582 | 597 |
| 13 | 28 | 43 | 58 | 73 | 88 | 103 | 118 | 133 | 148 | 163 | 178 | 193 | 208 | 223 | 238 | 253 | 268 | 283 | 298 | 313 | 328 | 343 | 358 | 373 | 388 | 403 | 418 | 433 | 448 | 463 | 478 | 493 | 508 | 523 | 538 | 553 | 568 | 583 | 598 |
| 14 | 29 | 44 | 59 | 74 | 89 | 104 | 119 | 134 | 149 | 164 | 179 | 194 | 209 | 224 | 239 | 254 | 269 | 284 | 299 | 314 | 329 | 344 | 359 | 374 | 389 | 404 | 419 | 434 | 449 | 464 | 479 | 494 | 509 | 524 | 539 | 554 | 569 | 584 | 599 |
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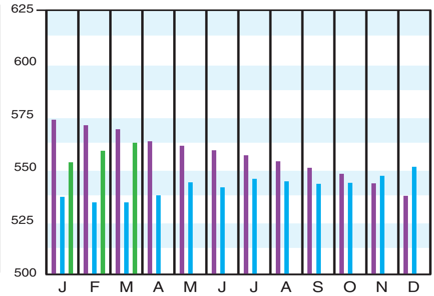
| Heat exchangers & tanks | 591.0 | 587.3 | 545.2 |
| Process machinery | 672.1 | 671.1 | 644.8 |
| Pipe, valves & fittings | 863.7 | 852.0 | 800.3 |
| Process instruments | 403.4 | 403.0 | 383.0 |
| Pumps & compressors | 982.3 | 973.1 | 969.7 |
| Electrical equipment | 514.3 | 512.1 | 508.3 |
| Structural supports & misc | 733.3 | 729.7 | 697.4 |
| Construction labor | 326.4 | 323.1 | 323.3 |
| Buildings | 555.4 | 552.2 | 538.4 |
| Engineering & supervision | 315.7 | 315.0 | 315.7 |

Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics

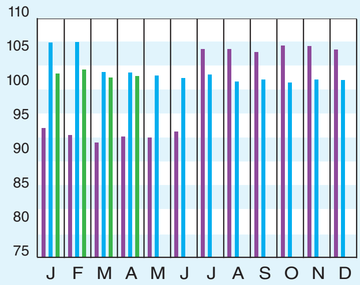
Annual Index:
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7



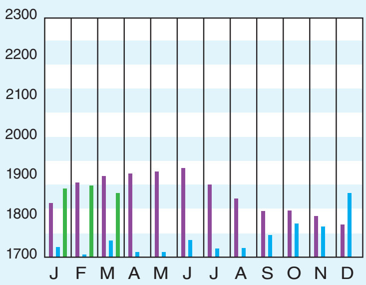

## CURRENT BUSINESS INDICATORS

| | LATEST | | | PREVIOUS | | | | | | YEAR AGO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CPI output index (2012 = 100) | Apr. '17 | = | 101.5 | Mar. '17 | = | 101.2 | Feb. '17 | = | 101.3 | Apr. '16 | = | 100.3 |
| CPI value of output, $ billions | Mar. '17 | = | 1,861.0 | Feb. '17 | = | 1,875.6 | Jan. '17 | = | 1,874.8 | Mar. '16 | = | 1,702.4 |
| CPI operating rate, % | Apr. '17 | = | 76.3 | Mar. '17 | = | 76.1 | Feb. '17 | = | 76.2 | Apr. '16 | = | 75.9 |
| Producer prices, industrial chemicals (1982 = 100) | Apr. '17 | = | 256.5 | Mar. '17 | = | 251.8 | Feb. '17 | = | 244.3 | Apr. '16 | = | 224.7 |
| Industrial Production in Manufacturing (2012=100)* | Apr. '17 | = | 103.8 | Mar. '17 | = | 102.8 | Feb. '17 | = | 103.2 | Apr. '16 | = | 102.1 |
| Hourly earnings index, chemical & allied products (1992 = 100) | Apr. '17 | = | 178.1 | Mar. '17 | = | 172.5 | Feb. '17 | = | 170.9 | Apr. '16 | = | 161.4 |
| Productivity index, chemicals & allied products (1992 = 100) | Apr. '17 | = | 102.6 | Mar. '17 | = | 103.2 | Feb. '17 | = | 102.3 | Apr. '16 | = | 102.5 |

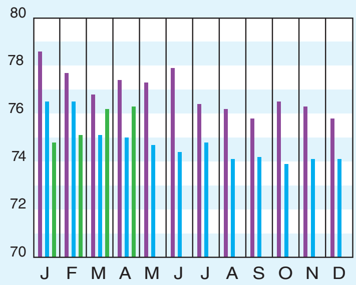
### CPI OUTPUT INDEX (2000 = 100)†




### CPI OUTPUT VALUE ($ BILLIONS)




### CPI OPERATING RATE (%)




*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.



## CURRENT TRENDS

The preliminary value for the March *CE* Plant Cost Index (CEPCI; top; the most recent available) rose compared to the previous month's value, continuing a string of six straight months of increasing values. All four of the major subindices — Equipment, Construction Labor, Buildings and Engineering & Supervision — increased in March compared to their respective February values. The preliminary overall monthly CEPCI value for March 2017 stands at 5.0% higher than the corresponding value from March 2016. Meanwhile, the latest Current Business Indicators (CBI; middle) saw a small rise in the CPI Output Index for April, while the March value for the CPI Value of Output declined slightly. The April Productivity Index decreased by a small margin.