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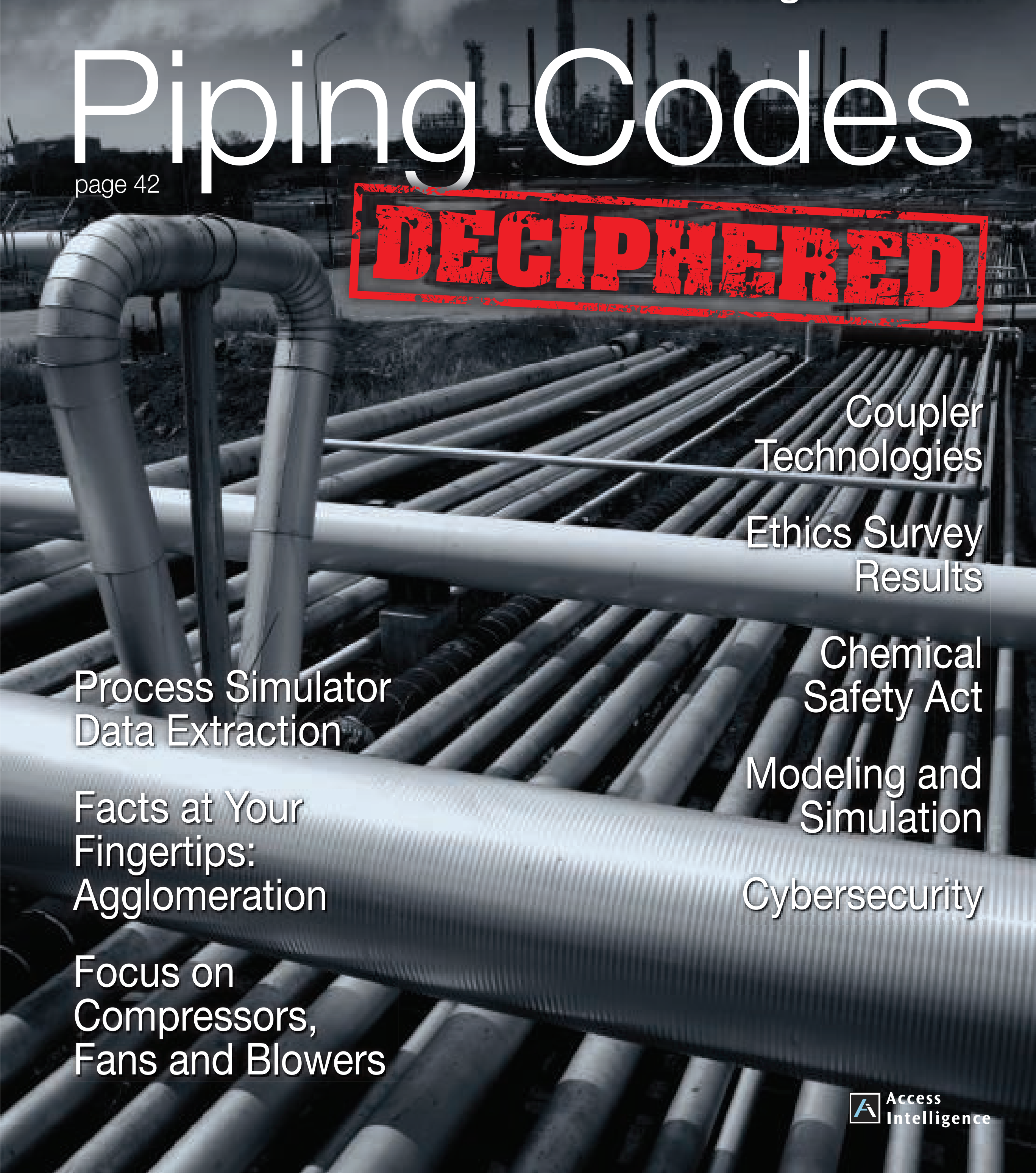

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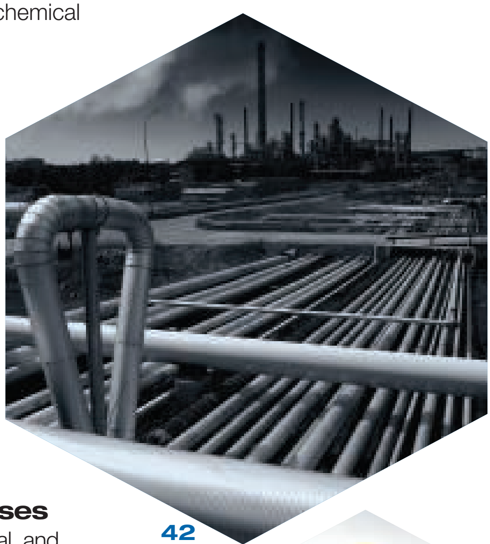

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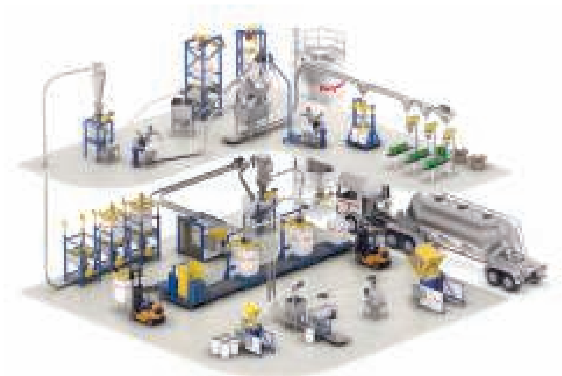

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BPA

Editor's Page

Working remotely

With the prevalence of sophisticated mobile devices today, and the almost ubiquitous availability of WiFi — even on airplanes now — we can almost always be connected to each other and to our jobs.

I, for one, enjoy the freedom that our mobile devices offer: the ability to keep in touch with people while traveling; to be able to join in meetings from almost any location; and to generally not be dependent on location in order to work and communicate. But even in writing that last sentence, I am aware of some irony in describing this phenomenon as "freeing," because sometimes, the ability to always be connected brings with it the expectation to always be connected. When one travels for work, for example, it is quite common these days to spend the days at whatever tasks you are traveling for, and the evenings catching up on the usual job tasks. Our "downtime" no longer comes simply from leaving the office environment — we have to plan it.

Telecommuting

Working remotely, whether part or full time, has gained momentum in recent years. A report by the Society for Human Resource Management (SHRM; www.shrm.org) on "2016 Employee Benefits Survey"[1] says that 60% of organizations in the U.S. allow their employees to telecommute. This is a threefold increase over 20 years ago — in 1996, only 20% of organizations reportedly allowed telecommuting. Of course, in that span of time, technology in mobile communications has advanced tremendously, making working from remote offices more feasible. Data from the U.S. Bureau of Labor Statistics' (BLS; www.bls.gov) "American Time Use Survey"[2] indicate that in 2015, 35% of workers in professional and related occupations and 38% of those in management, business and financial operations, did some or all of their work from home. Some jobs obviously cannot be done remotely, but for those that can, the decision to do so brings about a number of changes from the "traditional" workplace.

Advantages and challenges

A few of the pros of working from remote locations include: the ability of a company to hire and retain talented employees from a wider geographical pool; greater satisfaction from employees who want a better work/life balance; and the ability to keep operations going when an office may be closed due to extreme circumstances (as happened to our own offices during Superstorm Sandy). Some of the challenges include: potential feelings of isolation of employees; creating boundaries between home and work time; and effective communication.

Telecommuting is not for everyone. Those who are likely to be most comfortable and successful with it are employees who have reached a certain level of competency in their jobs, and who are self-starters with self discipline. Pro-active communication is key. Emails are effective and very convenient for day-to-day correspondence, particularly when working across time zones. Periodic phone calls and virtual meetings can facilitate communication and help to alleviate possible feelings of isolation. And, occasional meetings in-person are a great way to help develop team spirit and to have some of the "water cooler" type exchanges that may be otherwise missing. ■

Dorothy Lozowski, Editor in Chief

1. www.shrm.org/about-shrm/press-room/press-releases/pages/telecommuting-up-over-past-20-years.aspx; accessed 9-17-2016
2. www.bls.gov/news.release/atus.nr0.htm; accessed 9-17-2016

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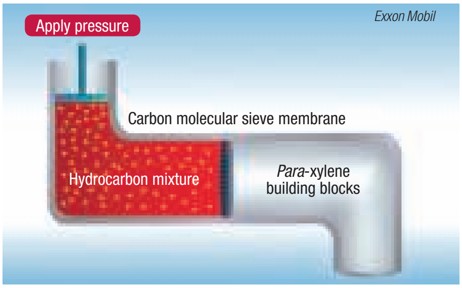
Purify *p*-xylene without the heat

Current commercial technologies for separating and purifying *p*-xylene — an important precursor for polyesters and plastics — from hydrocarbon mixtures involve phase-change techniques that require large amounts of thermal energy. Recently, a research team from Georgia Institute of Technology (Ga. Tech; Atlanta.; www.gatech.edu) and Exxon Mobil Corp. (Irving, Tex.; www.exxonmobil.com) demonstrated the separation of *p*-xylene at room temperature using organic-solvent reverse-osmosis (OSRO; diagram). Since it requires no thermal input, the OSRO method has the potential to significantly reduce the amount of energy required for *p*-xylene purification.

Although reverse osmosis has been used for decades in water desalination, this is said to be its first application for the separation of hydrocarbon mixtures. The keystone of the OSRO technology is the complex structure of the membrane. First, a hollow-fiber membrane (HFM) is constructed from a commercially available polymer. Then, the HFM is chemically modified with crosslinking molecules, which protect the membrane's mechanical properties. The fiber is next carbonized using a pyrolysis step, which converts the structure into a carbon molecular-sieve HFM. The molecular sieve has large pores,



which provide mechanical integrity without impeding mass transport. These larger pores eventually terminate into a 30-nm membrane layer with extremely small (less than 1 nm) micropores. It is here, at the micropore level, that the individual isomers of xylene can be isolated. At the laboratory scale, using just a single HFM, researchers enriched a hydrocarbon stream to over 80% *p*-xylene.

The membrane's carbon-based structure imbues stability under the high pressure (approximately 125 bars) required for reverse osmosis. Furthermore, the carbon fibers are inert in the presence of xylene mixtures and also allow for the pore sizes to be precisely tuned for molecular selectivity. Going forward, the team will continue to add more fibers to test OSRO, and will also seek to separate hydrocarbon streams of varying purity.

This ceramic membrane converts natural gas to liquid hydrocarbons

Converting natural gas to liquid hydrocarbons can theoretically be accomplished at high temperatures with the help of zeolite catalysts, but the reaction is hindered by two major factors. The conversion to products is thermodynamically limited, and coke formation on the zeolite surface rapidly decreases catalyst activity.

Now, technology involving a ceramic-membrane reactor offers a pathway around these obstacles. Along with scientists from the University of Oslo and the Institute of Chemical Technology in Valencia, Spain, engineered ceramics maker CoorsTek Inc. (Golden, Colo.; www.coorstek.com) has developed a reactor that integrates an ion-conducting membrane to shift the thermodynamic equilibrium of the reaction and drive the process toward increased product formation without generating CO_2.

"The membrane is a proton-conducting ceramic material with electrodes similar to a solid-oxide fuel cell," explains Per Vestre, managing director of CoorsTek Membrane Sciences. "It provides a means of removing hydrogen from the reaction and thus shifting the thermodynamic equilibrium toward formation of aromatic rings as reaction products." The CoorsTek reactor is also designed to allow oxygen to be injected across the membrane surface to remove carbon deposits, thus preventing coke buildup from killing catalyst activity, Vestre says.

Heated natural gas flows into the reactor, where it encounters shape-selective zeolite catalysts. As methane molecules are activated at catalyst active sites and products begin to form, hydrogen is transported across the solid ceramic membrane. Protons recombine as H_2 on the other side. Copper electrodes on the reaction side of the membrane and nickel electrodes on the hydrogen-permeate side aid the hydrogen transport process.

Further details of the process are described in the August 5 issue of *Science*.

Edited by:
Gerald Ondrey

MAKING CO FROM CO_2

Professor Rhosuke Suzuki at Hokkaido University (Sapporo City, Japan; www.eng.hokudai.ac.jp) has developed a molten-salt electrolysis process that can produce CO from high temperature CO_2 present in the fluegas of industrial furnaces. The process uses a molten salt containing $CaCl_2$-CaO melt as a media and a solid-state electrolyte, containing 8 mol% $YZrO_2$ in Y_2O_3, as the anode. Operating at temperatures of 800 to 1,000°C, the electrolyzer decomposes CO_2 into CO, with a conversion efficiency of 88.2% (at 1,000°C). The CO forms by the decomposition of carbonate ions, which coexist with the CaO as CO_2 is bubbled into the melt. Suzuki believes the process provides a way to utilize the CO_2 generated from industries having hot fluegases, such as steel and cement production, nonferrous metal smelting and waste incineration.

ELECTROLYSIS

Toshiba Corp. (Tokyo, Japan; www.toshiba.co.jp) has recently started up Japan's largest alkaline water-electrolysis system, which produces approximately 100 Nm^3/h of hydrogen — sufficient for fueling two fuel-cell-powered cars. Conventional water electrolysis uses an acidic electrolyte and requires precious metals for the electrodes. With alkaline electrolysis, less expensive metal oxides can be used, making it more economical for scaleup to large systems.

Toshiba had previously demonstrated and tested a smaller version of the system as part of the "Regional Co-operation and Low-Carbon Hydrogen Technology Demonstration Project," funded

(Continues on p. 8)

Note: For more information, circle the 56-digit number on p. 78, or use the website designation.

by Japan's Ministry of the Environment. Installed in the Shoro Dam in Shiranuka-cho, Shiranuka-gun, Hokkaido, the system produces approximately 35 Nm^3/h of hydrogen for a small community.

CO_2 TO CO

The research group of professor Yoshinori Naruta at Chubu University (Kasugai City, www3.chubu.ac.jp) has developed an iron-based photoelectrocatalyst that efficiently and selectively converts CO_2 into CO. The bio-inspired catalyst — a binuclear Ni/Fe carbon-monoxide dehydrogenase (CODH) — has shown a 93% selectivity for CO in the reduction of CO_2 at the anode of an electrochemical cell operating with artificial sunlight for 6 h.

The researchers used several co-facial porphyrin dimers with different substituents as suitable ligands for holding two Fe ions with suitable Fe-Fe separation to efficiently and selectively promote CO_2 to CO conversion with high turnover frequencies.

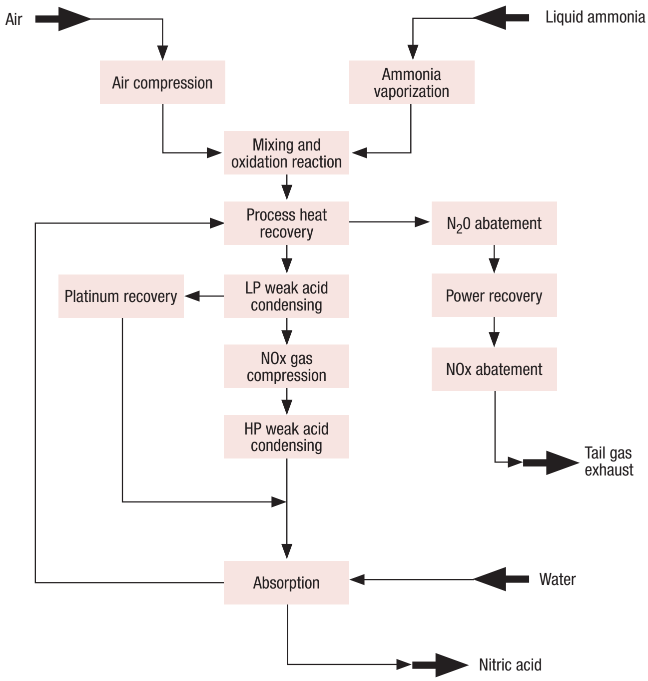
WASTE-FREE WAFERS

Silicon wafers are essential building blocks for the solar-energy industry, but their manufacture often results in a great deal of wasted materials, from scrap silicon to single-use cutting and sawing tools. A new production technique, dubbed Direct Wafer from 1366 Technologies Inc. (Bedford, Mass.; www.1366tech.com), enables Si wafer manufacture without the waste that

(Continues on p. 10)

This new, dual-pressure HNO_3 process is commercially available

Last month, Weatherly Inc., a wholly owned subsidiary of KBR Inc. (Houston; www.kbr.com) introduced its new dual-pressure nitric acid (DPNA) technology, which enables economically viable production of HNO_3 in large scale [over 1,000 metric tons per day (m.t./d)], as part of large fertilizer-production complexes. The technology was launched at the 2016 AN-NA (Ammonium Nitrate – Nitric Acid) conference (September 16–23; Eindhoven, the Netherlands).



In the DPNA process (diagram), ammonia is first oxidized with air over a platinum catalyst at high temperature and low pressure (LP). The product of the LP oxidation is passed through a heat exchanger to recover a major portion of the heat. The process gas is cooled and oxidized further in a LP cooler condenser, where NO, NO_2, O_2 and water combine to form dilute HNO_3. Some of the reaction energy is recovered and used to reheat the tail gas. The LP process gas is then compressed in the NOx-gas compressor, and fed to high-pressure (HP) cooler condenser and absorber to form product HNO_3 (68%). Tail gas from the absorber is reheated to 1,150°C and used to drive a hot-gas expander to generate power for the air compressor and NOx-gas compressors.

Weatherly's DPNA process is said to deliver lower operating costs with its more efficient heat-recovery design. Tail gas exits the system at 620°C, compared to the lower (490°C) temperature of alternative DPNA processes. This enables more efficient recovery of heat that is subsequently used to generate energy to power up the system. As a result, the new process offers an operating cost advantage over competing technologies of $4–5/ton of nitric acid produced, says KBR.

The DPNA process also utilizes Weatherly's vertical reactor — a compact, proven design widely used in mono-pressure HNO_3 plants — that requires less steel and piping than traditional plants. That means capital costs for Weatherly plants are 5–10% less than competing designs, says KBR.

Engineering bacteria to make muconic acid

Researchers at the Agency for Science, Technology and Research (A*STAR; Singapore; www.a-star.edu.sg), led by Sudhakar Jonnalagadda, have provided another step toward replacing petrochemicals with renewable resources in the manufacture of synthetic fibers and plastics. The team has genetically modified *Escherichia coli* bacteria to produce muconic acid from glucose. Muconic acid is a commercially important raw material used in pharmaceuticals, functional resins and agrochemicals, and is also a precursor of adipic acid, used to manufacture nylon.

Jonnalagadda says bacteria do not naturally produce the required substances in significant quantities, so the trick is to persuade these bacteria to become mini manufacturing plants for chemicals required by industry. The A*STAR team inserted three genes into *E. coli* to establish the metabolic pathway that produces muconic acid.

The challenge was to cause the bacteria to divert more glucose toward the desired products, Jonnalagadda says. The team had to control the combined activity of foreign and native genes to prevent the accumulation of metabolic intermediaries as well as optimize the efficiency of muconic acid production. Computer simulation was used to study the metabolism of the genetically engineered bacteria, and for deciding on the required genetic changes.

The team is now looking at other ways to improve the efficiency of muconic acid production. "We are at an early stage," says Jonnalagadda.

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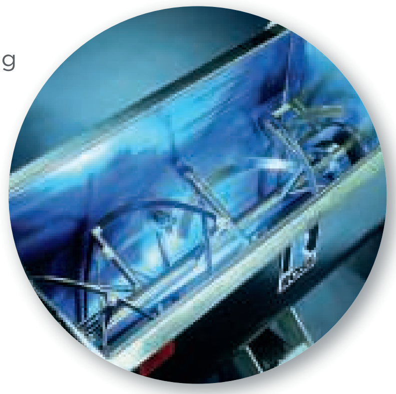

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is intrinsic to typical wafer-production processes. In a process similar to float-glass manufacturing, the Direct Wafer technology directly and continuously "grows" wafers from molten Si, rather than slicing the wafers from a cast ingot, explains Frank van Mierlo, 1366 Technologies' CEO.

The technology was first demonstrated using tin as a model material, and 1366 built its first full-scale furnace to produce industry-standard wafers in 2011. The company currently operates three wafer production lines in a pilot plant, but is working with authorities in New York to open a commercial-scale production facility. Si wafers produced via Direct Wafer have been deployed in solar modules in the U.S. and Germany, and the company recently shipped 100,000 wafers for an installation in Japan.

The Direct Wafer process has also opened the door for the creation of more efficient and complex wafers. Through precise control of the wafer-growing process, 1366 Technologies has recently demonstrated the ability to manipulate the wafers' structure, creating three-dimensional features on the surface. "We can do something that would never be possible with sawing, which is make the wafer thicker at the edges," says van Mierlo. "Cracks always start at the edges, and wafers can break during manufacturing processes," he explains. Traditional wafers are of a single thickness throughout, while these advanced

(Continues on p. 11)

Catalytic process converts sorted waste into aromatic compounds

The rising cost of landfilling trash creates a strong incentive to utilize the waste for saleable products. A recently piloted process is an example: the process can convert municipal solid waste (MSW) into a narrow range of valuable aromatic compounds. It depends on a two-component catalyst capable of first generating alcohols from synthesis gas (syngas), and then converting those to aromatic hydrocarbons.

The process was first developed by Mark White, professor emeritus at Mississippi State University (Starkville, Miss.; www.msstate.edu), and has been licensed for commercialization to Epurga LLC (Baton Rouge, La.; www.epurga.com).

An initial gasification step converts sorted trash or wood construction debris (or both) into syngas. After cleaning, the syngas is fed into a high-pressure (70 bars) reactor, where it passes over a catalyst consisting of molybdenum oxide (MoO_3) embedded inside a zeolite material (H-ZSM-5). The MoO_3 promotes conversion of syngas into alcohols, such as ethanol and propanol. The zeolite promotes reactions converting them into aromatic compounds, while the pore structure restricts the molecular weight (MW) distribution to ~78–160 g/mol. Major products include toluene, xylenes and trimethyl benzene — feedstocks for polystyrene, polyurethanes, polyesters and other polymers.

In addition to providing a source of bio-based aromatic species, the process offers lower operating costs than Fischer-Tropsch (F-T) processes, says Michael Harrelson, CEO of Epurga, by overcoming some of F-T's main limitations. By keeping the product size range narrow, the Epurga process eliminates the need for subsequent cracking operations to break the high-MW waxes into lower-MW species, as in F-T.

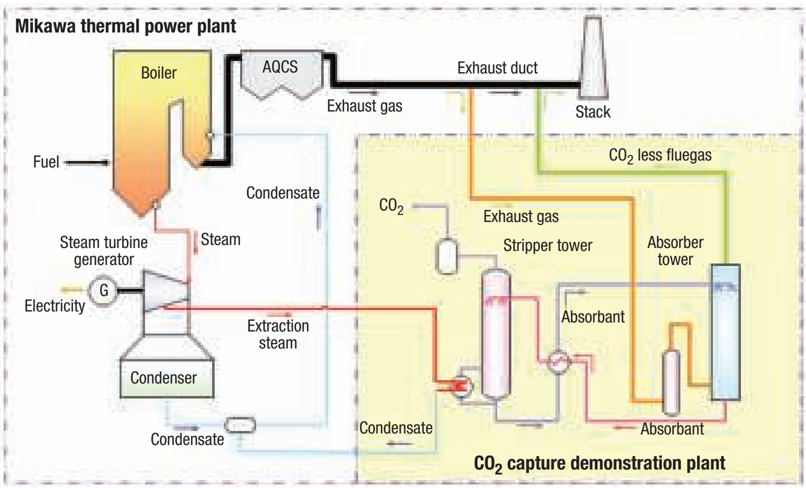
Also, because F-T synthesis requires H_2-rich feed gas, a water-gas shift unit operation is carried out to achieve the desired H_2-to-CO ratio (most gasifiers produce equal amounts of the two gases). In the Epurga process, MoO_3 also acts as a water-gas shift catalyst, operating in the same temperature range as the alcohol synthesis and avoiding the need for a separate water-gas shift step.

Epurga is building a plant to convert MSW into 200 ton/d of aromatic products on the banks of the Mississippi River in Port of Cates Landing, Tenn., and is looking for customers to purchase the MSW-derived aromatics, Harrelson says.

A Japanese consortium begins a five-year, large-scale carbon-capture project

Toshiba Corp. (www.toshiba.co.jp), Mizuho Information & Research Institute, Inc. (MHIR; both Tokyo, Japan; www.mizuho-ir.co.jp) and 11 other industrial and academic partners have been selected to carry out a five-year project, "Demonstration of Sustainable CCS Technology Project," sponsored by Japan's Ministry of the Environment (Tokyo; www.env.go.jp).

Toshiba will construct a carbon capture facility (diagram), a \$120-million investment designed to capture more than 500 ton/d of CO_2 — about half of its daily emissions — from the 48-MW Mikawa Power Plant, which is operated by Toshiba subsidiary Sigma Power Ariake Co. in Omuta, Fukuoka prefecture. The Mikawa Power Plant is now being retrofitted to accommodate both coal- and biomass-fired power generation. When the demonstration facility is completed in 2020, it will become the world's first biomass-fired power plant equipped with large-scale carbon capture, according to Toshiba.



The consortium will evaluate the technology's performance, cost and environmental impacts.

Control biofouling with I_2-vapor disinfection

A patented technology for infusing bubbles of elemental iodine into fluid or air can reduce microbial counts and potentially eliminate surface biofilms. Originally developed to remove biofilms from water lines in the dental industry, the technology is being used as a method for preventing biofouling on heat-exchanger surfaces.

Developed by I_2 Air Fluid Innovation Inc., Huntington Station, N.Y., (www.i2airfluidinnovation.com), the technology uses compressed air to strip iodine vapor from iodine-coated resin beads. The process generates nanoscale bubbles with elemental iodine at the surface in a liquid layer. When the bubbles come into contact with microbes, the I_2 oxidizes amino acids in the cell wall of the microbe, killing it.

"Among the advantages of this technology over other disinfectant methods are that it is not affected as greatly by organic matter in the water and works in a wider variety of water conditions," explains Michael Radicone, founder of I_2 Air Fluid Innovation. "University test results indicate drastic (log 7) and rapid (less than 90 s) microbial reductions" says Radicone. Douglas Call, a researcher at Washington State University who has tested the I_2 vapor technology, says it "performs exceptionally well against free-floating and biofilm-associated bacteria, and appears applicable for a range of activities, including drinking water treatment and reducing bacterial contamination in wastewater."

The technology has been licensed to Heat Transfer Research Inc. (HTRI; Navasota, Tex.; www.htri.net) for use on heat exchangers, and is being tested in a number of other applications involving biofouling and biofilms. The I_2 infusion technology is housed in an 18 × 18-in. device that can be mounted onto a heat exchanger, where it requires 7–8 g/mo of elemental iodine. A cartridge can be switched out easily when more iodine is required, Radicone says. Using I_2 Vapor Infusion can reduce the need for biocides and reduce fluid residues and chemical and storage costs, while also decreasing heat-exchanger maintenance requirements.

wafers are of targeted thickness at only the most vulnerable points to prevent breakage.

NEW COATING

A new spray-on, superhydrophobic material has been developed by scientists from Australian National University (ANU; Canberra; www.anu.edu.au), led by professor Antonio Tricoli. The material could be used to waterproof mobile phones, prevent ice from forming in aircraft or protect boat hulls against corrosion.

Up to now, applications of highly water-repellent surfaces have been limited by the poor mechanical and chemical stability of the fine hierarchical textures required.

The ANU scientists have created the new coating by combining two poly-

(Continues on p. 12)

mers, polyurethane and PMMA — poly(methyl methacrylate) — like two interwoven fishing nets made of different materials. "The key innovation is that this transparent coating is able to stabilize very fragile nanomaterials resulting in ultra-durable nanotextures with numerous real-world applications," Tricoli says.

The coating exhibits great resistance to abrasion, maintaining superhydrophobic water contact angles and a self-cleaning effect with sliding angles below 10 deg for up to 120 continuous abrasion cycles. It also has excellent chemical and photo stability. According to Tricoli, several companies have already expressed interest in the new material. ❏

This coating makes glass into a solar panel

A layered coating that acts as an organic semiconductor material allows building windows to generate electricity from direct, indirect, shaded, diffused and reflected sunlight, as well as from artificial light. Developer SolarWindow Technologies Inc. (Columbia, Md.; www.solarwindow.com) has designed and developed the system for ease-of-manufacturing, says John Conklin, CEO of SolarWindow. "Our organic semiconductor material can be adapted for application with many types of existing coating technologies, including spraying, rolling, and other application processes," he explains.

The SolarWindow coating consists of an organic polymer layer that contains light-harvesting organic molecules, along with elements of other species, sandwiched between electrically conducting layers. As each layer is coated onto the glass surface, it undergoes a curing step at ambient conditions. When finished, light can be absorbed by the organic coating, while the conducting layers govern a one-way flow of electrons using a proprietary Intra-Connection System that creates a discreet pattern of microscopic channels. These channels allow for the efficient transport of electricity within SolarWindow toward the surface of the glass. From there, the company's "invisible wire" technology uses microscopic conductors to convey electrons from the surface of the window to the wiring system of a building.

"The organic layer can be tuned for color," says Conklin, so that the coating remains transparent to light in the visible wavelength range, while harvesting other wavelengths of light necessary to generating electricity, he says.

Tall urban buildings have a small amount of roof space for conventional solar panels, but possess a large area of "vertical real estate" that can be used to generate electricity, Conklin points out. "We are looking to offset 30–50% of a skyscraper's energy demand with this technology," he adds, "and our modeled time to payback for the investment falls within one year."

The company is currently in a product development phase, and hopes to begin commercial-scale production of coated glass for windows by the end of 2017. ■

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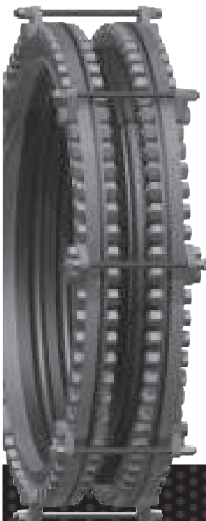

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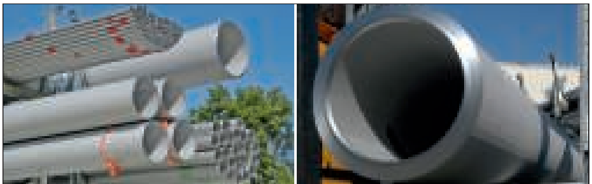

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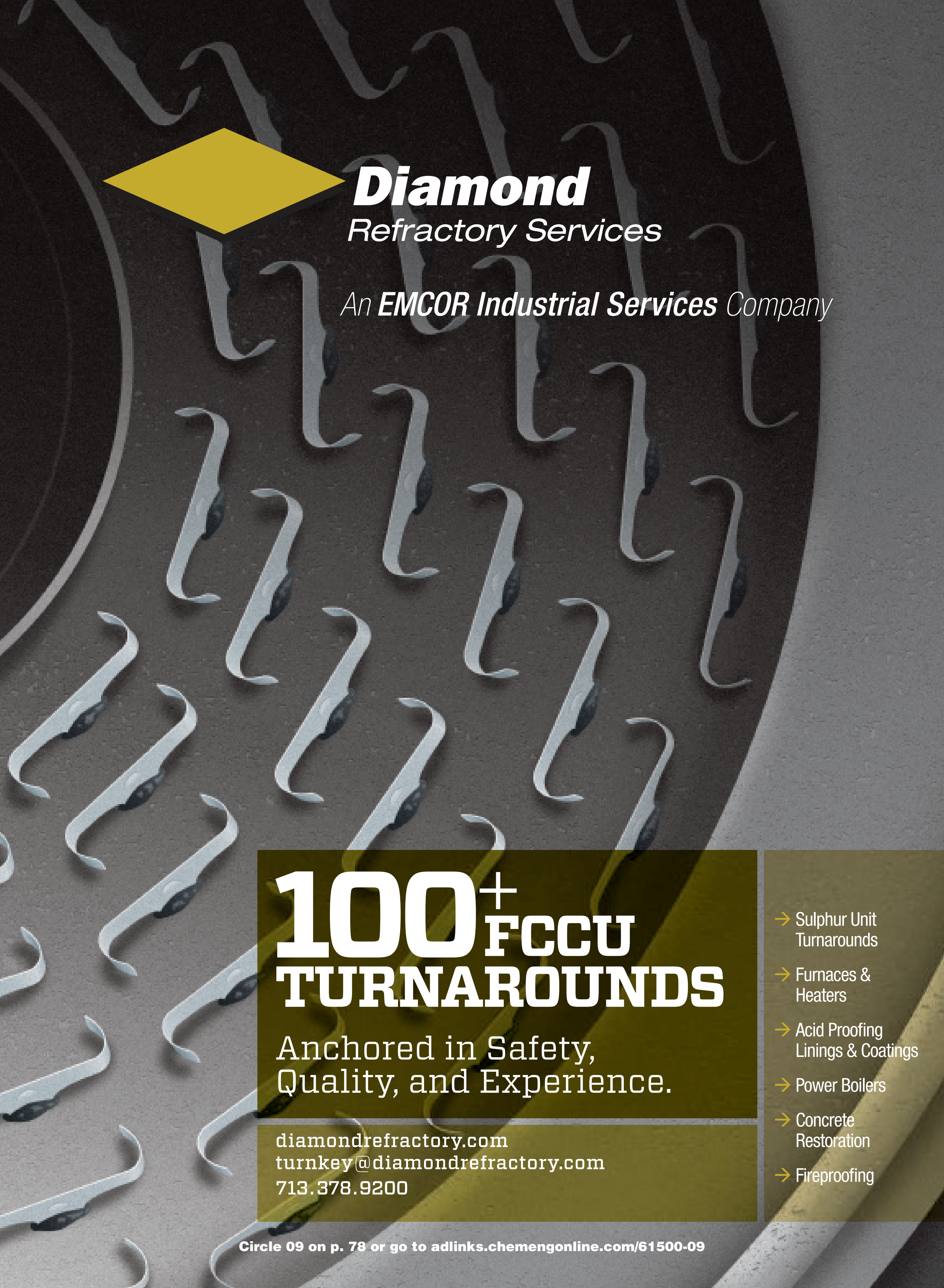
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Plant Watch

BASF expands global production capacity of Ultrason polyarylsulfone

September 8, 2016 — BASF SE (Ludwigshafen, Germany; www.basf.com) will set up an additional production line for Ultrason polyarylsulfone at its site in Yeosu, Korea. The new line will start up at the end of 2017, adding production capacity of 6,000 metric tons per year (m.t./yr) and bringing BASF's total capacity of Ultrason to 24,000 m.t./yr.

Solvay starts up hydrogen peroxide plant in China

September 6, 2016 — Solvay S.A. (Brussels, Belgium; www.solvay.com) has started hydrogen peroxide production at its new plant in Zhenjiang, China. This plant has a capacity of 60,000 m.t./yr. The plant is the first in China to use Solvay's peroxide technology.

Arkema to expand specialty polyamides production in China

September 6, 2016 — Arkema (Colombes, France; www.arkema.com) will expand specialty polyamides production at its Zhangjiagang site in China by increasing its compounding capacities. In 2017, the company will bring onstream two production lines to manufacture polyamide 11 in addition to polyamide 10.

Sadara starts up Saudi Arabia's first mixed-feed cracker

August 29, 2016 — Sadara Chemical Co. (Dhahran, Saudi Arabia; www.sadara.com) announced the startup of its mixed-feed cracker (MFC), the only one of its kind in Saudi Arabia. The MFC is made up of 12 furnaces; of these, seven will be used to crack ethane (gas), while the remaining five will be used to crack naphtha (liquid). Three of the five liquid furnaces are designed so that they can switch between gas and liquid feedstock.

AkzoNobel breaks ground on powder coatings plant in Mumbai

August 29, 2016 — Akzo Nobel N.V. (Amsterdam, the Netherlands; www.akzonobel.com) has started construction on its new €9-million powder coatings plant in Mumbai, India, which is slated for startup in late 2017. The new facility will complement AkzoNobel's existing plant in Bangalore.

Yara opens world's first modular ammonium nitrate plant

August 26, 2016 — Yara International ASA (Oslo, Norway; www.yara.com) has officially opened the world's first modular ammonium nitrate plant. The plant is located in Western Australia, northeast of Perth. The plant is currently in the commissioning phase, and is expected to be operational by the end of 2016. The plant will have capacity to produce 330,000 m.t./yr of ammonium nitrate.

Prayon to license phosphoric-acid technology for two new plants in Egypt

August 22, 2016 — Prayon Group (Engis, Belgium; www.prayon.com) will provide licenses and technical guidance for two new phosphoric acid plants to be built in Egypt as part of the NCIC Ain Sokhna Fertilizer Complex. The plants are expected to reach completion in 2018, and each plant will have a capacity of 600 m.t./d of phosphoric acid.

BASF opens construction chemicals plant in Sri Lanka

August 22, 2016 — BASF has opened its first production plant in Sri Lanka, which will produce standard and custom-made performance-based construction chemicals, including concrete admixtures products. The production plant is strategically located in the Lindel Estate at Sapugaskande, Sri Lanka, just outside Colombo.

Mergers & Acquisitions

Air Liquide finalizes divestiture of select U.S. assets to Matheson Tri-Gas

September 8, 2016 — Air Liquide (Paris, France; www.airliquide.com) has divested certain U.S. assets to Matheson Tri-Gas, Inc. (Basking Ridge, N.J.; www.mathesongas.com). The transaction, valued at $781 million, includes the sale of eighteen air separation units; two nitrous-oxide production facilities; and four liquid carbon-dioxide production facilities, including two dry-ice production facilities.

Sabic to divest Polymershapes business to U.S. investment firm

September 8, 2016 — Sabic (Riyadh, Saudi Arabia; www.sabic.com) has entered into a share-purchase agreement to divest its Polymershapes distribution business to Blackfriars Corp., a privately held investment company in the U.S. The transaction remains subject to customary closing conditions and is expected to be completed during the fourth quarter of 2016.

Tesoro to acquire renewable fuels producer Virent

September 7, 2016 — Tesoro Corp. (San Antonio, Tex.; www.tsocorp.com) has agreed to acquire renewable fuels and chemicals company Virent, Inc. (Madison, Wis.; www.virent.com). Tesoro will operate Virent as a wholly owned subsidiary. Included in the acquisition are existing collaboration agreements, licenses, intellectual property portfolio and pilot and demonstration facilities.

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Zachry acquires Clean Harbors' Catalyst Services business
September 6, 2016 — Zachry Group (San Antonio, Tex.; www.zachrygroup.com) has acquired Catalyst Services from Clean Harbors (Norwell, Mass.; www.cleanharbors.com). Catalyst Services is an international specialist in catalyst change-out services.

Chemours finalizes sale of Clean and Disinfect business to Lanxess
September 1, 2016 — The Chemours Co. (Wilmington, Del.; www.chemours.com) has completed the sale of its Clean and Disinfect business to Lanxess AG (Cologne, Germany; www.lanxess.com) for approximately $230 million. The Clean and Disinfect business includes a set of oxidation-chemistry businesses with a portfolio organized into three primary categories: disinfectants, Oxone and chlorine dioxide.

Jacobs acquires sulfuric acid converter technology from Bayer
August 31, 2016 — Jacobs Engineering Group Inc. (Pasadena, Calif.; www.jacobs.com) has acquired the patent rights for Bayqik quasi-isothermal sulfuric acid converter technology from Bayer AG (Leverkusen, Germany; www.bayer.com). Bayqik technology enables more efficient conversion of process gas with high SO_2 concentrations.

Albemarle to acquire lithium hydroxide and lithium carbonate assets in China
August 23, 2016 — Albemarle Corp. (Baton Rouge, La.; www.albemarle.com) will acquire the lithium-hydroxide and lithium-carbonate conversion assets and supporting business functions currently operated by Jiangxi Jiangli New Materials Science and Technology Co. The transaction is expected to close by the end of the first quarter of 2017.

Showa Denko and JX Nippon buy LyondellBasell's stake in PP JV
August 23, 2016 — Showa Denko K.K. (Tokyo, Japan; www.sdk.co.jp) and JX Nippon Oil & Energy Corp. have agreed to purchase LyondellBasell's (Rotterdam, the Netherlands; www.lyondellbasell.com) 50% stake in SunAllomer Ltd., a joint venture (JV) company among the three parties focused on polypropylene (PP) materials.

Teijin to acquire DuPont's stake in Asian polyester-film JVs
August 22, 2016 — Teijin Ltd. (Tokyo, Japan; www.teijin.com) will acquire the interests owned by DuPont (Wilmington, Del.; www.dupont.com) in the companies' film-business JVs in Japan and Indonesia. The ventures — Teijin DuPont Films Japan Ltd. and P.T.Indonesia Teijin Dupont Films — were formed in 2000 when Teijin and DuPont integrated their polyester film businesses.

Emerson to acquire Pentair's Valves & Controls business for $3.15 billion
August 19, 2016 — Emerson (St. Louis, Mo.; www.emerson.com) has signed an agreement to purchase the Valves & Controls business of Pentair plc (Manchester, U.K.; www.pentair.com) for $3.15 billion. The acquisition is expected to close in the next six months, subject to regulatory approvals. ■

Mary Page Bailey

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Ethics Survey Results: Your Responses

Responses from 2015 *CE* ethics survey range from hopeful to cynical, and both similarities and differences emerge when compared to earlier surveys

In October 2015, *Chemical Engineering* conducted a survey among chemical process industries (CPI) professionals about workplace ethics and ethical culture (*Chem. Eng*., October 2015, pp. 50–55). The survey asked a series of general questions about ethics culture in the CPI workplace and presented a number of hypothetical situations in chemical manufacturing in which ethics would play a role. This followup article reports results from that survey. In some cases, the questions and ethics scenarios repeated those found in earlier ethics surveys (see *Chem. Eng*., April 2007, pp. 50–53 and *Chem. Eng*., October 2007, pp. 60–67). Thank you to those who provided responses and input for the survey.

General questions results

In response to the question "In the past 6–10 years, have people become more ethical, less ethical or remained the same?," 46% of the almost 700 respondents said people have become less ethical than in the past, while 15% said "more ethical" (38.4% said people have remained the same). When the same question was asked in 2007, a smaller portion (42.8%) of respondents said people were less ethical, and a larger share said "more ethical" (21%). In 1980, the total was 41% of respondents saying people were less ethical, and 16.6% saying "more ethical."

When questioned about whether they had done something that would be considered unethical, 91% of survey respondents said "no," compared to 87.5% in 2007. However, for the question of whether respondents knew anyone at their company who had done something unethical, only 60.6% said "no" (39.4% reported "yes") in the 2015 survey. In the 2007 survey, it was 63.7% saying "no" (36.3% "yes).

The following are additional results from the general questions:

CE readers were also asked whether they felt punished in some way for making an ethically sound, but unpopular, decision. In 2015, 34.4% said "yes," compared to 29.7% in the 2007 survey.

Question no. 6 in the survey asked how respondents would rate various groups within their workplace, including upper-level managers, technical staff, human resources and administrative staff. The results indicate that respondents felt upper management at their workplace had "average" ethics, while technical staff was generally rated as having "above average" ethics.

Question no. 7 asked respondents to say how much they agreed or disagreed with the statement "Ethical decision-making is always good for business." Over 68% of respondents chose "Strongly agree," and 20% chose "Somewhat agree." Somewhat disagree came in at only 3.7%, and strongly disagree was 0.6%. The 2007 results for the same question were the following: 57.8% strongly agree; 29.3% agree; 6.8% neutral; 4.8% disagree; 1.3%.

Question no. 8 inquired about to what extent respondents agreed with the statement "Social responsibility and ethics are symbiotically related." The results for 2015 were the following: Strongly agree = 55.9%; somewhat agree = 27.2%; neither agree nor disagree = 10.5%; somewhat disagree = 3.7%; strongly disagree = 2.6%. For 2007, the results were: 66.1% strongly agree; 24.3 agree; 6.5 neutral; 1% disagree; 2.1% strongly agree.

TABLE 1. SURVEY RESULTS SUMMARY			
Case / question	1980 data	2007 data	2015 data
Case 1 (Just a pinch of poison)	61% said response 1 (report findings, but recommend additive not be used); 20% said "other"	77% responded with answer 1	91% responded with answer 1
Case 2 (To err is human)	54.2% said response 1 (inform government authorities, even though no harm resulted)	65.2% said answer 1	77% said answer 1
Case 3 (The missing gasket)	not available	69.4% said response #2 (order new gasket and postpone tests); 18.4% said "other"	83% said response 2
Case 4 (Insider information)	51.2% said response 2 (don't say anything, so consequences of inspection lead to changes in plant safety practices)	47.4% said response 2 15% said response 4 (anonymously inform OSHA about the knowledge revealed regarding the surprise inspection)	54.5% said response 2; 18% said response 4
General questions			
Q1 (In the last 6–10 years, do you think people have generally become more or less ethical?)	41% less ethical 37% same 16.6% more ethical	42.8% less ethical 36% same 21% more ethical	46% less ethical 38.4% same 15% more ethical
Q2 (Have you ever done something unethical at work that could, or did, have a harmful effect?)	not available	87.5% said no 12.5% said yes	91% said no 8% said yes
Q3 (Do you know of anyone at your company that has done something you consider unethical?)	not available	63.7% said no 36.3% said yes	60.6% said no 39.4% said yes
Q4 (Have you ever felt punished for making an ethical, but unpopular, decision in your workplace?)	not available	70.3% said no 29.7 said yes	65.6% said no 34.4% said yes
Q5 (Do pressures at work ever cause you to seriously think of doing something ethically wrong?)	not available	64.9% said no 35.1% said yes	72.3% said no 27.7% said yes

Ethics-related scenarios

The 2015 *CE* ethics survey also presented readers with several ethically charged situations and inquired about how they would react in such instances (see Table 1). The first four of the scenarios were repeated from the earlier *CE* surveys, and results are compared to those from previous years. The second set of four situations were new to last year's survey.

Case 1. A Pinch of Poison (A serendipitous discovery indicates that a minute amount of tin and lead salts, recognized poisons, can stabilize a product and increase profits). A wide majority of respondents (91% in 2015) said that they would report the findings on the potential profits, but recommend that the additive not be used at all, despite the fact that the levels are as low as what might be expected to leach out of soldered seams of cans.

Case 2. To Err is Human (Cyanide-containing water is dumped illegally into the sewer system, but no apparent harm results). The most common course of action chosen in the 2015 was to follow the law and report the incident to authorities (77%) and risk fines and discipline, even though no harm resulted. The total choosing this option was higher than what was reported in previous surveys.

Case 3. Missing Gasket (An operator must decide whether or not to go against policy to reuse a critical gasket in order to meet a test deadline). In this case, 83% of respondents said they would elect to postpone the pilot test until a new gasket can be obtained, although doing so would jeopardize the company's chances of winning a bid.

Case 4. Insider Information (An engineer learns of an impending surprise OSHA inspection in a confidential conversation). The most common response (54.5%) for this case was to keep the information private, and potentially subject the company to several changes in safety practice, rather than warn the plant's safety manager of the surprise safety inspection.

Case 5. Vendor Incentives (from Michael Pritchard at the Center for the Study of Ethics in Society at the Western Michigan University. The case involves an engineer in a situation in which they could help the relative of a vendor he knows and get a cheap place to stay for his vacation, but would violate company policy about accepting incentives). The responses were the following: 63% said they would discuss the situation with company management and let them decide; 31.2% said they would cancel their vacation plans to avoid accepting the incentive; 5.8% said they would go through with the vacation plans anyway.

Case 6. Internal Dissent (from Michael Pritchard; The scenario involves an engineer who is faced with the choice of following the orders of a superior, even though it would require falsifying a report). A high number of respondents (89%) said they would refuse to write the report on the grounds that it would be falsification, going against the boss's orders. Eleven percent said they would write the report as their superior asked.

Case 7. Getting Acquainted (from Michael Pritchard; This case involves a valve for a caustic tank that was mistakenly left open, resulting in the loss of caustic. Would you assign blame to a childhood friend who works under you, or acknowledge responsibility yourself?). In this question, 87.5% of respondents said they would acknowledge responsibility to their supervisor for leaving the valve open, while only 12.4% said they would identify their friend as the one who left the valve open.

Case 8. Chemical Waste Handling (from Michael Pritchard; The case involves a choice about moving leaking drums to prevent environmental problems despite a law prohibiting transport of chemical waste). Most respondents (69.3%) said they would tell the waste manager that they would inform superiors of the illegal act despite its potential to avoid environmental problems. Over 25% said they would recommend that the waste manager not move the drums, but allow him to go through with the plan. Four and a half percent said they would allow the waste manager to to go ahead with his plan, but not help. Only 1% of respondents said they would help the waste manager carry out his plan to move the drums illegally and potentially avoid any environmental problems.

In readers' own words

As part of the 2015 *CE* ethics survey, respondents were invited to offer open-ended, freeform comments on the current ethical culture within their industry sector. The following is a sample of the reader comments.

On the general ethics culture . . . "I believe that ethics are being gradually redefined to accommodate popular practices. I fear that societal impacts may be significant."

"Ethics can be a subjective issue. It needs to come from within and can not be enforced on people."

"The desire for some to get ahead or look good causes them to act unethically and then defend it by explaining that everyone else does it."

"[Ethics] has too low a profile and visibility in the workplace."

"As a society, we have divorced ourselves from any metric or standard of correctness. To fill the vacuum . . . folks have begun building their own, with varied degrees of success or ridiculousness . . . and [have] spawned two generations of people who don't recognize, or cater to, any standard at all."

"Ethics is seldom brought up in this industry. The focus tends to fall on safety and environment, with ethics often being overlooked or ignored."

"Political interference is normally the cause of most unethical decisions/acts. Our leaders have to seriously get over this problem."

"I believe that the vast majority of people try to live and work with high ethics. Unfortunately, ethical lapses receive lots of press, which probably makes the situation appear worse than it really is. With the high pressures to perform economically, it is easier to fall into unethical decisions."

"We may each have our own interpretation of ethics and social responsibility, which complicates matters."

"I think the most of the young generations learn less and less about ethics in their careers. Universities do not pay enough attention to the ethics in their curricula."

On the influence of money on ethics . . . "Economics drives all the decisions in my company. My company lobbies regulators for regulations that minimizes the impact on them at the cost of negative impacts on the safety of workers, harm to the environment and the potential health or environmental impact to the surrounding communities. This is done even if there is evidence that more strict regulations are needed to minimize the impact on human health and the environment. In my experience, as long as we remain legally compliant, our company could care less about how they are impacting others. They use compliance with the law to tout their commitment to 'worker safety,' 'social responsibility' and their desire to protect the environment."

"With the current state of the economy, it is easy for some people to look at short-term profits and put ethics on the side. We should always look at the long term instead and make the correct and ethical decision now."

"More ethics equals less money."

"Pressure from Wall Street for an organization to make money, almost at any cost, is significantly contributing to this unethical behavior."

"The present focus on cost is creating an environment that may impair ethical and social behaviors."

"Money and 'the bottom line' drives business nowadays, not ethics or social responsibility."

"Profit and business drives most decisions, and ethical dilemmas crop up as a result of cost-saving initiatives resulting in poor decisions being made by management not equipped to make these decisions. This results in accidents, added health and safety risk and bad morale."

"Tough times make it more difficult for people to do the right thing."

"Money drives most unethical decisions. Just look at the current VW diesel emissions scandal."

On ethics and business culture . . . "There are so many pressures in today's business climate that I feel that management and companies today do what they can to survive, but this unfortunately results in some less-than-ethical decisions at times."

"'Don't get caught' appears, unfortunately, to continue to be the ethical theme of American business."

"The chemical industry is generally more ethical than financial, entertainment, transportation/automotive businesses and far more ethical than any branch of government."

"Business culture is very much amoral, by policy and by nature, with only the goodness of most individuals within organizations sustaining ethical standards."

"Ethical culture in an industry is intimately linked to the ethical culture of society. Honest industrial leaders are left on the sidelines by unethical upstarts who form nexus with politicians. In other cases, pressures for performance result in unethical practices, which can result in consequences for companies. Hence, the only way to enforce ethical practices is strong audits and severe punishments, and an ethical political environment — is this utopia?"

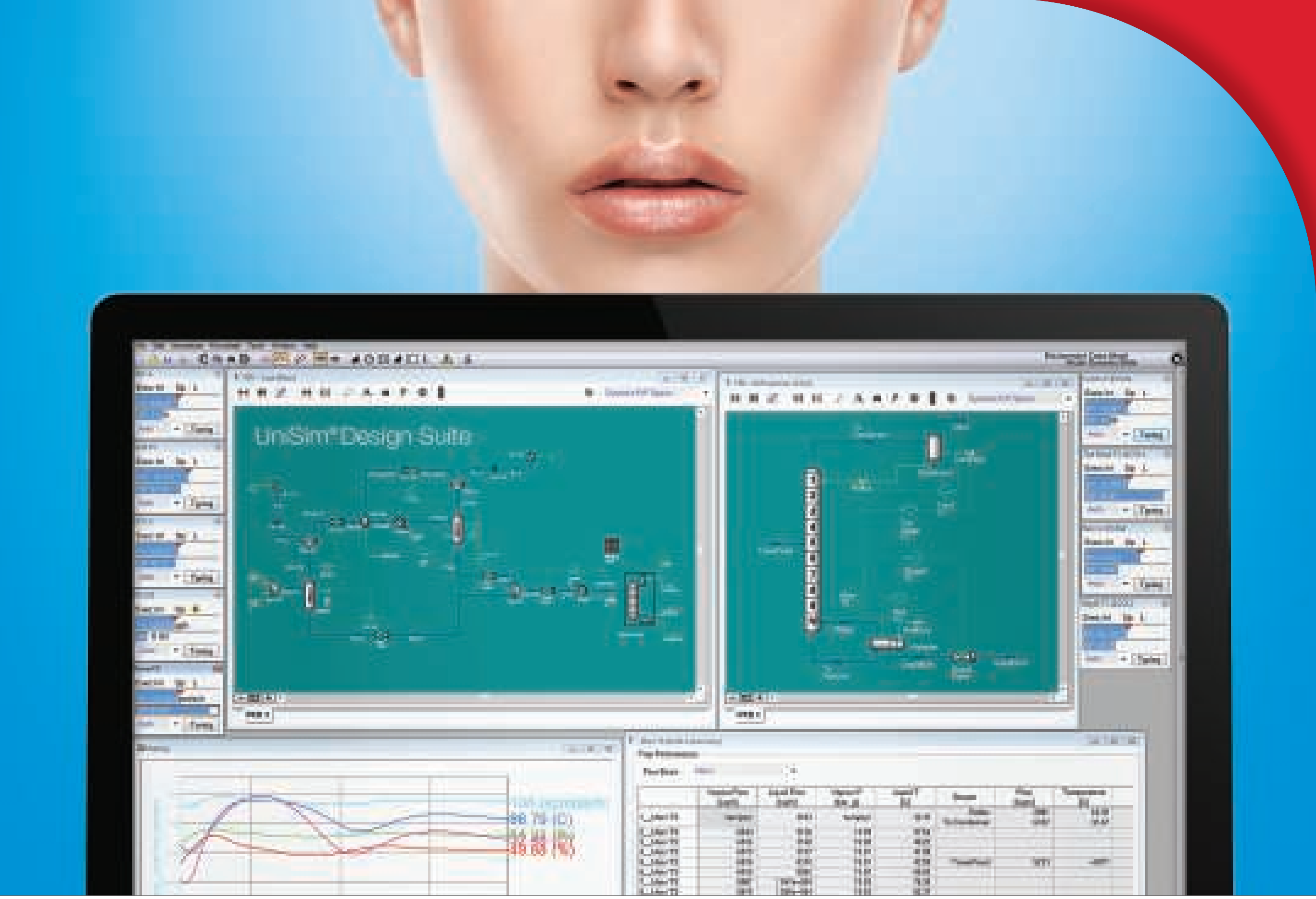
"Company leaders should do exactly that: lead by example by doing what is right and ethical, even if it means losing business. Unfortunately many of our government and senior officials don't see things the same way. This leads to an overall degeneration in society and ethical behavior by seemingly condoning non-ethical and corrupt practices."

"If you have to have ethics training for your employees, you are hiring the wrong people."

"Management 'talks the talk,' but does not always 'walk the walk' on ethics. Corporate politics and power gamesmanship trumps the message on how important ethical behavior is to the company."

"There is a conflict of interest between social and environmental ethics and big business, since large competitive companies' motto is 'profits, no matter what.'" ■

Scott Jenkins



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Chemical Safety: A Challenging Road Ahead

Passage of the Lautenberg Chemical Safety Act has created a long and challenging road ahead for U.S. EPA rulemaking

IN BRIEF

STAKEHOLDER INPUT

EPA ACTION

INITIAL RISK ASSESSMENTS

TSCA WORK PLAN CHEMICALS

On June 22, 2016, the Frank R. Lautenberg Chemical Safety for the 21st Century Act (LCSA) was signed into law with great fanfare as the successor to, and replacement for, the Toxic Substances Control Act (TSCA), which had not been updated since 1976. Among other provisions, the new law establishes a mandatory requirement for the U.S. Environmental Protection Agency (EPA; Washington, D.C.; www.epa.gov) to evaluate the safety risks associated with existing chemicals, creates a risk-based standard for determining whether the use of a chemical poses an "unreasonable risk" and lays the groundwork for a consistent source of funding for EPA to carry out its responsibilities under the law.

Although the law has enjoyed widespread support from many stakeholders, the details of how the law will be implemented are presenting a host of challenges, both philosophical and logistical, for the EPA and for industry. Among these challenges are how to conduct chemical safety evaluations, how to prioritize the chemicals up for review, and what fees will be assessed to chemical manufacturers. Developments over the last few months have moved toward resolving some of the questions, but a long and challenging road remains ahead.

"EPA has a big job in front of it," says Steve Owens, a principal with the law firm Squire Patton Boggs (Phoenix, Ariz.; www.squirepattonboggs.com), and a former EPA assistant administrator, "but virtually all of the stakeholders have been supportive so far, and [EPA] has handled it well to this point."

"So far, everybody has been 'on their best behavior' with the rollout of this law, but it is still early in the process, and there could be a lot of friction in the rulemaking process," Owens says. "There are four major rulemakings that need to be accomplished in one year, and that is very difficult to do, even under ideal circumstances," he explains. Lawsuits, Congressional action, or other unforeseen developments related to an election-year transition to a new administration could hinder the effort.

Stakeholder input

In an environment of stubborn partisan opposition, the LCSA was a rare piece of legislation that enjoyed widespread support from both U.S. political parties, as well as from industry groups. The American Chemistry Council (ACC; Washington, D.C.; www.americanchemistry.com), an industry organization that supports the law, says "Thanks to the LSCA, America's manufacturers will have the regulatory certainty they need to innovate, grow, create jobs and win in the global marketplace — at the same time that public health and the environment benefit from strong risk-based protections."

Chemical producers are on board. Mark Silvey, senior manager for corporate and government affairs at PPG (Pittsburgh, Pa.; www.ppg.com) says "passage of the [LCSA] . . . has secured a much-needed overhaul of our nation's chemical laws." The modernized chemical safety law "puts the protection of

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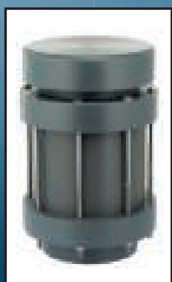

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human and environmental health and safety first, while also enabling America to retain its place as the world's leading innovator," he adds.

Environmental groups have also been generally supportive of the law's intent to strengthen EPA's authority to evaluate chemicals on a safety basis, and improving the existing TSCA law, which many have viewed as weak. However, some groups, including the public health advocacy organization Environmental Working Group (EWG; Washington, D.C.; www.ewg.org), think the law doesn't go far enough.

While it acknowledges that the law makes significant improvements over the previous TSCA law, the EWG argues that the law "does not provide EPA with the resources or clear legal authority to quickly review and, if needed, ban dangerous chemicals linked to cancer and other serious health problems."

Whether or not the law succeeds in its intent will be determined largely by how the rules and regulations associated with the law are developed, and the process of collecting stakeholder input for those rules is well underway. ACC says it wants to ensure that the rules developed under the LCSA are "written in a way that encourages effective and efficient implementation of the nation's updated national chemical regulatory system."

The EWG calls the rulemaking process for the LCSA "an unprecedented opportunity to perform robust risk evaluations and promulgate strong regulations to protect all Americans from the most toxic chemicals in our society."

EPA action

Immediately after the June passage, the EPA issued its "First Year Implementation Plan" for the LCSA. EPA says it intends the plan to be a "roadmap of major activities EPA will focus on during the initial year of implementation," but stressed that the plan would be a "living document" that is subject to further development over time.

In an effort to engage stakeholders early in the rulemaking process, EPA held a series of stakeholder meetings in Washington in August. One of the meetings dealt with determining which chemicals EPA would get initial risk evaluations by the agency. Another meeting focused on the agency's general process and criteria for identifying high-priority chemicals for risk evaluation and how to prioritize other chemicals in the future.

ACC says "A draft prioritization rule must: clearly define the criteria for designating high and low priority chemicals based on hazard and exposure potential, conditions of use and other factors; provide timeframes for EPA to complete its work and for manufacturers to provide information to the Agency; outline a prioritization methodology that allows for the incorporation of new exposure tools and methods over time; and, include ample opportunities for stakeholders to provide comments and information to the Agency."

The third stakeholder meeting had

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o- and *p*-Dichlorobenzene
3,3'-Dichlorobenzidine
3,3'-Dichlorobenzidine dihydrochloride
1,1- 1,2- and *trans*-1,2-Dichloroethylene
1,2-Dichloropropane
Dicyclohexyl phthalate
Di-ethylhexyl phthalate
Di-isobutyl phthalate
Di-isodecyl phthalate
Di-isononyl phthalate
1,2-Dimethoxyethane
2-Dimethylaminoethanol
di-*n*-Octyl phthalate
1,4-Dioxane
Ethanone, 1-(1,2,3,4,5,6,7,8-octahydro-2,3,5,5-tetramethyl-2-naphthalenyl)
Ethylbenzene
Ethylene dibromide
bis(2-Ethylhexyl) adipate
2-Ethylhexyl 2,3,4,5-tetrabromobenzoate
bis(2-Ethylhexyl)-3,4,5,6-tetrabromophthalate
Formaldehyde
2,5-Furandione
Hexabromocyclododecane (HBCD)
Hexachlorobutadiene
1-Hexadecanol
1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [γ]-2-benzopyran (HHCB)
2-Hydroxy-4-(octyloxy) benzophenone
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4,4'-Methylene bis(2-chloroaniline)
4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)
N-Methyl-2-pyrrolidone (NMP)
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N-Nitroso-diphenylamine
Nonylphenol and nonylphenol ethoxylates (NP/NPEs)
Octamethylcyclotetra-siloxane (D4)
4-*tert*-Octylphenol(4-(1,1,3,3-tetramethylbutyl)-phenol)
p,p'-Oxybis(benzenesulfonyl hydrazide)
p,p'-Oxybis(benzenesulfonyl hydrazide)
Phosphoric acid triphenyl ester (TPP)
Phthalic anhydride
Styrene
Tetrachloroethylene
Tribromoethane
1,1,2-Trichloroethane
Trichloroethylene
Triglycidyl isocyanurate
Tris(2-chloroethyl) phosphate
2,4,6-Tris(-*tert*-butyl)phenol
Vinyl chloride
m-, *p*-, and *o*-Xylene

to do with the collection of fees to help defray the cost of implementing provisions of the law and fees for the costs of industry-requested risk evaluations. EPA acknowledges the importance of completing a rule on fees in a timely manner.

Public comment periods for those three topics closed in late August, and many groups did submit comments. The agency is now reviewing those comments in preparation for its draft rules in those three areas.

Initial risk assessments

One of the major decisions for the EPA will involve which chemicals will be the subject of the first safety evaluations under the LCSA. As part of its implementation plan for LCSA, EPA will publish a list of ten chemicals on which it will conduct risk assessments, and formally initiate those studies. The list of the first ten chemicals, which EPA plans to reveal by mid-December, may be influenced by stakeholder comment, but will be drawn from a larger list established before the passage of LCSA. In 2014, EPA published a 2014 update to its "TSCA Workplan for Chemical Assessments," a list of 90 chemicals known to pose health risks and that the agency intends to consider for a risk assessment. The list was generated by considering factors that include a chemical's potential for reproductive or developmental effects, possible neurotoxic or carcinogenic effects, and its ability to persist, bioaccumulate and be toxic.

The TSCA Work Plan list includes a wide range of chemical types, including compounds of heavy metals, such as cadmium, nickel and arsenic, as well as solvents, such as benzene, toluene and xylenes and common monomers, such as vinyl chloride and styrene (see box). The work plan list of 90 chemicals includes four for which EPA has completed risk assessments under the previous legislation: antimony trioxide (a synergist for halogenated flame retardants), trichloroethylene, dichloromethane and HHCB (1,3,4,6,7,8-hexahydro-4,6,6,7,8,8,-hexamethylcyclopenta[γ]-2-benzopyran; a fragrance ingredient). For those four, previously governed under Section 6 of the TSCA law, EPA plans to publish rules on limiting those chemicals. EPA also has about eight additional chemicals in ongoing safety risk assessments.

Outside organizations have also weighed in on where the agency should start. For example, in July, the EWG published what it feels are the ten highest-priority chemicals for safety risk assessments. The list includes asbestos, bisphenol-A (along with its brominated form), phthalates, two classes of flame retardants (chlorinated phosphate flame retardants and brominated flame retardants), tetrachloroethylene (perchloroethylene), bis(2-ethylhexyl) adipate (DEHA), and *p*-dichlorobenzene. ■

Scott Jenkins

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Modeling and Simulation Go Beyond Design

More intuitive software allows new users to address optimization and complex tasks

IN BRIEF

- SIMPLIFIED SOFTWARE
- EXPERIMENTING WITH PARAMETERS
- MORE COMPLEX CAPABILITIES
- ON THE FOREFRONT

Honeywell Process Solutions

FIGURE 1. Honeywell Process Solutions' first-principles modeling platform is offered under the UniSim brand and is used in UniSim Design Suite and UniSim Competency Suite

Modeling and simulation software is finding more use in chemical processing facilities because software vendors are making it easier to use and, therefore, more accessible to a wider range of personnel, while also adding more complex capabilities for more detailed and specialized applications. As a result, the latest modeling and simulation packages are being employed not only for process design and detailed engineering projects, but also for modeling and simulating the plant lifecycle, from design through operations, as well as optimization, de-bottlenecking and revamping tasks.

"What we're seeing is the need for the chemical engineering, engineering and chemistry disciplines to work together in order for the facility to be at its most cost effective. Barriers are coming down, so sharing of data and information must be improved, while at the same time, the economic model must be considered, because in this downturned market, there's no room for waste," says Michael Doyle, director and principal scientist with Dassault Systemes Biovia (San Diego, Calif.; www.3ds.com). "So regarding modeling and simulation software, there's a need to have a model that goes all the way down to understand the chemistry and then all way up to understand the business economics, because they are co-dependent. If you have the wrong chemistry in the beginning or are running the plant in a non-optimal way and it results in inefficiencies, wasted materials or low-quality product, that affects the economics of the plant. Today's modeling and simulation software packages have to be able to manage all that."

Simplified software

One of the ways software providers are helping processors achieve these goals is by making modeling and simulation tools easier to use. It benefits the organization if many disciplines and employees have some level of simulation skill so they can use the software to solve smaller-scale, day-to-day issues that can come up, says Steve Brown, executive vice president and chief operating officer with Chemstations (Houston; www.chemstations.com). "For example, sometimes you just need to know the dewpoint of a mixture so that you don't drop below it in a line in the plant," he says. "Simulators are great for this type of calculation because they have a database of properties, mixture rules and phase-equilibrium calculation methods, so rather than doing a back-of-envelope calculation, someone who is not a simulation guru can do this quickly and easily using the software the company already owns. It's what we call 'democratization of simulation.'"

To aid in this effort, solution providers, such as Chemstations, are making the packages as easy to use as possible. Brown says the latest release of Chemstations' Chemcad 7 includes an overhaul of the graphical interface that allows it to be as user-friendly and intuitive as possible, while also making sure it has a similar feel to, and the ability to connect with, the other tools chemical processors are

Honeywell Process Solutions

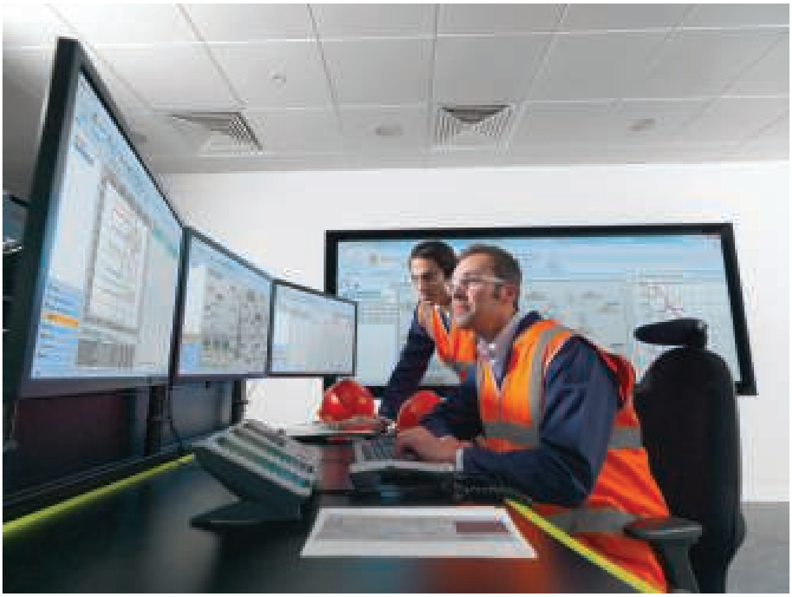

FIGURE 2. The improvements and advancements in modeling and simulation software tend to focus on improving the user experience, in terms of accuracy and performance

already using. "It was a major driving force to do a large-scale overhaul of our interface, using more modern libraries and paying close attention to what today's chemical processing computing landscape looks like."

Other simulation vendors, such as Honeywell Process Solutions (Houston; www.honeywellprocess.com), the provider of UniSim (Figure 1), are including features that make the software easier to use by more members of the facility, including tools to disassemble large simulation models into smaller parts so that they can be worked on and studied independently while being easily reassembled back to a large, integrated model; tools to import data in various formats directly into the simulation model environment; user alerts to highlight when equipment size is incorrect and when operating conditions are non-normal, says John Roffel, product director, simulation and competency with Honeywell. Other features include visualization capabilities to enhance user experience, such as a graphical depiction of pump curves and operating performance, he says (Figure 2).

The development of the application (app) culture is also having a significant impact on simplifying modeling and simulation, says Mark Matzopou-

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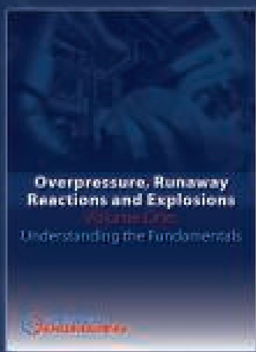

CHEMICAL ENGINEERING Learn more by visiting store.chemengonline.com los, marketing director with Process Systems Enterprise (PSE; London, England; www.psenterprise.com). "The mobile technology world is finally filtering through to the process industry, with end users being provided with capabilities to easily generate apps that hide the complexity of the underlying model from users. Often, the latter are 'non-modeling' users — operators, operations and planning, purchasing and R&D personnel — who simply need to perform a specific calculation without worrying about the underlying physics and chemistry."

As a result, he says, PSE is working with major customers to roll out an app capability that will allow them to generate an app from any of gPROMs (the company's modeling and simulation product) model — large or small, simple or complex — for distribution to selected users within the organization.

And, simulation provider Comsol (Boston, Mass.; www.comsol.com), also offers support for custom app development in the latest version of its LiveLink for Solidworks software geometry. The latest release of Comsol Multiphysics provides simulation experts with capabilities for building custom simulation applications. The software integrates highly productive model building, app design and the deployment tools that allow simulation apps to be easily run by users anywhere. About 50 new app examples are included in the Application Libraries, including membrane dialysis, water treatment, thermoelectric cooling, heat exchangers, pressure vessels and more.

"The offering of apps means that chemical engineers who want to make a change to optimize production can use these simple apps to look at what happens if they change this parameter or that one," explains Ed Fontes, chief technology officer with Comsol. "The value comes in having the tool accessible to perform quick calculations, check the status, look at and share the results of potential changes."

He continues: "Whether you are using process simulation software that can model the whole plant or packages that are more detailed for the design of a specific process or process step in the plant, having an app with a very simple user interface allows more people to study, understand and optimize the process."

Dassault Systemes Biovia

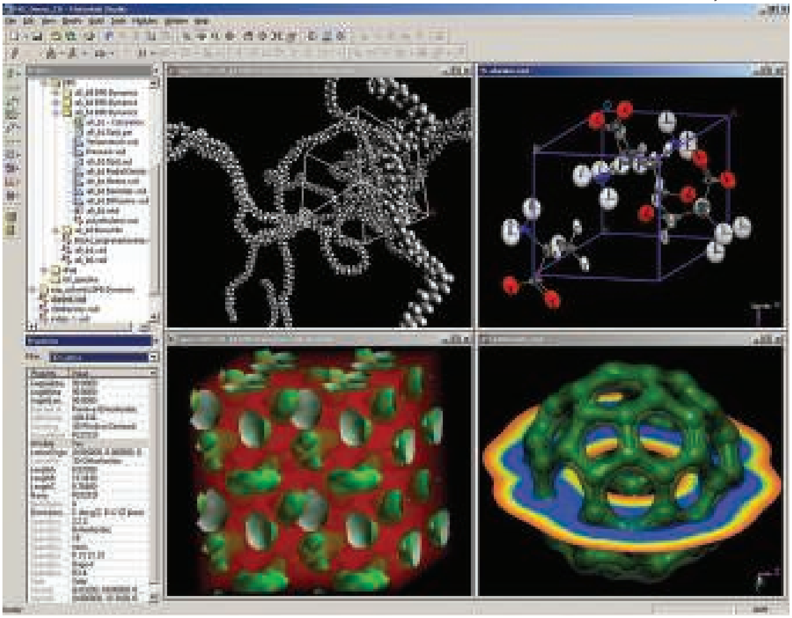

FIGURE 3. Materials Studio is a complete modeling and simulation environment designed to allow researchers in materials science and chemistry to predict and understand the relationships of a material's atomic and molecular structure with its properties and behavior

Experimenting with parameters

"The ability to easily model and simulate is essential for quickly optimizing a plant or process when parameters must change," says Comsol's Fontes. "In many continuous processes, manufactures have to change production parameters according to raw material prices, utility cost or increases and decreases in production yield. Simplified modeling and simulation tools can be used for that."

Biovia's Doyle agrees that easier-to-use, integrated modeling and simulation software allows processors to experiment with changing parameters and find and implement the most efficient scenario before making actual changes. "For example, in the [petroleum] refining industry, the incoming chemical feed may change dramatically based on oil prices, availability and quality, which necessitates changes that may upset the limits on the chemistry of the process and the stability of the process," he says. However, Doyle adds, processors can use simulation tools like Bovia's Materials Studio (Figure 3) to understand a range of possible chemistries and possible reactions that might occur when something in the process changes."

Optimizing a process via this type of modern environment allows processors to build the best-case scenario for operating the plant, even under changing conditions.

More complex capabilities

While improved interfaces, features and the introduction of apps are putting simulation tools in the hands of more personnel in an effort to optimize the ever-changing chemical facility, the addition of complex capabilities also allows processors to perform more detailed tasks, generating improvements in operational efficiencies.

First-generation process engineering simulations were based upon hand-generated calculations and Microsoft Excel spreadsheets that were based upon basic engineering design and empirical data, says Ravindra Aglave, director, chemical process, with CD-adapco (Melville, N.Y.; www.cd-adapco.com). As time progressed, he continues, the second generation of process simulation included flow


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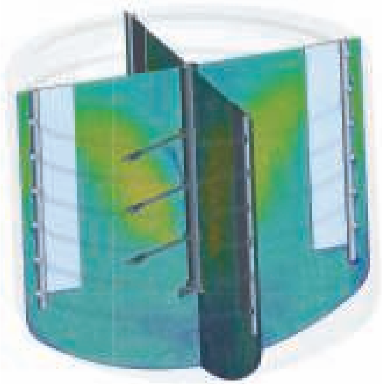

FIGURE 4. Computational fluid dynamics (CFD) simulation is used to answer the numerous mixing challenges that cannot be solved by analytical or experimental methods. An automated process via a virtual product-development tool called Admixtus is available. Admixtus seamlessly integrates with STAR-CCM+

sheets that were made into software tools that people could use to obtain more details regarding material properties and to investigate various situations. "And now we have the third generation where looking at design from a larger perspective isn't sufficient anymore," says Aglave. "Users want to get down into the details to see how they can improve detailed parts of the process to improve efficiencies, reduce waste, increase quality, and so on. What used to be specialized capabilities are now becoming commonplace because more people want to use the technology to perform more difficult tasks."

Along those lines, CD-adapco has added AdMixtus to its flagship product, Star CCM+ (Figure 4). "Mixing is a key process in almost every chemical plant, but simulation has not been employed here much because it's a difficult process to simulate," says Aglave. "But with the release of this tool, engineers who are involved with mixing processes but don't necessarily use simulation, can gain expertise in a short period of time. They can use the power that comes from this simulation tool to improve their mixing processes and overall production efficiency, as a result."

AspenTech (Bedford, Mass.; www.aspentech.com), too, has added more complex capabilities to its Aspen Plus product. Users can design a distillation column scheme with Aspen Distillation Synthesis, which allows them to model a distillation in Aspen Plus and use Aspen Rate-Based Distillation for rigorous design, providing more accurate simulations. "The models can be used to increase efficiency, because we can use these models to start identifying, in realtime, the issues that might be causing bottlenecking. This makes the operator aware of what is causing the column to perform badly and helps engineers make changes in column design that will save money and avoid potential problems going forward," says Matt Holland, vice president of chemicals with AspenTech. "And analytically, the software can be used to detect a pattern of data or a series of events and issue an alarm so that operators can act when they recognize potential errors in the process."

The use of state-estimation for "self-tuning" online models is another recent addition, says PSE's Matzopoulos. "One of the challenges of operational models used for monitoring or optimization is that, after a while, they may not represent the actual state of the plant very well," he says. "Heat exchangers foul, catalyst deactivates and it's very difficult to take this into account in a predictive model. State estimation techniques couple the plant model and plant data, exploiting any redundancy in plant measurement and taking into account the uncertainties in both, to effectively 'self-tune' the plant model."

He says a key application for PSE is in olefins, in particular ethylene yield and coking prediction. PSE's gCracker Online incorporates the latest in state-estimation technology to perform accurate yield prediction and prediction of coking, which has an effect on many aspects of the plant economics.

On the forefront

In a similar fashion, software providers, such as AspenTech, with experience in chemical and other process industries, are beginning to use data from their own experience and expertise to build even more detailed pattern recognition into the simulation and modeling products.

"With our current analytical package, we can capture the data and then use advanced techniques to see if the same situation has occurred before and determine the likely outcome. If we see some consistency, we can start using that pattern or trend to effectively start alarming," explains Holland. "This means that instead of basing alarms on just one pressure or temperature plot within the user's facility, we are basing them on patterns of recognized behavior. This type of pattern recognition capability is going to be a very powerful feature going forward."

Chemstation's Brown says his company is currently working on a major game-changer in the world of first-principle simulation. "In reality, very few people use first-principle simulation tools for major optimization projects because it is relatively slow to run for this purpose," says Brown. He adds that when running optimization scenarios, the software must be fast because it may need to run tens of thousands of times to find the optimum solution, which takes a long time and is expensive.

To address the speed of first-principle simulation tools, such as Chemcad, he says they are working on a complete rewrite of the calculation code base and are taking advantage of parallel processing. "This means that instead of using just one core of the user's computer, we are going to be able to spread the workload across as many cores as are available, which will speed the process considerably," explains Brown.

"We are seeing orders-of-magnitude faster execution of really big optimization problems. This puts us into the realm of being as fast as an equation-based solving system, but the advantage of first-principle simulators is that we offer a great graphical interface that's easy and faster to use than equation-based systems."

"This means that large-scope, large-scale optimization problems can be handled with first-principle simulation products," says Brown. ■

Joy LePree

Compressors, Fans and Blowers

This variable-speed drive for compressors pays for itself

The Vorecon (photo) is a variable-speed planetary gear that is used to control the speed of compressors, fans and pumps. The Vorecon combines reliable a mechnanical design with hydrodynamic power transmission, which is wear-free. This allows the device to achieve a mean time between failures (MTBF) of 48 years, says the company. By allowing the driven machine to operate at the speed required by the process, the Vorecon is said to allow for tremendous energy savings compared to throttle or bypass-control systems, helping to amortize its cost in just a few years of service. The unit is comprised of a speed-control system, gearbox and oil supply, and this design requires roughly 68% less installation space compared to comparable electronic variable-speed-drives. This reduces infrastructure costs, particularly in offshore installations. — *Voith Turbo GmbH, Crailsheim, Germany*
www.voith.com

Voith Turbo

Control turbomachinery overspeed to reduce faults

The FlexSILon TMC solution, operating on the fully redundant HIMax platform, is an integrated safety system that combines all components needed to achieve full automation of turbines and compressors in a single system. It provides a cost-effective alternative to using components from different manufacturers, according to the company. The solution provides overspeed protection for SIL 3 and meets API 670 while improving safety and flexibility, says the company. Turbomachinery operators benefit from reduced engineering, reduced cabinet space, simple wiring and one single communication system (reducing the risk of faults). — *Hima Paul Hildebrandt GmbH, Bruehl, Germany*
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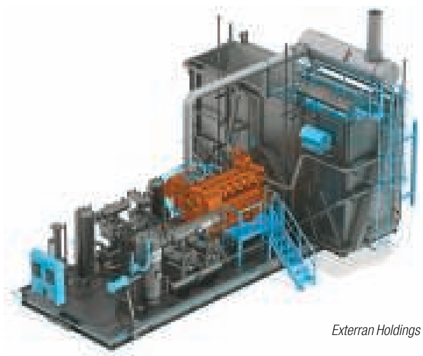
Hima Paul Hildebrandt

This gas-compression package has many configuration options

The C-Series 7044 Gas Compression package (photo) is the latest addition to the company's line of natural-gas compression products, which are designed for wellhead, gas-gathering, flare-elimination, processing, inlet and other applications. This pre-engineered system can be configured with more than 60 options, including advanced emissions-control systems, to meet most regulatory requirements, says the manufacturer. The package is built on heavy-duty steel skids and can be used in an array of natural gas applications, generally above 5 psig inlet pressure and up to 1,300 psig discharge pressure. — *Exterran Holdings, Houston*
www.exterran.com



Exterran Holdings

This temperature sensor withstands harsh conditions

The Model TF37 screw-in thermometer with connection lead is designed for mobile compressors, hydraulics and air-conditioning systems. The cable connection decouples the measuring point and connection point. This design makes the temperature sensor resistant to vibration, shock, temperature and pressure fluctuations. The connection lead of the model TF37 is made from PVC, PTFE or silicone, while the transition point to the thermowell is both dust-proof and waterproof (with ingress protection meeting IP65 or IP66/67 standards, according to the company). This compact thermometer provides a measuring range from –50 to 260°C and can be delivered with all common measuring elements. — *Wika Alexander Wiegand SE & Co. KG, Klingenberg, Germany*
www.wika.de

Fans to meet a diverse array of industrial applications

This company offers a wide range of fans for serving industrial boilers, gas turbine installations, and heat-recovery

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

Howden American Fan

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steam generators in combined-cycle installations. Direct-drive fans, including the popular industry-standard AF line of cast aluminum medium-pressure blowers, nine types of backwardly inclined fans, and turbo pressure blowers and industrial exhausters. Also available are dual skid-mounted fan assemblies (photo), including two fans connected to a common diverter damper mounted on a common unitary channel sub-base. This design provides one fan for everyday operation and one fan to serve as a standby unit, says the company. Non-standard packages can be customized to meet the site-specific needs of the application. — *Howden American Fan Co., Cincinnati, Ohio*
www.americanfan.com

This compressed-air system is energy efficient and quiet

The Boge C 16 F(D) is a new oil-injection, cooled-screw compressor that claims to have the highest volume of free-air delivery in the 11-kW compressor range. With the addition of a high-end IE3 motor, a virtually noise-free intake filter, and a robust cast-iron casing, this product is both energy efficient and quiet. This allows users to install it in close proximity to work spaces. It has integrated frequency-converter features that help users meet a wide range of compressed-air demands. — *Boge America, Powder Spring, Ga.*
www.usa.boge.com

High-power modular drives improve reliability, cut costs

This company has recently extended its range of high-power modular drives. Both its Unidrive M and Powerdrive F300 variable-speed drives are now available in the larger frame size 11, providing a flexible method of building compact, reliable high-power solutions, says the company. Unidrive M (photo) can control asynchronous and permanent-magnet motors in systems up to 2.8 MW (4,200 hp). The new frame 11 is a 250-kW (400 hp) module that allows system builders to create high-power solutions with the smallest number of components, keeping both footprint and cost to a minimum, says the manufacturer. Compared to competitor products, Unidrive M differentiates itself with extremely fast current-control algorithms and high switching frequencies, as well as unparalleled torque precision and power quality, says the manufacturer. The company also offers a range of high-powered drive products for compressors, fans and pumps from 90 kW to 2.8 MW. — *Emerson Industrial Automation, Control Techniques Ltd., Newtown, U.K.*
www.emersonindustrial.com

Simulation software enables critical design decisions

STAR-CCM+ V11.04 (photo) is part of the Siemens Simcenter Porfolio, a comprehensive suite of simulation and test solutions for predictive engineering analytics. The purpose of the Simcenter portfolio is to help users develop "digital twins" that can predict real-world behavior of products and address complex engineering challenges. The latest STAR-CCM+ software provides enhanced modeling capabilities (including expanded multiphase simulation capabilities), improved simulation workflows, and reductions in overall time-to-solution (thanks in part to increased accuracy, automatic time-step adjustment for transient runs, and improved steady-state fluid-film simulations), in engineering applications as varied as turbomachinery, oil-and-gas, aerospace, electric machines, transformers and plasma devices and more, says the company. — *CD-adapco, Houston*
www.cd-adapco.com

Portable electric compressors produce zero emissions

As an alternative to diesel units, this company has recently added electric-powered portable compressors (photo) to its family of M27, M31 and M50 compressors. These portable units are powered by motors rated at 15–25 kW, and provide flowrates ranging from 2 to 5 m^3/min for pressures from 7 to 14 bars. For any site that has an available power hookup, these machines make economic sense, says the company, because electricity is generally less costly than diesel fuel. An advanced Sigma Control Smart controller and the company's patented Anti-Frost Control system ease setup and operation and provide protection from frost and corrosion. Both mobile and stationary versions are available. — *Kaeser Kompressoren SE, Coburg, Germany*
www.kaeser.com

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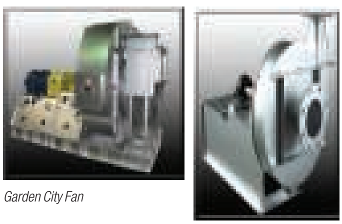
Atlas Copco Compressors

The Switch



Garden City Fan

Ingersoll Rand

Compressed-air unit's new filter cuts pressure

The UD+ two-in-one coalescing compressed-air filters (photo) combine two filtration processes into one product. They offer capacities of 19 to 16,950 std. ft^3/min, and reduce pressure drop by 40% compared to competing alternatives that rely on pleated filters to remove aerosol and particulate matter, says the company. The design uses wrapped-filter technology, which combines an innovative glass-fiber filter media package wrapped around a filter core. And these systems boast greater reliability compared to traditional pleated filters, which are prone to cracking, says the manufacturer. — *Atlas Copco Compressors LLC, Stockholm, Sweden*
www.atlascopco.com

These compressors provide maximum leakage control

The new triple-seal HD943 and HDL943 Oil-Free Reciprocating Gas Compressors feature a "double-distance piece" designed with three individual sets of packing, to maintain product purity and prevent oil migration. The non-lubricated (oil-free) design of these compressors includes two "distance-piece" compartments between the compressor's cylinder and crankcase. External ports at the top and bottom of the chambers can be used for purging, pressurizing or venting. — *Blackmer, Grand Rapids, Mich.*
www.blackmer.com

Fans and blowers withstand extreme high temperatures

This company's high-temperature, custom-engineered fans and blowers (photo) are able to meet the demanding operational challenges of temperatures up to 2,000°F, which makes them suitable for air circulation in refineries, ovens, kilns and furnaces, steel and glass production, and petrochemical refining applications. — *Garden City Fan, Fairfield, Ohio*
www.americanfan.com

Rotary-screw air compressors have variable-speed drive

The latest models in the Next Generation R-Series compressors (photo) incorporate advances in variable-speed drive (VSD) technology to increase air flow output by up to 15%, reduce energy costs by up to 35% and increase reliability, says the company. The RS30n and RS37n VSD models use totally enclosed, fan-cooled (TEFC) motors and Xc-Series controllers, which have customizable units of measure and built-in sequencing for up to four compressors. The controllers communicate directly to the inverter drive to determine the running speed of the air end. By limiting in-rush current during startup, minimizing peak power charges and lowering overall energy usage, both models decrease energy use during startup, which can draw up to 800% of the full load current. — *Ingersoll Rand, Davidson, N.C.*
www.ingersollrandproducts.com

High-speed turbo motors use an advanced drive-train design

This company's permanent-magnet direct-drive, high-speed turbo technology train and converter packages are designed for many industrial, marine and wind applications, and are available with speeds up to 15,000 rpm. The solid rotor-induction motor uses non-laminated rotor construction. This solid-rotor technology allows the mechanical gearbox to be eliminated for improved speed control, and stiff construction improves stability and balance. By integrating an electrical motor with the load machinery, space and weight needs are reduced, and the unit scales easily to higher powers and speed ranges, says the company. — *The Switch, Helsinki, Finland*
www.theswitch.com

Blowers feature clean, oil-free, maintenance-free operation

All Rotron blowers use advanced regenerative air technology that ensures proper air pressure and vacuum without the high energy and maintenance costs associated with larger, multi-stage or positive-air-displacement blowers and compressors. They can achieve maximum air flows of 1,800 std. ft^3/min, pressures to 9 psig, and vacuum to 14 in. Hg. These three-phase, 1-hp or greater regenerative blowers are available in three standard types: DR blowers for industrial use, CP chemical processing blowers, and EN environmental blowers. — *Ametek Dynamic Fluid Solutions, Kent, Ohio*
www.ametek.com ■

Suzanne Shelley

This pneumatic pump controller offers power flexibility

The recently enhanced CycleFlo pneumatic pump controller (photo) is designed to control pump speed and run time to deliver precise batching, metering and dosing of fluids at low and high pressures and flowrates. Featuring 32 batch presets and an intuitive programming interface, the CycleFlo controller ensures specific and repeatable fluid batches. Significant enhancements have been made to the controller in the area of power availability; previously, the company offered two CycleFlo units, each operating on a different input power. The new CycleFlo controller has the functionality of two units in one, operating on 100 to 240 V a.c. input power. The microprocessor-based unit can control pumps locally or in a remote location. When operating remotely, timers and pH controllers send signals to the CycleFlo controller to start and stop the pumping cycle once a preset volume of product has been dispensed — *Graco Inc., Minneapolis, Minn.*
www.graco.com


Graco

A jacketed reaction system with fast vessel changes

The Orb Pilot (photo) is a user-friendly, floor-standing scaleup jacketed reactor that is designed to provide flexible and cost-effective pilot-scale batch chemistry. Available in a choice of single and vacuum-jacketed vessels in sizes ranging from 10 to 50 L on a single system with a number of optional accessories and stirring options, the system can be customized to meet exact requirements. Engineered to withstand temperatures from –40 to 235°C, the reactor system features a rapid oil-drain mechanism that offers fast vessel changes, while a spring-loaded base avoids the need for frame adjustments to accommodate different vessels or thermal expansion. — *Syrris, Royston, U.K.*
www.syrris.com


Syrris

These metal filter cloths have precise pore sizes

As is the case for all MiniMesh S metal filter cloths, the pore size of MiniMesh RPD HiFlo-S metal filter cloth can be calculated precisely in advance and adapted to the respective requirements. These precision pores can achieve extremely high cut-points and dimensional stability, says the manufacturer. Previous filter cloths with small pore sizes lead to reduced flowrates and significant pressure loss in the production process. Due to the new three-dimensional cloth structure, the open surface over an area is significantly increased. For a given pore size, the flowrate is more than doubled compared to conventional woven-metal filter media, says the company. In addition, the flow conditions are optimized and turbulence around the filter cloth is effectively avoided. — *Haver & Boecker OHG, Drahtweberei und Maschinenfabrik, Oelde, Germany*
www.haverboecker.com

Remove debris from fluids with these upstream gasket strainers

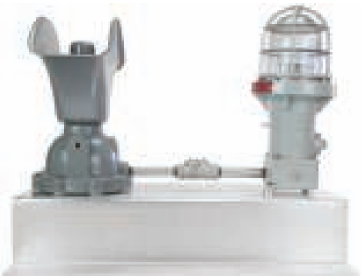
This company's line of strainer gaskets remove particulate matter and debris from process fluids. They are suitable for standard flanged connections and can be inserted upstream from sensitive and costly processing equipment. The gaskets may be deployed as a single filter or as a graduated system of several strainers that consume less space and at a lower cost than other methods, such as filtration cartridges. The strainer gaskets are offered in a variety of gasket materials and thicknesses. Stainless-steel plain mesh weave is standard, in 20, 40, 50, 60 or 100 mesh, or dual layers are also available. Other configurable options include the following: non-standard sizes including rectangular designs; optional tab for gasket installation and location identification; and inner diameters ranging from 1.2 to 30 in. — *Garlock, Palmyra, N.Y.*
www.garlock.com

Cloth-media filtration in a more compact footprint

The AquaPrime cloth-media filtration system (photo) utilizes a disk configuration and the OptiFiber cloth filtration media to effectively filter screened, de-gritted, raw sewage. The proven technology easily handles significantly higher solids loading rates compared to secondary clarified effluent (by a


Aqua-Aerobic Systems

Larson Electronics



Emerson Process Management

Cashco

Synavax

factor of 3 to 5) with the added ability to sustain a low total-suspended-solids concentration, says the manufacturer. Furthermore, the AquaPrime system operates in less than 10% of the footprint of conventional primary settling basins and offers the added advantage of improving gas production (energy harvesting) in the anaerobic digestion system due to significant reduction in organic materials. The cloth-media filtration system produces consistent effluent under variable influent conditions that are typical in both primary-treatment and wet-weather applications. — *Aqua-Aerobic Systems, Inc., Loves Park, Ill.*
www.aqua-aerobic.com

Configurable visual and audible indication of processing status

The EPL-TL-1X10W-C-PA LED signal light (photo) is equipped with an audible horn and approved for use in hazardous environments where explosive and flammable gases, vapors and dusts exist or have the potential to exist. This explosion-proof signal stack light is designed for processing-status indications in manufacturing facilities. The signal light is equipped with a single 10-W LED lamp that produces an optional color output of red, blue, green, amber, purple or white. — *Larson Electronics, Kemp, Tex.*
www.larsonelectronics.com

Energy harvester simplifies wireless technology adoption

This company has adopted advanced thermal-energy harvesting as a power source for its wireless products. Power Puck thermoelectric energy harvesters (photo) convert ambient heat commonly released in industrial processes into electricity for powering Rosemount wireless transmitters. Perpetua's Power Puck energy-harvesting solution is especially advantageous to wireless devices in power-intensive applications, where a conventional power module may require replacements more frequently. The Power Puck thermoelectric energy harvester provides continuous, reliable power for the life of the transmitter and includes an intrinsically safe power module for backup power. — *Emerson Process Management, Shakopee, Minn.*
www.emersonprocess.com

This sanitary vent offers setpoint flexibility

The Model 1100 sanitary vent (photo) is a stainless-steel sanitary vent designed to operate at multiple setpoints as a breather valve to avoid vacuum or overpressurization inside a tank or piping system. This unit comes with a true sanitary blanketing connection and is designed so that it can be used with this company's VCI Model 1088 sanitary blanketing valve. Available in 2-, 3-, 4- and 6-in. sizes, the Model 1100 is offered 316 or 304 stainless steel. The weather screen, which prevents debris from entering the tank, is also constructed of stainless steel. Pressure setpoints can range from 0.43 to 3.42 psi, while the vacuum setpoint range is 0.069 to 0.385 psi, depending on the size of the unit. — *Cashco, Inc., Ellsworth, Kan.*
www.cashco.com

New assessment service for parts management

This company's Parts Fingerprint service captures equipment configurations, audits parts stores, and develops recommendations and replacement strategies to reduce production risk and find cost efficiencies. The service can help users reduce the risk of production loss due to non-available parts, and to cut costs by identifying and addressing potential weaknesses in the parts supply chain. Industry trends such as lean manufacturing, compressed product lifecycles and the prevalence of third-party parts suppliers have driven companies to find new ways to maintain required part inventories to sustain production demands. According to the company, customers may underestimate their critical spare parts needs by as much as 60%, and many users have no visibility into escalating production risks due to parts inventory deficits. Parts Fingerprint aims to address these issues. — *ABB, Zurich, Switzerland*
www.abb.com

Spray-on insulation that also prevents corrosion

Heat Shield EPX-H2O (photo) is a two-part water-based reactive prepolymer that provides thermal insulation and corrosion prevention for a wide variety of industrial applications. Designed

to withstand harsh conditions and provide a spray-on application with no cladding or covering needed, the coating has the ability to reduce hot surface temperatures to a safe touch range in a thin layer. It also has excellent splash resistance to chemicals, and is resistant to a number of harsh chemicals, including 98% sulfuric acid, ammonia, bleach, bases and fuels. Furthermore, Heat Shield EPX-H2O is also hydrophobic and resistance to mold growth. The patented product can be used on surfaces up to 400°F. — *Synavax, Denver, Colo.*
www.synavax.com

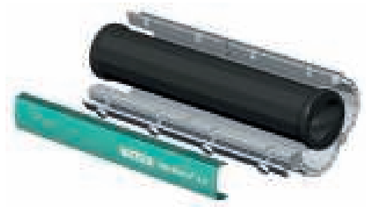
This stator system has reusable housing

The new iFD-Stator 2.0 (photo) features a two-part, reusable stator housing and replaceable stator, and is compatible with all NEMO NM Series progressing cavity pumps. According to the manufacturer, the iFD Stator 2.0 delivers reduced pulsation and improved fluid flow compared to conventional stator design, as well as a considerable increase in efficiency due to reduced starting and running torque. There is no limitation of speed or pressure when measured against the standard stator, and the axial mobility of the elastomer leads to a prolonged service lifetime. Replacement of the stator costs less than with traditional stator designs and is more environmentally friendly because the housing can be reused. — *Netzsch Pumps North America, LLC, Exton, Pa.*
pumps.netzsch.com

This portable gas analyzer has been enhanced

A number of enhancements have been made to the Lancom 4 Portable Gas Analyzer (photo) to improve usability. Now available as a free download, Lancom 4's data-acquisition software, Insight, allows users to interface their analyzer with a PC for remote control and data logging. Insight offers graphing and analysis tools for data visualization and reporting purposes, providing easier access

Netzsch Pumps North America



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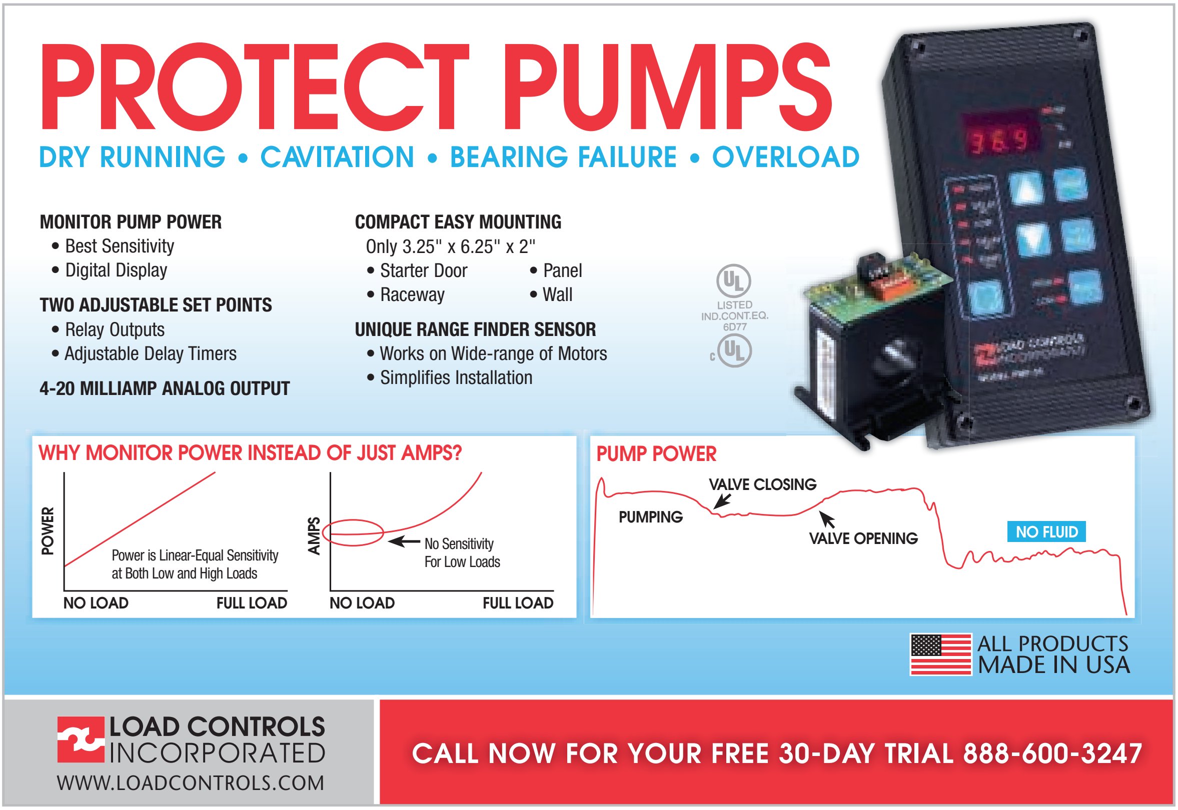

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Fullbrook Systems

to data. Communications between Insight and the user's PC require a USB-RS232 interface converter, which is now supplied with every Lancom 4 for quick and easy setup. In addition, Lancom 4 now includes Wake and Sleep functions, allowing measurements and data logs to be recorded over an extended period. The Lancom 4 fluegas analyzer can be used for checking or testing a boiler system or pollutant process, and can monitor up to 9 different gases, 17 measurement parameters, and has the ability to data log up to 250,000 records. — *Ametek Land, Dronfield, U.K.*
www.landinst.com

Vacuum dispersion system requires less handling & cleaning

The Vacuum Dispersion and Mixing System manufactured by VMA-Getzmann GmbH is now available from this company. This range of Dispermat CHS Vacuum Systems is ideal for small batches and sample production where vacuum is required. The Dispermat CHS vacuum system offers users exceptional versatility because it is designed to accept single-wall pails, buckets, non-standard and even users' own containers. This means that materials can be processed without the need for dedicated vacuum containers, significantly reducing the time associated with handling and cleaning. The Dispermat CHS30 (photo) accepts 30-L containers, but is also available for container volumes up to 60 L. An explosion-proof ATEX-certified version is also available. — *Fullbrook Systems Ltd., Hemel Hempstead, U.K.*
www.fullbrooksytems.com

A lean approach to paperless manufacturing

In August, this company launched Version 6.1 of its Simatic IT eBR software (photo, p. 37), which is at the heart of its Manufacturing Operation Management for the life science industries. The new Version enables users to easily implement paperless manufacturing solutions by offering two main features: A new web-based MBR (Master Batch

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Siemens AG

Record) module, which facilitates the management of key process parameters, and native integration with the company's automation layer, Simatic PCS 7 process control system and human-machine-interface (HMI) systems. The new version reduces the work involved in engineering and operation, helps users to enforce standardization and makes for a more transparent production process, thereby shortening the time to market, says the company. — *Siemens AG, Munich, Germany*
www.siemens.com

The first fully integrated upstream biotech platform

Sartorius Stedim Biotech

This fully integrated technology platform (photo) combines an expression system with equipment and process control for the rapid development and scaleup of robust, high-titer commercial manufacturing processes. By leveraging this upstream technology platform, biopharmaceutical manufacturers will be able to reach the clinic in 14 months, says the company. The system accelerates clone selection and scales up readily to Biostat STR single-use bioreactors, which biomanufacturers have successfully implemented at pilot and GMP production scales. — *Sartorius Stedim Biotech, Göttingen, Germany*
www.sartorius-stedim.com

A new heat exchanger for LPG/E cargo condensers

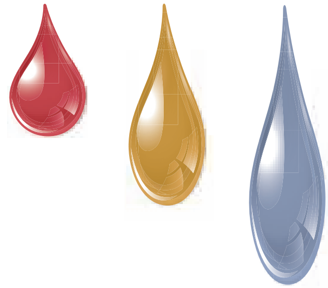
Alfa Laval

DuroShell (photo) is a specially engineered plate-and-shell heat exchanger with unique design capabilities. Already used in the offshore oil-and-gas industry, it is now being introduced for demanding marine duties such as LPG/E (liquefied propane gas and ethane) cargo reliquefaction. An innovative construction and a patented roller-coaster plate pattern make DuroShell significantly more robust, allowing it to condense cargo with a higher ethane content. DuroShell withstands pressures up to 35 bars when titanium plates are used, along with temperatures as low as –198°C. — *Alfa Laval AB, Lund, Sweden*
www.alfalaval.com

Two new sizes of mag-drive centrifugal pumps

Tapflo

This company's centrifugal magnetic-drive pump range is now being supplemented with two new sizes



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Scott Safety

— CTM40 and CTM50 (photo, p. 37). The new pumps offer a wide spectrum of application with heads going up to 21 m and flowrates up to 29 m^3/h. All CTM pumps are available with BSP thread, flange or hose connections. The pumps can be used for chemically corrosive and toxic liquids, as well as for clean and thin liquids, such as pure chemicals, acids and alkalis, because the wetted components are non-metallic, injection-molded thermoplastics that offer excellent corrosion resistance. — *Tapflo AB, Kungälv, Sweden*
www.tapflo.com

This respirator has realtime airflow control

Duraflow is a lightweight and ergonomically designed Powered Air Respirator (photo) with realtime airflow control technology. The new solution gives complete wearer assurance of respiratory protection to focus on the job rather than the protective equipment itself, in a multitude of hazardous situations and industries. Duraflow's automatic-monitoring features ensure the airflow rate is maintained at precisely the correct level to afford protection for the user. Visual and audible diagnostics alert the user of any drop in airflow below the required level or when the battery needs re-charging. Duraflow is compatible with the company's headtops, filters and accessories. — *Scott Safety, Skelmersdale, Lancashire, U.K.*
www.scottsafety.com

New release of this ERP software focused on R&D

Premier 10.7 is the latest release of this company's enterprise resource planning (ERP) software. This most recent release gives special focus to research and development (R&D) functionality and usability. The R&D functionality enables users to easily develop and experiment in a "sandbox" environment without interfering with live production. Users can leverage existing cost history while quickly adding new items for R&D purposes only, while also supporting simplified conversion of R&D items into the live production environ-

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ment. A cost update routine allows R&D to maintain accurate item costs based on current costs from the live production environment, and new and future item costs can be updated for quoting purposes. — *Process Pro, St. Cloud, Minn.*
www.processproerp.com

These fork sensors withstand harsh conditions


Balluff

This company's line of fork sensors now includes IP69K-rated self-contained through-beam sensors (photo) that incorporate a 316L stainless-steel housing that is able to withstand exposure to aggressive cleaning solutions, coolants and lubricants. The protection provided by the housing makes these sensors suitable for the food and beverage, packaging, metalworking and pharmaceutical industries. These sensors are available in 50- and 80-mm widths, and feature normally open and normally closed outputs that allow for easy integration into control schemes. The sensors are equipped with power infrared light sources, as well as LEDs for power and switching indication in the connector. — *Balluff Inc., Florence Ky.*
www.baluff.us

New radar level transmitters for challenging tank installations

Two new models of level transmitter — Type 2290 and 2291 (photo) — have been designed for use in challenging tank applications where other contacting or non-contacting measuring principles face limitations. Type 2290 is a compact non-contact radar level transmitter that is available in a variety of materials to resist very corrosive environments. With its tank mapping function, it is easy to block out objects like internal pipes, welding seams, stirrers or heating


GF Piping Systems

elements. Type 2291 is a guided-radar level transmitter that provides measurement even in very turbulent process vessels. The radar signal is sent down the probe assembly, eliminating the interferences caused by low dielectric liquids, heavy fuming, slightly conductive foams or internal tank obstructions. Both transmitters are suited for applications in harsh environments, and communication can be either via HART or analog. — *GF Piping Systems Ltd., Schaffhausen, Switzerland*
www.gfps.com

Manage supply-chain solutions with this software portfolio

Symphonite is a comprehensive portfolio of supply-chain and production-management software services designed to boost reliability, responsiveness, agility and efficiency for a range of manufacturing industries. Symphonite is broadly grouped into two areas: Supply Chain solutions and Production Management solutions. New software releases available with the Symphonite portfolio include the following: Refinery and Petrochemical Modeling System (RPMS R510), which enables users to optimize profitability and reduce planning cycle times; Capacity and Distribution Planner (CDP R230), which improves production and inventory forecasting; and Production Accounting and Reconciliation (PAR2000), which introduces an integrated graphical workflow with an enhanced statistical solver. — *Honeywell Process Solutions, Houston*
www.honeywellprocess.com ■

Mary Page Bailey and Gerald Ondrey

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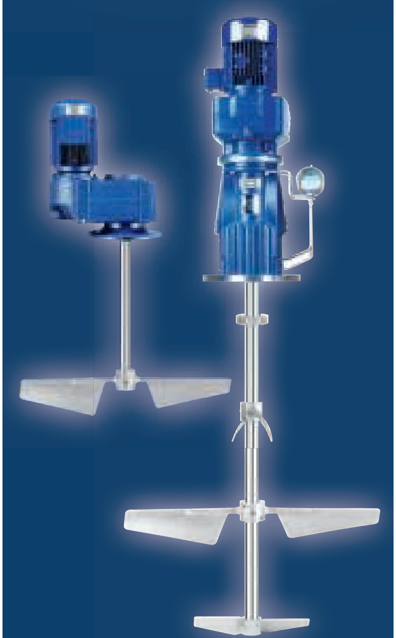

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Agglomeration Processes

Department Editor: Scott Jenkins

Agglomeration is a natural phenomenon in which solid particles stick to each other or to surfaces. When unwanted, agglomeration can cause problems, such as caking, buildup or lumping, but it is also an important particle-size enlargement process widely used in the chemical process industries (CPI) to help overcome challenges, including segregation, difficult flow, low bulk density and others. Agglomeration can also help control particle-size distribution and reduce potentially hazardous aspects of the solids, such as dust. This one-page reference provides information on agitation, compression and sintering methods of agglomeration and their mechanisms.

Agglomeration methods to enlarge particulate solids can be broadly broken down into three general categories: agglomeration by agitation (sometimes referred to as wet agglomeration or tumble/growth agglomeration; pressure (compaction) agglomeration, and agglomeration using heat (sintering).

Wet agglomeration

Wet agglomeration processes combine powder, liquid (usually water) and, if necessary, a binder to impart shear to form agglomerates. Processing equipment may include rotating drums, disc or pan agglomerators, pin or ribbon mixers or fluidized beds. Agglomeration can be induced by a solvent or slurry atomized onto the bed of particles, or by the controlled sintering or partial melting of a binder component of the feed (Figure 1). Next, moist particles join together to form so-called green agglomerates. Drying or curing takes place in a final stage. The wet agglomerates are created by first forming nuclei that then grow into larger aggregates by layering or coalescence. In some cases, nucleation and aggregate growth take place in two separate pieces of equipment that are operated in series.

Nucleation gives rise to seed particles, which are formed when several individual particles adhere to each other. The nucleation stage can be time-consuming because the seed agglomerates are weakly bonded and readily disintegrate back into individual particles. Eventually, larger aggregates are formed when small agglomerates coalesce or individual particles adhere to larger agglomerates. Once larger agglomerates are created, growth becomes accelerated as the increased mass and higher kinetic energy of agglomerates cause them to pick up individual particles more rapidly and incorporate them onto their surfaces. The relative rates of size enlargement (nucleation, coalescence and layering) and size reduction (attrition and consolidation) establish the final particle size along with the material's tendency to wick moisture from its core to outer layers. The optimal amount of liquid added to a powder — the amount that gives the resultant agglomerates their greatest integrity and resistance to breakage — is typically 40–90% of its liquid saturation. The liquid saturation is the fraction of total void space that can be filled with the liquid. When water (or another liquid) is added to a dry bulk solid, liquid bridges will begin to form at contact points between particles. This is known as the pendular stage of saturation. All free moisture is attracted to the interfaces between the solid particles by capillary effects, and surface tension draws the particles together. As saturation levels are increased, the funicular stage is eventually reached where all internal solid surfaces become surrounded by liquid. At this point, the mixture becomes more fluid-like, tensional forces disappear, and the agglomerates become weaker. When the powder becomes fully saturated, it reaches its capillary state, and at higher moisture levels, the system begins to behave as a slurry.

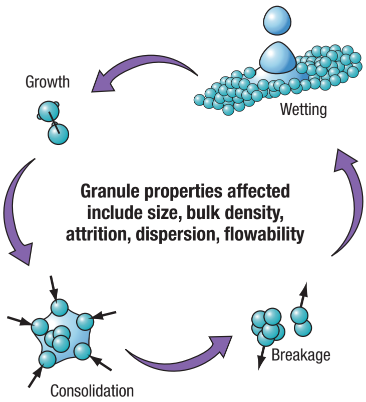

FIGURE 1. In wet agglomeration, a wetting step leads to nucleation and particle growth

Compaction agglomeration

Pressure agglomeration works by applying external forces to dry particulate solids to form enlarged particles. Continuous sheets of solid material are produced, as in roll pressing, or some solid form is made, such as a briquette or tablet. Continuous sheets or strands may either break down in subsequent handling to form a granulated material, or the material may be further processed through a variety of chopping, spheronizing or forced screening methods. A key factor in compression agglomeration is the level of force applied. Compaction processes range from confined compression devices, such as tabletting, briquetting machines and ram extrusion to unconfined devices, such as roll presses and a variety of pellet mills.

Heat sintering

In agglomeration using heat (sintering), atoms and molecules begin to migrate across the interface where particles touch each other. This happens at a certain elevated temperature, which is different for various materials. While still in solid state, diffused matter forms bridge-like structures between the surfaces, which solidify upon cooling. In the post-treatment of agglomerates, this phenomenon produces strong permanent bonds or specific final properties in parts that may have been manufactured by virtually any of the other agglomeration techniques. ■

Editor's note: Portions of this column have been adapted from the following articles: Mehos, G. and Kozicki, C., Consider Wet Agglomeration to Improve Powder Flow, *Chem. Eng.*, January 2011, pp. 46–49; and Ennis, B.J., Agglomeration Technology: Mechanisms, *Chem. Eng.*, March 2010, pp. 34–39. Additional references include the following: Sochon, R.P.J and Salman, A.D., Particle Growth and Agglomeration Processes, chapter in Chemical Engineering and Chemical Process Technology, Vol. II, "Encyclopedia of Life Support Systems;" and Pietsch, W., What is Agglomeration?, *Power and Bulk Solids*, Feb. 27, 2008.

Aluminum Chloride Production

By Intratec Solutions

Aluminum chloride ($AlCl_3$) is among the most widely used Lewis acids in industry, and is also one of the most powerful. The compound is employed as a catalyst in the manufacture of a multitude of organic chemicals produced by several different reaction mechanisms, including isomerization, alkylation and polymerization.

The main applications of $AlCl_3$ are in the production of ethylbenzene and dyes. $AlCl_3$ catalyzes the ethylation of benzene with ethylene to yield ethylbenzene, which, in turn, is used in the production of styrene. In the dyestuffs industry, $AlCl_3$ is used as a catalyst in the production of anthraquinone and its derivatives, as well as in the production of pigments.

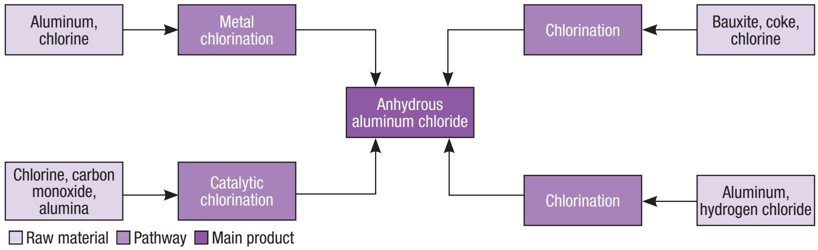

FIGURE 2. Several possible production pathways exist for $AlCl_3$

The process

The following paragraphs describe a conventional process for anhydrous $AlCl_3$ production from aluminum metal and chlorine. Figure 1 presents a simplified flow diagram of the process.

Reaction. The reaction takes place in ceramic-lined, tube-shaped reactors containing molten aluminum. Chlorine gas is injected below the surface of the molten aluminum pool, leading to the formation of aluminum chloride vapor in a highly exothermic and practically instantaneous reaction. The reaction occurs at 670–850°C. The temperature is maintained in this range by controlling the feedrates of chlorine and aluminum and by cooling the reactor walls with water.

The $AlCl_3$ vapor from the reactors is fed to air-cooled condensers, which are vertical cylinders with conical bottoms. As the $AlCl_3$ vapor comes into contact with the condenser walls, it loses its heat of sublimation, and is deposited on the walls. The deposited solid $AlCl_3$ is withdrawn from the condenser walls at regular intervals, and subsequently conveyed to holding silos.

Crushing and sizing. $AlCl_3$ crystals from the holding silos are crushed and sized by sieving under a dry-air atmosphere. After sizing, the $AlCl_3$ product is obtained.

Scrubber. The condensing, crushing and sizing operations, as well as storage facilities, are designed to avoid the entrance of moist atmospheric air. To achieve this, a vent system linked to those pieces of equipment directs the offgas (containing unreacted chlorine and uncondensed gases) to a caustic scrubber. The scrubbed gas is vented to the atmosphere, while the scrubber's bottom stream is treated as wastewater.

$AlCl_3$ pathways

Initially, aluminum chloride was produced on a commercial scale from calcined bauxite and coke. New routes have emerged, however, that present advantages over the bauxite process. The advantages are derived from a reduced occurrence of reactor corrosion and from the production of a higher-purity product. Currently, the most important raw materials for $AlCl_3$ production are either aluminum metal or pure aluminum oxide. Figure 2 presents different pathways for $AlCl_3$ production.

Economic performance

The total capital investment estimated to construct a plant based on the process in Figure 1 with capacity to produce 5,000 metric ton per year of $AlCl_3$ in the U.S. is about \$8 million (data from the second quarter of 2013). This capital investment includes fixed capital, working capital and additional capital requirements.

This column is based on "Aluminum Chloride Production Process – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/aluminum-chloride-production-cost. ■

Edited by Scott Jenkins

Editor's note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are prepared on the basis of publicly available and non-confidential information. The content represents the opinions of Intratec only. More information about the methodology for preparing analysis can be found, along with terms of use, at www.intratec.us/che.

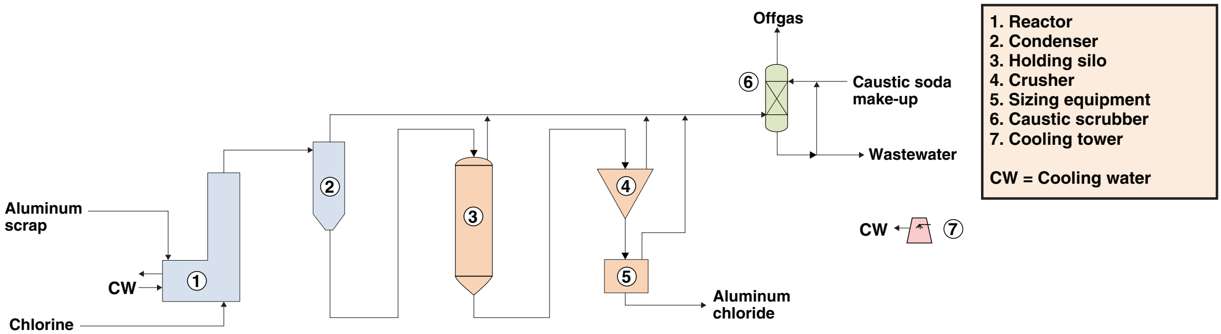

FIGURE 1. This figure shows a conventional process for the production of $AlCl_3$ from aluminum and chlorine

Piping Codes:

What the CPI Engineer Should Know

An overview of the codes and standards that are most pertinent to chemical processing facilities

William M. Huitt
W. M. Huitt Co.

IN BRIEF

- A BRIEF HISTORY
- CODES AND STANDARDS RELEVANT TO THE CPI
- ASME CODES TODAY
- EXTERNAL PIPING
- PRESSURE VESSELS
- ASSIGNING PIPING CODES
- MODIFICATIONS, REPAIRS AND RETROFITS

Look for more Tables and clarifications in the online version of this article at www.chemengonline.com

FIGURE 1. The aftermath of the 1905 explosion and fire at the R.B. Grover Shoe Factory in Brockton, Mass. The trajectory of the boiler is shown as the red arc

Moving a process fluid from one stage of its processing cycle to the next requires the transfer of fluids between pressure vessels, through pressure piping with the assistance of pressure equipment. Aside from the elemental objective of making an intermediate or finished product, the immediate goal, and what should be of primary importance, is to make these fluid transfers, or the overall handling of such process fluids, in a safe and productive manner.

Handling such process fluids (including utility fluids) presupposes that we select an appropriate material of construction (MOC) for each fluid service; that we properly size the piping and components for the needed flowrate; determine a mechanical-joint pressure rating that will safely contain the fluid being transferred; and that we design and construct pressure vessels and equipment in accordance with accredited consensus standards. Such aspects of fluid handling, in the design and engineering of a chemical processing facility (CPF), is an ever-changing selective process in which many fluid service variations may exist, and each fluid may have its own distinct set of requirements. These requirements can range from construction material compatibility to safe containment of the process fluid, and from regulatory requirements to jurisdictional code requirements. The many variables presented in the design of a process system create a challenge in the effort to achieve quantifiable productivity while meeting all respective code and regulatory demands.

Safety considerations in the design, construction and operation of a chemical process industries (CPI) facility is not simply a rhetorical aspect of the design function, it is instead the very essence of the codes and standards that affect the safety and well-being of not only the operations and plant personnel, but in many cases, the people who live in the surrounding neighborhoods — neighborhoods that are in close proximity to what could be considered a high-risk industrial facility. This is where code and regulatory compliance interact with the design, engineering and construction activities of a CPF.

The respective codes and standards affect everything from the materials and methods used in manufacturing the individual components that make up the piping systems in a processing unit to how the piping system is engineered and constructed. Given the fact that the operation of a CPF is inherently dangerous — some significantly more than others — it was the lessons learned back at the turn of the twentieth century from incidents, such as the R. B. Grover Shoe Factory devastation (Figure 1) that prompted the need for the development and promulgation of U.S. consensus standards and government safety regulations.

A brief history

The lessons learned in Massachusetts with the 1905 boiler explosion in Brockton, only to be accented the following year by the 1906 boiler explosion in Lynn, dislodged the complacency of the legislature in that state to do something about the issue of unregulated boiler and pressure vessel design and construction. Boilers were at that time, typically housed in areas adjacent to personnel work space. The complacency at the time stemmed largely from the politicians and industry experts attempting to chart a path through the uncharted territory of consensus engineering and safety regulation.

The step that Massachusetts took by enacting regulation in 1909 brought the American Soc. of Mechanical Engineering (ASME; New York, N.Y.; www.asme.org) to the forefront with the work they had been doing on what, in 1911, would become the International Boiler and Pressure Vessel Code (BPVC). This effort by ASME culminated in 1915 with the first publication of the BPVC.

With the creation of such engineering societies and the standardization process that emanated from them, government was given the means and resources it needed for initiating safety regulations. The need for a basis of design and construction, one that would provide the consistently safe manufacture of pressure equipment, which was, incidentally, the impetus for creation of the ASME in the first place, put them at center stage in this effort.

ASME was born from the dire need to create a safe work environment back in the early 1900s, which to this day guides the basic precept in the writing of today's codes and standards and gives credence to its focus on safety and integrity of design and construction. That premise leads to the reason for a statement found within the Introduction of the various ASME B31 piping codes, which reads, *"The Code sets forth engineering*

CODES AND STANDARDS RELEVANT TO THE CPI

The entire boiler and pressure vessel package of codes is referred to as the BPVC. This ensemble of codes is a multiple and distinct set of codes made up of two overarching codes that include the Boiler Code and the Pressure Vessel Code. The entire package of codes is further divided into 31 books consisting of some 17,000 pages. But not all of it pertains to the interest and responsibilities of the CPI engineer. Those sections typically not of interest to the CPI engineer include: Section III Rules for Construction of Nuclear Facility Components; Section XI Rules for In-service Inspection of Nuclear Power Plant Components; and Section XII Transport Tanks. What does pertain to the CPI engineer, with regard to BPVC, are the following:

Boiler Codes

Those codes specific to the design, construction, and ongoing maintenance of boilers include the following:

- Section I — Power Boilers: *"Provides requirements for all methods of construction of power, electric, and miniature boilers; high temperature water boilers, heat recovery steam generators, and certain fired pressure vessels to be used in stationary service… Rules pertaining to use of the single ASME certification mark with the V, A, M, PP, S, and E designators are also included."*
- Section IV — Heating Boilers: *"Provides requirements for design, fabrication, installation and inspection of steam heating, hot water heating, hot water supply boilers, and potable water heaters intended for low pressure service that are directly fired by oil, gas, electricity, coal or other solid or liquid fuels."*
- Section VI — Care and Operation of Heating Boilers: *"Covers operation guidelines applicable to steel and cast-iron boilers limited to the operating ranges of Section IV Heating Boilers. Section VI includes guidelines for associated controls and automatic fuel-burning equipment. Also included is a glossary of terms commonly associated with boilers, controls, and fuel-burning equipment."*
- Section VII — Care of Power Boilers: *"Provides guidelines to assist those directly responsible for operating, maintaining, and inspecting power boilers. These boilers include stationary, portable, and traction type boilers, but not locomotive and high-temperature water boilers, nuclear power-plant boilers (see Section XI), heating boilers (see Section VI), pressure vessels, or marine boilers. Guidelines are also provided for operation of auxiliary equipment and appliances that affect the safe and reliable operation of power boilers."*

Note that Sections IV and VI for Heating Boilers are typically specified for commercial applications rather than for industrial type applications. They are listed here for reference only and will not be a part of this ongoing discussion.

Pressure Vessel Codes

Code requirements for pressure vessels are captured under Sections VIII and X.

- Section VIII — Pressure Vessels: The Pressure Vessel Code is made up of three Divisions, as follows:
  - Division 1: *"Provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig. Such vessels may be fired or unfired. This pressure may be obtained from an external source or by the application of heat from a direct or indirect source, or any combination thereof. Specific requirements apply to several classes of material used in pressure vessel construction, and also to fabrication methods such as welding, forging and brazing. Division 1 [also] contains mandatory and non-mandatory appendices detailing supplementary design criteria, nondestructive examination and inspection acceptance standards. Rules pertaining to the use of the single ASME certification mark with the U, UM and UV designators are also included."*
  - Division 2: Provides *"Requirements on materials, design, and nondestructive examination are more rigorous than in Division 1; however, higher design stress intensity values are permitted. These rules may also apply to human occupancy pressure vessels typically in the diving industry. Rules pertaining to the use of the single ASME certification mark with the U2 and UV designators are also included."*
  - *Division 3: Provides "Requirements [that] are applicable to pressure vessels operating at either internal or external pressures generally above 10,000 psi. It does not establish maximum pressure limits for either Section VIII, Divisions 1 or 2, nor minimum pressure limits for this Division. Rules pertaining to the use of the single ASME certification mark with the U3 and UV3 designator are also included."*
- Section X — Fiber Reinforced Plastic Pressure Vessels: *"Provides requirements for construction of a fiber-reinforced plastic pressure vessel (FRP) in conformance with a*

Continued on page 44

manufacturer's design report. It includes production, processing, fabrication, inspection and testing methods required for the vessel." Section X includes three Classes of vessel design:

- Class I: Class I and Class III — qualification through the destructive test of a prototype
- Class II — mandatory design rules and acceptance testing by nondestructive methods

These vessels are not permitted to store, handle or process lethal fluids. Vessel fabrication is limited to the following processes: bag-molding, centrifugal casting and filament-winding and contact molding. Rules pertaining to the use of the single ASME certification mark with the RP designator are also included.

BPV Service Codes

This set of codes augment and support the primary set of codes mentioned above, and are thereby referred to simply as Service Codes.

- Section II – Materials: Together the *"…four parts of Section II [as listed below] comprise a "service Code" to other BPVC Sections, providing material specifications adequate for safety in the field of pressure equipment. These specifications contain requirements for chemical and mechanical properties, heat treatment, manufacture, heat and product analyses, and methods of testing. Part A and Part B specifications are designated by SA or SB numbers, respectively, and are identical with or similar to those of specifications published by ASTM and other recognized national or international organizations. Part C specifications are designated by SFA numbers and are derived from AWS specifications."*
  - Part A – Ferrous materials
  - Part B – Nonferrous material
  - Part C – Welding rods, Electrodes, and Filler Metal
  - Part D – Material Properties in both Customary and Metric Units
- Section V — Nondestructive Examination: *"…requirements and methods for nondestructive examination which are referenced and required by other BPVC Sections. It also includes manufacturer's examination responsibilities, duties of authorized inspectors and requirements for qualification of personnel, inspection and examination. Examination methods are intended to detect surface and internal discontinuities in materials, welds, and fabricated parts and components. A glossary of related terms is included."*
- Section IX — Welding, Brazing, and Fusing Qualifications: *"…rules relating to the qualification of welding, brazing, and fusing procedures as required by other BPVC Sections. It also covers rules relating to the qualification and requalification of welders, brazers, and welding and brazing operators in order that they may perform welding or brazing in component manufacture. Welding, brazing and fusing data cover essential and nonessential variables specific to the welding, brazing or fusing process used."*

Piping Codes

Piping codes fall under the ASME B31 Code for Pressure Piping Standards Committee. Some of the various piping codes that fall under the responsibility of the B31 Committee are the following:

- B31.1 — Power Piping Section Committee: The first paragraph in the scope of B31.1 reads as follows: *"Rules for this Code Section have been developed considering the needs for applications that include piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems."* This code continues in great lengths, with both text and graphics, to describe its jurisdictional scope and boundaries.
- B31.3 — Process Piping Section Committee: The first paragraph in the scope of B31.3 reads as follows: *"Rules for the Process Piping Code Section B31.31 have been developed considering piping typically found in petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants; and related processing plants and terminals."* It goes on to state that, *"This Code prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping." It applies to all fluids including, but not limited to, "…raw, intermediate, and finished chemicals, petroleum products, gas, steam, air, and water, fluidized solids, refrigerants and cryogenic fluids."*
- B31.4 — Liquid and Slurry Piping Transportation Systems: This code, *"…prescribes requirements for the design, materials, construction, assembly, inspection, testing, operation, and maintenance of liquid pipeline systems between production fields or facilities, tank farms, above- or below-ground storage facilities, natural gas processing plants, refineries, pump stations, ammonia plants, terminals (marine, rail, and truck), and other delivery and receiving points, as well as pipelines transporting liquids within pump stations, tank farms, and terminals associated with liquid pipeline systems. This Code also*

Continued on page 46

requirements deemed necessary for safe design and construction of pressure piping."

ASME code today

Presently, there are four U.S. states and all of the provinces and territories of Canada that have adopted and require the application and use of the ASME B31.3 Process Piping code in the design and construction of a CPF. This is the only piping code with a scope and content broad enough to encompass the wide variety of fluids and operating conditions found in CPI facilities.

When designing a CPI facility in a state other than California, Kentucky, Michigan and Oregon, the four states that have adopted B31.3, or outside of Canada, it is suggested by this author that the B31.3 code be written into the design specifications for such a facility. Even for a facility that either has been or is currently in operation, it is essential that requirements as comprehensive as the B31.3 piping code be an integral part of not only the design of a new facility, but an ongoing part of a facility's maintenance program.

With the myriad of codes and standards, not to mention government regulations, that apply to the design and construction of a CPF, how is it determined which of these documents apply to the design and operation of a specific facility? To begin, we need to identify the various aspects of design, engineering and construction for which codes and standards will be needed. That would include the following:

- Boiler design and fabrication
- Pressure vessel design & fabrication
- Piping design, fabrication and installation
- Piping component design and pressure ratings

Each of these four categories of need are addressed in the box starting on p. 43. Quotes taken from the respective code or standard developer used in describing these documents is presented in italics. Some points of clarification are presented below.

External piping

The Boiler Code, Sections I and VII, as applicable, will apply to the design/build of a CPF only if a boiler installation or modification is part of the facility design. ASME B31.3, in paragraph 300.1.3 Exclusions, subparagraph (b) states that among the exclusions are, *"power boilers in accordance with BPV Code Section I and boiler external piping that is required to conform to B31.1,"* making it clear that boiler external piping is excluded from the scope of B31.3. Therefore, if the installation or modification of boiler external piping is part of a project, then the rules and compliance of the B31.1 Power Piping Code would go into effect, in addition to that of the B31.3 Process Piping Code for piping other than boiler external piping.

Boiler external piping is defined under ASME B31.1, paragraph 100.1.2(A) as follows: *"Boiler external piping shall be considered as piping that begins where the boiler proper terminates at: (1) the first circumferential joint for welding end connections; or (2) the face of the first flange in bolted flanged connections; or (3) the first threaded joint in that type of connection; and that extends up to and including the valve or valves required by para. 122.1. The terminal points themselves are considered part of the boiler external piping."*

In understanding fully the jurisdictional limits, when the installation or modification of a boiler and its associated boiler external piping is at play, and the points at which one safety code ends and another begins, there are two additional terms, beyond that of "boiler external piping" defined above, that also need to be understood. Those terms are "boiler proper" and "nonboiler external piping." These two terms are defined as follows:

- ***Boiler proper*** is clarified in the Preamble of the BPVC Section I, in which it states that, *"Superheaters, economizers, and other pressure parts connected directly to the boiler without intervening valves shall be considered as parts of the boiler proper, and their construction shall conform to Section I rules."*
- ***Nonboiler external piping***, in accordance with B31.1, paragraph 100.1.2(B), *"…includes all the piping covered by this Code* [B31.1] *except for that portion defined above* [in Para. 100.1.2(A)] *as boiler external piping."* The implication can be made that if B31.3 is in effect for all piping except boiler external piping, then nonboiler external piping can also be covered by B31.3. These are code boundary limits that need to be made explicit and definitive in procedures, guidelines, scopes of work and drawings that are followed by those engineers and constructors that are designing and constructing CPI facilities.

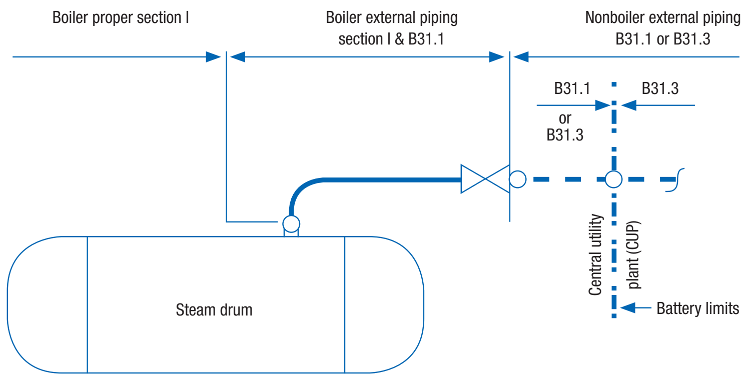

FIGURE 2. Shown here is an example of code jurisdiction and transitioning

With the three boiler terms clarified, we can now discuss code jurisdiction as it relates to steam generation. In doing so we will begin at the "boiler proper," which, as mentioned above, is the pressure equipment plus its interconnecting tubing and components that make up the boiler package, whether preassembled or assembled on-site. Both the administrative jurisdiction and technical responsibility of the boiler proper is governed by Section I of the Boiler Code. The "boiler external piping" that connects directly to the "boiler proper" is an interface or transitional segment of piping in which the administrative jurisdiction is governed by the Section I Boiler Code, but the technical responsibility is owned by the B31.1 Power Piping Committee. Extent of the boiler external piping includes the joint connection made at the boiler proper and extends through the valve or valves as required by B31.1 Paragraph 122.1.

While the technical responsibility of boiler external piping is governed by B31.1, the piping that connects to the boiler external piping at a point opposite from that of the boiler proper connection can either be accomplished in accordance with B31.1 or B31.3. If the owner, or their

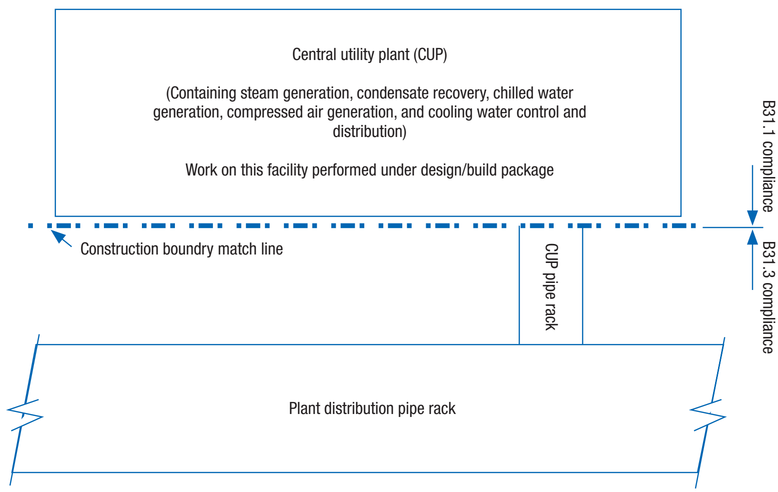

FIGURE 3. This schematic shows piping code compliance jurisdiction

prescribes requirements for the design, materials, construction, assembly, inspection, testing, operation, and maintenance of piping transporting aqueous slurries of nonhazardous materials such as coal, mineral ores, concentrates, and other solid materials, between a slurry processing plant or terminal and a receiving plant or terminal."

- B31.5 — Refrigeration Piping and Heat Transfer Components: This code *"…covers refrigerant, heat transfer components, and secondary coolant piping for temperatures as low as –320°F (–196°C), whether erected on the premises or factory assembled. Users are advised that other piping Code Sections may provide requirements for refrigeration piping in their respective jurisdictions. "This Code does not apply to any self-contained or unit systems subject to the requirements of Underwriters Laboratories or other nationally recognized testing laboratory. It also does not apply to water piping; piping designed for external or internal gage pressure not exceeding 15 psi (105 kPa) regardless of size; or pressure vessels, compressors, or pumps. However, B31.5 does include all connecting refrigerant and secondary coolant piping starting at the first joint adjacent to such apparatus."*
- B31.8 — Gas Transmission and Distribution Piping Systems Section Committee: This code, *"…covers gas transmission and distribution piping systems, including gas pipelines, gas compressor stations, gas metering and regulation stations, gas mains, and service lines up to the outlet of the customer's meter set assembly. It includes gas transmission and gathering pipelines, including appurtenances that are installed offshore for the purpose of transporting gas from production facilities to onshore locations; gas storage equipment of the closed pipe type that is fabricated or forged from pipe or fabricated from pipe and fittings; and gas storage lines."*
- B31.9 — Building Services Section Committee: *"…has rules for piping in industrial, institutional, commercial and public buildings, and multi-unit residences, which does not require the range of sizes, pressures, and temperatures covered in ASME's B31.1 Code for Power Piping [or B31.3 Process Piping]. It includes piping systems either in the building or within the property limits."*
- B31.12 — Hydrogen Piping and Pipelines: This code, *"…is applicable to piping in gaseous and liquid hydrogen service and to pipelines in gaseous hydrogen service."* B31.12 *"…is applicable up to and including the joint connecting the piping to associated pressure vessels and equipment but not to the vessels and equipment themselves. It is applicable to the location and type of support elements but not to the structure to which the support elements are attached."* It is divided into three parts as follows:
  - Part GR — General Requirements: This part *"…contains requirements applicable to and referenced by other parts. It contains definitions and requirements for materials, welding, brazing, heat treating, forming, testing, inspection, examination, operation, and maintenance. It also contains quality system topics common to the other parts."*
  - Part IP — Industrial Piping: This part *"…includes requirements for components, design, fabrication, assembly, erection, inspection, examination, and testing of piping."*
  - Part PL — Pipelines: This part *"…sets forth requirements for components, design, installation, and testing of hydrogen pipelines."*

Piping Standard

The Bioprocessing Equipment (BPE) is considered a standard and is adjunct to the B31.3 piping code. Both documents are intended to work in tandem where high purity fluid services have been designated in accordance with B31.3. This standard provides the essential elements in the design, material of construction, fabrication, and installation of both piping and equipment. It goes beyond the precept of a construction code in providing design elements as an integral part of its requisite criteria. The Introduction in paragraph GR-1 states, in part: *"The ASME Bioprocessing Equipment Standard was developed to aid in the design and construction of new fluid processing equipment used in the manufacture of biopharmaceuticals, where a defined level of purity and bioburden control is required."*

But the standard goes further to make clear a much broader scope and use of the standard in paragraph G-2 where it states, in part: *"The ASME BPE Standard provides requirements for systems and components that are subject to cleaning and sanitization and/or sterilization including systems that are cleaned in place (CIP'd) and/or steamed in place (SIP'd) and/or other suitable processes used in the manufacturing of biopharmaceuticals. This Standard also provides requirements for single use systems and components used in the above listed systems and components. This Standard may be used, in whole or in part, for other systems and components where bioburden risk is a concern."*

Piping Directive of the European Community.

The Pressure Equipment Directive (PED), regarding harmonization of national safety laws by and for European Member States, in what is referred to collectively as the European

Continued on page 48

engineering representative has specified the project piping code (plant wide) to be B31.3 then it would make sense to make the transition from the boiler external piping to the nonboiler external piping in accordance with B31.3 at that point. Graphically, such a transitioning of codes would look like that shown in Figure 2. An option, as indicated at the Battery Limits line, would be to retain B31.1 up to the battery limits then make the transition to B31.3 upon leaving the central utility plant (CUP) limits.

Further to the above point, regarding the transition from boiler external piping to nonboiler external piping, that transition could also be based on contractual battery limits. Meaning that, should a contract package be written for the design/build of a boiler facility or CUP, piping for the entire design/build package could be governed by B31.1 up to the battery limits (see Figures 2 and 3) as defined in the contract. Beyond those battery limits a transition to the plant-wide compliance of B31.3 could then be made.

To be clear: "battery limits" is a term used in engineering and construction as a means to establish definable boundaries that can either be fictitious or physical boundaries. In many cases the battery limits established during design and construction are carried over into plant operations to use those boundary limits or create new ones to be used for plant-wide accounting breakout and maintenance purposes.

The ASME Boiler Code is required compliance in all U.S. states except Idaho and Wyoming, and is also required in all Canadian Provinces and Territories, and is recognized in more than 112 countries worldwide. The Pressure Equipment Directive (PED) is the boiler-code counterpart in the E.U., and the India Boiler Regulation (IBR) is the counterpart in India.

Pressure vessels

The design and fabrication of pressure vessels will fall under Section VIII (metallic) or Section X (nonmetallic) of the BPVC. These are self-contained equipment items that may contain integrated components and supplemental equipment, such

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Economic Area (EEA), includes oversight of design, manufacture, testing and compliance requirements of pressure equipment and assemblies of pressure equipment. This Directive applies to the design, manufacture and conformity assessment of pressure equipment and assemblies of pressure equipment with a maximum allowable pressure greater than 0.5 bar gage pressure (1.5 bar absolute pressure). The term "allowable pressure" is defined in the PED as the pressure rating for an assembly or device.

Piping Component Standards

For this discussion, the term "piping component" includes pipe, tubing, fittings, flanges (plus other mechanical type piping joint assemblies), line blanks, valves, and miscellaneous items associated with piping systems. There are accredited standards for each of these pressure-containing or pressure-restraining components (see online version of this article for Table A, a partial, modified replication of ASME B31.3 Table 326.1, at www.chemengonline.com). Such standards, as those found in B31.3 Table 326.1, are referred to as listed standards. A listed standard is defined in B31.3 as: *"…a material or component that conforms to a specification in Appendix A, Appendix B, or Appendix K or to a standard in Table 326.1, A326.1, or K326.1."*

The following are titles of the above referenced Appendices and Tables:

- Appendix A: Allowable Stresses and Quality Factors for Metallic Piping and Bolting Materials
- Appendix B: Stress Tables and Allowable Pressure Tables for Nonmetals
- Appendix K: Allowable Stresses for High Pressure Piping
- Table 326.1: Component Standards (for metallic components)
- Table A326.1: Component Standards (for nonmetallic components)
- Table K326.1: Component Standards (for high pressure metallic components)

The difference, under B31.3, between "listed" and "unlisted" is that, "listed" components, in accordance with B31.3 paragraph 303, *"…shall be considered suitable for use at pressure–temperature ratings in accordance with para. 302.2.1* [Listed Components Having Established Ratings.] *or para. 302.2.2* [Listed Components Not Having Specific Ratings]*, as applicable."* "Unlisted" components, on the other hand, shall conform to B31.3 paragraph 304, which states that such designation is, *"…intended for pressure design of components not covered in Table 326.1, but may be used for a special or more-rigorous design of such components, or to satisfy requirements of para. 302.2.2* [Listed Components Not Having Specific Ratings.]. *Designs shall be checked for adequacy of mechanical strength as described in para. 302.5* [Mechanical Strength]." Paragraph 302.5 states, in its first sentence that, *"Designs shall be checked for adequacy of mechanical strength under applicable loadings."* It then goes on to state various qualifiers with regard to that statement. ❑

as a bayonet-type heat exchanger, coils, dip tubes, spargers, eductors and agitators, to name a few. Such items may be delivered to the job site pre-installed in or on the pressure vessel, or delivered separately and installed on-site. Design, construction and testing of these added components may fall separately under code or standardized requirements specific to their own characteristics. But the mounting design and affected load demands on the pressure vessel will be part of the Section VIII or X code requirements.

What is often referred to as the "pressure boundary" of a Section VIII pressure vessel, is defined in Section VIII under Part U-1 Scope, with regard to the extent or boundary limits of the code, as defined in paragraph U-1(e), which states the following: *"U-1(e) In relation to geometry of pressure-containing parts, the scope of this Division shall include the following: U-1(e) (1) where external piping; other pressure vessels including heat exchangers; or mechanical devices, such as pumps, mixers, or compressors, are to be connected to the vessel: (a) the welding end connection for the first circumferential joint for welded connections [see UW-13(h); (b) the first threaded joint for screwed connections; (c) the face of the first flange for bolted, flanged connections; (d) the first sealing surface for proprietary connections or fittings."*

It goes on to elaborate on non-pressure parts welded internally or externally directly to a pressure vessel, pressure-containing covers for vessel openings and so on.

In accordance with Section VIII, paragraph UG-98 Maximum Allowable Working Pressure: *"UG-98(a) The maximum allowable working pressure for a vessel is the maximum pressure permissible at the top of the vessel in its normal operating position at the designated coincident temperature specified for that pressure…"*

The pressure rating of a vessel so rated in accordance with UG-98(a), will not itself be affected by the attachment of valves or instruments connected directly to the vessel. What is affected is the system or assembly rating in which the vessel has become a part. A piping system or assembly has a maximum pressure rating that cannot exceed that of the rating of the weakest component or equipment item in the system or assembly.

The "service codes," as mentioned earlier, will provide the engineer with the mechanical properties of "listed material" found under Section II. Section V explains the specifics of non-destructive examination (NDE) requirements. And Section IX provides not only qualification requirements for welding, brazing and fusing procedures; welders; brazers; and welding, brazing and fusing operators, but also provides suggested forms to use in documenting such procedures and requirements.

Up to this point, things have been largely straightforward with regard to selecting codes that apply to key processing elements, such as boilers and pressure vessels, equipment essential to the manufacture of chemicals, food products, fuels and pharmaceuticals. The use and application of codes, such as the BPVC, are extremely complex and requires expert experience and know-how to properly navigate, interpret and apply the requirements appropriately.

The ASME Pressure Vessel Code is required compliance in all but eleven states, namely: Conn., Fla., Idaho, La., Mich., Mont., N.M., S.C., S.D., Tex. and W.Va. It is also required compliance in all Canadian Provinces and Territories, and is recognized in more than 112 countries worldwide. The PED is the counterpart in the E.U.

Assigning piping codes

With piping systems transporting a broad range of chemical and utility fluids throughout a CPI facility's multiple processing units, it can become a little disconcerting to decide what piping code or standard applies to what piping system. From a CPI standpoint, the piping codes that could be of interest include:

- B31.1 Power Piping
- B31.3 Process Piping
- B31.4 Liquid and Slurry Piping Transportation Systems
- B31.5 Refrigeration Piping and Heat Transfer Components Code
- B31.9 Building Services Piping
- B31.12 Hydrogen Piping and Pipelines
- Bioprocessing Equipment (BPE)
- E.U. PED

As mentioned, there are four U.S. states (California, Kentucky, Michigan and Oregon), along with all of the Canadian Provinces and Territories that have codified ASME B31.3. A facility, either currently operating or being designed and built and located anywhere else on this planet, will find it necessary to adopt the B31.3 piping code procedurally, making it a contractual obligation, if they require the facility to be designed, constructed or maintained under the rules of that, or any other piping code they so choose.

In jurisdictions that have codified the B31.3 piping code for CPI facilities, it becomes requisite that the piping design and construction for any such facility be done in accordance with the requirements of B31.3. And while the ability to design and construct all piping in accordance with a single code greatly simplifies the engineering and construction process, there are circumstances, and indeed requirements in some cases, in which multiple piping codes and standards for a single facility would be logistically more beneficial and pragmatic. In consideration of this, the various ASME codes and standards, and to a large degree the European PED, are harmonized in order to allow for such "stacking" of codes.

Central utility facility. Figure 4 represents the hypothetical layout of, what is referred to here as a central utility plant (CUP). But such a facility might also be referred to as a boiler house, energy facility, utility building, or any number of other terminologies that lend a descriptive name to such a utilitarian facility. Packing this facility with multiple utility systems gives us a microcosm example of code jurisdictions either as codified or as contractual requirements.

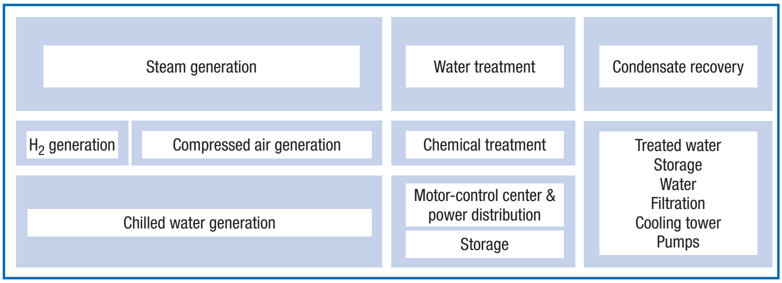


FIGURE 4. Shown here is the arrangement for a hypothetical central utility plant

But before focusing on the CUP facility, a governing piping code needs to be designated for the entire plant site or facility. Since this is a chemical processing facility, the governing code, either by statutory regulation or by common-sense edict, will, for reasons given earlier, be the ASME B31.3 Process Piping code. And depending on the varied types of processing and utility-service operating or processing units within this facility, other codes and standards may be applied as needed, such as those that will be shown in the CUP facility example discussed below.

Assigning code requirements, as a contractual obligation for the engineer and constructor, is a process of nuancing regulatory requirements and making pragmatic choices. In referring again to Figure 4, we will assign governing codes and standards in a way that will meet regulatory requirements, as well as assign codes based on more philosophical and pragmatic engineering methodologies.

Assigning codes and standards to the piping in a facility is done in a somewhat hierarchical manner. The implication is that there will be an overarching, or governing piping code for, in this case, the CUP facility, in which the requirements of all other codes and standards within the CUP will need to address different subject matter, or be equal to or more stringent in their requirements than that of the governing code.

The overall governing code within the CUP facility is the ASME B31.1 Power Piping code. This code directly impacts the steam, water, condensate and compressed-air piping systems, while the chemical-treatment piping system falls under the added requirements of B31.3 Process Piping, and the hydrogen generation piping system falls under the guidance and requirements of B31.12 Hydrogen Piping and Pipelines.

In broadening the scope of this discussion, we will address the assignment of piping codes on a plant-wide basis. It was mentioned earlier that, *"Since this is a chemical processing facility the governing code, either by statutory regulation or by common sense edict, will be the ASME B31.3 Process Piping code."* Adopting B31.3 for the entire plant site does two major things:

First, it puts in place the requirement under B31.3, paragraph 300(a)(b)(1) in stating that, *"The owner of a piping installation shall have overall responsibility for compliance with this* [B31.3] *Code, and for establishing the requirements for design, construction, examination, inspection, and testing that will govern the entire fluid handling or process installation of which the piping is a part.* ***The owner is also responsible for designating piping in Category D, Category M, High Pressure, and High Purity Fluid Services, and for determining if a specific Quality System is to be employed.*** [See paragraphs 300(d)(4) through (7) and Appendix Q.] *Where applicable, the owner shall consider requirements imposed by the authority having jurisdiction regarding the piping installation."*

Selecting and assigning a fluid service category to every fluid service in a facility is an essential element in determining the *"…selection and application of materials, components, and joints."* These fluid service requirements also, *"…include prohibitions, limitations, and conditions, such as temperature limits or a requirement for safeguarding."* The degree of re-

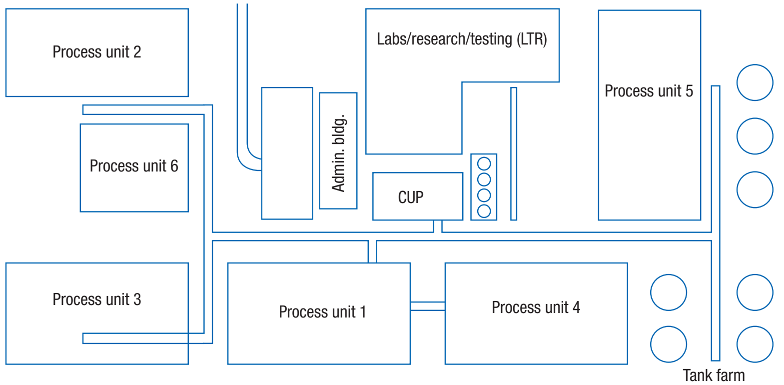


FIGURE 6. Here is the arrangement for a hypothetical CPI facility

TABLE 1. PIPING CODE ASSIGNMENTS PER IN-PLANT FACILITY

In-plant facility	Governing piping code	Code augmentation
Process unit 1	B31.3	
Process unit 2		
Process unit 3		
Process unit 4 (fermentation step)		BPE
Process unit 5		
Process unit 6		
Central utility plant (CUP)		B31.1/B31.3/B31.12
Tank Farm		
Laboratory/research/testing facility		B31.9/B31.5
Administration building		International Plumbing Code

quired inspection and testing is also based on a piping systems designated fluid service category.

Secondly, in selecting the B31.3 Process Piping code as the plant-wide governing piping code, overall coverage is provided throughout the plant site, with the exception of "boiler external piping," as described above. There is no other piping code with the breadth of coverage provided under B31.3. But there are circumstances, much like those described in assigning codes within the CUP example above, in which it may be more appropriate and logistically make more sense to specify requirements under another piping code other than B31.3 or to augment the B31.3 piping code with another code or standard.

CPI facility. We will now step through the process of assigning piping codes to the hypothetical CPI plant layout shown in Figure 6. Table 1 shows that the governing plant-wide piping code for our hypothetical CPI facility is B31.3, with augmenting codes, if any, recommended for the facility. So, process units 1, 2, 3, 5, 6, and the tank farm can all be designed in accordance with B31.3. It is recommended that process unit 4, the CUP, laboratory/research/testing (LRT) facility, and administration building specify the inclusion of additional code requirements.

Process unit 4. Process unit 4 has a fermentation step in the process. The fermentation system itself will require a cleanable approach to system design in order to safeguard the system against batch upsets and non-conformance issues due to bacterial infection. Infection caused by bacterial residue from one batch to another is caused by a system that is not properly designed for cleanability.

While many fermentation systems used in manufacturing products outside the high-purity demands of the pharmaceutical, food and beverage industries do not require the full scope of the ASME Bioprocessing Equipment (BPE) Standard, BPE does provide the guidance on cleanability needed in other industries outside the purview of the U.S. Food and Drug Admin. (FDA) regulation, such as the biofuel industry. Handling yeast or a bacteria in a fermentation process requires a cleaning protocol that prevents the onset of bacterial infection and growth on the process-contact surfaces of a piping system. Such lack of consideration for the design of a fermentation system that possesses the essential ability to be properly cleaned on a regular basis, will be at the detriment of production yield.

Installing a fermentation system that integrates a clean-in-place (CIP) or steam-in-place (SIP) system is imperative. In providing guidance and understanding of that philosophy, the BPE Standard becomes an essential part of the design and construction process for such a facility. The engineer must pull from the standard only those cleanability elements of design and construction that pertain to their particular needs.

Central utility plant. As alluded to earlier, the CUP facility has been packaged out, which means the battery limits have been established and defined, and everything within those battery limits is done under a packaged contract separate from that of the rest of the plant–site. In this way the CUP part of the plant-wide project can be bid to perhaps design/build groups that specialize in such utility facilities. In this case, we can isolate the CUP facility from the rest of the plant. Following the code-assignment decision tree shown in Figure 7, we can specify B31.1 as the governing code. This keeps with the need to meet or exceed the requirements of B31.3 with regard to the fluid services contained in the CUP. But because of the chemical treatment piping, B31.3 will be specified, and for the hydrogen piping, B31.12 will be specified. Both codes augment B31.1.

Laboratories/research/testing facility (LRT). The relatively low pressure, ambient temperature and narrow range of fluid services found in laboratories, research and testing facilities typically fall within the scope of ASME B31.9. If refrigeration piping is required in the facility, then B31.5 can be included. For chemical piping that may fall outside the scope of B31.9 the overarching requirements for the plant-wide B31.3 code can be implemented as well. And when more than one code is included in design, it will be necessary to identify and define the limits as to exactly where the code boundaries exist for each piping system.

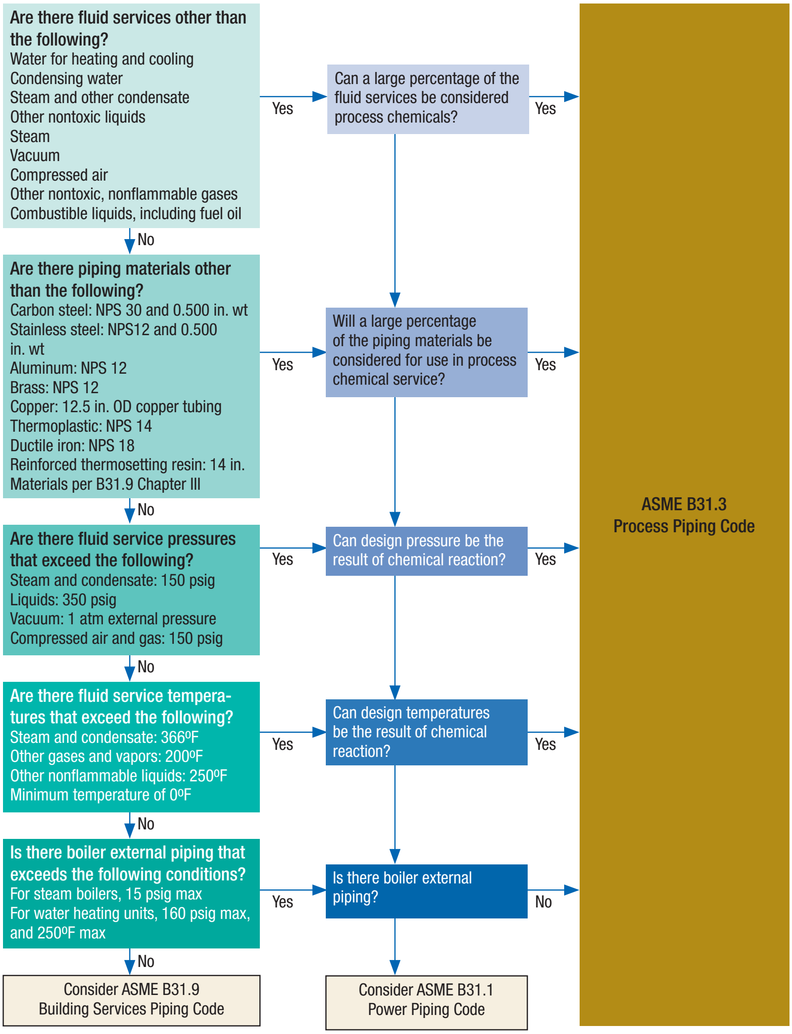


FIGURE 7. A decision tree for determining the piping code required

Administration building. The only piping typically found in an administration building would be considered plumbing, which is outside the scope of the ASME piping codes. Compliance plumbing codes for such a facility will be either the International Plumbing Code or those written or adopted and codified by the governing jurisdiction where the facility is located.

Modifications, repairs, retrofits

ASME B31.3 paragraph 300(c)(2) states the following: *"This Code is not intended to apply to the operation, examination, inspection, testing, maintenance, or repair of piping that has been placed in service. The provisions of this Code may optionally be applied for those purposes, although other considerations may also be necessary."* In making that statement the code is, in fact, acknowledging that while it can be, and most certainly is used for guidance and contractual directives for piping that has been or is in-service, there are indeed fitness-for-service (FFS) considerations that need to be assessed (for instance, corrosion or erosion to the pipe wall, pitting, under-insulation corrosion, localized dynamic pressure impacts, and so on). A topic such as FFS is too broad to cover here, but details can be found in API 579-1/ASME FFS-1 — Fitness-for-Service standard for guidance.

Before continuing with this topic it must be understood that this discussion goes beyond the scope of B31.3. As with this entire article, any guidance or stated recommendations within this brief section are also those of the author and are not those of any particular code.

The more complex issue of FFS aside, explicit code requirements, when it comes to making modifications, repairs or retrofits to in-service piping systems, are not just a little vague, they are non-existent. Determining how the more current code requirements should blend with an existing system that was designed, constructed and installed in accordance with an earlier version of perhaps the same code is left to the user. This intentional avoidance in the code, of providing guidance or recommendations with regard to working with or connecting to existing piping systems, is in keeping with its scope. The question then becomes how to properly reconcile the transitional interface of the old system with that of the new piping and equipment while still maintaining the essential elements of the code. In other words, it is an attempt to follow, not the word of the code, but rather its philosophical intent. That is therefore the intent of the following.

The first step when modifying, repairing or retrofitting a processing system that has been in operation for a period of time, is in understanding the following: so long as the operating or design conditions have not changed, or the piping modified, the designated code under which the original design, fabrication and installation were performed can remain in effect. Only those segments of piping to which a tie-in (TI) connection is made or a piping segment otherwise modified to the extent that the pressure containing integrity of that segment of piping has been altered, will need to comply with the most current B31.3 piping code.

In making the assumption in the following example that all operating and design conditions will remain unchanged with regard to a modified existing piping system, all unchanged piping will remain under the same earlier issue of the code under which it was designed, fabricated and installed. However, when modifying, repairing, or otherwise tying into an existing piping system, the following guidelines are recommended:

- At the tie-in interface point when connecting new piping to an

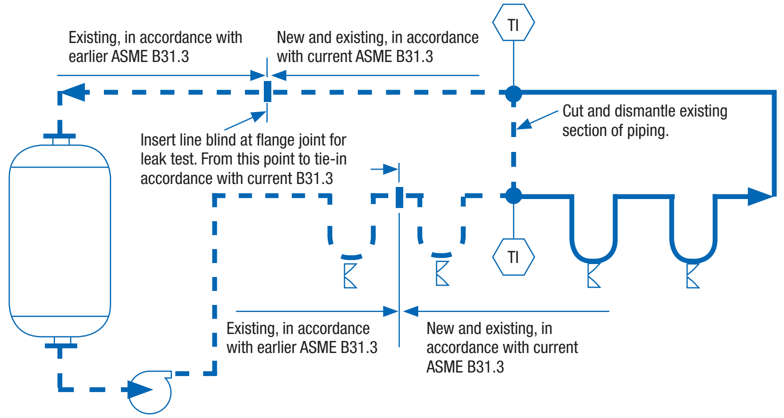


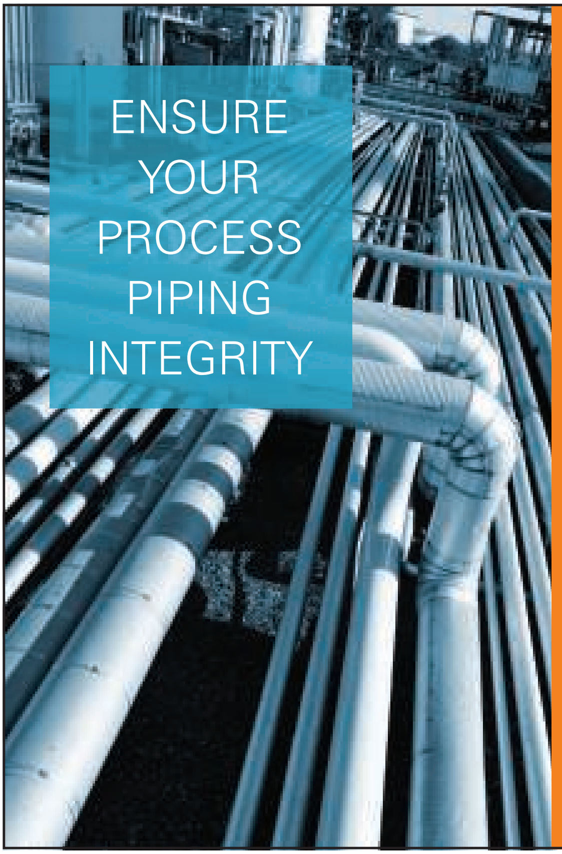
FIGURE 8. Shown here is the difference between the tie-in (TI) point, where the new piping connects to existing piping, and the point further along the existing piping at which the most current code issue will apply

existing system the following are recommended:

- A new weld joint connection made to an existing pipe shall comply with all applicable requirements as stated in the most current code at the time the project specifications were written and agreed to, or, in the case of a repair or modification, at the time the work order was written
- When connecting to an existing flange, whether on pipe or as an integral part of a component or equipment item, it shall be inspected and approved as being compliant and without sufficient damage or distortion to be cause for rejection

- Including the tie-in interface point, a leak test shall be performed on both the entire portion of a newly installed piping system and that portion of the existing system extending from the tie-in interface to a point at which the existing section of piping can be blocked in a manner that will withstand leak-test pressure
- All rules of the most current code should apply, not only to all of the newly added piping, but also to that portion of the existing piping circuit included in the leak test

The following guidance attempts to bring a philosophical approach to how the code may still be utilized and where its boundaries lie. The above bullet points describe the difference between the tie-in point, where the new piping connects to the existing piping, and the point further along the existing piping at which the most current code issue will apply. As shown in Figure 8, that difference, or segment of piping, is represented by the existing piping that lies between the "TI" indication and the existing flange joint in which a line blind is inserted. This



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makes that line segment the extent of existing piping covered by the requirements of the most current code issue.

Bear in mind that the basis and methodology for how new piping systems, repairs or modifications are integrated into an existing system are done so at the prerogative of the owner. It is recommended here that, when engineering the integration of new piping with existing piping, due diligence be performed in ascertaining the quality and integrity of the existing piping system. The years in service and the degree to which harsh service conditions or environment may affect the piping will certainly dictate the extent to which a system is examined and analyzed. Such examination and analysis entails, but is not limited to, the following concerns:

- Wall thickness examination (establish minimum criteria before examination)
- Examination for under-insulation corrosion
- Determine condition of bolts, flanges, and other mechanical joint hardware
- Examine for pitting and stress corrosion cracking
- Look for damage resulting from natural forces
- Look for damage resulting from human error (heavy equipment impact, standing, or otherwise overloading small diameter pipelines)
- Damage having occurred during excavation

There is much more involved with integrating new piping systems with existing piping systems. But the above should provide a degree of information sufficient to at least develop a process and procedure to assess and document the condition of the existing piping prior to proceeding with making modifications.

Other piping-related standards

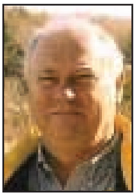
This article has focused mainly on the ASME codes and standards relative to piping and equipment. Even when augmenting a primary piping code, such as B31.3, it was done so with additional ASME codes. And while the primary and even secondary codes and standards are created by ASME, there are additional standards that focus on added safety considerations, comprehensive design requirements and methodologies for specific fluids. Rather than provide an exhaustive, but potentially incomplete listing of all of the possible standards and guidelines that might be of interest, a list of the standards developers and other organizations that create and publish such standards and guidelines is provided (Table B) with the online version of this article at www.chemengonline.com. A brief listing is given below. ■

Edited by Gerald Ondrey

Organizations

1. American Gas Association (AGA; www.aga.org).
2. American Petroleum Institute (API; www.api.org).
3. American Society of Mechanical Engineers (ASME; www.asme.org).
4. ASTM International (www.astm.org).
5. British Standards Institute (BSI; www.bsigroup.com).
6. Compressed Gas Association (CGA; www.cganet.com).
7. European Hygienic Engineering and Design Group (EHEDG; www.ehedg.org).
8. International Organization for Standardization (ISO; www.iso.org).
9. International Society of Pharmaceutical Engineers (ISPE: www.ispe.org).
10. NACE International (www.nace.org).
11. National Fire Protection Association (NFPA; www.nfpa.org).
12. Pressure Equipment Directive (PED: http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1474018784663&uri=CELEX:32014L0068)
13. Tubular Exchanger Manufacturers Association, Inc. (TEMA; www.tema.org).

Author



William M. (Bill) Huitt has been involved in industrial piping design, engineering and construction since 1965. Positions have included design engineer, piping design instructor, project engineer, project supervisor, piping department supervisor, engineering manager and president of piping consulting firm W.M. Huitt Co. (P.O. Box 31154, St. Louis, MO 63131-0154; Phone: 314-966-8919; Email: mhuitt@aol.com; URL: www.wmhuittco.com), which he founded in 1987. His experience covers both the engineering and construction fields crossing industry lines to include work on petroleum refining, chemical, petrochemical, pharmaceutical, pulp & paper, nuclear power, biofuel, and coal gasification. In addition to writing numerous specifications, guidelines, papers and magazine articles on the topic of piping design and engineering, he has also authored "Bioprocessing Piping and Equipment Design — A companion guide for the ASME BPE Standard," which is considered the companion guide on the ASME Bioprocessing Equipment Standard. Huitt is a past member of ISPE and CSI, and is a current member of ASME. He is a member of the B31.3 section committee, B31.3 Subgroup H on High Purity Piping, a member of four ASME-BPE subcommittees and several Task Groups, ASME Board on Conformity Assessment for BPE Certification where he serves as vice chair, a member of the API Task Group for RP-2611, and he serves on two corporate specification review boards. Huitt also authored the training program and provides training to ASME consultants wishing to audit applicants for ASME BPE Certification.

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KNOW WHAT IS NEEDED

PLUNGING AHEAD

DOUBLE BALL-VALVE COUPLERS

FIGURE 1. CPI site operators must be certain that the liquid-transfer equipment and loading systems they employ, including dry-disconnect couplers, constantly meet the highest levels of quality and safe, reliable operation

According to the National Response Center's (NRC) "Spills and Accidents" database, which collects data on toxic chemical spills and other accidents ranging from an oil sheen on water to the release of thousands of gallons, there were a total of 26,987 reported spill incidents in the U.S. in 2015. State-by-state, they ranged from a high of 3,228 reported events in Louisiana to a low of 35 incidents in South Dakota.

Across those state-specific numbers, 42% of the spill events involved mobile vehicles, 30% took place at a fixed site and 11% occurred at a storage tank, platform or pipeline. In other words, those three categories accounted for 83% of the total number of incidents in 2015. Looking at the causes of these chemical spills and accidents, 24% were due to equipment failure, while operator error and transport accidents both accounted for 7% of the total.

Knowing these numbers, it's not hard to imagine a great deal of sleepless nights for the people who manufacture, store, transport, dose, blend, mix, bottle and package finished chemical products or their feedstocks as the ever-present threat of a catastrophic spill hangs precariously over their heads. The complexity of chemicals processing facilities (Figure 1) demands excellence with regard to safety and security. Because of the many transfer points in the manufacturing and handling supply chains in the chemical process industries (CPI), operators must constantly ensure that their liquid-transfer equipment and loading systems are of the highest quality and reliability.

This includes the loading arms, hoses and disconnects that are used to transfer chemical products and feedstocks from, for example, barges, railcars, transport vehicles and pipelines to storage tanks, and from production lines to bottling, packaging and tote-filling operations. This article details the operation of various types of dry-disconnect couplers, and illustrates how selecting the proper style of coupler can help increase safety, optimize flowrates and prevent the types of costly and dangerous chemical spills or accidents that the NRC so fervently monitors.

Know what is needed

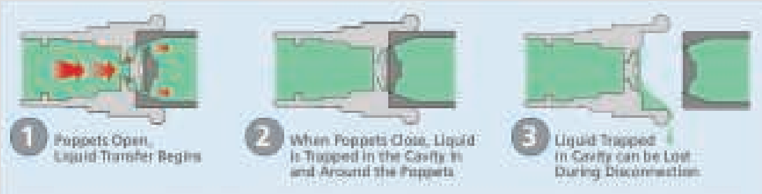
In general, designing and constructing a loading system for chemicals is a complex process. Many different variables must be accounted for, and no two systems are ever exactly alike. For example, will finished products or raw feedstocks be loaded onto or unloaded from railcars, barges, pipelines or tanker trucks? Will the loading and unloading take place from bottom outlet valves on the transport vehicles, or will they be top-loading operations, which will require the use of loading arms and support structures? All of these questions are critical considerations and their answers will help determine which specific loading-system components will be required. This also means that the engineers who fashion these systems and their individual components must work closely with users to create systems that meet unique needs, while also building units that deliver reliability and safety. Before a loading system is ever installed and the first ounce of chemical transferred, the following are some of the most important operational considerations that must be taken into account:

- Is it a top-, bottom- or side-loading application? Knowing the configuration will help determine the overall design of the system
- What are the ambient weather conditions where the system will be used, and will the equipment encounter extremely cold or hot temperatures? Environmental conditions must always be taken into consideration when working with chemicals that possess unique traits
- Do the products being handled produce extreme temperatures that must be accounted for? If so, proper metals and elastomers for these temperature conditions must be used
- What type of products will the loading system be used for? Temperature, corrosiveness and viscosity are just some of the considerations here
- Will any type of cleaning or purging procedure be employed?
- What materials of construction (metals, elastomers and so on) are most compatible with the products to be handled? Materials that are not compatible with products to be handled are more susceptible to failures that can lead to catastrophic spill incidents
- How long must the loading arms be? The precise dimensions of the loading system must be known and the system designed to exactly meet those parameters
- Will railcars or trucks need to be spotted from various distances, requiring more flexibility?
- What level of product flowrates will be required? Loading and unloading times must be optimized,

POPPET-STYLE VERSUS BALL-VALVE DRY DISCONNECT COUPLERS

The differing operational mechanisms of poppet and ball-valve dry-disconnect couplers are described in the sections below.

Poppet Style Design



When utilizing poppet-style disconnects, liquid transfer is initiated when the poppets are opened by the operator (Step 1). The liquid transfer is completed when the operator closes the poppets (Step 2). However, at this time, a small amount of liquid can be trapped, and during disconnection, it is possible that the trapped liquid can escape, leading to a minor product spill (Step 3).

Ball-Valve Style Design

The operation of double ball-valve dry disconnects allows a convex ball to seat with a concave ball when the valve is opened (Step 1). This straight-through design allows the liquid to transfer through the adaptor and coupling with no reduction in flowrate (Step 2). Upon disconnection there are no cavities created in which product can nest, meaning no product will be spilled. This no-spill operation is accomplished through the use of five independent and redundant mechanical interlocks that require deliberate sequential action by users, thereby eliminating unintentional spills and catastrophic chemical releases.

FIGURE 2. Numerous variables and components must be carefully considered when designing a loading system to ensure that leaks are kept to a minimum

especially at facilities where high volumes of finished products and feedstocks must be transferred on a daily basis
- Will any specialized welding be needed for the job? More specifically, is it a hygienic or sanitary application that requires a special weld procedure to ensure that there is no buildup of bacteria on the interior of the loading arm or its components?
- What is the design of the support structure, and is it capable of handling heavier, longer loading arms?
- Are there any specialized material-handling requirements that must be accounted for? For example, will the system be handling a chemical that can explode in the presence of air, which would necessitate an entirely leak-free operation?
- Is the loading system ergonomically designed so that it is not only safe for the application, but also minimizes the physical demands on the operator?

While all of these questions are crucial to designing the proper loading system, many operators, oftentimes by necessity, are known as "first cost" equipment buyers, meaning that they look for equipment with a low initial cost, regardless of brand or quality. However, while the initial cost may be low, these operators can expect higher costs on the back end in the form of increased maintenance and downtime, service and replacement charges, not to mention the incalculable cost incurred if a high-profile incident occurs, such as an equipment failure that results in the leak of a hazardous chemical. Another item to consider is the potential damage to the environment and the facility's reputation that can occur when failing equipment results in a product leak that can lead to personal injury or contamination to the air, soil or groundwater.

Facility operators who are quick to embrace low initial cost for their loading-system purchases would be wise to first conduct a lifecycle cost analysis (LCA) for their site. This would include not only the "first cost" of the equipment, but cost estimates for any subsequent maintenance, service and replacement instances that can result in excessive loading-system downtime or an environmental incident. Those that do complete an LCA will find more

Circle 38 on p. 78 or go to adlinks.chemengonline.com/61500-38

FIGURE 3. Maximized product flowrates and shutoff reliability in the coupling connection allow for improved product containment

often than not that choosing equipment based on quality construction is a much better choice than relying solely on price first.

Even after acknowledging and addressing the questions that must be considered before deciding on the proper loading system for the operation, finding the operational optimum in manufacturing and handling requires many specific steps to be completed succinctly and reliably. Consider the transfer of liquids in the process — as mentioned, there are many specific transfer points that must be taken into account, and throughout the myriad liquid-transfer processes, chemical manufacturers and handlers aim to optimize two critical areas: the safety of production personnel and the environment; and the time needed to complete the manufacturing process.

Ensuring personal and environmental safety is important because not only the end products, but also many of the raw materials used in chemical manufacture, can be volatile, hazardous or corrosive — from general categories like acids and solvents to more specific formulations such as butadiene, xylene and toluene — so they therefore must be treated with the utmost respect and properly contained.

Additionally, preventing spills or leaks is vital because any that occur, besides being dangerous on various levels, have the potential to interrupt the production schedule, which not only delays product completion, but can also lead to the loss of high-value, expensive ingredients and the incurrence of prohibitive cleanup costs.

Plunging ahead

When considering the dry-disconnect couplers that will play an important and prominent role at the end of hoses and loading arms in the safe transfer of hazardous chemicals and their feedstocks, a certain type of technology has charged to the forefront over the years. This technology is referred to in the industry as either a bayonet-and-plunger or poppet style dry-disconnect coupler.

The bayonet-and-plunger dry-disconnect coupler technology has gained acceptance because its design and operation possesses a number of benefits for the user. Most importantly, there is relatively little fluid loss when the coupler is disconnected — as little as 0.5 mL of fluid, or the equivalent of 1/10th of a teaspoon. These couplers are also generally equipped with safety locks that prevent the coupler from opening accidentally as the liquid is flowing through it.

Most brands of bayonet-and-plunger couplers are lightweight and easy to maneuver, which eliminates undue operational stress and strain on hoses and loading arms, as well as the person operating the loading system. Their low cost also makes them attractive to manufacturers who are looking to streamline

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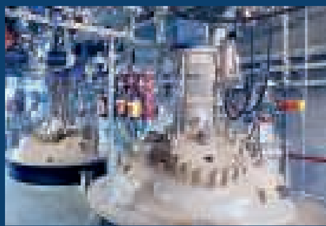

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capital expenditures and protect the operation's bottom line.

With all that being said, bayonet-and-plunger couplers do have several operational characteristics that can potentially limit their optimal application in chemical manufacturing settings. First, while an extremely small amount of fluid may be lost during disconnection, there are other coupler technologies that have been proven to lose less fluid.

From an operational standpoint, the biggest shortfall of bayonet-and-plunger couplers is their internal design, which puts a number of parts in direct contact with the fluid flow. Any type of flowrate restriction will negatively affect the production process. For example, if an engineer specifies a 2-in. line and a bayonet-and-plunger coupler with a 2-in. I.D. is installed, the flowrate will actually be less than what is to be expected from a free-flow 2-in. line because the liquid will have to work its way around the coupler parts that it comes into contact with. This may also necessitate the installation of a larger-than-necessary 2.5- or 3-in. coupler, which can be more expensive.

Additionally, the bayonet-and-plunger coupler's internal components (things such as springs, guides and poppets) can also create areas where the liquid can collect and nest, which makes it difficult to clear the lines and maintain a clean pumping environment. This is especially true when handling liquids with higher viscosities.

Bayonet-and-plunger couplers can be at a disadvantage when manufacturers choose to incorporate a closed-loop fluid-transfer system. The drawback is that in a closed-loop system, there may be numerous valves deployed, meaning that, at some point, the closing of two valves will leave product trapped in the hose between the closed valves. The pressure that is created when the downstream valve is subsequently opened has the potential to damage the dry-disconnect coupler downstream of it, which can lead to leaks and product spills.

Lastly, bayonet-and-plunger couplers are harder to repair or maintain inline because of the number of parts they contain. In fact, many bayonet-and-plunger suppliers require the coupler to be removed and returned to the manufacturer for repairs. If the coupler can be repaired in the field, the number of steps in the repair process, along with the number of parts to consider, can make it difficult or confusing for the maintenance technician, which could result in a repair job that leaves the coupler vulnerable to less than optimum operation and an increased risk of leaks or spills.

Double ball-valve couplers

In addition to bayonet-and-plunger dry-disconnect couplers, an emerging coupler technology is the low-spill dry-disconnect coupler (Figure 2) that operates via a double ball-valve design. This technology features a convex ball that rests in a concave ball, resulting in the elimination of any cavity between the mating halves. This guarantees that no residual fluid will be trapped there, lowering the risk of spills and giving the liquid virtually no place to collect or hide, which eases cleaning. The box on page 55 compares the differing flow mechanisms of double ball-valve and poppet-style dry-disconnect couplers.

The double ball-valve design also incorporates multiple safety interlocks that allow the valve to open and close only through a deliberate action by the user. This prevents any accidental opening of the valve, which lowers the risk of unintentional spills and catastrophic chemical releases. This is not only critical when transferring raw materials from large storage vessels, but also during the numerous tote-filling operations that are a staple of chemical manufacture. This constant on-and-off filling of smaller-capacity containers can put undue strain on the couplers, but the double ball-valve design and

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unique method of operation nullify the harmful effects.

The ball-valve design of the coupler also enables it to offer an unrestricted flow path (Figure 3), which minimizes pressure drop. In other words, a liquid-transfer system that calls for a 2-in. hose can utilize a 2-in. double ball-valve coupler model without any reduction or restriction to the required flowrate. In addition to allowing the plant operator to correctly size his or her equipment, an unrestricted flow path optimizes flowrates, resulting in faster loading and unloading times and a more efficient and cost-effective operation.

Since the design of double ball-valve couplers incorporates fewer parts than poppet-style technologies, they can be repaired onsite, with no need for time-consuming returns to the manufacturer or in-the-field repair personnel to battle with complicated and confusing repair or maintenance instructions.

Secure product handling is key for full containment. For extremely product-sensitive operations, the double ball-valve-style dry-disconnect coupler offers a keyed interface option that locks out and isolates transfer lines. This means a specific coupler can only be used with a specific hose or loading arm. This capability helps prevent cross-contamination of liquids at sites where numerous unique formulations are handled extensively, and must be transferred through common piping systems.

Achieving safe operation and cost-effectiveness is a day-to-day challenge for chemical manufacturers and handlers, especially when both the finished products and raw materials are hazardous and expensive. With many production operations requiring large tank farms and the transfer of thousands of gallons of raw materials and end products on a daily basis, the type of dry-disconnect coupler used, and the technology's ability to optimize reliability, safety and cost is a critical consideration.

A careful understanding of the operational advantages of different dry-disconnect technologies — including leak-free product containment and ease of repair and maintenance — will enable manufacturers and handlers to achieve a peace of mind and hopefully decrease the workload of organizations like the National Response Center. ■

Edited by Mary Page Bailey

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Cybersecurity: You Cannot Secure What You Cannot See

Follow this guidance to understand today's cybersecurity risk landscape and take the necessary steps to create a sound industrial control system cybersecurity program, including the development of a comprehensive, in-depth cyber-asset inventory

David Zahn
PAS, Inc.

FIGURE 1. Cybersecurity risks can arise from several scenarios — malicious attack, human errors and the intentional actions of disgruntled current or former employees

In industrial facilities, cyber incidents typically result from three basic scenarios: a malicious attack from an outside individual or group; a cyber incident that results from an engineer making a mistake that alters a control process or diminishes safe operations; or the work of a disgruntled employee or ex-employee. No matter which of these scenarios you believe is real or presents the most risk, companies must take steps to protect their industrial control systems (ICS) from cyber incidents. What should companies do and how far should they go to ensure that risk is managed to a sufficient level? This article addresses the fundamental elements that an ICS cybersecurity program must contain, and shares guidance on how to develop an in-depth cyber asset inventory.

Cyber incidents

A malicious attack from an outside individual or group. Although such attacks have affected physical operations in a number of well-publicized cases, most outsider attacks to date have focused on proliferation and reconnaissance (get in, spread, gather information, and report back) as their primary objectives. The passive nature of these attacks has lulled many into believing there is more hype than reality in the likelihood of a malicious attack. Most cybersecurity experts would agree that attacks of this type to date are merely a prelude to attacks that will take more directed action in the future. The attack on a power plant in the Ukraine in December 2015 in which hundreds of thousands of people lost power in the dead of winter is a testament to what is to come.

A cyber incident resulting from human error. These mistakes can go undetected until it is too late. Most engineers who have worked in chemical process industries (CPI) facilities long enough can share stories of when such incidences have occurred.

The work of a disgruntled employee or ex-employee. With the spate of layoffs during the last several years — particularly in the oil-and-gas sector — the potential for an insider threat is a rising concern for chief information security officers. Georgia-Pacific recently incurred the wrath of a fired employee who, soon after being laid off, accessed and altered control systems from his home. The company required a significant amount of time to recover from the damage he had inflicted. That employee was successfully prosecuted.

Know your cyber assets

In the race for better ICS cybersecurity, CPI companies all face the same challenge — knowing what cyber assets they have in the plant. Operators and managers tend to have good insight into the non-proprietary assets, such as workstations and routers, but they often lack sufficient visibility into the proprietary assets that run critical processes and keep plants safe. This lack of visibility introduces a level of risk that negatively impacts cybersecurity, safety and compliance efforts.

To what extent does this lack of visibility exist? In one real-world example, an inventory at a plant site showed that 20% of the cyber assets were traditional information technology (IT) systems that standard protocols — for example, Windows Management Instrumentation (WMI) and Simple Network Management Protocol (SNMP) — could interrogate for detailed configuration information. These systems include Microsoft Windows workstations, servers, routers and switches that sit in front of the proprietary control systems. An inventory of these is important to have, but it only paints a partial picture of what is happening within the overall control network.

In our example, the remaining 80% of cyber assets came from the proprietary industrial control systems, such as distributed control systems (DCS), programmable logic controllers (PLC), or safety instrumented systems (SIS). Unlike a workstation, ICS systems have no standard protocols to pull detailed configuration information (such as I/O cards, firmware, software installed, and control strategies).

There is also no option to put an agent on such systems to push data out, as doing so invalidates vendor support. These systems give hackers the greatest opportunity to wreak havoc in a plant, and they also create opportunities for well-intentioned engineers to make mistakes that adversely affect operations.

Create a cyber asset inventory

Efforts to collect an inventory of cyber assets within a control network typically take three forms — manual, vendor-supplied, and IT-only. The following discussion examines the positives and negatives of each approach.

Manual inventory. Manual gathering of inventory data is the most prevalent approach used today. Companies will send engineers into plants to perform a physical inventory, and they will gather a limited set of common data points, related to such information as manufacturer, model and version. The data are consolidated in a spreadsheet and used organizationally.

This approach is convenient, but is not economical, because engineers walking a plant are expensive resources and having them carry out inventory duty has high opportunity costs. Similarly, the manual gathering of inventory data is inherently prone to errors due to the human element, and this approach will typically yield an incomplete assessment, potentially missing swaths of important information, including control logic and shutdown interlocks. Such a data inventory can also quickly become outdated over time. Finally, there are few options for automation using a simple spreadsheet, as such a tool does not enable security policy monitoring and management-of-change processes.

Vendor-supplied solutions. Control system vendors often provide a managed service offering that essentially throws additional outside help at manual inventory efforts. All of the problems with a manual inventory still exist, but internal resources noted previously are freed to do other high-value duties. Many vendors will also offer tools to manage cyber asset inventories, but these tools rarely extend beyond their own control systems. Companies that adopt such tools run the risk of creating solution silos that ultimately add complexity to a cybersecurity

FIGURE 2. Knowing, in detail, the full extent of the facility's (and the company's) cyber assets is a critical step for developing a plan to both prevent and respond effectively to potential cybersecurity threats

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According to the Industrial Control Systems Cyber Emergency Response Team (ICS-CERT), effective physical and environmental protection requires "a detailed inventory of all hardware and software components utilized in support of operations, including detailed information pertaining to device/model type, serial number and firmware version" [*1*].

environment. Complexity is counterproductive to building an effective ICS cybersecurity program.

IT-only solutions. There are many solutions available that can discover non-proprietary systems and provide detailed configuration information, as well as advanced analytics. Such products are quite good at these tasks and given the number of solution providers with such capabilities, this has become a commodity offering. CPI companies must have non-proprietary information as part of their cybersecurity program.

However, they must also recognize that the resulting data come from only about 20% of the cyber assets in a process control network. Ultimately, IT-only solution architectures cannot scale to include the much more complex, proprietary systems that comprise the remaining 80% of cyber assets in a plant.

Exploring 'Inventory in Depth'

A best practice solution must overcome the limitations of today's approaches to inventory. It must gather inventory data for both non-proprietary and proprietary cyber assets, it must contain deep configuration information, and it must break down data silos so that the wide variety of manufacturer control systems are made visible.

Next, we explore the elements for developing a best practice, comprehensive cyber asset inventory. We'll refer to the end product as Inventory in Depth.

One database to rule them all. The first element of an Inventory in Depth approach is to have both non-proprietary (IT) and proprietary operational technology (OT) data in a single repository. The ability to carry out automated vulnerability assessments, security policy enforcement, unauthorized change investigations, patch management processes, analytics and more is only as good as the breadth and depth of the inventory such efforts utilize. Gathering OT and IT assets into a single database ensures breadth; ensuring depth requires having all configuration data, such as I/O cards, firmware, software installed, and control strategies. Detailed configuration information gives engineers and cybersecurity personnel the same view of data, which translates into more consistent, coordinated, and speedier decisions — important capabilities when the goal is to prevent potential plant upsets or harm to personnel. Finally, the costs to maintain an inventory can decrease by as much as 90% as Inventory in Depth relies on automated data gathering; depending on the frequency, an evergreen inventory is also achievable.

Criticality, priority, and interdependency. Not all cyber assets have the same risk profile in light of plant processes. Therefore, when an unauthorized change happens on a critical asset, such as a safety instrumented

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system (SIS), the incident- response protocol will have different steps and degrees of urgency than protocols for other systems, such as a data historian. Discriminating between cyber assets means having a method of categorizing the systems so that each can receive appropriate scrutiny and responsiveness if an incident occurs.

Since few systems act independently in a plant, it is also important to understand how systems are related to each other. Should the system go down due to a cyber attack or engineering mistake, personnel can make better recovery decisions based on knowing what other systems are affected. Having this information is a good engineering practice that also allows cybersecurity personnel to better manage risk across the entire enterprise.

New device discovery. While a simple "ping sweep" will identify new assets on a network, finding new or changed proprietary cyber assets relies on a different tactic — digging into the configuration files of proprietary systems and finding system references that are not currently inventoried. Once an asset is recognized, cybersecurity or engineering personnel should ideally receive notifications of a new device, as well as missing ones (for instance, those resulting from a system upgrade). Then, established workflows can guide them through the process of updating data imports, policies, processes and other cybersecurity functions.

Enabling new usage scenarios

An OT and IT inventory opens up new ICS cybersecurity use cases that were previously unavailable or difficult to achieve. Cybersecurity and operations personnel can now perform the following tasks:

1. Identify exposure to published vulnerabilities

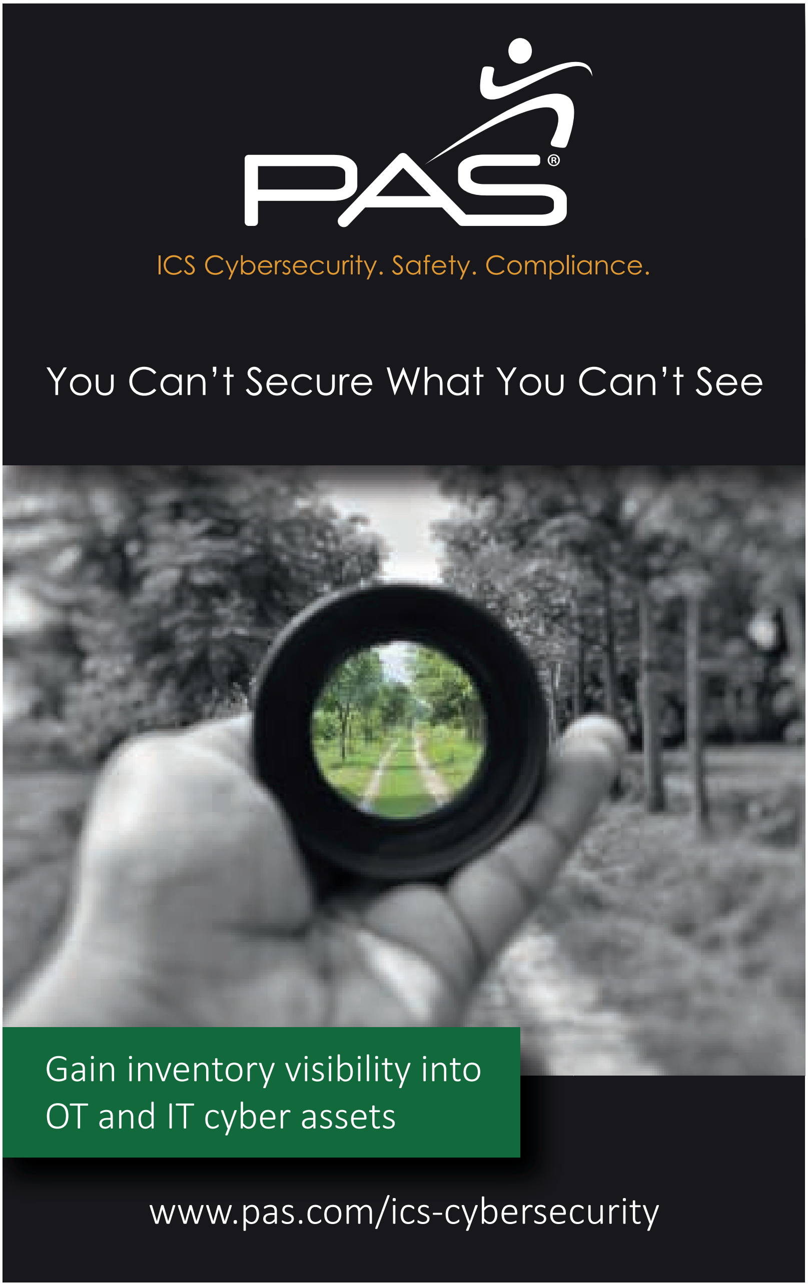
Scenario: ICS-CERT (Box, p. 62) [2] published a critical vulnerability advisory in early 2015 concerning multiple models and versions of a specific transmitter. This transmitter works across any manufacturer's control system and not just the manufacturer's. The advisory describes the vulnerability as critical, noting that it has the potential to impact operations if left unaddressed.

Solution: If a comprehensive OT inventory exists, a simple query will immediately identify every control system that has this transmitter. Only an inventory that spans the heterogeneous, proprietary control systems in a plant will provide complete results. Once the situation is remediated, to prevent future occurrences of this vulnerability, an automated policy can look for and flag instances of when that same transmitter is reintroduced into the control environment (for example, through the spares inventory).

2. Unauthorized change to a control strategy

Scenario: An engineer connects to a particular safety system to make a simple change. The engineer mistakenly removes the ability for the operator to recognize the availability of that safety system.

Solution: Inventoried configuration data are analyzed for changes, with unauthorized changes flagged for



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investigation. An incident-response protocol drives remediating actions needed to restore the safety system. The next data import captures evidence that the safety system's configuration was properly restored.

3. Preparing for the inevitable breach

Scenario: Hackers gain access to systems in Level 1 and below. A multi-threaded attack includes firmware updates to serial-to-Ethernet devices, similar to the Ukrainian power plant hack carried out in December 2015.

Solution: Change detection utilizing a security baseline will surface the malicious firmware updates, and change management procedures and automated workflows will drive needed actions. If a worst-case scenario occurs, automated backups taken during the Inventory in Depth process will speed recovery, as part of a comprehensive disaster recovery plan.

Today, the majority of CPI operating companies cannot effectively execute these three use cases. Where they stumble is not having an accurate, comprehensive inventory of all their cyber assets, which hinders swift, consistent action when these security policies are violated.

A comprehensive solution

A best-in-class inventory management solution deciphers and integrates control-system configuration data from both proprietary and non-proprietary systems into a single repository. Such a solution detects new or missing devices, provides a facility for asset classification, enables appropriately leveled incident response protocols, and accurately captures system interdependencies in sufficient detail.

An automated, normalized inventory data across all major IT and OT assets in the control network presents a holistic view of control system assets — beyond the reach of traditional manual, vendor-supplied, or IT-only solutions. Plant personnel monitor and detect unauthorized changes centrally and then investigate, remediate, and mitigate through automated policies and workflows. The result is greater operational efficiency, improved audit capabilities for compliance, closed-loop patch-management processes, and a speedy recovery in the event of a lost production system. ■

Edited by Suzanne Shelley

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Some 3,100 exhibitors from almost 60 nations will be showing their products and services on more than 170,000 m^2 of net exhibition space during K 2016 (Düsseldorf, Germany; October 19–26) — the international trade fair for plastics and rubber. "Nowhere in the world can one experience the full breadth of raw materials, processing and application equipment as completely as at K in Düsseldorf," says Werner Dornscheidt, president and CEO of Messe Düsseldorf, the show's organizer (www.k-online.com).

As always, K 2016 will occupy all the exhibition space at Messe Düsseldorf, with products and services filling all of the venue's 19 halls. All of the industry's core business areas are present, including machines and equipment, raw materials and auxiliaries, semi-finished products, technical parts and reinforced plastics, and services.

A small sample of products and services on display during K 2016 is presented below.

A new approach to plant planning

Nowadays, billion-euro investment decisions in the plastics production and processing industry are made in a very short time. According to this company's managing director, Rochus Hofmann, the time between an investment decision and commissioning is less than half of what it was a few years ago. These challenges can only be met with better and faster planning. At K 2016, this company is demonstrating its new approach to planning and designing plants for the plastics industry. While a traditional machine construction company focuses on the machine, a plant engineering company's planning will keep the total plant in mind, using various planning tools. One of them is the Zeppelin Value Engineering concept, which enables extensive discussions and the optimization of the plant concept in digital form at a very early stage. This leads to better concept solutions such as optimized piping, improved room layout or perfect positioning of all components, and shorter distances. This company's planning software supports this process (photo). In the future, focus will be set on innovatively developing the planning process, for example by further improving digitalization — not only when planning, but also with the use of components that can communicate in a digital network. Therefore, this company focuses its component development on a new product segment named "smart components" and will also present new ideas regarding Industry 4.0. Hall 9, Booth B41 — *Zeppelin Systems GmbH, Friedrichshafen, Germany*
www.zeppelin-systems.com

High-tech microgranules for brilliant colors

This company's Rhein Chemie Additives business unit is showcasing its organic Macrolex Gran colorants (photo, p. I2) for the brilliant coloring of amorphous and semicrystalline plastics. Thanks to their microgranule form, the colorants compare extremely favorably with powders


Zeppelin Systems

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and compact granules owing to their excellent dispersion and processing properties and safe handling, says the manufacturer. Macrolex microgranules consist of hollow spheres that can be very easily crushed, which means they can be quickly, evenly and completely distributed and incorporated into the plastic. The excellent processability of the product is due to the fact that the hollow spheres comprise particularly small primary particles of around 2–10 µm, depending on the color. The good free-flowing properties of the 0.3-mm spheres make precise metering easier and prevent clumping in the mixing process. The four-times higher bulk density compared with powder pays dividends in processing, transport and storage alike. Hall 6, Stand C78 — *Lanxess AG, Cologne, Germany*
www.lanxess.com

Precise metering of blowing agents and additives

When manufacturing insulation panels, packaging foils or molded parts, blowing agents must be metered into the plastic melt under high pressure and extreme temperatures in order to achieve a high-quality result. The Ecofoam system (photo) is a new complete solution that includes pump, measuring and control technology that delivers precision and minimized downtime. It pumps the blowing agents (such as CO_2, propane, butane, halogenated hydrocarbon and pentane) in quantities proportional to the speed of the extruder, thereby guaranteeing precise metering, even when pressures are fluctuating. For liquids that naturally display a wax-like consistency, this company has also developed heatable systems that are designed for temperatures of up to 130°C and pressures of up to 500 bars. These metering systems are suitable for a large variety of additives, including flame retardants, lubricants and static inhibitors, as well as plasticizers. Hall 7a, Stand B26 — *LEWA GmbH, Leonberg, Germany*
www.lewa.de

More sustainable additives, pigments, colorants and more

This company is said to be the first producer of quinacridone pigments based on bio-based succinic acid. PV Fast Pink E/E01 offers bright colors for everyday products from toys to food packaging and textiles, with durability comparable to petrochemical equivalents. The use of bio-succinic acid reduces the company's carbon footprint by up to 90% compared to petrochemical-based products. Other innovations being exhibited at K 2016 include: The new Polysynthren Black H infra-red (IR) transparent polymer-soluble dye, which enables easy sorting of black-colored articles during the recycling process; colorant solutions based on the unique pigment PV Fast Yellow H4G, to replace lead chromates; the new Licocene PE 3101 TP nucleating agent for expanded polystyrene (EPS) applications; and more. Hall 8a, Stand J11 — *Clariant AG, Muttenz, Switzerland*
www.clariant.com

Thinner, stable films reduce consumption of raw materials

This company's multilayer and polymer blend technology for flexible packaging (photo) can help manufacturers to reduce transport losses, optimize protection of goods, maximize pallet stability by increasing holding force of collation shrink and stretch films used to protect food packaging, making them stronger. They may help reduce the environmental impact of packaging by enabling down-gauging while improving the holding force. Manufacturers may achieve down-gauging options that reduce thicknesses by up to 20% compared to current film concepts. Thinner products reduce plastic consumption and allow for higher processing speeds. The company's LDPE (low-density polyethylene) film grade is a new product for manufacturing very thin-gauge packaging. It offers excellent draw-down ability, running stable at a film thickness as low as 12 µm, using less raw material and enabling higher production line speed, says the company. Hall 6, Stand D42 — *SABIC Holding Europe B.V., Sittard, the Netherlands*
www.sabic.com

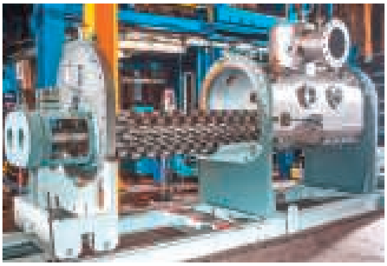
Conductive silicone rubber dispersion for the cable industry

Powersil 403 silicone rubber dispersion (photo) is an electrically conductive dispersion developed for manufacturing the outer conductive film on cable accessories for transmission and distribution cables. The two-component

formulation contains addition-curing silicone rubber, which adheres well to the insulating silicone substrate while forming a flexible film. Elongation at break is roughly 650% for this formulation, and its tear strength is 20 N/mm. This means that a conductive film made from Powersil 403 can withstand extreme elongation, without cracking. The low-viscosity liquid contains no toluene, and can be easily applied by spraying, dipping or brushing. Its electrical properties also make the dispersion suitable for use in antistatic coatings for textiles. Hall 6, Stand A10 — *Wacker Chemie AG, Munich, Germany*
www.wacker.com

A large volume processor for highly viscous products

The Large Volume Processor (photo) consists of horizontally arranged, heated reactors with either co- or



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counter-rotating shafts that provide intensive mixing and kneading for effective polymerization and devolatilization of products with viscosities up to 15,000 Pa·s. These highly versatile processors are characterized by large process volumes and self-cleaning. They allow for the efficient treatment of difficult-to-handle products or materials undergoing phase changes. They permit the economic realization of long residence times, and combine various process steps into a single unit. Hall 12, Stand A51 — *Buss-SMS-Canzler GmbH, Pratteln, Switzerland*
www.sms-vt.com

A new proprietary process to improve fuel economy of tires

At K 2016, this company is introducing a newly developed technology for the production of functionalized solution rubbers. The application of this new technology to both styrene butadiene rubber (S-SBR) and functionalized butadiene rubber — in particular neodymium-catalyzed butadiene rubber (Nd-BR) — increases the interaction with fillers, helping to improve the dynamic properties of tire tread compounds. As the filler becomes more easily dispersed into the compound, a more elastic network is built up. This reduces the rolling resistance and thus improves the fuel economy of the tire. In some cases, traction properties can also be enhanced. The new functionalized solution rubbers offer immediate benefits to the tire industry. However, in the longer term, they can be adopted for use in other applications where excellent dynamic properties are required, for example in conveyor belting and anti-vibration applications. Hall 6, Stand C78 —*Arlanxeo Deutschland GmbH, Dormagen, Germany*
www.arlanxeo.com

Innovative and sustainable materials developed here

Having developed components for the Solar Impulse solar-powered aircraft mission, such as an ultra-lightweight and thermal-insulating polyurethane (PU) foam that lends the cockpit its required strength while protecting the pilots from temperature extremes, this company has also used the Solar Impulse aircraft as a flying laboratory for further developing materials and making them suitable for completely different applications. The above-mentioned rigid PU foam will be used in the future as high-efficiency insulation in refrigeration systems, where it reduces energy consumption and CO_2 emissions. The company also recently opened a new production plant at its Dormagen site for CO_2-based polyether polyols, which will be used to manufacture flexible PU foam for mattresses and upholstered furniture. Hall 6, Stand 75A — *Covestro AG, Leverkusen, Germany*
www.covestro.com

Efficient and flexible underwater pelletizing systems

This company is showcasing a new underwater pelletizing system (photo) that is a result of the synergies that have been created through the integration of the recently acquired Gala underwater pelletizing and RE Scheer

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strand pelletizing and pulverizing system product portfolios. The end result is an underwater pelletizing system that successfully combines the know-how of multiple industry leaders in a design that promises to set a new standard for the pellet-processing industry, says the company. The system has been designed to be a one-stop solution for its users as all of the components, from the tip of the extruder screw to the finished plastic pellets. That includes the melt pumps, screen changers, diverter valves, die plates, cutting chambers, water bath, strand dies, cutter systems, interlocking systems, cutter hubs, system controls, cutting tools, support frame and any other required equipment. Hall 9, Stand A4 — *Maag, a Dover company, Oberglatt, Switzerland*
www.maag.com

The next generation in chemical-free moisture analysis

The Computrac Vapor Pro XL (VPXL; photo) is said to be the latest in a long line of accurate, reliable and easy to use moisture analyzers. The VPXL is a chemical free, moisture-specific alternative to Karl Fischer titration. It features an upgraded heater, which increases the upper limit for testing temperatures to 300°C and allows for improved control over testing temperatures. The VPXL is also compatible with multiple sizes of sample vials and is equipped with stepped temperature testing capabilities for enhanced method development. The brand new touch screen and intuitive user interface makes the Vapor Pro XL the most user-friendly Computrac yet. The Vapor Pro XL is can be used in accordance with ASTM D7191-10 and ASTM D7546-15 standard methods, and also correlates well with many popular methods. Hall 13, Stand B91-13 — *Arizona Instrument LLC, Chandler, Ariz.*
www.azic.com

Continuous drying in minutes instead of hours

The Infrared Rotary Dryer (IRD; photo) is used for crystallizing and drying virgin or regrind materials for a wide range of plastics. Through the use of the continuously functioning IRD, the need for energy-intensive processing using dry air is completely eliminated, easily resulting in energy savings of an average of 30%, says the company. Raw material is heated directly and gently with IR light, which diverts the vaporizing moisture from the core of the material toward the outside. Clumping is eliminated as the material is conveyed through the machine, and the slow rotation of the drum leads to even heating while avoiding abrasion and breaking of the product, thereby reducing dust formation. Retrofitting of the IRD into existing plants can significantly increase plant throughput and product quality, says the company. Hall 9, Stand A55 — *Kreyenborg Plant Technology GmbH & Co. KG, Senden, Germany*
www.kreyenborg.com

Longer service life for concrete buildings

This company's concrete protection liners (photo) are made of chemically stable plastics and firmly seal the surfaces of concrete buildings and structures, protecting them against corrosion. The wide range of available materials (polyethylene, polypropylene, polyvinylidene difluoride and ethylene chlorotrifluoroethylene) allows solutions for every requirement, from wastewater treatment up to potable water tanks. These concrete protective liners are said to be simple to assemble and easy to weld, and are designed for a long service life and high operational reliability. Hall 5, Stand 5C02— *AGRU Kunststofftechnik GmbH, Bad Hall, Austria*
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High-performance polymers through solution viscometry

The performance of polymers is mainly determined by the chain length and degree of polymerization. Solution viscometry reliably provides knowledge of these parameters and enables predictions to be made about mechanical properties. This company is presenting the modular options of automatic viscosity. The Duo.Visc, with two independent thermo-electric heating and cooling systems, is said to guarantee stable and precise measurements on the smallest footprint for kinematic viscosity measurements. Hall 10, Stand B21 — *Laude Scientific GmbH, Lauda-Königshofen, Germany*
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Using Excel VBA for Process-Simulator Data Extraction

Engineers can make better use of the results of process simulations by automatically exporting data into heat and material balance tables in Microsoft Excel

Babak Firoozi
Fluor Corp.

Chemical engineering projects require process simulation to validate the chemical reactions and mechanical operations of the process (Figure 1). Each project then requires a heat and material balance (HMB) report based on the simulation results as a basic step of the process engineering. The HMB should contain thermodynamic and other physical property data, such as chemical composition, specific heat, density, viscosity and so on. Additionally, some HMB documents may contain the heat duty required by the process. These data, along with the material flow, become the basis for equipment sizing, line sizing, utility demands, chemical and catalyst provisions, as well as other requirements to complete the process design of the project.

Each project requires its own HMB format based on the feedstock, product, fluid phase or (perhaps most importantly) client preference. Some HMB formats prefer to separate the fluid's vapor and liquid flows and properties. Some projects require British units (such as lb/h, psig, gal/min, and so on), while others prefer SI units (such as kg/h, barg, m^3/h and so on). Commercial process simulators do not directly output the data in a custom format, making it potentially very labor intensive to obtain a properly formatted HMB. In fact, the data reports from simulators may sometimes be difficult to analyze because of the excessive information provided by the simulation.

This necessitates some extra effort from engineers, but with the guidelines presented in this article, formatting HMB data can become much less painful. The examples in this article relate directly to Hysys, a frequently used process simulator, but similar programming principles could be applied to other simulation software products. Many commercially available process simulators communicate with the Visual Basic for Applications (VBA) portion of the spreadsheet program Microsoft Excel. A VBA macro (a series of procedures "recorded" for automatic execution) can be programmed to extract HMB data from the different streams in a simulation and then report that HMB data in an Excel spreadsheet that is customized for the project format.

Aspen Technology

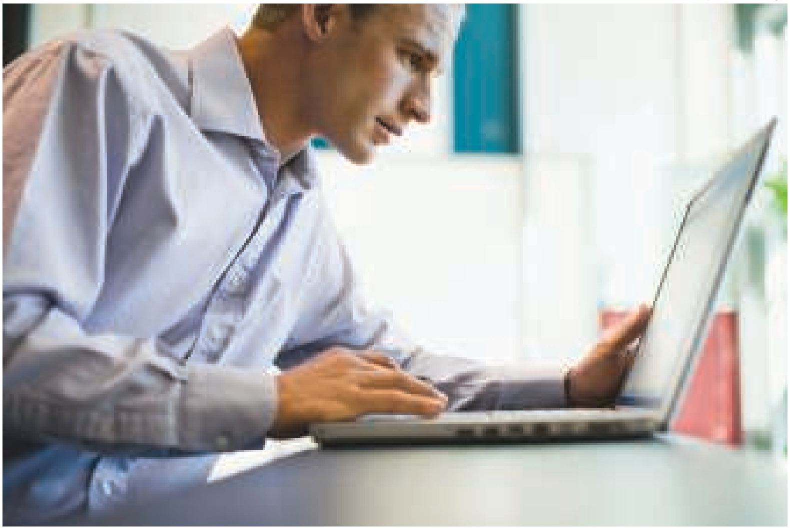

FIGURE 1. Process simulation software helps capture a full picture of a plant's performance and can enable engineers to access large amounts of design data for projects

Spreadsheets are used for project HMBs because of the flexibility of presentation. One method of populating a spreadsheet-based HMB requires a copy-and-paste operation from the simulation to the HMB file. This could create problems if material streams, or rows or columns, are added or deleted in the HMB. A stream from the HMB page could point to the incorrect stream on the pasted page after an insertion or deletion, which could create errors in the equipment sizing, potentially delay the project and ultimately affect the project cost estimate. In the worst-case scenario, if the error is not discovered, the actual equipment could be sized incorrectly and the process would not work.

A better option is to write code using VBA in Microsoft Excel to extract the data from the simulation and then populate the spreadsheet. Microsoft Excel's VBA programming module can be used to automate many processes, such as the creation of a table, which otherwise might require several copy-and-paste operations. Actions that could be automated are typically the source of human error. Accidental copying in the wrong cell, highlighting the wrong cells and deleting or inserting rows and columns all can

FIGURE 2. The Object Browser in Microsoft Excel contains all the properties and methods associated with a particular object

be sources of data-transfer errors. VBA programs that automate data transfer eliminate that human error.

One of the greatest benefits of HMB extraction by VBA is that the VBA communication avoids the potential for human errors in data transfer that are common in copy-and-paste techniques. This article presents code examples and basic programming techniques to aid chemical engineers who are familiar with the basics of Hysys or other process simulators.

Getting started with Excel VBA

VBA is based on object-oriented programming techniques, a hierarchism of objects, properties and methods.

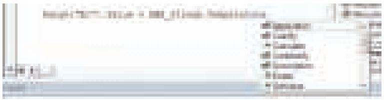

FIGURE 3. Valuable information about an object can be found quickly in the Object Browser

An object is an item of the simulation, such as a *Material Stream* or *Heat Exchanger Operation*. Each object has its own properties, such as *Temperature* for *Material Streams* and *Duty* for *Heat Exchanger Operations.* Each object and its properties also have their own methods, such as *GetValue*, which returns the value of temperature or heat duty in the user's specified units.

Let us say the simulation has a material stream (an object) named "100", which has several properties, such as pressure, mass flowrate, component mass fractions and so on. The engineer may want to extract these properties and populate them in the spreadsheet. Example code utilizing the *GetValue* command is shown in the box on p. 68.

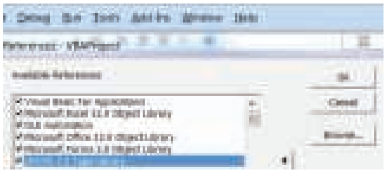

FIGURE 4. Ensuring that the proper references are added to the Excel file is crucial for VBA code to execute correctly

Tips and tricks

The transfer of stream data from process simulators to Excel via VBA is fast and convenient. However, engineering review of the material balance results is required to catch simulation errors. The engineer should consider that a process simulator like Hysys is not able to calculate stream properties for all conditions. For example, properties that may not be calculated are viscosity in two-phase streams or a property outside of the fluid package's temperature limits. That stream property would read as "*<empty>*" and VBA would not extract the data correctly.

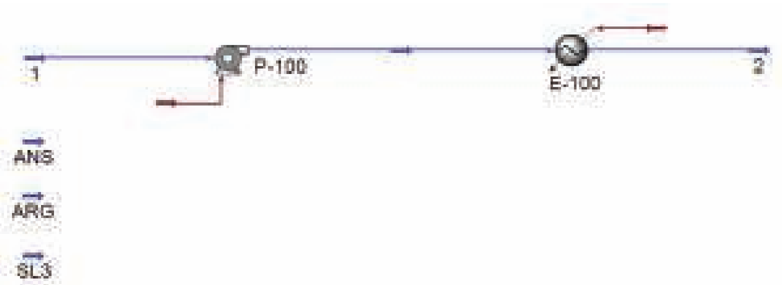

FIGURE 5. A simple flowsheet is given to demonstrate the generation of the HMB table for three crude slates

Mistakes in programming VBA code are also common. After all, we are only human. An error as simple as entering the stream temperature values in the spreadsheet row that is set up for pressure values is an easy mistake to make. The process engineer should always review the HMB for these types of errors.

VBA will extract all properties and conditions by the variable unit exactly as defined by the process simulator. For example, the Hysys unit for pounds per hour is "lb/hr," not "lbs/h" and kilograms per hour is "kg/h," not "kg/hr". These must be consistent in order for the code to function correctly.

Not only can VBA extract data from the simulation, but it can also write data to the simulation. This becomes useful if the engineer needs to modify the simulation with data in the spreadsheet and then extract data that results from the user upload. For example, an engineer may need to extract HMB data for a process with different material feed conditions, such as temperature, flow or pressure. The engineer would use the *SetValue* method to change the stream properties. Then the code would extract the simulation data that result from the updated feed properties.

The Developer tab in Excel has a function called "Record Macro." This is a very useful function that automatically generates code for the user. For example, if a user clicks "Record Macro" and then changes the color of any cell, VBA will automatically generate the necessary code to change the color of a cell. To record a macro, first, set up Excel to show the Developer tab. The user should press the Office button, click on Excel options and then check, "Show Developer tab in the Ribbon" from the Popular page.

The Object Browser (Figure 2) from the VBA Editor View menu is helpful to find the available properties and methods of each object.

Many properties have their own properties and methods. These are easily found by placing a period after the first property, and a drop-down list will appear (Figure 3).

It is important to remember to add references to your Excel file. From the VBA editor, click the Tools menu, click References, and then enable the Hysys Type Library (Figure 4) check box (or whichever library is appropriate for your process simulator of choice).

Another critical step to get started is variable declaration. Declaring the VBA variables for the Hysys HMB file and assigning these variables to the simulation forms the "skeleton" for the code that will be written.

CODE EXAMPLE FOR *GETVALUE* COMMAND

The following code presents a simple example of the *GetValue* command for the given spreadsheet data:

```
Set HMB_stream = ProjectSimulation.Flowsheet.MaterialStreams.Item("100")
Range("B2").Value = HMB_stream.Pressure.GetValue("kPa")
Range("B3").Value = HMB_stream.MassFlow.GetValue("kg/h")
Range("B5").Value = HMB_stream.ComponentMassFraction(0)
Range("B6").Value = HMB_stream.ComponentMassFraction(1)
```
❑

	A	B
1	Stream Number	100
2	Pressure, kPa	200
3	Flow, kg/h	1,000
4	Mass Fraction	
5	Component (a)	0.7
6	Component (b)	0.3

Crude slate example

In many cases, the owner would like to analyze different operating cases for the same (or similar) process configurations. These cases could differ with regard to feed composition, operating temperature and pressure, flowrate or product quality. Instead of creating different simulation files, VBA could be used with different parameters to set the values within the simulation. Then, once converged, the spreadsheet could get the values from the simulation to populate the HMB.

Consider the example of a petroleum refinery processing different crude slates. Each crude slate assay would have various components, composition and true boiling-point (TBP) data. This could consist of over 100 components once the crude assay is input into Hysys. A simple method would be to use VBA to assign an assay composition to the feed and allow the simulation to converge for its unique material balance. Consider this simple example of three different crude slates, each with its own process requirement of temperature and pressure (Figures 5 and 6).

The user would write the VBA code to select the assay and assign the composition to the unit feedstream. The code would then assign the feed flowrate, temperature and pressure, as well as the temperature and pressure downstream of the heat exchanger.

A real-world, practical example of an application of VBA automation to a process with several different operating configurations is demonstrated by a request from one of the author's recent clients, a petroleum refinery. The client wanted to analyze eight different cases and determine which configuration would provide the greatest profit versus performance, as well as verify the process against different feedstocks. The engineering team reviewed two different feedstocks, and four different operating conditions for each. That is, several different operating points (pressure at the distillation column, temperature at the outlet of different heat exchangers and column pump-

	A	C	D
5	Crude State	ANS	
6	Flow	2000	BPD
7	Stream Number	1	2
8	Description of Stream	Unit Feed	Hot Feed
9	Total Flow, lb/hr	25,000	25,000
10	Temperature, °F	100	350
11	Pressure, psig	10	50
12			
13	Vapor fraction (molar basis)	0.0000	1.0000

FIGURE 6. An HMB table can be easily generated for multiple design cases using VBA

around rates) were adjusted via VBA in a method similar to the examples in this article.

One could imagine the difficulty of developing eight different simulation files or manually adjusting each file for each HMB case. Errors would likely occur and all of the effort to develop the analysis would be wrong. Not only that, this would take much longer to input the data than by automation.

Of course, eight different simulation cases is an extreme example. However, owners many times analyze 2–3 different cases, because, in reality, variables such as feedstocks, temperatures and pressures change. In these real-world scenarios, one can easily see the benefit of using VBA automation with Hysys and other process-simulation software products. ■

Edited by Mary Page Bailey

Editor's note: Expanded code examples can be found with the online version of this article at www.chemengonline.com.

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Author

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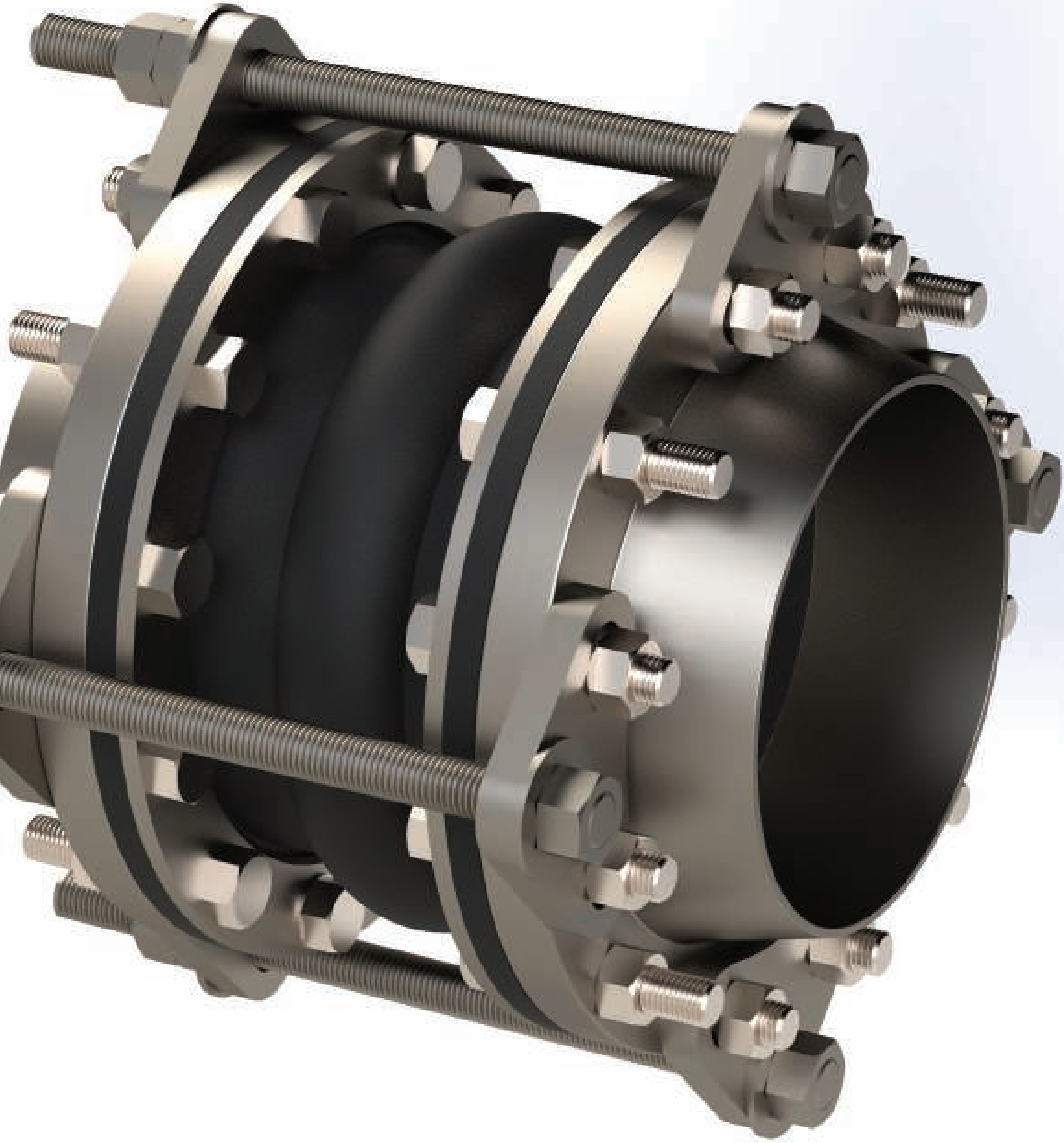

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Spreading the word on sealing technology

Sealing plays a vital role in cutting fugitive emissions and keeping plants safe. The Fluid Sealing Association works hard to promote the topic at all levels

Sealing products play an important part in the reliability of process plants and systems. Yet, their detailed operating principles – and especially how to install them correctly – are often still not properly understood, notes Rob Coffee, a director of the **Fluid Sealing Assoc.** (FSA; Wayne, Pa.; www.fluidsealing.com). The FSA continues to work to spread the word on sealing at all levels, from governments to maintenance technicians.

Through its people, website, and publications, the FSA is an excellent resource to help engineers, managers and legislators understand the importance of sealing technology, Coffee says. The Association has five divisions representing, respectively, mechanical seals; compression packings for pumps and valves; gaskets; rubber and PTFE expansion joints for piping; and fabric expansion joints for ductwork.

"I am extremely happy to see how much positive change and forward movement the Association has made in the past two years," said outgoing FSA president Mike Shorts of gasket manufacturer Triangle Fluid Controls Ltd. (Belleville, Ont.). "The current management staff, executive team, and Board of the FSA are a top-notch group with strong leadership skills, business knowledge, and desire to make the FSA the fluid sealing industry's best trade association."

At the start of 2015 Shorts and the FSA laid out a new strategic plan to focus on environmental compliance and energy conservation, and to turn the Association from a standards-setting body to one founded on knowledge. "All industries rely on our technology and installation best practices to reduce their emissions and leaks," Shorts continued. "As manufacturers of key components for reducing greenhouse gases and containing fugitive emissions and fluid leaks, it is our responsibility to ensure that we strengthen our Association in order to help the process industries as a whole."

FSA continues to lobby legislators

Under the umbrella of its Government Affairs Committee, the FSA continues to work at high level to convince legislators of the environmental importance of sealing technology. Following the G20 summit in China at the beginning of September, FSA Technical Director Henri Azibert spoke about progress on the global Environmental Goods Agreement (EGA) being developed by the World Trade Organization (WTO; Geneva, Switzerland; www.wto.org). The FSA has been lobbying to have sealing technology listed under the EGA; if this is successful, sealing products will not be subject to trade tariffs. Azibert is hopeful that the EGA will be agreed by the end of 2016.

On the U.S. government's Climate Action Plan to reduce methane emissions in the oil and gas industry, the FSA continues to promote advanced sealing solutions as part of the solution. "We are monitoring developments as the EPA and State Agencies gather data for regulation implementation," said Azibert.

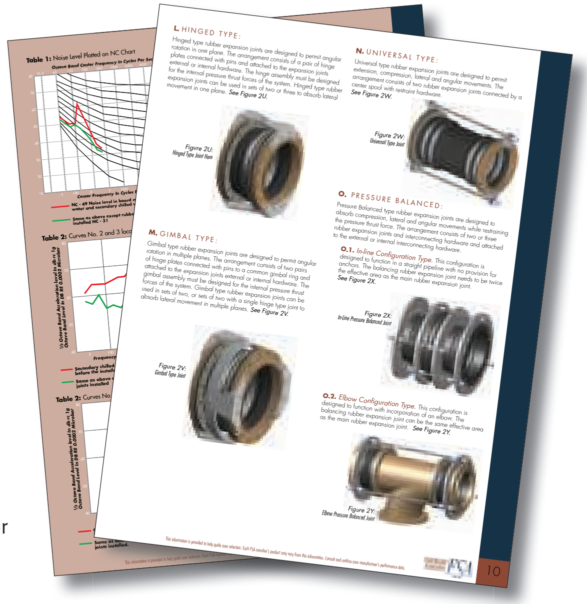
Canada, Mexico, and several U.S. states including Ohio, Pennsylvania and California have announced similar plans for methane control, Shorts said. The FSA is monitoring developments and will promote sealing technology as the opportunity arises.

Piping expansion joints explained

A recent example of the FSA's technical expertise is the new 8.0 edition of the Piping Expansion Joints Technical Handbook, which was on the point of being published as this issue of *CE* went to press. Coffee, along with his peers in the Piping Division, has worked on the new document as an extension of his day job as Vice President, Sales & Marketing, with rubber expansion joint manufacturer Proco Products, Inc. (Stockton, Calif.).

The new edition looks more professional than the previous one, Coffee says, with an attractive layout and professionally drawn diagrams and photos to replace sketches. Running to 50 pages, the publication explains the various piping expansion joint layouts and how to choose, install, and maintain them. The extensive list of terms and definitions has been updated to match those used in other industries, Coffee says.

A PDF of the previous (7.3) edition is free to download from the FSA website, and the new 8.0 edition will follow soon. Some FSA divisions may continue to charge



The latest edition of the *Piping Expansion Joints Technical Handbook* is just one example of the FSA's work in educating design engineers and maintenance professionals

for their publications, especially in printed form. But, says Coffee, free downloads ensure that the expansion joint divisions' publications are widely distributed and read.

The Gasket, Compression Packing, and Fabric Expansion Joint divisions are also revising their handbooks.

Knowledge base nears release

The FSA's Mechanical Seal division is gearing up to launch its Knowledge Base initiative by the end of this year. Taking advantage of modern Web technology for viewing on portable devices as well as desktop computers, the Knowledge Base will replace static manuals with dynamic content that is always up to date. In this way it will become a unified platform for all of the division's technical information. The content will include videos as well as text, diagrams and photos.

The Education Committee, meanwhile, is active in developing FSA-run webinars. Several have already been created, and are now available on demand via the FSA website, while several more are in preparation.

www.fluidsealing.com

Optimizing high-pressure mechanical seals

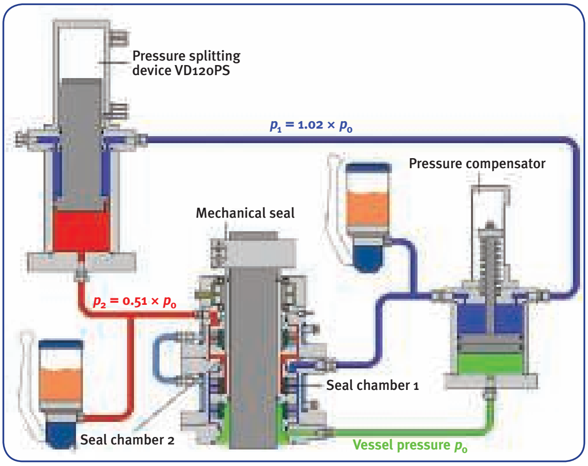
Using passive pressure-splitting devices, EKATO is able to manage seal chamber pressures automatically, with no need for pumps or control valves

EKATO RMT, a member of the EKATO Group, has further optimized the application of high-pressure mechanical seals to rotating equipment in the process industries. By using a pressure-splitting device it is possible to ensure pre-defined pressures within the two seal chambers of a triple-acting mechanical seal such as the EKATO ESD66H. The seal pressures adjust automatically according to the vessel pressure, with no need for pumps or control valves.

With this system, the pressure from the vessel to the atmosphere decreases in steps, thus reducing the pressure to which the individual seal ring pairs are exposed. The hydraulic piston action of the pressure splitter automatically adjusts the pressure within the seal chambers, depending on the pressure in the vessel. In this way the pressure splitter extends the lifetime of the seal, while keeping investment costs relatively low.

Since the system does not require circulation pumps or control valves, it is immune to power outages, instrumentation problems, and control system failures. Using a mechanical seal with a pressure splitting device therefore guarantees increased operational safety. The system is particularly suitable for use in toxic or highly hazardous processes with temperatures up to 400°C and pressures up to 200 bar.

Founded in 1933, the EKATO Group specializes in mechanical agitators for fluid systems, including rotary shaft sealing systems and their auxilary equipment. The group has more than 700 employees worldwide and a turnover of EUR 160 million – of which around 7% is spent on research and development. **www.ekato.com**



(Right) A triple-acting mechanical seal from EKATO RMT with two seal chambers and two pressure splitters. The pressure splitters shown here are types VD120 and VD120 PS

Kammprofile gaskets are ideal for difficult applications

Where it is necessary to achieve tight sealing at low bolting loads, or accommodate large amounts of thermal expansion, Kammprofile gaskets from Lamons may be the answer

Kammprofile gasket technology (image, left) is recognized as a problem-solver for standard flanges, heat exchangers, large vessels and equipment that experiences excessive movement due to thermal expansion, says gasket manufacturer **Lamons**. The Kammprofile engineered design provides one of the tightest seals available, combined with superior load-bearing characteristics.

Kammprofile gaskets consist of a metal sealing core with or without a guide ring. The sealing core is a solid metal gasket with concentric serrations on both sealing surfaces. It is faced with a soft material such as PTFE, graphite or Lamons' graphite-based High Temperature Graphite (HTG) material, depending on the operating conditions.

The Kammprofile is the preferred design when excellent sealing performance is needed at low seating stresses. The combination of a highly compressible facing material with the solid metal core, the tips of whose serrations penetrate the facing material to a limited extent, allows both materials to perform to their optimum capabilities.

Kammprofile gaskets can be made in non-circular shapes with extreme accuracy, and custom-engineered for specific applications. They come in three basic designs:

- LP1, manufactured without a guide ring, is for tongue-and-groove or recessed-flange applications.
- LP2 is constructed with an integral guide ring for alignment purposes.
- LP3 utilizes a loose-fitting guide ring. This popular design is preferred for nominal pipe size and pressure class raised-face flanges. It is used in equipment with excessive radial shear characteristics, thermal cycling, or thermal expansion.

Kammprofile engineered gaskets combine with Lamons' SPC4 load-indicating fasteners to create a complete package for leak-free installation. Users can monitor the clamping load of any SPC4 bolted joint, whether static or dynamic, by attaching an indicator datum disc located on the end of the fastener and reading the value with a user-friendly mechanical indicator. The SPC4 technology requires minimal modification of the fastener, so integrity is retained. **www.lamons.com**

With its three-layer construction (image, left), a Kammprofile gasket can seal where other types fail

Integral tie rods simplify maintenance

PROCO's approach to integral tie rod design controls flange loads and eases access for maintenance

The improved tie rod design from PROCO

Expansion joint specialist **PROCO Products, Inc.** offers an integral tie rod (ITR) design with an optional demounting feature on all its rubber expansion joints. The demounting feature is ideal for applications where maintenance operations require the expansion joint to be retracted away from an adjacent pump or valve.

As the image above shows, this ITR design also eliminates concerns with pump or valve casing interference, which may be a problem when installing control rod plates of standard triangular design. Further, it avoids any chance of pressure thrust forces being transmitted to the backside of the pump or valve mating flange.

This ITR design concept can also be applied to non-metallic piping systems, where plastic or fiberglass mating flanges may not tolerate the thrust loads applied via a traditional triangular rod plate arrangement.

PROCO's integral tie rods are designed to withstand 1.5 times the maximum pressure rating of the rubber expansion joint itself. The company's standard in-stock control rods are AS F1544-Grade 36 Melt USA with AS A563 A finished hex nuts and USS flat washers zinc plated to AS B633 Type 3 clear zinc. Optional hot dipped galvanized hi-tensile A193 B7 rod with A194 2H hex nuts are available on request.

This ITR arrangement is also ideally suited to address unequal flange pattern applications such as ANSI 150# drill x DIN PN 16 drill patterns. **www.procoproducts.com**

Save money with expansion joints

Alongside its high-performance products, General Rubber shows how to cut both capital and maintenance costs

36 in. ID x 15 in. FF Style 1102, 1202 double (2) wide arch expansion joint

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General Rubber, which is certified to both ISO 9001 and ISO 14001, leverages its state-of-the-art U.S. manufacturing facility to lower operating costs while respecting the environment. The company is committed to providing quality, defect-free performance products at competitive prices.

General Rubber is particularly proud of its programs that focus respectively on engineering, procurement and construction (EPC), and maintenance, repair and operations (MRO). For the EPC sector, it offers a Best Piping Practice and Optimization (BPPO) program with benefits including reduced material and construction costs as well smaller system footprint. For the MRO sector, General Rubber offers a Plant Reliability and Efficiency Program (PREP) to transition customers from an overly conservative calendar-based replacement program, or a somewhat reckless run-to-failure based approach, to a condition-based predictive maintenance program.

General Rubber's use of advanced materials and technologies has differentiated the company as a leader in the industry, and is the principal reason its performance products range "From the Simple to the Simply Amazing". **www.general-rubber.com**

Fluoropolymers resist corrosion

Unaflex expansion joints and hoses suit tough conditions

Unaflex LLC is the industry leader in "combined" technologies for the expansion joint and flexible hose industries. Since 1972 Unaflex has been dedicated to state-of-the-art technologies combined with proven manufacturing processes. Unaflex has orientated its PTFE and FEP product lines toward safety and double containment. Flexible tooling allows the company to produce PTFE- and FEP-lined expansion joints in any size up to 144 in. diameter.

PTFE-lined metal bellows are available in 2–144 in. sizes with pressure capabilities up to 400 psi. Two- to three-ply solid FEP expansion joints are translucent and available in 14–144 in. sizes, with pressures reaching 50 psi. Where elevated pressures are a concern, Unaflex offers PTFE- and FEP-lined rubber joints for service at up to 300 psi.

All the company's expansion joints are available in custom sizes and non-standard face-to-face dimensions. Floating flanged designs are available to compensate for piping misalignment. Unaflex's entire PTFE and FEP product line is manufactured in the U.S., and the company is certified to ISO 9001:2008.

Unaflex PTFE expansion joints

The complete product range includes:

- Large-diameter solid FEP joints similar to styles 112, 113 and 115, available in sizes up to 144 in.
- PTFE-lined metal hose offering a combination of superior strength with excellent chemical resistance.
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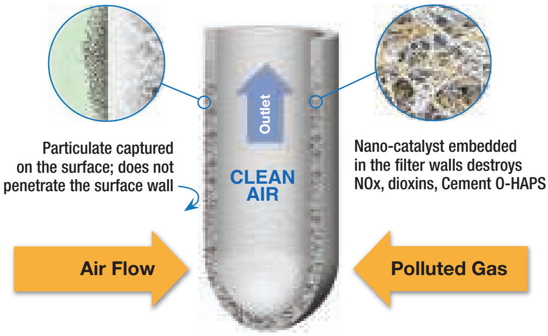

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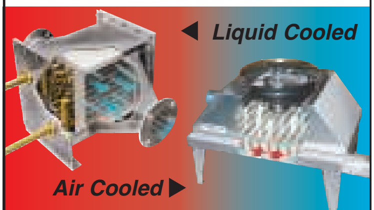

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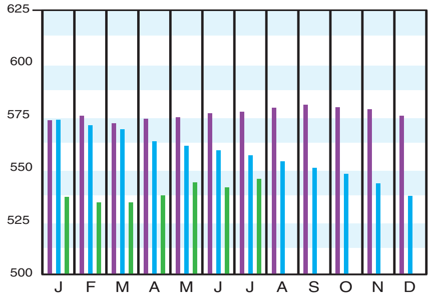
CE Index	545.1	540.9	556.3
Equipment	650.4	645.3	669.7
Heat exchangers & tanks	560.3	558.9	597.9
Process machinery	651.9	651.1	658.5
Pipe, valves & fittings	822.8	801.0	829.1
Process instruments	389.3	385.4	394.7
Pumps & compressors	970.1	970.5	956.5
Electrical equipment	510.7	506.8	512.5
Structural supports & misc	707.9	708.4	737.7
Construction labor	329.6	326.0	321.6
Buildings	547.1	544.0	541.8
Engineering & supervision	315.5	315.1	318.5

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:
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8



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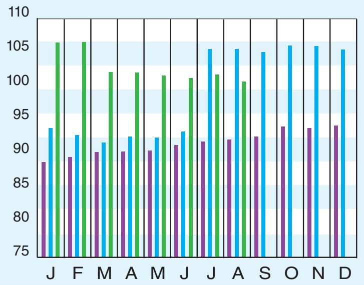
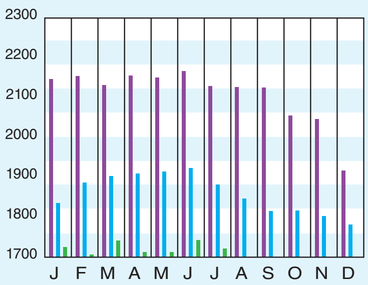
CPI value of output, $ billions	Jul. '16	= 1,722.1	Jun. '16	= 1,739.8	May '16	= 1,718.4	Jul. '15	= 1,832.1
CPI operating rate, %	Aug. '16	= 74.1	Jul. '16	= 74.4	Jun. '16	= 74.3	Aug. '15	= 74.6
Producer prices, industrial chemicals (1982 = 100)	Aug. '16	= 226.6	Jul. '16	= 223.2	Jun. '16	= 227.9	Aug. '15	= 245.2
Industrial Production in Manufacturing (2012=100)*	Aug. '16	= 103.0	Jul. '16	= 103.4	Jun. '16	= 103.0	Aug. '15	= 103.4
Hourly earnings index, chemical & allied products (1992 = 100)	Aug. '16	= 168.1	Jul. '16	= 169.0	Jun. '16	= 166.6	Aug. '15	= 158.6
Productivity index, chemicals & allied products (1992 = 100)	Aug. '16	= 101.6	Jul. '16	= 101.5	Jun. '16	= 101.3	Aug. '15	= 101.8

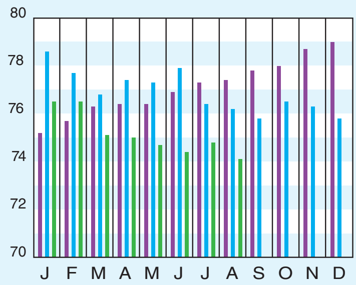
CPI OUTPUT INDEX (2000 = 100)†



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.

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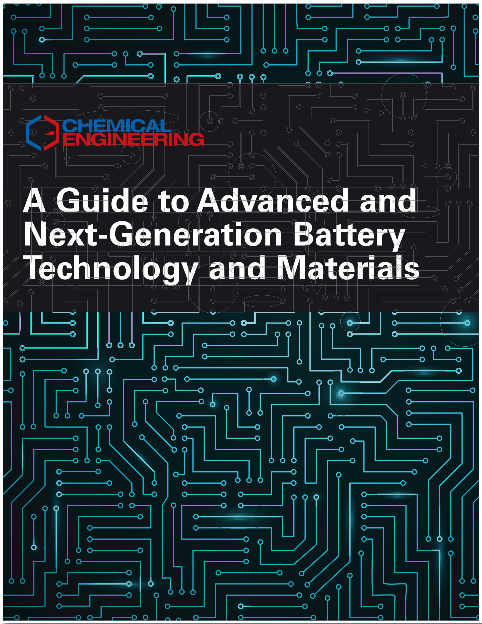
CURRENT TRENDS

The July 2016 preliminary value for the *CE* Plant Cost Index (CEPCI; top; the most recent available) was substantially higher than the previous month's value, reversing the small decrease from the June CPI value. All four of the subindices rose, with the largest increase observed in the Equipment subindex. The preliminary July 2016 CEPCI value is 2.0% lower than the corresponding value from July of last year. Meanwhile, the latest Current Business Indicators (CBI; middle) for August 2016 showed a small increase in the CPI output index compared to the previous month. Producer prices for industrial chemicals rose in August, while the July value for the CPI value of output index declined from the previous month.

CHEMICAL ENGINEERING

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.

- Major application areas for advanced and next-generation batteries
- Key parameters for advanced and next-generation batteries
- A sampling of academic and national laboratory research groups and lead investigators that are focused on technology for advanced batteries

Details Include:

- Driving forces
- Battery materials
- Supply-chain logistics
- Advanced batteries
- Li-ion variants
- Next-generation batteries
- Developments by application area
- Grid-energy storage
- Lithium-ion technology
- Advanced lead-acid batteries
- Wearable batteries
- Lithium-sulfur battery technology
- Redox flow batteries
- Battery materials and components
- Production capacity
- Research stage
- Advanced battery companies and specific technologies
- References

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