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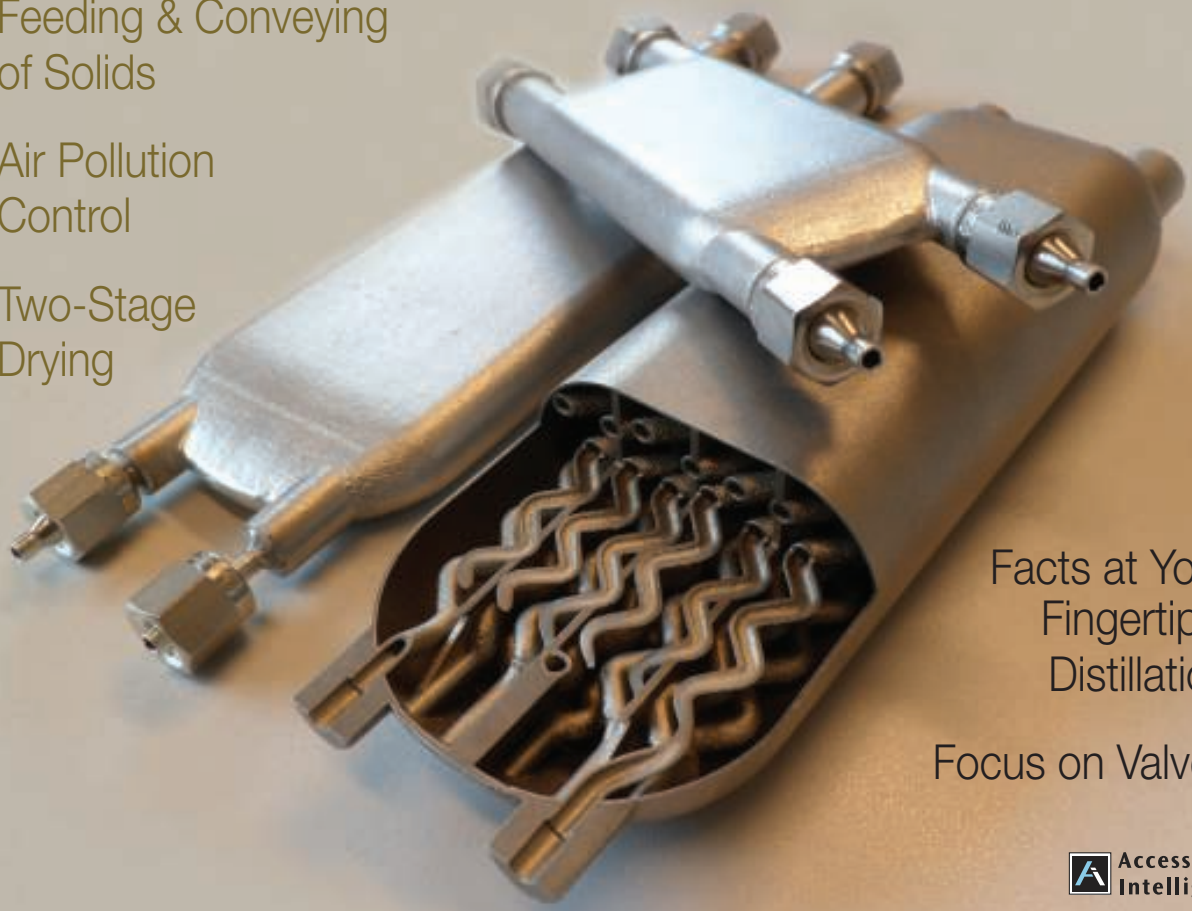

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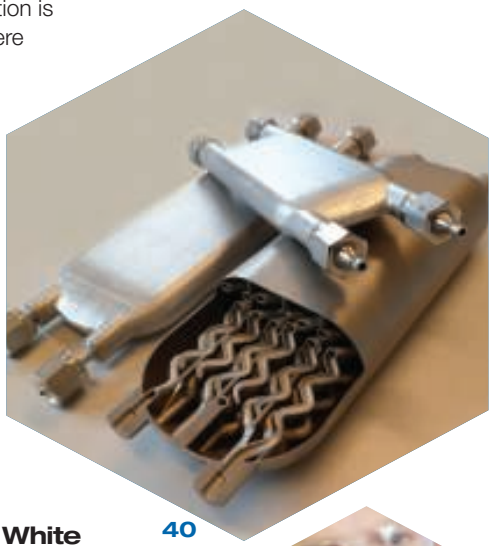
Cover Story

In the News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Look for: **Feature Reports** on Wastewater Treatment; and Pumps; A **Focus** on Process Chemicals and Performance Materials; A **Facts at your Fingertips** on Water Analysis; **News Articles** on Flow Batteries; and Mobile Apps; an **Engineering Practice** article on Design of Experiments; **New Products**; and much more

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Cover photo: Courtesy of DSM, the photo shows flow reactor modules manufactured by 3-D printing

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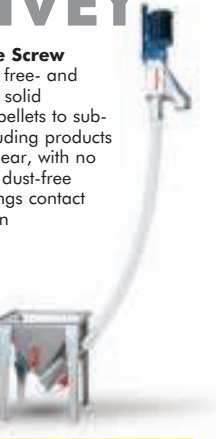

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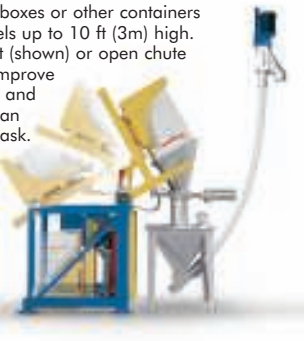

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Editor's Page

Winning for 'green chemistry'

Each year, the U.S. Environmental Protection Agency (EPA; Washington, D.C.; www. epa.gov) recognizes "green chemistry" achievements — innovative technologies that reduce hazards to humans and the environment, as well as the leading scientists who contribute to this end. These achievements turn potential problem areas into opportunities by developing safer and environmentally sustainable processes, which is an important goal for the chemical process industries (CPI). Details about the award and selection criteria can be found on the EPA's website.

The winners of the 2016 Presidential Green Chemistry Challenge Awards, in each of five categories, are described here (Source: EPA).

Designing Greener Chemicals and Specific Environmental Benefit: Climate Change Award — Newlight Technologies (Costa Mesa, Calif.; www.newlight.com) has developed and commercialized a new process that allows thermoplastic polymers to be manufactured from methane more cost effectively than from petroleum-based raw materials. A newly developed biocatalyst can produce nine times more product for the same amount of catalyst input as compared to earlier technologies. In the AirCarbon process*, air and methane are mixed with the biocatalyst to produce polymer at ambient operating conditions. A number of leading companies have adopted AirCarbon within two years of scaleup, to make a variety of products, including bags and containers, cell phone cases and furniture.

Greener Reaction Conditions Award — Dow AgroSciences, LLC (Indianapolis, Ind.; www.dowagro.com) was honored for development and commercialization of its aqueous microcapsule suspension product, Instinct. This technology reduces leaching of nitrates from fertilizers to ground and surface waters, thereby retaining applied nitrogen longer at plants' roots for better crop yield, and reducing potential emissions of nitrous oxide

Greener Synthetic Pathways Award — CB&I (The Woodlands, Tex.; www.cbi.com) and Albemarle (Baton Rouge, La.; albemarle.com) developed the AlkyClean* solid-acid alkylation process. In the process, Albemarle's AlkyStar catalyst is combined with CB&I's novel reactor scheme*, to produce high quality alkylates without the use of liquid acid catalysts, making the process safer with a lower environmental impact.

Academic Award — Paul Chirik, professor at Princeton University (Princeton, N.J.; www.princeton.edu) was recognized for his work in developing a new class of hydrosilylation catalysts* that are based on metals such as iron and cobalt, which are more readily available and whose use results in a lower environmental impact than the existing platinum-based catalysts.

Small Business Award — Verdezyne (Carlsbad, Calif.; verdezine.com) won this award for developing a yeast fermentation technology that focuses on the production of dicarboxylic acid chemical intermediates. The process uses renewable resources, such as fatty acid feedstocks from vegetable refining. In addition to using plant-based rather than fossil-based feedstocks, the process is considered to be safer because it eliminates the need for high temperatures and pressures, as well as the use of nitric acid. ■

Dorothy Lozowski, Editor in Chief

* For more on these topics, see www.chemengonline.com, including The 43rd Kirkpatrick Award: Winner Announced, December, 2015; Iron-based catalyst shows promise for alkene hydrosilylations, May, 2012; New Developments Take Shape for U.S. Refiners, May, 2016;

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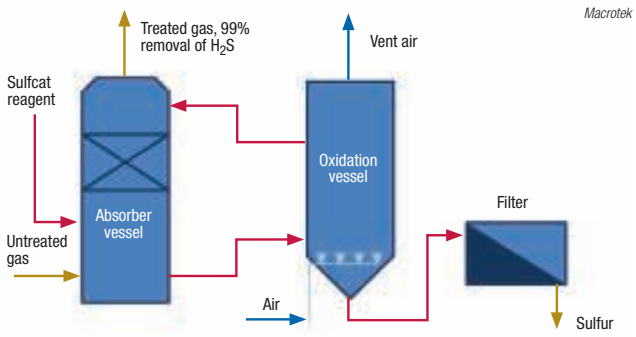
H_2S scrubbing process regenerates reagent, produces sulfur

An innovative H_2S-scrubbing process employs iron particles to catalyze reactions that convert H_2S to elemental sulfur. The new approach improves upon traditional H_2S-scrubbing processes that constantly consume reagents (like NaOH and bleach) and generate sulfate-laden wastewater that must be treated. The new process also improves upon more recent approaches that use chelated iron compounds to oxidize sulfur, because the chelates degrade over time and the ligands pose potential health and environmental concerns.



Developed by Macrotek Inc. (Markham, Ont.; www.macrotek.com), the Sulfcat process dramatically reduces the amount of consumable reagents and water required, significantly lowers wastewater treatment costs and generates a potentially marketable byproduct (elemental sulfur). Emissions of H_2S are removed at levels greater than 99%, and the process can be configured to remove H_2S down to less than 1 part per million (ppm) if needed, says Chris Ristevski, development engineer at Macrotek.

The Sulfcat process (diagram) works by first absorbing H_2S from the gas stream with a specially designed absorber system. The H_2S then undergoes a series of reactions that convert the absorbed gas to elemental S and water. The reactions are promoted by a suspension of stabilized, sub-micron-sized iron-based particles. The addition of air in an oxidation vessel regenerates the iron reagent. Elemental S is filtered for recovery.

Macrotek's Ristevski says the company continues to optimize the technology to further lower operating costs. Sulfcat will be used to capture H_2S in syngas production and landfill gas treatment, wastewater treatment, petroleum refining and other areas where efficient removal of H_2S is required, the company says.

Eventus APC, LLC (Neshanic Station, NJ; www.eventusapc.com) has been retained by Macrotek to represent it in the commercial deployment of the Sulfcat technology.

Dow validates recyclable polyethylene packaging that performs as barrier

The Dow Chemical Co. (Midland, Mich.; www.dow.com) recently announced that it has completed validation of a new plastic film technology that can be recycled in existing processes for flexible polyethylene (PE) packaging, but that also performs well as an oxygen barrier in food packaging applications.

PE is a poor barrier for oxygen, so it has been paired with polyester and other materials to make suitable food packages. But the layered multi-polymer film cannot be recycled because it is difficult to separate the layers. Recyclable, all-PE films have been developed, but their O_2-barrier performance is not good, limiting their use to frozen and certain dry foods. Dow's new offering provides recyclability with greatly improved barrier performance.

Using polymer-based additives, known as Retain, the Dow RecycleReady Technology allows PE to be blended with ethylene vinyl alcohol (EVOH), which possesses good O_2-barrier properties. "Normally, PE and EVOH are not compatible," says Stacy Fields, North American director of packaging solutions for Dow Packaging and Specialty Plastics. "Dow's Retain polymer modifier allows the EVOH to disperse efficiently into the PE, analogous to the way a surfactant could be used to disperse oil into water."

The new technology is currently being tested in customer trials and Dow anticipates seeing barrier recyclable packaging on store shelves by the end of 2016, Fields says. The product is Dow's second in a planned series of packaging materials designed for recyclability and barrier performance.

Edited by:
Gerald Ondrey

MODIFIED YEAST

Researchers at the Joint BioEnergy Institute (JBEI; Emeryville, Calif.; www.jbei.org) have developed a genetically engineered strain of *Saccharomyces cerevisiae* that is capable of utilizing both glucose (a six-carbon sugar), and xylose (a five-carbon sugar) when presented with plant biomass sugars in bioprocessing operations. "By using pentose and hexose sugars as a carbon source, this strain of yeast is capable of producing a variety of compounds from a greater proportion of the starting material," the JBEI researchers say. Native yeasts have a minimal ability to metabolize xylose. The strain is available for licensing or for collaborative research and development projects.

FAST REACTIONS

A microfluidic technique that outpaces the very rapid anionic Fries rearrangement reaction to selectively functionalize iodophenyl carbamates at the ortho position has been developed by the research groups of professor Jun-ichi Yoshida at Kyoto University (Japan; Kyoto, www.sbchem.kyoto-u.ac.jp) and professor Dong-Pyo Kim at Pohang University of Science and Technology (South Korea; www.postech.ac.kr).

The researchers designed and fabricated a chip microreactor (CMR) consisting of six heat-tolerant polyamide films with fine channels created by laser ablation. The CMR has a reaction volume of 25 nL, and is capable of operating at cryogenic temperatures — a feature that enables the device to perform reactions that occur within less than 10 ms. As a result, reactions with short-lived intermediates can be performed before side reactions or isomerizations can occur.

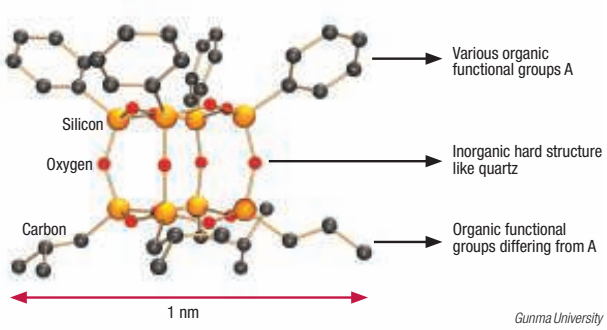
(Continues on p. 10)

Note: For more information, circle the 56-digit number on p. 82, or use the website designation.

A new, economical way to synthesize ‘two-faced’ organosilicons

Professor Masafumi Unno and colleagues at Gunma University (Kiryu City, Japan; element.chem-bio.st.gunma-u.ac.jp) have developed a simple method for the synthesis of “Janus cubes,” which are nano-sized organosilicons with two different substituents (diagram). These nanoparticles — named after the two-faced Roman god — are useful raw materials with a unique structure used in the creation of high-performance silicon and silicone materials, but an economical process for making them has eluded researchers until now.

The Gunma chemists synthesized and characterized a “perfect” Janus cube, octasilsesquioxane, which is an organosilane containing fluorine. It was made by a novel siloxane bond-forming reaction involving coupling a silanol salt and fluorosilane: the cross-coupling of sodium cyclosiloxanolate and cyclic fluorosiloxane “half-cubes.” The reaction is performed under mild conditions, does not generate any by-products and is expected to be applicable for making organic-inorganic hybrid materials, the researchers say.



Gunma University

The achievement is part of a project that is being led by Kazuhiko Satoh at the National Institute of Advanced Industrial Science and Technology (AIST; Tsukuba; www.aist.go.jp) with support from the New Energy and Industrial Technology Development Organization (NEDO, Kawasaki City, both Japan; www.nedo.go.jp). Organosilicon compounds are widely used in a number of industry fields, such as the manufacture of “green” automobile tires, which have enhanced, fuel-saving performance. The market for such tires is projected to be worth $10 billion by 2030, and NEDO aims to contribute to Japan’s competitiveness through the expanded exporting of Japanese organosilicon components.

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CO_2-free ethanol production from lignocellulose

The research group of professor Shiro Saka at the Dept. of Socio-Environmental Energy Science, Graduate School of Energy Science, Kyoto University (Kyoto, Japan; www.ecs.energy.kyoto-u.ac.jp) has developed a new process that efficiently produces bioethanol from non-edible lignocellulose resources, without generating carbon dioxide. The two-step process is able to produce 700 L of ethanol per ton of biomass — more than double the 300-L/ton yield of existing fermentation methods, which also discharge about one third of the total carbon as CO_2.

In the process, lignocellulose is first decomposed by hot, pressurized water. In a two-culture fermentation process, the decomposition products are then converted to acetic acid, followed by esterification and hydrogenolysis to produce ethanol.

The researchers believe their achievement will contribute to reducing CO_2 emissions, and are working to enhance the process, as well as beginning collaboration with industrial partners.

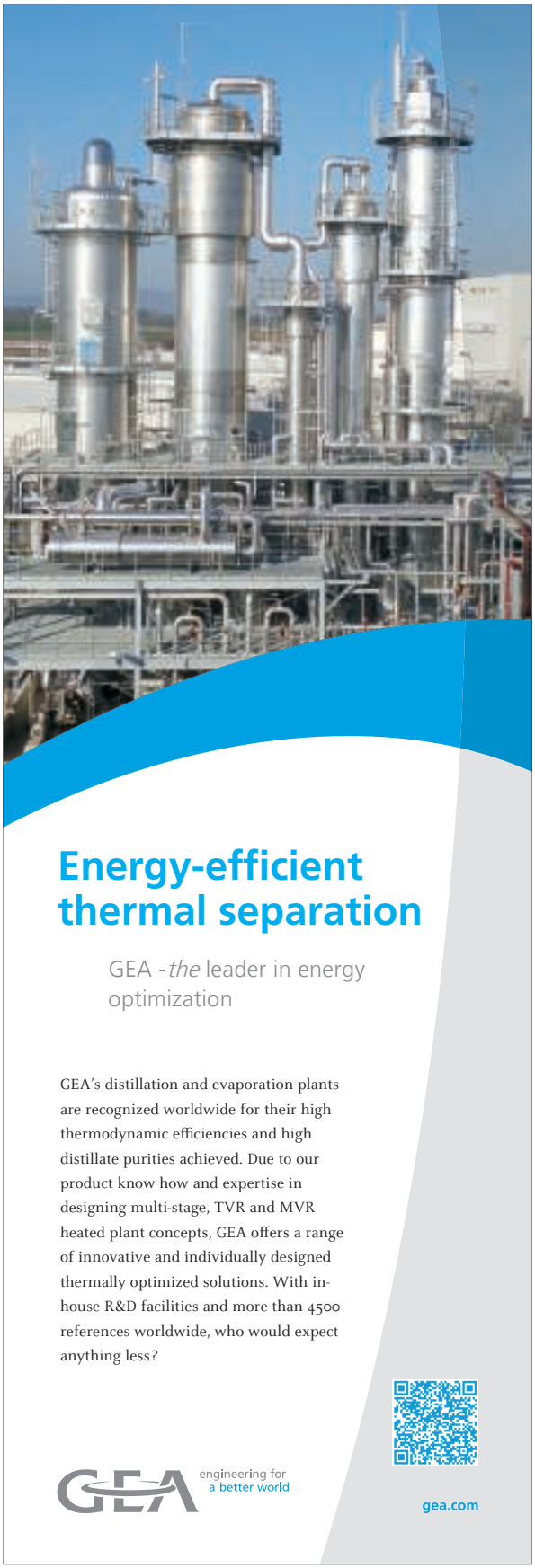
This paper has antibacterial activity

The main mineral component of our bones and teeth — hydroxyapatite [HAP; $Ca_{10}(OH)_2(PO_4)_6$] — has been used by a Chinese team to develop a highly flexible paper with high antibacterial activity. The paper, made from silver nanoparticle-decorated ultra-long HAP nanowires (HAPNWs@AgNPs) has been developed by a team from the Shanghai Institute of Ceramics of the Chinese Academy of Sciences (www.sic.cas.cn) led by professor Ying-Jie Zhu. In a previous study (*Chem. Eng.*, April 2014, p. 12), the team had developed a highly flexible and fire-resistant inorganic paper, also made from HAP nanowires.

The HAPNWs@AgNPs nanocomposites were synthesized by a simple one-step solvo-thermal procedure and used for constructing the paper by vacuum filtration. The nanowires have a diameter of about 20 nm and lengths from several tens of micrometers to more than 100 micrometers. In the HAPNWs@AgNPs, the surface of the nanowires is decorated with abundant and well-dispersed silver nanoparticles (AgNPs). AgNPs exhibit a narrow particle size distribution with an average size of 22.5 nm.

According to the team, the ultralong HAP nanowires endow the paper with high biocompatibility and high thermal stability and the AgNPs endow the paper with excellent antibacterial function.

The team says that in recent years, many nanostructured antimicrobials have been developed, including AgNPs. However, the practical application of AgNPs has been hampered by their strong tendency toward nanoparticle aggregation, which limits their antimicrobial activity. The various methods that have been developed involved complex and tedious preparation procedures. High-cost and biocompatibility problems have further limited their applications. The team expects that the advantages of its HAPNWs@AgNPs paper make it a promising material for many biomedical applications.



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The device was used for the one-step synthesis of 2-(acetyloxy)-5-chloro-N-(2-chloronitrophenyl)-benzamide, a bioactive molecule (tradenamed Afesal) exhibiting anthelmintic activity. After a reaction time of 2 s at –70°C, the CMR achieved a 67% yield with a productivity of 5.3 g/h.

NANOFILTERS

Scientists at Nanyang Technological University (NTU; Singapore; www.ntu.edu.sg) have invented a new type of nanofilter that could reduce the energy needed to treat wastewater by up to five times. The proprietary nanofiltration hollow-fiber membrane is said to eliminate the need for both ultrafiltration and reverse osmosis (RO) by combining these two operations. Unlike RO, which requires pressures of 10 bars or more, the NTU nanofilters operate at 2 bars to achieve comparable water purity, thereby significantly reducing operating costs for wastewater treatment, says NTU.

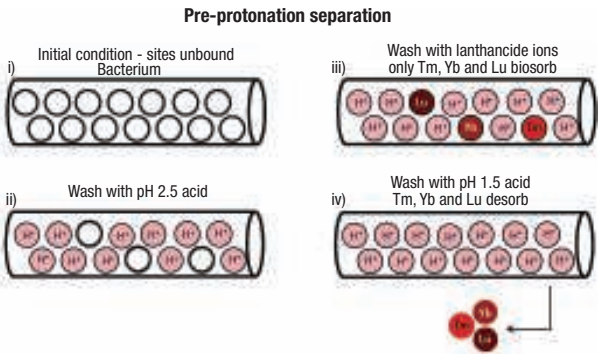
This breakthrough technology took about two years to develop, and is now being commercialized by an NTU spin-off company, De.Mem Pte. Ltd. (Singapore; www.dememb ranes.com). De.Mem, which owns water treatment plants in Vietnam and Singapore, will be building a pilot-production plant in Singapore to manufacture the new membranes.

GLASS-LINED PARTS

De Dietrich Process Systems Inc. (Mountainside, N.J.; www.dedietrich.com) has developed a new exterior coating for glass-lined parts, such as manhole covers, protecting rings, some reactor covers and piping. Traditionally, the external protection of process equipment in glass-lined steel is protected by paint, which, although offering excellent corrosion protection, can be subjected to mechanical stress, and flake. The new nickel coating provides corrosion protection, while eliminating the risk of chipping.

Highly selective rare-earth separation using bacteria filters

Mixtures of rare-earth metals (REMs) are notoriously difficult to separate, but a team of researchers from Harvard University (Cambridge, Ma.; www.seas.harvard.edu) has developed a method for efficiently extracting REMs with a high level of selectivity. By taking advantage of the complex surface chemistry of bacteria-coated filters, the team discovered that it could essentially tailor the filter to control the bio-absorption of certain REMs while allowing others to pass through the filter for extraction. The key to this selectivity is the affinity of the bacteria's surface groups for bioabsorbing different REMs. By passing various low-pH solutions through the filter prior to any REMs — a step the team calls "pre-protonation" — certain surface groups become occupied with protons, and the REMs for which these occupied groups have affinity will pass through the filter (see diagram). The team found that pre-protonation with subsequently lower-pH solutions resulted in the extraction of heavier REMs. By fine-tuning the pre-protonation step, the filter can differentiate between extremely similar REMs, even among neighboring lanthanides. The REMs are recovered from the filtrate using traditional extractive metallurgy techniques.



The team believes the scaleup potential for this process is promising, and provides many benefits over current industrial practices. REMs are typically separated using liquid-liquid extraction processes that can often require over 50 passes to achieve useful purity. The bacteria-filter technology would not only work more efficiently, and with a much smaller footprint, but would also be more environmentally benign, as fewer harsh chemicals are required.

To further the technology's potential for customization, the team is investigating the use of various types of bacteria with different binding affinities. Recycling REMs is another area where the technology could be employed, and the team has demonstrated the use of bacteria filters for REM recovery from magnets in the laboratory.

Pilot trials completed for a new SNG process

Last month, Clariant AG (Muttenz, Switzerland; www.clariant.com) said that the pilot plant of a new process for making substitute natural gas (SNG) has been successfully tested, signifying that the technology is ready for commercial application. The process, called Vesta Once-through Methanation New Technology with Wide H_2/CO Flexibility, is a joint development of Clariant, Wison Engineering (Shanghai; www.wison-engineering.com) and Amec Foster Wheeler (London, U.K.; www.amecfwc.com).

Clariant provided the proprietary catalyst, Wison Engineering has been responsible for the engineering design, construction and operational management of the pilot plant, and Amec Foster Wheeler offered the authorized technology. The pilot plant — located in Shanghai — was built in June 2014 and all pilot tests were completed by the end of April 2016.

Vesta is a methanation technology for producing SNG from synthesis gas obtained from gasification of either coal or petroleum coke. It is a once-through operation with no need for expensive compressors. The SNG production is easy to operate, since it does not require strict control of the hydrogen-to-carbon ratio, and therefore, the product quality is more stable and reliable. The CO_2 and H_2O content of the methane gas product can be controlled to a minimal level so it can be operated without triethylene glycol (TEG) dehydration systems, which in turn lowers system installation investment where one-off investment can be reduced by 20% or more, say the companies. The catalyst is also more active, says Clariant, with a higher conversion rate and a wider operating temperature range (230–700°C). Clariant's methantion catalyst was also successfully used in an industrial application in 2015.

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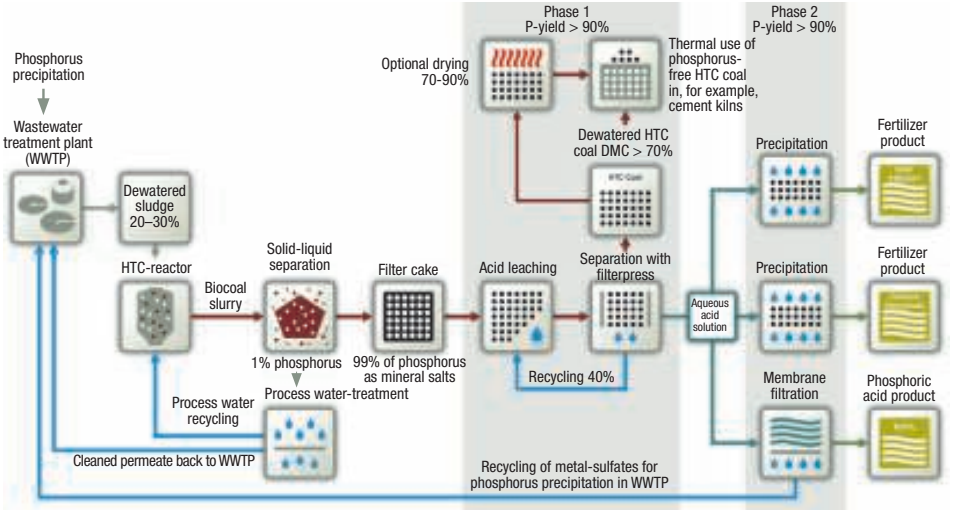
Scaleup for a new P-recovery process



Last month, AVA-CO2 AG (Zug, Switzerland; www.ava-co2.com) started up a pilot plant to further develop its AVA cleanphos process. The process recovers valuable phosphorus from "biocoal," which is being produced from municipal wastewater sewage sludge through the company's patented hydrothermal carbonization (HTC) process. The HTC process offers an economically interesting alternative to mono-incineration and other conventional sludge-treatment methods by allowing the use of HTC coal as a replacement for fossil coal in, for example, cement kilns. In addition, the process allows for an efficient phosphorus recovery, which in Germany will soon be required by an amendment in the German Sewage Sludge Ordinance, says chief marketing officer Thomas Kläusli.

Dewatered sludge enters the HTC reactor where it is heated up to a temperature of around 210°C. At a pressure of 22 bars and in the absence of O_2, the sludge is "cooked" for 2–4 h. Under these conditions, the sludge undergoes a number of thermochemical reactions — mainly hydrolysis, carbonization and condensation — to create a slurry of HTC coal. After separating the water from the solids with filter presses, the HTC coal is then leached with acid to remove phosphorus, which consequently can be recovered by either precipitation as a fertilizer (calcium phosphate or monoammonium phosphate) or by membrane separation as phosphoric acid (flow diagram).

In laboratory trials, the AVA cleanphos process has achieved an 80% overall recovery of all the phosphates present in sewage sludge, says Kläusli. Details on energy and operating costs will be made available by the end of this year, he says, adding that he expects the revenues generated from sale of fertilizer and HTC coal will probably cover the process costs. "One big advantage of the AVA cleanphos process is that the phosphates are much easier to be recovered from the HTC coal than from sewage-sludge ash — meaning less cost," he says.

Over the next 12 months, AVA-CO_2 and project partners from the University of Hohenheim (Stuttgart; www.uni-hohenheim.de) and the Fraunhofer Institute for Silicate Research (Würzburg; www.isc.fraunhofer.de) will perform tests in the pilot plant, which is located at AVA Green Chemistry Development GmbH (Karlsruhe, Germany). The project is being supported by the German Federal Environmental Foundation (DBU; Osnabrück; www.dbu.de).

Converting PE waste into liquid fuels and waxes

Each year, a large amount of plastic waste is generated, with 60% of the total plastic content of municipal solid waste composed of high-, low- and linear-low density polyethylene (HDPE, LDPE and LLDPE) and polypropylene (PP). Existing methods for degrading such plastics have not been completely satisfactory, either because they required fairly high temperatures (above 400°C), or because they led to the formation of unwanted substances with poor product control. Now, an efficient and inexpensive method for the degradation of PEs into liquid fuels and waxes has been reported by a research group from the Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences (www.sioc.ac.cn) led by Zheng Huang, in collaboration with the group of professor Zhibin Guan at the University of California at Irvine (www.uci.edu).

The new method involves a tandem-catalytic, cross-alkane metathesis process, whereby one catalyst is used for alkane dehydrogenation and another catalyst for olefin metathesis. First, an iridium-based dehydrogenation catalyst removes hydrogen from both PE and a light alkane in a sealed system to form unsaturated species and Ir-H_2. Next, a rhenium olefin-metathesis catalyst scrambles the alkanes, resulting in the breakdown of PE chains. Finally, hydrogenation of the newly formed alkanes with Ir-H_2 affords saturated alkanes. The metathesis of PE with the light alkane reduces the chain length of PE when an internal double bond of PE scrambles with a double bond of the light alkane. PE is eventually transformed into liquid hydrocarbons suitable for transportation fuels after multiple cycles of cross alkane metathesis with light alkanes. ■

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Plant Watch

Dow technology selected for new MEGlobal production facility

July 11, 2016 — MEGlobal, a wholly owned subsidiary of Equate Petrochemical Co., has selected process technology from the Dow Chemical Company (Midland, Mich.; www.dow.com) for its monoethylene glycol (MEG) production facility in Freeport, Tex. The new MEG production facility has a capacity of 700,000 metric tons per year (m.t./yr), and is expected to come online in mid-2019.

BASF and Markor start up polytetrahydrofuran plant in China

July 8, 2016 — BASF SE (Ludwigshafen, Germany; www.basf.com) and Xinjiang Markor Chemical Industry Co. inaugurated a new polytetrahydrofuran plant in northwest China. The plant, with an annual capacity of 50,000 m.t. of polytetrahydrofuran, is operated by a joint venture between BASF and Markor.

Ineos to expand ethyl acetate production capacity at Hull facility

July 7, 2016 — Ineos (Rolle, Switzerland; www.ineos.com) is embarking on a multi-million-pound expansion of its Hull, U.K. manufacturing facility to increase production of ethyl acetate by 100,000 m.t./yr. It is expected that the additional capacity will be available by the end of next year.

Covestro opens new world-scale plant for precursor HDI in Shanghai

July 7, 2016 — Covestro AG (Leverkusen, Germany; www.covestro.com) has inaugurated a new world-scale plant in Shanghai to produce the precursor hexamethylene dissocyanate (HDI). The new plant can produce up to 50,000 m.t./yr of HDI, and is part of an investment program for the site worth more than €3 billion.

Solvay to build integrated hydrogen peroxide unit at pulp-mill site in Brazil

July 6, 2016 — Solvay SA (Brussels, Belgium; www.solvay.com) and its affiliate Peroxidos do Brasil have agreed with Suzano Papel e Celulose to build a dedicated hydrogen peroxide production unit using Solvay's myH_2O_2 technology, at Suzano's pulp-mill site in Imperatriz, Maranhão, Brazil. This is the first agreement that Solvay has signed for its myH_2O_2 peroxide technology.

Mitsui to expand production capacity of high-performance nonwoven materials

July 5, 2016 — Mitsui Chemicals Inc. (Tokyo; www.mitsuichem.com) will expand the Yokkaichi, Japan production facilities of wholly owned subsidiary Sunrex Industry Co. to produce premium high-performance nonwoven materials with elasticity and expandability. The augmentation of Sunrex facilities, when completed in November 2017, represents a capacity increase of 6,000 m.t./yr.

Clariant boosts capacity for water-based pigments in Mexico

June 23, 2016 — Clariant (Muttenz, Switzerland; www.clariant.com) inaugurated its new plant for water-based pigment preparations in Santa Clara, Mexico. The new plant doubles Clariant's annual production capacity for water-based pigment preparations in Mexico. To complement this capacity increase, Clariant is also scheduled to start up a new plant for solvent-based pigment preparations at the same site in the fourth quarter of 2016.

Wacker expands production capacity for silicones in South Korea

June 22, 2016 — Wacker Chemie AG (Munich, Germany; www.wacker.com) is expanding its silicone-elastomer production capacity in Jincheon, South Korea. The new facilities will include production plants for silicone sealants, specialty silicones and liquid silicone rubber. Investments for the expansion will total around €16 million. Production is expected to begin in the first quarter of 2018.

Jacobs wins detailed engineering contract for PVC plant expansion in Egypt

June 20, 2016 — Jacobs Engineering Group Inc. (Pasadena, Calif.; www.jacobs.com) received a contract to provide detailed engineering and procurement assistance services to TCI Sanmar Chemical S.A.E. for its polyvinyl chloride (PVC) plant expansion project in Port Said, Egypt. When complete, the facility's production capacity is expected to be 200,000 m.t./yr.

Honeywell UOP opens new catalyst production line in Shreveport

June 20, 2016 — Honeywell UOP (Des Plaines, Ill.; www.uop.com) opened a new production line at its catalyst manufacturing facility in Shreveport, La. The $150-million investment will enable the company to produce a new range of catalysts for the petroleum-refining industry at the facility.

Mergers & Acquisitions

Ineos completes acquisition of Inovyn joint venture

July 8, 2016 — Ineos has completed its acquisition of the full shareholding stake in Inovyn, which Ineos and Solvay formed as a 50-50 joint venture in July 2015. Solvay received a final exit payment of €335 million. Solvay's exit of the joint venture originally was planned for July 2018, but in March it announced its intent to exit early.

Lubrizol acquires U.K.-based Diamond Dispersions
July 5, 2016 — The Lubrizol Corp. (Wickliffe, Ohio; www.lubrizol.com) announced that it has acquired Diamond Dispersions Ltd. (Sheffield, U.K.), a company exclusively focused on the production of water-based dye and pigment dispersions for inks used in digital printing. Diamond Dispersions is now part of Lubrizol Advanced Materials, reporting into Lubrizol's Performance Coatings business.

Grace completes purchase of BASF Polyolefin Catalysts business
July 5, 2016 — W.R. Grace & Co. (Columbia, Md.; www.grace.com) completed the acquisition of the assets of the BASF Polyolefin Catalysts business. The acquisition includes LYNX high-activity polyethylene (PE) catalyst technologies that are used commercially in slurry processes for the production of high-density PE resins such as bimodal film and pipe. Grace acquired technologies, patents, trademarks and production plants in Pasadena, Tex. and Tarragona, Spain.

Veolia acquires plastic recycling assets in London
July 5, 2016 — Veolia (Paris; www.veolia.com) has acquired manufacturing assets in East London that will allow the company to collect raw feedstock and produce around 10,000 m.t. of high-quality food-grade HDPE pellets annually from recycled consumer plastics.

Tesoro acquires refining business in North Dakota
June 28, 2016 — Tesoro Corp. (San Antonio, Tex.; www.tsocorp.com) has acquired Dakota Prairie Refining, LLC (DPR), which owns a petroleum refinery near Dickinson, N.D. DPR's refinery has a crude-oil capacity of 20,000 barrels per day (bbl/d), and produces ultra-low sulfur diesel, naphtha and resid.

Wacker Chemie forms strategic partnership for solar industry
Silicon wafer manufacturer 1366 Technologies, Inc. (Bedford, Ma.; www.1366tech.com) and Wacker Chemie have formed a longterm partnership to accelerate both companies' growth in the solar industry. Under the terms of the partnership, Wacker will provide 1366 with polysilicon for a planned commercial manufacturing plant.

Technip acquires ethanol dehydration technology from BP
June 22, 2016 — Technip (Paris, France; www.technip.com) has completed the acquisition of Hummingbird ethanol-to-ethylene technology from BP Chemicals Ltd. (London, U.K.; www.bp.com). The process uses a wide range of ethanol feedstocks and can be integrated into existing ethylene facilities.

PPG sells European fiber-glass operations to Nippon Electric Glass
June 20, 2016 — PPG Industries, Inc. (Pittsburgh, Pa.; www.ppg.com) has signed an agreement for the sale of its European fiber-glass operations to glass manufacturer Nippon Electric Glass Co. (NEG). PPG and NEG expect to close the transaction in the second half of 2016. ■

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Pigments: Going Beyond Black and White

Advanced materials and sustainability efforts are driving the evolution of modern pigment and coloration technologies

IN BRIEF

The complex chemistries that enable pigments to provide bright colors also open up much potential for advances in production and performance. Although pigments from nature have been used for centuries, synthetic pigments continue to evolve, and in some cases, mimic their biological predecessors. Some advances in pigment technologies, as well as the industry trends that support more sustainable operations, are presented here.

Lanxess

FIGURE 1. Lanxess recently employed a new production technique for yellow-red pigments at a site in Ningbo, China

Globally sustainable operations

As with countless other industries, globalization trends are impacting pigments producers. "The leading paints and coatings manufacturers have become increasingly international in their activities ever since the onset of market globalization. Consequently, pigment suppliers are now expected to grow worldwide along with them, and to make pigments of consistent quality available everywhere in the world," explains Hans-Peter Baldus, head of Lanxess AG's (Cologne, Germany; www.lanxess.com) Inorganic Pigments business unit in North America. At the same time, consolidation is bringing about change as well, specifically in the global industry for the production of synthetic iron-oxide pigments, which are produced in red, yellow, brown, black and a wide variety of additional shades in between. "This effect is most noticeable in China," explains Baldus, where production capacities have shrunk considerably and a significant number of small- and medium-sized producers have exited the market since 2014. Baldus attributes this trend to the recent establishment of environmental restrictions by Chinese authorities.

To address the environmental implications of the Penniman Red process — the traditional production technique for yellow-red iron-oxide pigments in China — Lanxess developed an alternative production method that is more efficient and sustainable. The company employed this production process for the first time earlier this year at a plant in Ningbo, China (Figure 1). The hallmark of the technology is the comprehensive waste-gas treatment process, which eliminates harmful nitrous oxide emissions. Furthermore, Lanxess' patented Ningbo Process integrates an efficient water-treatment system and also incorporates precise control of the formation reaction and altered synthesis of the starting materials. "This process," says Baldus, "sets new standards worldwide in

FIGURE 2. The Ningbo Process produces a wide range of yellow and red pigments in a more environmentally friendly manner than traditional techniques

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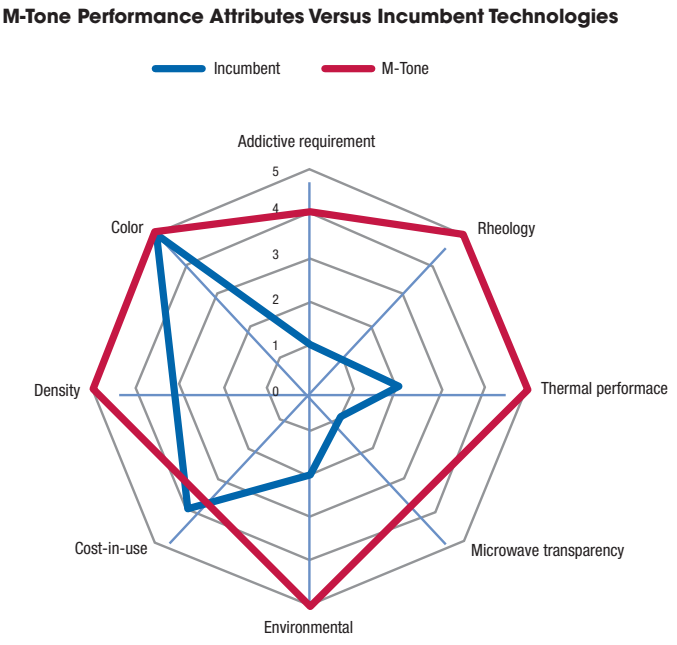

FIGURE 3. The ceramic nature of M-Tone pigments gives them beneficial properties and capabilities when compared to traditional black pigments

sustainable iron oxide production." Beyond the environmental benefits, the process also results in pigments with extremely high chromaticity, says the company, allowing for the production of the classic color range of yellow-red pigments, as well as new, stronger reds not previously available (Figure 2). The plant is built for a capacity of 25,000 metric tons per year (m.t./yr) of iron oxide pigments. At the same site, the company also operates a mixing and milling plant for pigments with an annual capacity of 70,000 m.t. For more information on the Ningbo production facility, please see "A Greener Route for Making Red Pigments," *Chem. Eng.*, Feb. 2016, p. 9.

In terms of volume, Lanxess' largest pigment demand comes from the construction industry. The company has achieved certification from third-party environmental program SCS Global Services (Emeryville, Calif.; www.scsglobalservices.com), meaning that recycled material makes up to 94% of the iron raw materials used in the production of its pigments. Pigments from SCS-certified suppliers comply with Leadership in Energy and Environmental Design (LEED; www.usgbc.org/leed) certification, making them approved for sustainable building applications.

In May, Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com) opened a new pigments production plant in Augusta, Ga. The facility, which produces 30,000 m.t./yr of yellow, red and black iron-oxide pigments, sources its iron raw materials from the waste streams of neighboring sites. According to the company, the $172-million plant also boasts advanced process automation and the elimination of a drying step that is typically required for standalone pigments plants, making the pigment-production process more efficient.

Huntsman produces several pigment products that are designed to address specific environmental challenges. For instance, the company has developed a line of infrared reflecting pigments, called Altiris, that are specifically designed for use on surfaces that are exposed to solar energy. The pigments' reflective properties allow for structures to stay colder in the sun, decreasing the energy consumption for cooling. The cooling capability is especially important for polymer materials, which tend to warp and can even fail when exposed to high heat levels. Huntsman is also investing in the development of pigments that are designed specifically for paints that are low in volatile organic compounds (VOCs).

The new black

The chemistry of creating vibrant colors occupies much of the work being done in the industrial pigments sector, but there is equally complex technology for creating those colors that are seemingly the simplest — black and white.

A new polymer-derived ceramic material M-Tone from PicOnyx Inc., a spin-out company of Melior Innovations (Houston; www.meliorinnovations.com) aims to provide black pigmentation with added performance benefits and without some of the inherent challenges in use and processing typically associated with traditional black pigments (Figure 3).

Produced via Melior Innovations' proprietary polymer-to-ceramics process, M-Tone pigments are amorphous ceramics that contain free carbon within the ceramic structure. "The free carbon performs as the chromophore, so pigmenting to black with carbon is where the similarity between M-Tone and carbon black ends" says David Bening, vice president of corporate development for Melior and acting chief operating officer of PicOnyx. This unique chemistry brings with it many benefits, both environmentally and operationally. M-Tone's extremely inert nature allows it to provide color without interfering with the properties of the materials it contacts. This makes it especially suitable for use with thermoset systems, where other pigments can interfere with curing mechanisms, impacting color uniformity and dispersion. M-Tone pigments are also resistant to thermal oxidation at temperatures greater than 600°C.

Another major advantage is the fact that M-Tone is a non-dusting particulate pigment. This means that users may avoid risks stemming from airborne exposure to residual hydro-

Surrey Nanosystems

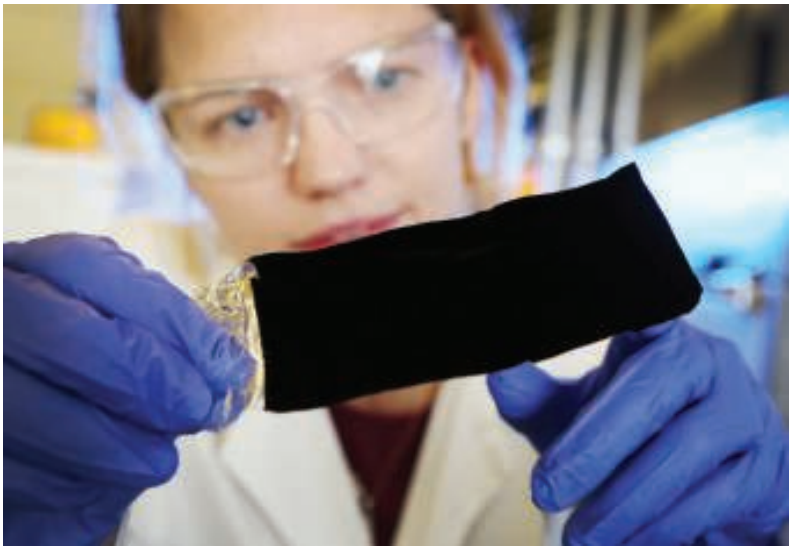

FIGURE 4. Precisely aligned arrays of carbon nanotubes enable Vantablack's distinctive light-absorbing behavior

carbons or heavy metals present in the incumbent traditional black pigment systems. "M-Tone may be used dry without the traditional health, safety and housekeeping challenges associated with competing materials," explains Bening. He cites the ability to be used dry, as a stir-in pigment, or as a highly loaded dispersion paste, as an economical benefit, since no expensive high-shear mixing or milling processes are required for dispersion. There are also no issues with settling or reagglomeration, and, unlike carbon black, which can require periodic re-dispersion, M-Tone pigments remain well dispersed in both aqueous and organic solutions. Furthermore, M-Tone pigments may be loaded into liquid polymer systems without incurring the significant viscosity increase common to carbon blacks. It is non-thixotropic, and therefore does not require viscosity management through the use of rheology additives or diluents. These attributes make M-Tone suitable for use across a breadth of diverse polymer and diluent systems in the plastics, inks, coatings and adhesives industries, explains Bening.

M-Tone pigments are created from a family of proprietary polymers. The polymers are cured and subsequently produced at temperatures greater than 1,000°C. Then, they undergo processing steps to manage particle size and geometry. The manipulation of the polymer precursor allows for precise control over the finished material's properties. For instance, the electrical and thermal conductivity M-Tone pigments can be "tuned" by manipulating the polymer chemistry and the processing parameters. PicOnyx is currently producing M-Tone pigment grades at industrial capacities at qualified third-party manufacturing sites.

PicOnyx has also demonstrated that M-Tone materials can, in addition to providing black pigmentation, act as a functional reinforcing additive that can potentially enhance hardness, stiffness and impact resistance. Its performance in polymer-matrix systems is currently being evaluated by PicOnyx. "M-Tone, due to its ceramic nature and compatibility across many chemistries," emphasizes Bening, "has great potential to be positioned as a performance-enhancing additive." PicOnyx is also actively engaged in developing M-Tone's application in black effect pigments that impart luminescence and sparkle into coatings, inks and plastics.

Another innovation in black coloration comes from Surrey Nanosystems (Newhaven, U.K.; www.surreynanosystems.com), the manufacturer of Vantablack (Vertically Aligned Nanotube Array black), a black thin-film coating material made of carbon nanotubes (Figure 4). Light

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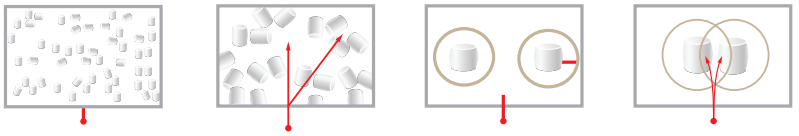

In a typical formulation, TiO_2 distribution is random

As a formulation dries, crowding creates areas of high and low concentration

Where concentration is low, gaps in the resulting film may occur

Where concentration is high, overlap creates inefficiency

FIGURE 5. Hollow-sphere polymers interact with titanium dioxide to increase formulations' efficiency

radiation is rapidly absorbed by the material as it bounces between the equally aligned nanotubes, unable to escape, making Vantablack materials distinctively dark. The light energy is reflected between tubes until it dissipates as negligible heat. Vantablack can be applied as a coating to a diverse variety of surfaces, including aluminum alloys, cobalt, copper, silicon and stainless steel. A sprayable version became available in March of this year. Created via a chemical-vapor-deposition process, the nanostructure of Vantablack imparts resilience to shock, vibration and thermal cycling. However, due to its intricate arrangement of nanotubes, the material is susceptible to abrasion and breakage.

According to the company, potential applications for Vantablack include infrared cameras, spectroscopy, solar collectors and improving the sensitivity of sensors, but the most attractive area for its use is in space and satellite applications. In May 2016, Surrey Nanosystems announced Vantablack's first use in space, absorbing light for a satellite positioning-control system.

Taking care with TiO_2

Titanium dioxide (TiO_2) has been the most commonly used white pigment for decades, but there are some shortcomings to its efficiency. TiO_2 particles tend to crowd together, creating regions of uneven distribution, which can impact the performance of a formulation. Also, from a sustainability standpoint, processors are seeking ways to decrease their consumption of natural resources like TiO_2. The Dow Chemical Company's Coatings Materials business (Midland Mich.; www.coatings.dow.com) saw the need to address these TiO_2-related concerns in the pigments sector. "Producing TiO_2 is an energy-intensive process subject to price fluctuation, and it contributes substantially to the environmental profile of an end product," says Sylvia Insogna, North America marketing director for Dow Coating Materials.

The company has developed opaque polymer materials that act as an alternative to traditional white pigments, and can augment the performance of TiO_2 in formulations. Dow's Ropaque material is a hollow spherical polymer with light-scattering effects that effectively acts as a pigment. As formulations dry, the polymer develops air voids, which scatter light in a similar manner to TiO_2, allowing for the Ropaque polymer to be used as a direct replacement material. "This can benefit formulators who want to improve end-product performance properties that may be negatively impacted by increased levels of TiO_2, who want to rely on a resource other than TiO_2 when supply is limited and expensive, who would prefer to diversify and rely on two pigment sources, or who are looking to reduce the environmental footprint of their product," says Insogna. Taking TiO_2 enhancement a step further, the company also developed the pre-composite polymer technology known as Evoque, which interacts with a formulation's remaining TiO_2 to optimize performance, improve distribution and further reduce the reliance on TiO_2. "Essentially, the technology surrounds the TiO_2 molecules and forms polymer-pigment composites that physically separate the TiO_2 in a polymer-pigment matrix, which dries into a tight, even film with a polymer-rich surface," explains Dave Fasano, application scientist for Dow Coatings Materials. These interactions can decrease TiO_2 usage by up to 20% by providing efficient light scattering. The technology can also increase stain and corrosion resistance, overall coverage and durability, says Dow.

Getting back to nature

Historically, pigments of every color were derived from naturally occurring sources. Industrial advances brought about fully synthetic pigments, but with recent increased awareness of sustainability, there has been a push for products that contain more bio-based components. Quinocridone pigments — typically pink, red and purple — are now being manufactured using bio-based succinic acid by Clariant (Muttenz, Switzerland; www.clariant.com). Succinic acid is an important raw material for the production of quinocridones, and, according to Clariant, switching to bio-succinic acid supplied by biotechnology company Myriant Corp. (Woburn, Ma.; www.myriant.com) reduces the carbon footprint of these pigments by up to 90%. The bio-succinic acid is sourced from cellulosic materials, including corn husks, leaves and fibrous matter from processed sugarcane.

Molecules of the isoprenoid family are another useful component in the production of various types of pigments. In June, Deinove (Grabels, France; www.deinove.com) received €1.5 million in funding to develop a process for bio-sourced isoprenoids using *Deinococcus* bacteria. According to the company, the bio-based isoprenoids could be used for the production of specialty pigments, including red, orange and yellow carotenoids. Deinove is currently focused on cultivating bacterial strains that will efficiently produce carotenoids via fermentation. Deinove is said to be the only company currently investigating the industrial use of *Deinococcus*.

Going forward, a larger emphasis will surely continue to be placed on renewable raw materials in the pigments industry as sustainability efforts drive technological developments. ■

Mary Page Bailey

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Keeping Solids Moving

Updated feeding and conveying products help improve product flow

IN BRIEF

REDUCING DEGRADATION/ SEPARATION

SIMPLIFIED CLEANING

INCREASING RELIABILITY AND UPTIME

INTEGRATION AND SMARTER CONTROLS

When it comes to feeding and conveying operations, chemical processors struggle to minimize unplanned downtime and maximize throughput. For this reason, they require reliable equipment that is easy to clean in an effort to prevent cross contamination, feeders and conveyors that do not degrade or separate their product, and systems that eliminate material handling issues related to difficult-to-process materials. "Time is money and processors have labor costs, capital equipment depreciation and overhead costs. Losses from wasted ingredients, reagents, revenue and profit only make the issues more significant," explains Gordon Fenton, engineering and product development manager with Seepex (Enon, Ohio; www.seepex.com). "And the stakes are so much higher for chemical processors, since many processes are batch-oriented. Batch processes have increased risks because of the potential for wasted batches when the component chemical costs can be so high."

Nol-Tec

FIGURE 1. To overcome resistance in the conveying line, Nol-Tec Air Assits are placed strategically to distribute energy throughout the transport system. This results in increased efficiency and reliability

Selecting the best equipment design for a specific application and its challenges, as well as integrating new equipment with precise controls into existing facilities, can help chemical processors improve the flow of product through their facility, while keeping costs associated with downtime and decreased throughput to a minimum.

The biggest feeding and conveying challenges for chemical producers include degradation and separation of product, cross contamination, downtime and difficult-to-process materials, so manufacturers of this equipment are working closely with chemical processors to understand the specific needs of the industry and are developing units and systems designed to tackle the chemical process industries' (CPI) greatest issues.

Reducing degradation/separation

"One of the biggest challenges of handling bulk material is maintaining product integrity from start to finish. The constant particle-to-particle and particle-to-surface contact during the conveying and material-handling processes breaks down the material quality. The goal is to mitigate these negative effects by reducing material turbulence within the conveyor," notes Greg Patterson, vice president of Hapman (Kalamazoo, Mich.; www.hapman.com).

Segregation, according to Patterson, is another common issue. "There are a number of factors that influence whether your material segregates as it moves through the process. The size, shape, density and moisture content of the ingredients; the speed of transfer; whether it is conveyed mechanically or with air; the length and angle of the conveyor; even the presence of static electricity influences the stability of the blend," he says.

One example of a conveyor designed to combat these issues is a tubular drag chain conveyor. "The design of this type of conveyor prevents product from being stirred or blown during movement, so there is no

Seepex

FIGURE 2. Seepex now offers a single- (shown here) and two-stage Smart Conveying Technology (SCT) pump design that allows the pump stator and/or rotor to be changed without disturbing suction or discharge piping to increase reliability and decrease downtime

damage or separation as it moves along the process," explains Patterson. "Often degradation and separation of product occur at conveyor transfer points, but with a tubular drag conveyor, you can replace multiple conveyors and multiple transfer points with one unit that can go horizontal, vertical, handle angles and go around corners. We can provide many configurations with one conveyor so there is no need for multiple transfer points, thus mitigating many of these challenges."

Nol-Tec Systems (Lionel Lakes, Minn.; www.nol-tec.com) suggests dense-phase transporter systems to users who must avoid degradation in powder and granular bulk-solids moving through a pipeline at low velocity. In a typical cycle, the transport vessel fills via gravity. When the transporter is full, the inlet and vent valves close and the system is pressurized, allowing material to flow into the conveying line and on to the

Flexicon

FIGURE 3. Flexicon's Bulk-Out bulk bag dischargers are available with several accessories designed to increase efficiency and deal with difficult-to-handle materials, including the Spout-Lock clamp ring and Tele-Tube telescoping tube

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Hapman

FIGURE 4. Hapman provides control packages that range from smaller panels with on/off and alarm notifications to fully integrated packages, which incorporate multiple pieces of equipment and link directly to a range of hardware options and HMI interfaces for customer-specified components and notification requirements

destination. "The low velocity minimizes degradation to materials that are fragile," says Mike Weyandt, corporate sales manager with Nol-Tec. "Imagine moving a Rice Krispie at high velocity. At the end of the conveyor it wouldn't be a Rice Krispie anymore. It would be powder."

Though this type of technology is not new, Nol-Tec is adding features to further improve performance, says Weyandt. To overcome the overall resistance in the conveying line, Air Assists are placed strategically to distribute energy throughout the system (Figure 1). This results in increased efficiency and reliability. The Air Assist technology prevents back feeding, which may be experienced with low-pressure manifold systems. On longer systems, Air Mizer technology can be added to further reduce compressed air costs. This version of Air Assist technology introduces air only when required.

Simplified cleaning

"Many processors don't have systems that are dedicated to the same material 24/7/365. Instead, they may be a compounder who can't have two colors mixed or running two incompatible materials, so cross-contamination is a major concern," says Todd Messmer, applications engineering manager with Schenck Process (Whitewater, Wis.; www.schenckprocess.com). "Because cleanability and the time associated with cleaning are concerns we have to take into consideration, we've come up with a couple of systems that assist processors with cleaning conveying equipment, such as quick-disconnect piping, couplings that fit together and come apart without tools, as well as a pigging system."

Messmer says the pigging system was designed to help processors with long conveying lines clean and avoid cross-contamination. "The device is shaped like a torpedo and is launched into the conveying line and, as it moves through, scrapes and cleans the inside of the conveying line and pushes the debris into a common collection point," explains Messmer. "This pigging system is clearly a better, faster, more thorough way to clean pneumatic conveying lines without having to disassemble the whole thing."

Another take on simplified cleaning is the addition of tubular trays to vibratory feeders, says Rob Yandrick, product manager, vibratory/screening, with Eriez (Erie, Pa.; www.eriez.com). Trays are designed for fast removal and cleanout to avoid cross contamination of materials and decreased production line downtime. Many trays offer quick-release clamps that allow the tray and cover to be removed without tools so that the tray is easily lifted and disconnected from the frame for easy cleaning. In addition to assisting processors with avoiding cross contamination, the tubular trays also help with general housekeeping and dust containment, says Yandrick.

Increasing reliability and uptime

"The most valuable advances in processing are improving mean time before failure, predictive maintenance and making installation and maintenance quicker, safer and cheaper," says Seepex's Fenton. "In the past, progressive-cavity pump manufacturers fell short on the serviceability aspect, but Seepex now offers a single- and two-stage Smart Conveying Technology (SCT) pump designs that allows the pump stator or rotor (or both) to be changed without disturbing suction or discharge piping (Figure 2). The design also does not require the rotor and stator to be removed as a cartridge and separated later. This change makes most maintenance operations a one-person operation, cuts maintenance time by up to 85% and decreases spare part costs, says the company.

The company's Intelligent Metering Pump (IMP) is also helping to increase uptime. It offers an Electronic Programming Module (EPM) memory chip on which parameters can be pre-configured. This makes replacement of a drive simple, quick and accurate. Users can plug the EPM chip from the previous drive into the new one and be up and running.

It has also allowed many processors to convert from a batch to a continuous process and eliminate bottlenecks, says Fenton. "When combining chemicals, one of the main components is some sort of metering pump. Metering this type of application used to require a pump that pulsated and that pulsation required them to work in a batched process to get a homogeneous mixture," he says. "However, the IMP does not have to pulsate. It offers a continuous flow, which allows some processors to convert to a continuous process, allowing them to increase their throughput."

The flow of difficult materials

"One of the greatest obstacles to uptime in feeding and conveying applications is dealing with problematic materials, such as those that are sticky, or exhibit bridging or agglomeration, because they can reduce flow, which may result when materials don't come out of the containers," says David Boger, vice president, global business development, with Flexicon (Bethlehem, Pa.; www.flexicon.com). "But, the proper bulk bag discharge system can help rectify this issue and get product flowing."

Flexicon's Bulk-Out bulk bag dischargers (Figure 3) are available in several frame configurations, including the BFF Series dischargers with bag lifting frame for forklift loading and unloading of bulk bags and BFC Series dischargers with cantilevered I-beam, electric hoist and trolley for loading and unloading of bulk bags without the use of a forklift.

The dischargers are offered with several accessories designed to increase efficiency and deal with difficult-to-handle materials, including the Spout-Lock clamp ring and Tele-

Tube telescoping tube. The clamp ring creates a high-integrity, sealed connection between the clean side of the bag outlet spout and the clean side of the telescoping tube. This prevents contamination of the product, while eliminating the plant contamination that occurs when falling materials displace air and dust from the hopper.

The telescoping tube prevents dead spots and promotes flow by raising the Spout-Lock clamp ring for connection to the bag spout, then lowers, applying continual downward tension. As a result, the spout is kept taut at all times, preventing excess spout material from bulging outward (creating dead pockets) or falling inward (creating flow restrictions).

The company's pneumatically activated Flow-Flexer bag activators promote material flow through bag spouts. The bag activators raise and lower the bottom edges of the bag to direct material into the bag outlet spout and to raise the bag into a steep "V" shape to promote total evacuation. Bulk bag conditioners are also available for loosening materials solidified in bulk bags.

Integration and smarter controls

To pull all these pieces of equipment and their benefits together, many equipment providers are also offering custom-engineered, integrated systems. Flexicon, for example, can evaluate bulk materials, plant layout, throughput rates, residual product limitations, cleanliness requirements, access, cost, cycle times and other parameters and outline a solution for the situation.

Along with this type of sophisticated system, processors are requesting more integrated and smarter controls. "Processors want to see more of what's going on with their system and they often want to see it from a remote location," says Nol-Tec's Weyandt. "At the same time, they're asking for more automated controls for functions that were previously manually adjusted."

Hapman's Patterson agrees: "The integrated solutions and the desire to have smarter control systems required an improvement in our control capabilities. We needed to be able to handle functions from scanning barcodes to keeping track of all the elements in a conveying system as product moves through the circuit, which mandated smarter control systems."

As such, Hapman currently offers control packages that range from smaller panels with on/off and alarm notifications to fully integrated packages, which incorporate multiple pieces of equipment and link directly to a range of hardware options and HMI interfaces for customer-specified components and notification requirements (Figure 4). "Our customers want smart equipment that can tell them how it is performing and when performance isn't quite where it needs to be," he says. "So, we have to make sure our equipment and controls are providing the kind of feedback processors require so they can continue to keep their product and process flowing." ■

Joy LePree

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Process Instruments	441.4	437.2	379.5
Pumps and Compressions	788.9	788.3	756.3
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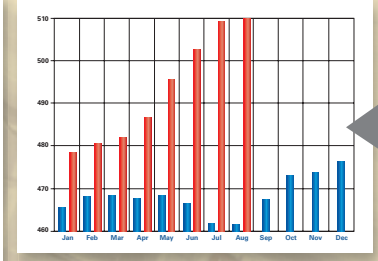

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Valves

Coperion K-Tron

Conval, Inc.

Rotary valve controls the flow of powders and granules

The Coperion ZRD Heavy-Duty Premium rotary valve (photo) is designed for industrial applications with pressure differentials up to 1.5 barg (21 psig), and temperatures to 100°C (212°F); higher-temperature versions are also available. The ZRD is used as a discharging and metering valve for conveying powders in granular and powdered form (with particle size smaller than 1 mm). Various materials of construction are available for the housing and endplates. These valve rotors are constructed of stainless steel DIN 1.4541 (AISI 321L). The valves handle a throughputs ranging from 0.1 to 300 ton/h. Thanks to its heavy-duty construction, the ZRD has an explosion-pressure shockproof rating of 10 barg, says the company. — *Coperion K-Tron Salina, Inc., Salina, Kan.*
www.coperion.com

These severe-service valves come in 12,000 configurations

Clampseal forged globe-stop, check and stop-check valves (photo) are U.S.-made and are available in sizes from 0.5 to 4 in., through ASME 4500 Class. A variety of connections, including socket-weld, butt-weld, threaded, clamp-connector, and flanged-end options, are available. Materials include carbon steel SA 105, low-alloy SA 182-F22 and F91, stainless steel SA 182-F316, and SA 182-F347. The valves conform to ASME B16.34, and they feature a pressure-seal bonnet, quick-replacement packing chamber, and a single-piece gland with and integral gland wrench for easy maintenance. Addtional options include fire-safe and cryogenic valves and actuated valve packages. — *Conval, Inc., Somers, Conn.*
www.conval.com

Borrowing best practices gives this gate valve an edge

The new forged Equiwedge Gate Valve incorporates two industry best practices into one design, says the manufacturer, to increase wall thicknesses found in critical areas of the valves (designed in accordance with U.S. standards) while still capitalizing on the reduced-weight benefits of equivalent European standards. This allows the valve to perform under difficult pressure and temperature conditions, such as those found in supercritical and ultra-supercritical coal-fired power plants — which can operate at 290 bars or 4,200 psig, and over 600°C or 1,100°F — while ensuring power plant productivity, safety and reliability. Single-piece body manufacturing helps to eliminate fabrication welds, which reduces the opportunity for welding-related failures. The valve features a split-wedge gate design, which improves operating reliability by minimizing thermal binding and stress on valve components, says the company. — *Flowserve, Irving, Tex.*
www.flowserve.com/equiwedge

Diaghragm valves meet the demands of sterile applications

The DV-ST UltraPure family of diaphragm valves provides reliable operation in sterile and asceptic operations. The DV-ST UltraPure is a compact, lightweight valve with a modular design, enabling a wide range of purpose-built configurations. The specified sulfur content is standard for all forged and block valves, safeguarding high-quality welds, says the company. The spring pressure can be adjusted using a pneumatic actuator. For all handles, over-closure protection in manual operations ensures a defined closing pressure against the diaphragm. The innovative design of the DV-P UltraPure allows for more-precise flow regulation and doubles the flowrate compared to conventional diaghpram valve designs at a given pressure drop, says the company. This enables the use of smaller feed pumps, which helps to reduce energy and installation costs. —*Alfa Laval, Richmond, Va.*
www.alfalaval.com

Note: For more information, circle the 3-digit number on p. 82, or use the website designation.

Firesafe ball valve ensure leak-tight protection

The latest addition to the 344 Series Valves is a three-piece, firesafe ball valve (photo) that is designed to ensure the operational integrity of the valve in the extreme heat of a petroleum refinery fire. Available in sizes from 1.4 to 2 in., the 344 Series comes standard with an ASME Class 900 body and TFM seats. The valve's firesafe seating surface and spring-energized stem seals self-adjust to compensate for wear and changes in pressure and temperature, ensuring a leak-tight seal to prevent both downstream and external leakage, says the company. It can be supplied with various end pieces to match a variety of process connections. Its ISO 5211 dual-pattern, direct-mount pad eliminates the need for a bracket or drive coupling for automation, and prevents side loading, which helps to improve the valve's cycle life and reduces the height of the package. — *Inline Industries, Inc., Baldwin Park, Calif.*
www.ballvalve.com

Pressure- and vacuum-relief valves minimize fugitive losses

The Anderson Greenwood 4000 Series pressure- and vacuum-relief valves (photo) are compliant with the latest (7th Ed.) of the API 2000 standard, which covers normal and emergency vapor-venting requirements for bulk-liquid storage tanks. These valves are engineered to open fully at 10% overpressure, helping to protect tanks from physical damage caused by internal pressure fluctuations. As a result, the valves can be set more closely to a storage tank's maximum allowable working pressure (MAWP) or maximum allowable working vacuum (MAWV), allowing users to fill and empty tanks more quickly and operate at higher pressures, says the company. The 4000 Series valves remain closed longer, resulting in increased productivity and reduced evaporation and fugitive emissions loss. The valve range is available in weight- or spring-loaded designs. It comes in sizes ranging from 2 to 12 in. A variety of coatings are available to provide enhanced protection from extreme temperatures and exposure to corrosive media. — *Pentair Valves & Controls, Minneapolis, Minn.*
www.valves.pentair.com

Air-activated isolation valves provide added safety

The Series P Pneumatic Isolation Valves are pressure-activated valves that provide protection for applications facing potentially explosive or flammable conditions. The valves are particularly well-suited for applications where the use of air instead of electricity to actuate the valve makes sense, such as potentially explosive and flammable environments, says the company. These two-way and three-way valves are available with orifice sizes from 1.8 to 6 mm. Several models are available, with wetted parts that are suitable for use in applications involving high-purity and chemically aggressive media. Certain models are designed for applications that may contain particulate matter in the fluid stream. — *Clark Solutions, Hudson, Mass.*
www.clarksol.com

Miniature solenoid valves are designed for long service

Wattmizer solenoid valves (photos) are designed for compact areas. These energy-efficient solenoid valves have relatively low-wattage coils (ranging from 0.65 to 9 W), and have operating pressures up to 1,200 psi. They are available to operate on both alternating and direct current, respond rapidly in 6 to 9 ms, and provide a wide range of pressure and flow ratings, says the company. They come standard with brass or stainless-steel bodies, and stainless-steel internal parts, making them suitable for most fluid and gas applications. Tests have demonstrated that these valves can function in excess of 60 million cycles without failure, according to the manufacturer. —*Solenoid Solutions, Erie, Pa.*
www.solenoidsolutionsinc.com

Compact press-regulating valves withstand harsh fluids

This family of pressure-regulating valves (PRVs; photo) features compact size, modular design and highly chemical-resistant plastic construction with no exposed metal parts. Offered in two models, the

Inline Industries, Inc.

Pentair Valves & Controls

Solenoid Solutions

GF Piping Systems

DMN

AS-Schneider

Roto-Disc

pressure-reducing Type 582 valve is designed to maintain constant outlet pressure, while the pressure-retaining Type 586 valve is designed to maintain constant inlet pressure. Both are well-suited to function reliabilty in the face of aggressive chemical process conditions, says the manufacturer. Available in sizes from 3/8 to 2 in., standards include ISO 9393 for tighness and EN 1266 for leak rating. — *GF Piping Systems, Irvine, Calif.*
www.gfps.com

Rotary airlock valves move and protect bulk solids

The DMN High-Pressure Rotary Airlock Valve (photo) has a special body and rotor configuration that protects the product against degradation, and prevents axial air leakage. It is said to reduce air leakage by 30% compared to competing standard high-pressure valves. The DMN HP rotary airlock valves are suitable for use during metering and pneumatic conveying of granular products. The configuration of the body, rotor and seals is designed to retain the best possible pocket-fill efficiency while reducing product degradation, says the company. They are supplied with a Type 316 stainless steel body and aluminum end covers to withstand wear. The HP valves are available in 8-, 10- and 12-in. models, which can handle products up to 176°F. — *DMN Inc., Memphis, Tenn.*
www.dmn-inc.com

Compact valve reliably controls air ingress and egress

The ASU-CAV is an automatic, high-pressure, single-body combination air valve, which is suited for clean or dirty service applications in mining, petrochemical, water-treatment, reverse osmosis and high-pressure (150–300 psi) wastewater-treatment applications. Its venting design provides varied and predictable air flow over a wide range of air release and air/vacuum conditions. A large-dia. air/vacuum disc provdes high-volume air flow for rapid venting during pipeline filling, and allows high volumes of air to enter a pipeline during draining. During normal pipeline flow, the dual-range air-release design prevents air buildup and associated flow restrictions under changing conditions and through the full flow range. Available in sizes 1 to 4 in., with all stainless-steel construction, this valve has a relatively lightweight, low-profile design that provides excellent corrosion resistance, and operates without linkages to ensure reliable operation and durability, meeting AWWA C512 requirements, says the firm. — *DeZurik/APCO/Hilton, Sartell, Minn.*
www.dezurik.com

These ball valves withstand tough operating conditions

The new KB and KC Ball Valve Series products (photo) are designed for the most demanding CPI and petroleum-refining applications. A floating ball allows for relatively low torque, even under difficult conditions. They withstand pressures up to 420 bars, and temperatures of –30 to 232°C. Carbon steel and stainless steel are available as standard body materials, but other special alloys (such as Alloy 400 and Alloy C-276) can be used for the body. Polyether ether ketone (PEEK) and reinforced polyetrafluoroethylene (PTFE) are used for the ball seat. The valves are tested and certified according to ISO 15858 and are also Fire Safe tested and certified according to ISO 10497/API 607. — *AS-Schneider, Nordheim, Germany*
www.as-schneider.com

Valve device meters product into or out of processes

The Roto-Disc Airlock/Double-Dump valves (photo) are used to feed and measure product into and out of pressure and vacuum environments. The Roto-Disc Cycle Timer, coupled with enhancements to its accumulator chamber, allows these devices to be used for both volumetric and gravimetric measuring, in addition to traditional timed and manual control during feeding. Included among the latest capabilities is the ability to switch among these modes of operation seamlessly. The load-cell mounts and level sensor ports are located on the chamber, according to the application requirements. — *Roto-Disc, Inc., Erlanger.*
www.rotodisc.com ■

Suzanne Shelley

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New Products

RheoSense

Measure viscosity over a wide temperature range

The VROC initium automatic viscometer (photo) measures absolute viscosity as a function of shear rate across a wide temperature range with high repeatability. Equipped with automatic sample loading and cleaning, the small-footprint, high-capacity device facilitates 96-well plates, as well as 40 vial racks. Sample volumes can be as small as 10 µL, making early-stage development more cost-effective. Automatic intrinsic viscosity measurements provide the size of molecules in various formulations and conditions. — *RheoSense, Inc., San Ramon, Calif.*
www.rheosense.com

Gill Sensors & Controls

Monitor debris in hydraulic and lubrication systems

This company's new oil-debris sensor (photo) offers continuous, real-time monitoring of particle accumulation and contamination in hydraulic and lubrication systems. The sensor features a three-channel output that provides both an early warning of damaged bearings or gears that need maintenance to prevent unexpected downtime. Typical applications include monitoring gas-turbine engines, turbine gearboxes and other industrial applications. Solid particle contamination is a major cause for breakdown in hydraulic and lubrication oil systems, which can not only be costly to fix, but when compounded with unscheduled downtime, can cause even higher recovery costs. — *Gill Sensors & Controls Ltd., Hampshire, U.K.*
www.gillsc.com

Vertiflo Pump

Inspect this pump without disturbing piping layout

The Model 1400LF low-flow centrifugal pump (photo) can handle flowrates up to 50 gal/min and heads up to 345 ft, at temperatures as high as 250°F. Applications for this base-mounted horizontal pump include boiler feed, chemical processing, washdown and spray washers. Back pullout construction allows for simplified inspection or maintenance without disturbing the piping to the pump. Packing or various mechanical-seal arrangements are available as standard options. Construction material selection includes ductile iron, bronze fitted, 316 stainless-steel fitted and all 316 stainless steel. — *Vertiflo Pump Co., Cincinnati, Ohio*
www.vertiflopump.com

Quintex

A smart pH sensor available in PVDF construction

The PH10 is a smart pH sensor and transmitter that features an industry first — a rugged polyvinylidene difluoride (PVDF) body. The device can be calibrated at any time against a standard or reference transmitter, or laptop PC, in the instrument shop. The calibration parameters are then stored in an onboard memory chip. When performing a field calibration, operators simply take the pre-calibrated sensor to the field, connect it to the transmitter, and allow the transmitter to upload the calibration parameters. The sensor's design incorporates a flat membrane sensing electrode and an ion barrier to protect the internals and reduce fouling. The sensor also stores other parameters, such as glass resistance, reference resistance, date of manufacture, serial number and history logs to help manage the deployment and performance of the pH sensor. — *Schneider Electric, Foxboro, Mass.*
www.schneider-electric.com

Stainless-steel local control stations can be designed online

After this company created the possibility to design GRP (glass-reinforced polymer) control stations for use in hazardous areas, it has now made this possible with stainless-steel local control stations with up to 15 modules (photo). The selection and placement follows the same procedure as for GRP control boxes. Users simply choose the maximum quantity of required modules on the company's homepage. Based on the scheme chosen, users can then select the appropriate functions on a new definition page. By leaving out certain points, users can create special user-friendly stations that the operator can use intuitively. — *Quintex GmbH, Lauda-Königshofen, Germany*
www.quintex.eu

Sanitary rupture discs available in Hastelloy construction

The Axius SC Sanitary Rupture Disc, specifically designed for the stringent sanitary and aseptic requirements of the biotechnology and pharmaceutical industries, is now available in Hastelloy C276 material. In many situations, Hastelloy is preferred over stainless steel because of its corrosion resistance in demanding applications. In both Hastelloy and stainless steel, the Axius SC is free of any indentations, crevices or other design features that may trap process contaminants. The Axius SC in Hastelloy C276 material is available with a broad burst-pressure range, with full vacuum resistance at all burst pressures, similar to the existing 316/316L stainless-steel models. Suitable for both gas and liquid applications, the non-fragmenting rupture discs are able to fit directly into standard industry ferrule connections. — *Fike Corp., Blue Springs, Mo.*

www.fike.com

This PLC securely integrates devices from multiple vendors

Honeywell Process Solutions

The recently launched ControlEdge programmable logic controller (PLC; photo), when combined with this company's Experion Process Knowledge System, provides secure connectivity and tight integration to instruments, equipment and software from multiple vendors. ControlEdge is said to be the first PLC to offer Universal I/O, providing remote configuration and flexibility for late-phase design changes, leading to improved project implementation. ControlEdge PLC is designed for process industries that require discrete control for specific PLC applications, such as water treatment, balance-of-plant modular equipment, terminal automation, and coal and ash handling. — *Honeywell Process Solutions, Houston*

www.honeywellprocess.com/plc

A valve manifold with zoned safety capabilities

ASCO Valve

The Numatics 503 Series valve manifold (photo) enables end users to configure up to three safety circuits in a production machine. The manifold can create up to three independent electro-pneumatic safety zones, while also allowing independent non-safe sections to coexist within one manifold assembly. The operator does not

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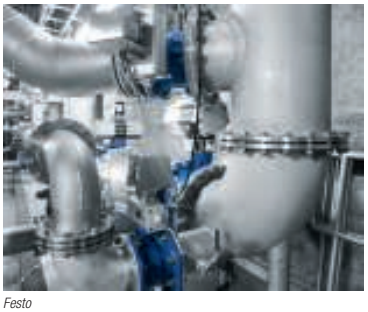
Rohrback Cosasco Systems

Pepperl+Fuchs



Festo

have to shut down the entire machine by releasing compressed air with a redundant safety or control dump valve. Instead, the Numatics 503 Series valve manifold can be configured to shut down air and power only to the group of valves that controls the machine's motion in the operator's vicinity. The flexible approach also significantly reduces safety system cost and allows machine space to be saved for other purposes, says the company. — *ASCO Valve, Inc., Florham Park, N.J.*

www.asco.com

New software for enhanced corrosion management

This company's new Data Offline software (photo) provides corrosion-management personnel with enhanced analytics and reporting that enable new levels of insight for controlling corrosion. The software is compatible with all offline Microcor, ER, LPR and Ultracorr ultrasonic corrosion-monitoring field instruments. The software package gives users a comprehensive look at a total system or plant, while illustrating the factors that affect corrosion rates. Imported data from corrosion-monitoring points and other process parameters, including laboratory analysis, inspections and chemical injection rates, can be analyzed, correlated and compared. The software produces time-related graphical displays of corrosion data, allowing direct correlation with other factors, such as temperature and pressure, for optimal corrosion control. — *Rohrback Cosasco Systems, Inc., Sante Fe Springs, Calif.*

www.cosasco.com

This segment coupler provides speed on Profibus DP

With the basic segment coupler (photo) — the successor to SK1 and SK2 — Profibus PA nodes appear as DP nodes in the distributed control system (DCS) and can be configured and diagnosed without additional tools. The basic segment coupler provides this transparency without any configuration of its own. The simplicity of this design assists in efficient generation of big data for optimized process management. At the same time, both transmission rate and timing of the two systems are completely de-coupled. Communication to the DCS benefits from responses with zero delay by the PA nodes at a transmission rate of up to 1.5 megabits/s on Profibus DP. The basic segment coupler from FieldConnex supports a high segment count per cabinet requiring only 20 mm on the DIN-rail and very low heat dissipation. — *Pepperl+Fuchs GmbH, Mannheim, Germany*

www.pepperl+fuchs.com

Reduce investment and operating costs with pneumatics

Water supply company Landeswasserversorgung (Stuttgart, Germany) employed this company's pneumatic automation technology for the construction of the multimedia and activated-carbon filtering basins in a new groundwater filtration system. The automation technology controls the water flow using pneumatic valve actuators (photo) and process valves for regulation and shutoff, as well as for preventing return flow. The company installed seven open two-tier filters in the new groundwater filtration system. During backwashing of one multimedia filter, the pipelines are opened and closed by 10 shutoff valves, which are actuated by this company's DAPS pneumatic quarter-turn actuators. The actuators are controlled by valve terminals with a Profinet connection. Overall, the technology saved Landeswasserversorgung 10% on its investment and operating costs compared to electric automation, says this company. — *Festo AG, Esslingen am Neckar, Germany*

www.festo.com/water

Comprehensive materials data for corrosion prevention

The Dechema Materials Table (Dechema-Werkstoff-Tabelle; DWT) is now available as an online version. The new online edition of the DWT provides detailed information about the corrosion and chemical resistance of all important metallic, non-metallic and organic materials in contact with over 1,000 cor-

rosive media. It provides important guidance for preventing corrosion damage and is thus an important decision-making aid. Additional benefits include the following: fast and worldwide availability of data; guaranteed online access at all times; simple and immediate access; and no additional software installation is necessary. Single and multi-user versions are available. — *Dechema e.V., Frankfurt am Main, Germany*
www.dechema.de

These hygienic pumps are easy to clean and quick to strip

The range of CSF CS, CSA and CSM centrifugal pumps (photo) are capable of handling capacities from 1 to 550 m^3/h at heads up to 155 m. These pumps possess the ease of cleaning and maintenance that are necessary for transferring liquids in food, brewing, pharmaceutical and other similar hygienic process applications. CSF pumps are manufac-

Pump Engineering

tured in investment-cast AISI 316L stainless steel, with stainless steel for all wetted parts. They also feature a six-vane impeller, which ensures gentle and effective handling of the ingredients used in many food and pharmaceutical processing applications, even those containing particles or small solids. The pumps are designed with clean-in-place (CIP) capability to ensure the absence of dead areas and feature electro-polished finishing of all surfaces. CSF pumps are available with standard or ATEX-certified motors, which are designed for back pull-out and fitted with a quick-release clamp to enable fast and simple dismantling. — *Pump Engineering Ltd., Littlehampton, U.K.*
www.pumpeng.co.uk

New wirelessly monitored storage-tank emergency vents

Emerson Process Management

The new wirelessly monitored Enardo 2000 emergency pressure-relief vents (EPRVs; photo) provide safety control by managing abnormally high storage-tank pressures in the oil-and-gas, chemical, petrochemical and pharmaceutical industries. Under normal operating conditions, an EPRV remains

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Sartorius Stedim Biotech

Voith Turbo

Pfeiffer Vacuum

closed. The immediate knowledge of an open position can be vital and should warrant quick investigation. However, because these EPRVs are located on top of storage tanks, they are difficult to monitor. Site managers are increasingly looking for ways to increase safety and efficiencies. The new product design consists of a proximity indicator and wireless transmitter integrated with an EPRV. The proximity indicator senses movement of the emergency vent. "Open" or "closed" signals are received by the wireless transmitter and can be sent to a control room via a WirelessHART gateway. — *Emerson Process Management, Austin, Tex.*
www.emersonprocess.com

This modular mini-bioreactor system has scaleup potential

The new ambr 250 modular system (photo) is an innovative benchtop mini bioreactor system for parallel fermentation or cell culture. This system combines a unique single-use bioreactor vessel and expandable system design to offer bioprocess scientists access to advanced benchtop bioreactor technology for process development. The new ambr 250 modular system consists of a workstation with two, four, six or eight single-use bioreactors, with a working volume range of 100 to 250 mL. These mini bioreactors, based on the same stirred-tank bioreactors in the well-established ambr 250 high-throughput system, contain impellers suitable for fermentation or cell culture and demonstrate excellent scaleup to larger bioreactors, says the company. They are also fully integrated with liquid reservoirs and syringe pumps, allowing rapid experimental setup and turnaround, significantly increasing lab efficiency. — *Sartorius Stedim Biotech, Goettingen, Germany*
www.sartorius.com

A new variable-speed gear for lower speed ranges

The Vorecon variable-speed planetary gear provides speed control with maximum reliability and low lifecycle costs. With the new NX series (photo), this company has now further developed the proven principle specifically for applications in the low power range (up to 10 MW). The Vorecon NX provides an increase in efficiency of up to 8% in part load. In the new series, an optimized torque converter provides efficient speed control, which uses only a small portion of the input power. Depending on the speed required, this power is fed back to the driveline by way of the planetary gear on the driven side. Adjustable pump blades in the torque converter provide stepless and wear-free control. — *Voith Turbo, a Group Division of Voith GmbH, Crailsheim, Germany*
www.voith.com

Tank cleaning capacity is expanded in Krems

Operators of tanker and tank-container fleets now have access to a new eco-friendly cleaning facility in Krems an der Donau (in Lower Austria). In June, this company expanded its tank-interior cleaning center for all kinds of chemical products and foodstuffs by opening a third cleaning bay. The facility is not only able to clean tankers and tank containers, but also silo vehicles and tipper trucks. The special features of the new cleaning bay include automated cleaning for dispersions and synthetic resins by machine, where the water and cleaning agents are recycled. This provides major improvements to the interior cleaning process and reduces water consumption and manual cleaning work. When removing any chemical residue with water pressure of 8 bars and a temperature of up to 90°C, only certified, environmentally friendly cleaning agents are used. — *Imperial Chemical Transport GmbH, Krems, Austria*
www.imperial-international.com

A high-performance compact turbopump for ultra-high vacuum

The new HiPace 300 H turbopump (photo) is said to be the highest compression turbopump in the pumping speed class of 300 L/s currently on the market. With a compression ratio of 107 for hydrogen, it is suitable for producing high and ultra-high vacuum. The high compression ratio

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generates a low residual gas spectrum in the chamber, which is desirable for mass spectroscopy applications. The vacuum pump comes in a radiation-resistant version with external electronics as an option. With its sophisticated rotor design, the HiPace 300 H has a very high backing pressure compatibility of 30 hPa. This helps the pump achieve ultra-high vacuum when operating with high backing pressure in combination with diaphragm pumps. The HiPace 300 H also has an integrated "intermittent operation" function that switches on a backing pump only when the backing pressure is no longer sufficient. This lowers the energy consumption of the entire vacuum system by up to 90%, says the company. — *Pfeiffer Vacuum GmbH, Asslar, Germany*
www.pfeiffer-vacuum.com

This mechanical discharge system is very flexible

The ADM type Kokeisl mechanical discharge and dosing module is used for discharging bulk material in any amount desired from silos, containers and other vessels. From a few grams to several tons of material, discharge is realized accurately according to the scale resolution. The machine can be used for local applications, such as dosing on a single machine, as well as integrated into highly automated bagging machines, complex multi-component weighing systems, or even complete container systems. Due to its electropolished surfaces and seals that conform to FDA regulations, the Kokeisl is also suitable for the pharmaceutical industry. The module is available in three sizes with a maximum outlet aperture diameter of 90, 150 or 200 mm. — *Zeppelin Systems GmbH, Friedrichshafen, Germany*
www.zeppelin-systems.com

Save energy with passive aeration wastewater treatment

This company's flat-sheet Membrane Aerated Biofilm Reactors (MABR; photo) provide high-effluent wastewater-treatment solutions with 90% less energy and 50% less sludge, according to the manufacturer. The MABR is a spirally wound air sleeve submerged in a tank, to which wastewater is fed continuously and effluent is discharged by overflow. This passive aeration process saves energy by eliminating the need to blow air. The design is said to ensure robust, efficient, durable, clog-free operation. The MABR is suitable for small- to medium-sized plants, providing quiet and odorless wastewater treatment solutions, while enabling the re-use of wastewater for irrigation. — *Emefcy Ltd., Caesarea Industrial Park, Israel*
www.emefcy.com

A new filter range for conveying systems

The new, ultra-fine secondary air-filter range (photo) is designed for use with this company's vacuum conveying systems. Available as standard accessories, the sterile filters are of the ultra-fine filtration class — U15-17 — or ultra-low penetration air (ULPA) filters. The filtration efficiency is rated at 99.9999%. The new filter units offer greatly improved filtration performance when compared with the high-efficiency particulate air (HEPA) filters that are often used in industry settings. Designed to fit the capacity of any compressed-air-driven vacuum pump, the filters can be used in a broad range of vacuum conveying applications. — *Piab AB, Täby, Sweden*
www.piab.com

Total screen rotation simplifies this mill's inspection

MK-3 centrifugal mill sifters (photo) include a new basket design that enables 360-deg screen rotation within the machine, providing flexibility to meet the demands of both quality inspection and hygiene within the food, chemical and pharmaceutical industries. The mill's design simplifies inspection by allowing a single operator to conduct inspection from one side of the sifter, while eliminating manual handling and the inherent hygiene implications of removing the screen on a regular basis for inspection. Standard machines include bearings at both ends. In addition to the traditional nylon screens, antistatic, perforated-plate and wedge wire screens are available to suit many applications. — *Gericke USA, Inc., Somerset, N.J.*
www.gerickeusa.com

New models of metal-sealed internal-gear pumps

This company's G Series of metal-sealed internal-gear pumps has been expanded to include models in three new sizes (photo): 3, 4 and 6-in. The new models are available in cast iron, carbon steel and stainless steel, and can deliver flowrates up to 500 gpm. The pumps are offered with both packing and mechanical seal options. The pump casing can be easily rotated for multiple liquid porting positions, making these pumps very simple to install into existing internal-gear pump applications, says the manufacturer. G Series pumps also have an enlarged bearing housing at the backside of the pump that allows for convenient drive-end access to the shaft seal and single-point end-clearance adjustment. Providing a positive, non-pulsating flow, G Series pumps can operate equally in both directions. — *EnviroGear Pumps, Grand Terrace, Calif.*

www.envirogearpump.com

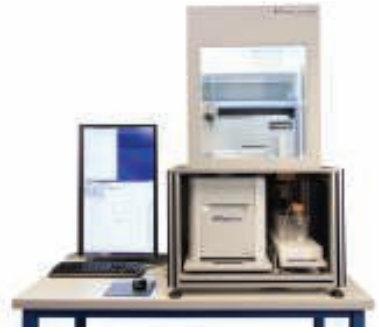
Automated sample handling for particle analysis data

The FlowCam ALH automated liquid-handling system (photo) automatically processes up to 96 samples per run without requiring human involvement or supervision. This eliminates the potential for human error in sample handling and pipetting, and ensures that data are accurate. Ideal for particle characterization and quality control in a variety of liquid and dry particle-analysis applications, the FlowCam autosampler includes built-in mixing, heating and cooling for sample conditioning, control over evaporation and protection against sample degradation. The FlowCam ALH liquid-handling system is entirely self-contained on a compact footprint in a protective enclosure suitable for cleanrooms to prevent contamination and outside activities from disturbing the operation. — *Fluid Imaging Technologies, Inc., Scarborough, Me.*

www.fluidimaging.com

Mary Page Bailey and Gerald Ondrey

Fluid Imaging Technologies



EnviroGear Pumps

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Distillation Column Design Factors

Department Editor: Scott Jenkins

Distillation is a critical separation tool for many applications in the chemical process industries (CPI), and the intelligent design of a distillation column can have a large impact on eventual process performance and efficiency. This reference sheet outlines the design process for distillation columns and defines several key design factors in this area.

Column design process

Distillation column design is best accomplished using process simulation software, such as Aspen HYSYS or a similar program. Balancing the key design factors shown in Table 1 starts by sizing the column for maximum superficial vapor velocity (vapor factor F_S).

Once a working design is established, engineers should check the ratio between flowrate (gallons-per-minute; gpm) and column area (gpm/ft^2). The next step should be to ensure that flood ratio, weeping point, reflux ratio, and efficiency ratios are all within reasonable parameters.

For basic categories of column internals, the appropriate ratio ranges are shown in Table 2. Column designers should use these ranges as a guide to ensure that the appropriate column design and packing have been selected.

TABLE 2.

Column internals style	*Fs*	gpm/ft^2	Efficiency	ΔP (mmHg)
Trays	0.2–1.6	1–20	50–80%	4–10 mmHg / Tray
Random/dumped packing	0.5–2	1–20	HETP 30–40 in.	0.7–1.5 mmHg / ft
Structured packing	0.2–3.5	1–20	HETP 12–30 in.	0.2–0.5 mmHg / ft

Best practices for factors

For the flood ratios, the limit is 100%. A good rule of thumb for new column designs is to keep the limit closer to 85%. Turndown is a vapor-pressure balancing act — the objective is to maintain appropriate vapor velocities but also allow the ability to turndown without having to worry about weeping or dumping, which can crash the column outright.

Entrainment ratio relates to physically carrying liquid from one tray to the one above it with vapor velocity. This ratio should be minimized wherever possible. The higher the amount of reflux in the column, the larger the required column size, but the purer the distillate will be.

Other factors not covered here, such as feed location, exact packing type, control scheme and so on will affect the final design of the column. Column design is the art of balancing these factors to achieve an optimized design that can be confidently built and operated with long-term return on investment. ■

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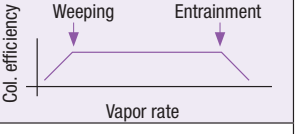
TABLE 1. DISTILLATION COLUMN DESIGN FACTORS

Factor	What does it measure?	When is it applied?	Limits and formulas
Flood ratio	Accumulation of liquid in the column		
Jet flood		To all packing types	Design for 85% for new trays and packing
Downcomer flood		Only applies to columns with trays	Design for 85% for new trays
Weeping point	Low vapor flow allowing liquid to fall through the vapor perforations	To all columns	Less than 50% is acceptable
Entrainment ratio	Entrained liquid carried by the vapor to the tray above	To any column	Less than 10% is acceptable
Efficiency ratio	Separation efficiency, based on weeping ratio, reflux ratio and vapor rate	Most useful for trayed columns	There are many formulas that can be applied here. In general, the relationship should be visualized as: 
HETP	Height equivalent of a theoretical plate	Used for packed columns	HETP = (Height of packing) ÷ (Number of theoretical plates)
F_s vapor	Value used to determine preliminary column sizing	To all columns	$F_s = Us \times \sqrt{\rho_v}$ ρ_v = Vapor density lb/ft^3 F_s = Vapor F factor U_s = Vapor superficial velocity, ft/s
Liquid ratio: gpm/ft^2	Ratio used to find column area requirements and to determine initial equipment sizing	To all columns	gal/min per ft^2 = (liquid gal/min) ÷ (column area) where: gpm = gallons per minute area = ft^2

Chlorine Production from NaCl (Chlor-Alkali)

By Intratec Solutions

Chlorine is among the most important chemical commodities — it is used in the manufacture of a multitude of end products (for example, plastics, solvents, pesticides, pharmaceuticals, disinfection chemicals and others), as well as in processes that produce industrial chemicals via organochlorine intermediates, such as polycarbonates, silicones, polyurethanes and others.

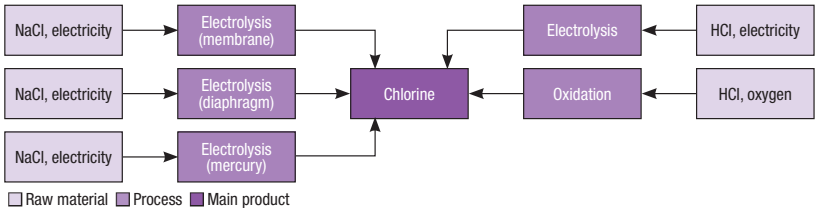


FIGURE 2. Several viable pathways exist for industrial chlorine production

The process

The following describes chlorine production by the electrolysis of aqueous sodium chloride (brine) using a conventional membrane process (Figure 1).

Brine purification. Initially, recycled, depleted brine is mixed with water and re-saturated with fresh sodium chloride. Since other metal ions (such as Ca^{2+} and Mg^{2+}) present in the brine would harm the membranes, the brine is treated with precipitants, so that the metals precipitate. The precipitated solids form a sludge, which is removed by settling in a clarifier. Subsequently, the clarified solution is filtered and purified by ion-exchange resins to remove residual hardness and achieve acceptable levels of Ca^{2+} and Mg^{2+} ions.

Electrolysis. The ultrapure brine and electricity are the main inputs for the electrolysis section. The brine is fed into the anolyte compartments (electrolyte near the anode) of the electrochemical cells. These are separated from the catholyte by cation-exchange membranes. Chlorine gas is generated at the anodes and sodium ions migrate through the membranes into the catholyte solution. The depleted brine from the anode compartments is dechlorinated downstream and then returned to the brine saturation step.

On the catholyte side, water is electrolyzed, generating H_2 gas and hydroxyl (OH^-) ions. Membranes prevent the migration of OH^- ions into the anolytes, in such a way that hydroxyl ions combine with the sodium ions to form caustic soda (NaOH). The addition of demineralized water keeps the catholyte concentration at the desired level.

Product recovery. Hydrogen from the electrolysis process is compressed for sale to consumers. The caustic soda solution is concentrated to a saturated 50 wt.% NaOH solution — the traditional commercial form of the material. The Cl_2 gas produced is sent to drying towers where concentrated sulfuric acid circulates as a dehydrating agent. The dry Cl_2 gas is compressed and liquefied before being sent to storage.

Chlorine pathways

Most chlorine produced at commercial scale is based on electrolysis of aqueous sodium chloride (chlor-alkali process). Aside from the process described above, electrolytic production of chlorine can be accomplished by two other basic processes: diaphragm cell and mercury cell processes. Figure 2 shows these electrochemical processes and other pathways for chlorine production.

Economic performance

The total capital investment estimated to be required to construct a plant with a capacity of 500,000 metric tons per year of chlorine in the U.S. is about $820 million (data from the first quarter of 2014). The capital investment includes fixed capital, working capital and additional capital requirements. The production costs (raw materials, utilities, fixed costs, corporate overhead and depreciation costs) are about $500 per metric ton of chlorine produced (credits from sales of hydrogen and caustic soda co-products were not taken into account).

This column is based on "Chlorine Production from Sodium Chloride — Cost Analysis," a report by Intratec. It can be found at: www.intratec.us/analysis/chlorine-production-cost. ■

Edited by Scott Jenkins

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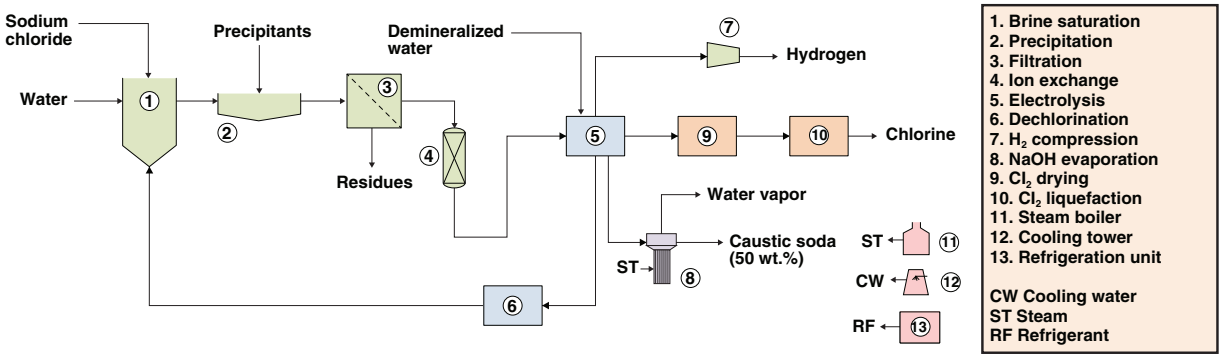

FIGURE 1. The above diagram shows chlorine production by the electrolysis of aqueous sodium chloride via a conventional membrane process

Microreactors: Lessons Learned From Industrial Applications

Implementing microreactors in chemical production is quite a challenge. How these challenges can be met is described here

Raf Reintjens and André de Vries
DSM

IN BRIEF

At the heart of a chemical process is the reactor, where the conversion of reactants to products occurs. Depending on the need for efficiency or flexibility, the chemical process industries (CPI) optimize their processing "solutions" towards continuous, world-scale plants for bulk chemicals, or to batch operated, multi-product plants for complex fine chemicals. The struggle to stay competitive and deliver high quality product at low cost drives the industry towards the use of increasingly larger-scale reactors. This economy-of-scale principle helps to lower the cost level, but also imposes serious limitations on mass- and heat-transfer, often resulting in moderate space-time yield or productivity.

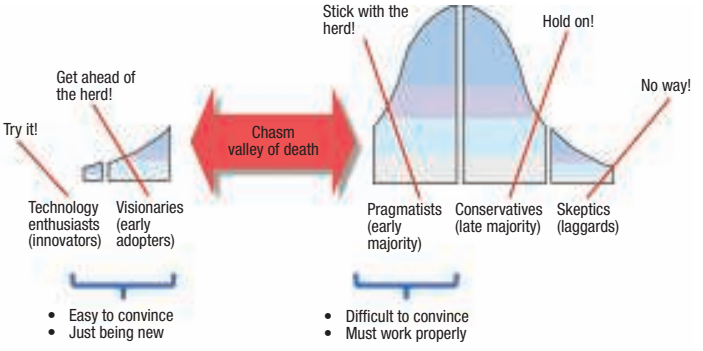

FIGURE 1. The critical point in the adoption of a high-tech innovation is reached when the early majority needs to be convinced of their adoption decision by proven feasibility (*y*-axis is percentage of adopters)

PI as an engine for innovation

Process intensification (PI) takes a different approach to optimizing reactions. When looking at the underlying fundamental physical and chemical processes and fluxes that occur during a chemical conversion, we can define an "optimal pathway" for the molecules [*1, 2*]. The aim is to fulfill the needs of the reaction, in the sense of bringing reactant molecules together in the right stoichiometry at the right time and extracting the released reaction enthalpy in a perfect way to avoid overheating and selectivity loss. The virtual absence of concentration and temperature gradients, combined with near to ideal plug flow, would ensure that every product molecule experiences the same processing history.

By increasing the temperature, we could accelerate the rate of reaction and explore ever higher productivity levels. Of course, the "landscape" of possible chemical pathways would still require delicate navigation to avoid unwanted consecutive or side reactions and maintain sufficient chemical selectivity. In the end, when we could design this ideal reactor that allows us to follow the "optimal pathway," the limitation to the productivity increase would come from the chemistry itself rather than the capabilities of the reactor.

The approach of PI towards improving cost efficiency, boils down to maximizing the performance-to-cost ratio. The volumetric cost level of an intensified reactor may exceed that of conventional reactors due to increased complexity. But as long as the productivity gain is more than proportional, the net cost per unit of production capacity will go down.

Basic principles

Over the past decades, the use of microreactors in chemical synthesis became the subject of many papers [*3, 4*]. Laboratory-

Capacity	Reactor volume	Pressure drop	Number of channels
(1,000 ton/yr)	(L)	(bar)	
1	1–10	~2	$10^5 – 10^6$
10	10–100	~2	$10^6 – 10^7$
100	100–1,000	~2	$10^7 – 10^8$

Channel: 100 µm ID, 1 m length
Productivity 10,000 – 100,000 kg/m³h

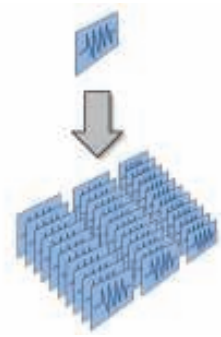

FIGURE 2. Numbering up requires astronomically high numbers of parallel channels

scale experiments revealed high heat- and mass-transfer capabilities, making it possible to control very demanding chemistries [*5, 6*]. To run a reaction under kinetic control, the characteristic time for transfer must be much lower than the characteristic time of the reaction. This characteristic time for transfer scales with the square of the transfer distance. Ten times shorter distance results in a hundred times faster transfer.

Nature already applied this basic principle long ago when pulmonary vesicles and capillary veins evolved to enable the rise of multicellular organisms. The drive for intensification of transfer capabilities in reactor engineering led to reinvention of the conventional tube reactor. Innovative manufacturing technologies made it possible to etch reaction channels in glass chips with diameters in the micrometer domain. Although small in size, these microreactors provided the processing conditions to reach a thousand-fold increase in productivity.

Dynamics of innovation

Despite its widespread success in the laboratory, there are just a few reported microreactor applications on industrial scale. In our opinion, the reason for this should not be attributed to the unwillingness of industry to adopt to new technology, as is often suggested. For a better understanding, we must take a closer look at the dynamics of innovation and the factors that influence it.

In the mid 1990s, Mokyr [*7*] presented a theory of technological change (innovation) based upon evolutionary principles. Technologies can be seen as species in a habitat, they emerge, survive and reproduce or become extinct. As in biology, there are selective forces at work through which technologies compete with each other. The selection criteria come from success in the market, such as favorable economics, robustness, better satisfying the needs, or even fulfilling unmet needs (niches). To earn their foothold in the habitat and survive, emerging technologies must outcompete conventional technologies. Take for example the hardware revolutions in television sets when color broadcasting or flat-panel technologies were introduced. Plasma displays came first on the market, followed soon by liquid-crystal (LCD) and light-emitting-diode (LED) displays. Although more expensive than cathode-ray-tube (CRT) based technology, emerging devices got a foothold. Finally, CRT and plasma lost this struggle for survival, and LED-based screens became the dominant species.

Further, Mokyr's theory differentiates between the technical know-how and the expression of it into the artifact (product). The expression is the ability to turn blueprints into reality, which requires complementary factors, such as skilled craftsmen, manufacturing technology and high-quality materials. Lack of these complementary factors can cause an incubation period between the moment the invention was made and the start of commercial success. As an example, we can look at the development of the light bulb. The basic principle that a

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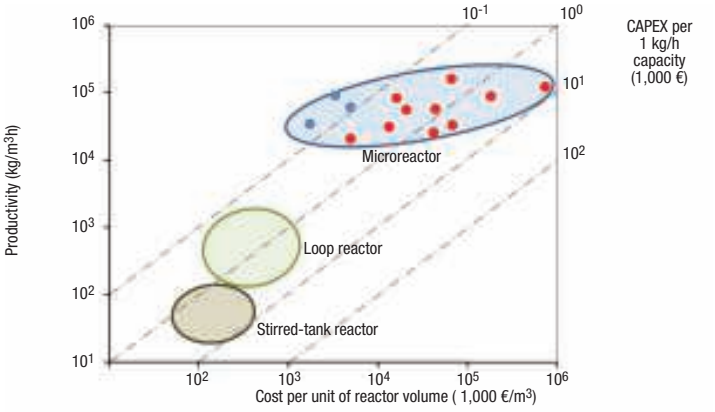
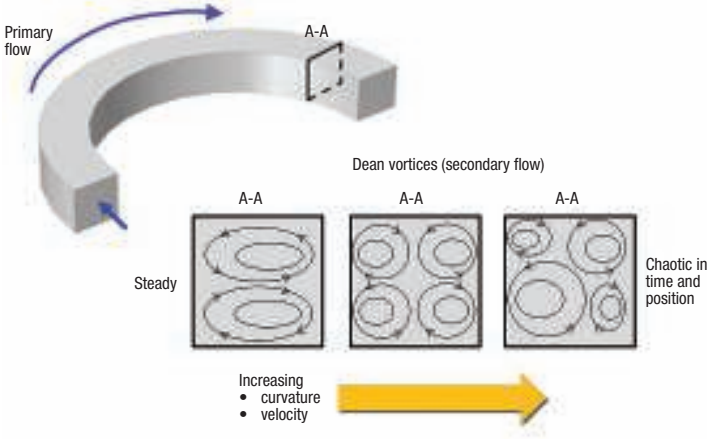


FIGURE 3. Shown here are benchmarking metrics for industrial microreactors

flow of electric current can produce visible light was found by Davy in 1802, but it took another 75 years before Edison made it a commercial success. Better vacuum-pump technology and filament material needed to be developed first.

Other useful insights can be found in the diffusion-of-innovation theory of Rogers [*8*], where the adoption of a new technology is explained in a more behavioral context. The rate of adoption into a community can be described by the difference in behavior between five categories of adopters. The degree of adoption over time (since the invention was made) follows a bell-curve. In the beginning, the adoption is driven by the technology enthusiasts and visionaries who are willing to take a risk, and motivated by newness rather than robustness. Adoption rate is low and a lot of the prototyping fails with the subsequent shake-out of the start-up companies. The expression of the technology can be hampered by missing complementary factors. The inflated expectations are brought back to reality, and without further development, the actual adoption can even be stalled.

FIGURE 4. This schematic shows the secondary flow phenomena that occurs perpendicular to the flow direction in a curved channel



Moore [*9*] expanded the model by focusing on this critical point (chasm) in the bell-curve between early adopters and early majority (Figure 1). The most difficult step is making this transition because the expectations of the adopters change. The early majority is more pragmatic in their decision. They need to be convinced by real benefits and performance. A lack of technology readiness is not accepted. Both economic and technical feasibility need to reach a satisfying level. In our opinion this is the true reason for the reluctance to implement industrial microreactors.

Hurdles toward industrial application

Let's go back to the adoption of microreactor technology in the chemical industry. The early success in the laboratory demonstrated the potential of the technology and created high expectations. The *product* of laboratory-scale experiments, however, is information, and for this we don't need volume. A microliter-sized reactor can tell us about the reaction kinetics and the achievable selectivity, or produce a few grams of substance for a library. The microreactor may be a costly prototype as long as the *value* of the information is satisfactory. Things change when the *product* is mass, when tons of substance are required, when operation has to meet plant and business requirements.

The first hurdle we perceived was that of scaleup to a sufficiently large volume to deliver the required production capacity. Although productivity in a microreactor can reach up to 100,000 kg/m^{3}h, the required reactor volume is still substantial and a single channel will not be sufficient. Astronomically high numbers of parallel channels would be required (Figure 2). Numbering-up is often hailed as the solution with the added benefit of avoiding scaleup effects. In theory this is true, but the practical implications on the technical feasibility (manifolding) are enormous, let alone the impact on the economics of the reactor construction. This problem poses a true dilemma. The performance of a microreactor comes from its micrometer-sized channel dimension, and traditional scaling-up would inevitably result in loss of that performance, bringing us back to conventional tube reactors.

The second hurdle that we encountered was the manufacturability and its impact on the cost level. In the early 2000s, with the technology still in its infancy, it was difficult to find a technology provider who could solve the numbering-up challenge on a technical

level. Finding someone that could do this at a cost level that wouldn't kill the business case was even harder.

The manufacturing cost of an industrial microreactor is influenced by many factors. The dominant factors are choice of construction material, intrinsic cost level of the required manufacturing technology and complexity of the design. It's evident that the selected construction material should fulfil the need for corrosion or solvent resistance, and provide satisfying heat conductivity along with mechanical strength to withstand process conditions. Metals and ceramics seem to present better properties and easier compatibility with a plant environment in comparison to glass and polymers. The choice of construction material also impacts the manufacturing process since it limits the options; for example, it's difficult to weld a ceramic.

In the universe of manufacturing technologies, we predominantly see microreactor channels being shaped by removing material from a large foil or plate. Sometimes this process delivers multiple channels in parallel (etching, punching) but mostly the channel is made in a serial operation, one-by-one (machining, sandblasting). This leads to high manufacturing cost and high consumption of material per unit of reactor volume, which is especially important with expensive corrosion-resistant materials. After the channel shaping, the assembly of the reactor often requires stacking of such 2-D plates and bonding them tightly together (diffusion bonding, clamping) to obtain the industrial microreactor. The most influential factor will be the complexity of the reactor design, which is a direct consequence of the numbering-up strategy.

Crossing the chasm

In the mid 2000s, it became obvious that the technology readiness level (TRL) was insufficient. Economic feasibility could only be reached in niches. The expression of the basic principles into feasible industrial microreactors required complementary developments. The challenge was big and the necessity to improve the manufacturability would lead us to unfamiliar terrain. Open innovation with strategic cooperation between know-how providers, equipment suppliers and industrial end-users was chosen as the way forward.

We applied the principle of P. Drucker — "If you can't measure it, you can't improve it" — to direct our efforts. We needed to benchmark the solutions that equipment suppliers offered amongst each other and compare them to conventional state-of-the-art technologies. This was a classic example of trying to compare apples with oranges. Information in publications was mostly useless since the microreactor achievement was compared with a suboptimal conventional process.

We developed our own metrics based on the ratio of the "volumetric

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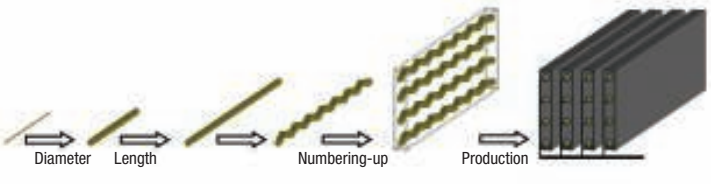


FIGURE 5. This diagram illustrates the design strategy for industrial microreactors

cost level" of a reactor system and the attainable productivity, or "volumetric production capacity." Of course the business case is influenced by many more factors, but it allowed us to benchmark the economic feasibility of reactor technologies that showed a wide range in achievable productivity (kg/m^{3}h) and applied different technology principles. Assuming that license-to-operate and safety requirements are met, the cost-to-performance ratio is reflected to a large extent in the investment level to install a certain production capacity. Two technologies can have a different background, but if they result in the same cost-per-unit production capacity, they are business-wise meaningful alternatives. An exception should be made for the comparison of existing to emerging technologies. Here, there should be an additional value proposition to reward the risk that's taken with the unproven technology. We admit that this is a simplification of the reality, but it gives a first estimate that allows convincing of decision makers in the "business."

We set off to get real input data by executing pilot projects with suppliers that were identified as capable to deliver a microreactor with at least 1 L of volume. With a prototype, we investigated the achievable productivity and tried to boost it to the maximum level. From the supplier quotation and negotiations, we derived the achievable cost level. Over time, we filled our database with information about an increasing number of suppliers, and kept it up to date by following their developments.

The dots in the diagram shown in Figure 3 represent individual microreactor suppliers. The first striking thing is the relatively wide span in cost level of the microreactor technology. Probably this is typical for an emerging technology where shake-out of uncompetitive players has not yet occurred. Furthermore, we believe this is caused by the broad choice in construction materials (plastics, ceramics, glass, metals) and the associated range of manufacturing technologies.

We found that the majority of the microreactor suppliers are represented by the red dots that are not delivering a better capacity cost compared to conventional technologies. The early start-ups founded by technology enthusiasts often lack basic manufacturing skills and construction-material knowledge. This translated into feasibility issues or relatively high cost levels when they tried to develop further toward industrial reactors. However, they can be successful on the market for laboratory-scale microreactors. To our surprise, most of microreactor suppliers that outcompeted the conventional technologies — represented by the blue dots — were not in the first wave of start-ups. These suppliers were often unaware that their skills and expertise could bring feasible microreactors. They had a running business that generated the budget to diversify, and they had expertise in manufacturing and the specific construction material. In fact, they contributed the lacking complementary factors to express the basic technology principles. What they mostly lacked was the expertise to apply the basic principles and generate a high-performing reactor design.

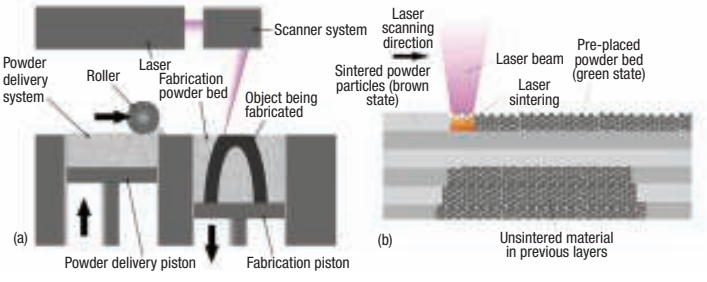
It became clear that the way forward was found in close cooperation with a select number of equipment suppliers, building on each other's competence, striving for designs that bring higher productivity while lowering the manufacturing challenges.

Manufacturability versus performance

The need for lower unit cost through easier manufacturability required wider channels. This need posed the fundamental dilemma that we needed to solve. How can we achieve "micrometer" performance in a channel with a millimeter-sized diameter?

In the laminar flow (Re <10) regime of the conventional micrometer-sized channels, heat and mass transfer relied on diffusion and conduction. This principle loses performance rapidly at millimeter-sized channels. On the other hand, fully turbulent flow (Re >2,300) would result in too high of a pressure drop per unit of channel length. Secondary flow phenomena (Figure 4) in the transient domain between laminar and turbulent offered a way out. When fluid flows around a bend at sufficiently high velocity [*10–12*], it generates vorticies perpendicular to the direction of flow. The induced

FIGURE 6. This schematic illustrates selective laser melting (a), with a closeup of of the laser and metal powder (b)



vorticity, on its turn, creates thin fluid lamella, which shortens the transfer distance down to micrometers as in the basic principles. The directional change or bend could be designed in multiple ways, constant (spiral, for example) or periodic (such as zigzag channels). A set of geometric parameters influenced the secondary flow, and therefore needed to be optimized [*13–17*]. In the end, this led to a significant performance increase of the channel [*18, 19*]).

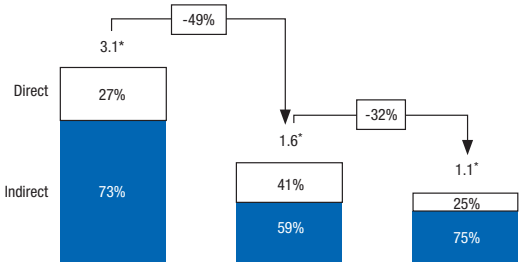
This proved to be the key to solving our dilemma. Of course there was a price to be paid. The pressure drop increased, but at much lower levels compared to fully turbulent flow. Also, the volumetric heat-transfer area decreased, but there were still several thousand square meters per cubic meter (m^2/m^3) remaining. Overall, the heat-transfer performance remained at a sufficiently high level to cope with the challenging chemistries.

Design strategy for industrial reactors

Technically, we should speak of millireactors or flow reactors since we are no longer in the micrometer domain. The design strategy had the objective to maximize the performance-to-cost ratio by optimizing the design space given by manufacturability and performance parameters. Finding the optimum for a certain chemical conversion and desired capacity requires some iterations (Figure 5), as follows:

1. The hydraulic diameter is maximized to the millimeter domain (0.5–5 mm), with the upper limit determined by the required heat-

Forecast metal additive manufacturing costs [*€/cm^3]



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Build speed	10 cm^3/h	40 cm^3/h	80 cm^3/h
Machine costs	€500,000	€700,000	€800,000
Share of monitoring	5%	2%	0%
Machine utilization	86%	84%	81%
Powder price	€89/kg	€70/kg	€30/kg
Post-processing effort	1.52 h/kg	1.05 h/kg	0.96 h/kg

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Source: EPSRC; DMRC; expert interviews; Roland Berger [*21*]

FIGURE 7. A forecast for 3-D metal printing cost for stainless steel 316L is shown here

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transfer capacity and the overall heat-transfer coefficient (W/m^2K) that can be obtained. For this purpose the diameter can be varied over the length of the reactor to have the highest heat-transfer capabilities at the beginning of the channel.

2. The channel length is maximized to several meters, and is limited mainly by the maximum-allowed pressure drop. The result is a relatively large channel volume that requires less parallelization and is easier to manufacture.
3. The channel geometry and cross-sectional shape is chosen such that secondary flow is generated perpetually over the length of the channel. Again, the curvature, shape and frequency of bends can be varied over the length to position the most intense effect at the beginning.
4. Multiple channels are combined in a single module. Flow distribution is achieved by passive control with an internal manifold.
5. Multiple modules are combined to reach the desired reactor volume. Flow distribution is achieved by passive control (external manifold) or actively by flow controllers.

Such a modular design provided flexibility and agility. Modules could harbor different functionalities (mixing, heat transfer, residence time). The modules acted as "building blocks" and reduced the need for custom design by facilitating simple configuration. Furthermore, they allowed adoption of production capacity to growing market demands. And their redundancy enhanced robustness because maintenance or a problem could be taken care of by replacement and offline repairs. In 2008, this design strategy was successfully demonstrated on an industrial scale in the production of an active pharmaceutical ingredient [*20*].

Additive manufacturing

In 2010, our search for game-changing manufacturing technologies came across additive manufacturing, in particular 3-D metal printing.

Additive manufacturing, or 3-D printing, is an innovative technology, developed in the 1980s, that allowed the construction of three-dimensional solid plastic objects based on digital design files. In the late 1990s, it became possible to print metals as well. The process starts from a digital design generated with computer-aided design (CAD) tools. The 3-D printer uses this design information sliced in 2-D layers to direct an electron beam (EBM) or a powerful laser (SLM) on a bed of fine atomized metal powder (Figure 6). The atmosphere in the build chamber is inert gas or vacuum to avoid oxidation of the metal powder. At the point of focus, the metal particles are fused together. A full dense metal object is built layer by layer by repeatedly lowering the build platform and depositing a fresh layer of metal powder. At the end of the printing process, the unused metal powder is removed (recycled) and the printed object is heat treated to relieve thermal stress. Typical feature sizes are about 50 µm. The final printed metal has almost the same mechanical properties as the original metal.

3-D metal printing is truly a disruptive manufacturing technology. It changes the shaping of a channel from removing material where we don't want it to putting material were we need it (channel wall).

Its main advantages are: almost unlimited design freedom; low material consumption; rapid product development; and the ability to reduce weight of engineered parts. This led over the past years to exponential growth in markets, such as medical- and dental implants, aerospace, aviation, automotive, tools and molds making. Complexity comes almost for free, and structures that were impossible to produce with conventional techniques became possible. Of course there are also disadvantages, such as relatively slow build rates, high printer investment cost and limited build size (about 60 cm × 40 cm × 50 cm).

But translated to the world of microreactor manufacturing, the advantages greatly outweigh the disadvantages. The enormous freedom in design allows one to design the most intricate channel geometries, thereby harnessing what the sec-

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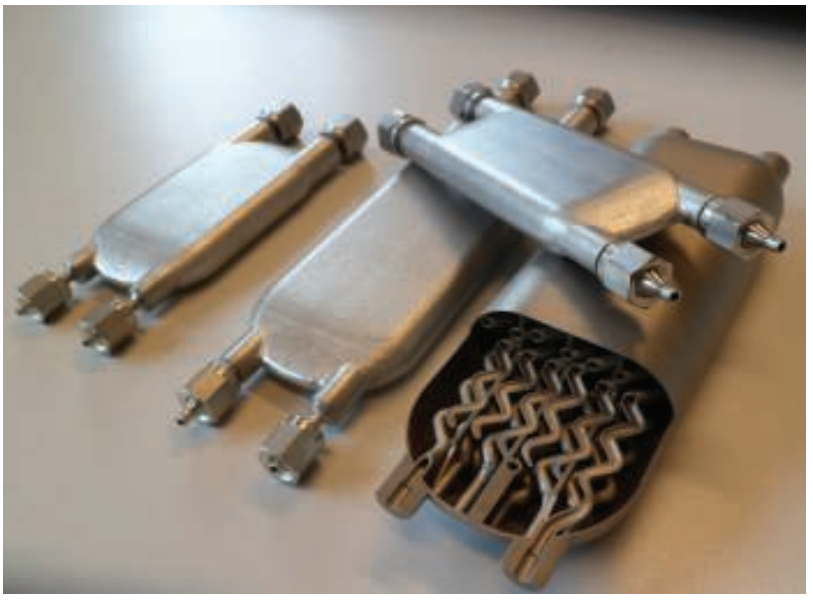

FIGURE 8. These flow-reactor modules were manufactured by 3-D metal printing

ondary flow universe has to offer. So far, we were able to develop 3-D printed microreactor modules with up to 600,000 kg/m^{3}h productivity. At this level, a single liter of reactor volume achieves close to 5,000-ton/yr production capacity.

With channel walls less than a millimeter thick and capable to withstand hundreds of bars internal pressure, the required consumption of construction material is extremely low. This feature allowed us to apply very expensive corrosion-resistant metals, such as tantalum (when needed), without jeopardizing the economic feasibility.

The cost structure for 3-D printing is largely determined by the high investment levels for a printer and the relatively low building speed. Fixed cost is therefore the main driver. Fired by its success in the exponentially growing markets, technological development is pushing firmly towards further reduction of printing cost. Technology experts expect that the cost for atomized metal powder and printer investment will drop significantly over the coming decade, as shown in Figure 7 [*21*]. Especially high-tech applications with low consumption of construction material will benefit. 3-D printing of microreactors (Figure 8) is such an application.

Concluding remarks

Process-intensification "thinking" led to the invention of the microreactor. The early success in the laboratory demonstrated the potential of the technology and created high expectations. The expression of that know-how into industrial microreactors failed badly, not in the least by the initially proposed numbering-up approach. The vast number of required micrometer-sized channels to come close to relevant production capacity led the industry into a dead-end street.

The insight that not the diameter, but merely the distance between adjacent fluid lamellae in the secondary flow needed to be micrometer sized was the key to unlock the stalled situation. Applying such secondary flow phenomena enabled high performance in reactors with channel diameters in the range of millimeters. The jump in manufacturability led to economic feasibility for production of high-value pharmaceuticals. Nevertheless, the cost related to the conventional manufacturing technologies withheld mainstream application in chemical production.

With the arrival of 3-D metal printing in the manufacturing arena, we are witnessing a further significant improvement of the feasibility. We strongly believe that 3-D metal printing is the disruptive manufacturing technology that will push industrial microreactors across the chasm and allow innovative chemical companies to develop feasible applications. ■

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Managing SIS Process Measurement Risk and Cost

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IN BRIEF

FIGURE 1. Flowmeters like the one shown here can play key roles in reducing risks with safety instrumented systems (SIS)

Successful implementation and management of a safety instrumented system (SIS) requires designers and operators to address a range of risks. First among these involves the specification of a proven measurement instrument, such as a flowmeter (Figure 1), and its proper installation for a given application, an undertaking that is fundamental to achieving the initial targeted risk reduction.

Second is the definition of the support required to keep the flowmeter (or other measurement subsystem) available at that targeted level of risk reduction throughout the life of the SIS equipment. The support for the flowmeter must be defined in the design and implementation phase.

Third involves following the recommendations found in the standard IEC 61511/ISA 84 (International Electrotechnical Commission; Geneva, Switzerland; www.iec.ch and International Society for Automation; Research Triangle Park, N.C.; www.isa.org), which provides "good engineering practice" guidance for SIS development and management. The emerging IEC 61511 Edition 2 introduces some changes to these guidelines, strengthening emphasis on the requirements for end users to collect reliability data to qualify or justify specifications and designs.

This article shows how to address those risks and describes several tools, capabilities and procedures that can be considered for designing and managing a SIS installation in flow-measurement applications.

Risk sources for SIS

Under IEC 61511-ANSI/ISA 84, operators and SIS designers are required to qualify the appropriateness of a SIS measurement subsystem to be effective in addressing an application-specific safety instrumented function (SIF). This not only includes the initial design of the SIS itself, but the qualification of the measurement subsystem used in that service.

The capture and assessment of data is used to qualify the use of measurement instruments in SIS applications. Even after this qualification, operational data and management of change of these instruments over their lifetimes in SIS applications must still be captured and assessed.

SIS measurement subsystems are typically exposed to challenging process and environmental conditions, so they tend to contribute a higher risk to the availability of the SIS than safety controllers, which are normally installed in a controlled environment.

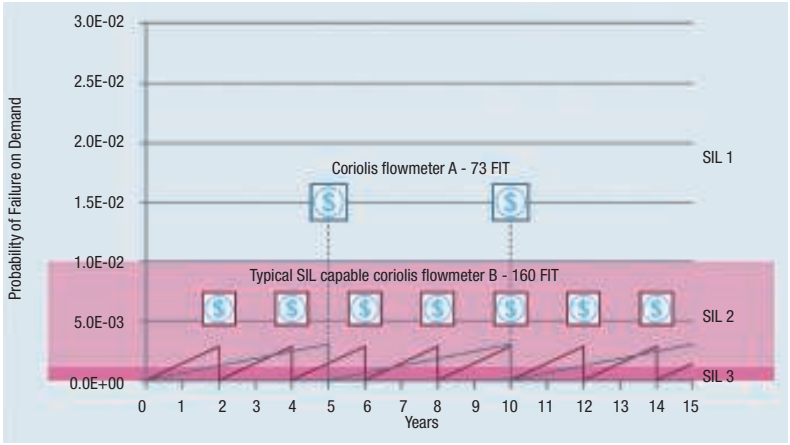

FIGURE 2. Flowmeters with a lower "dangerous undetected" (⌧du) FIT and in-situ testing capabilities may allow extension of the interval time needed for proof tests

Maintaing low PFD and λdu

Risk of failure to perform an expected function can come from probabilistic failure sources. For example, this includes the collective probabilistic failures of electronic components in a transmitter. Required maintenance and proof-test procedures must be determined and executed to keep both the probability of failure on demand (PFD) average and the lambda dangerous undetected (λdu; the failure rate for all dangerous undetected failures) fault risk (that is outside the reach of diagnostics) below a required average risk-reduction target.

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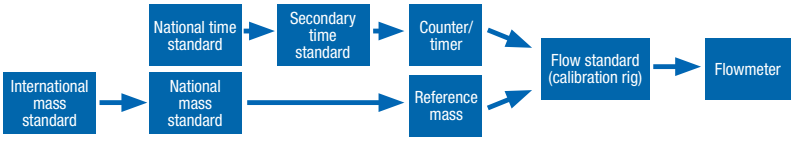

FIGURE 3. The figure shows a traceability chain for a mass flowmeter

Risk of failure to perform an expected function can also come from systematic failure sources. This could include damage to a sensor while being tested, for example. Systematic fault risk may be created by properties of the process fluids, operating conditions, build-up, corrosion or other factors. Periodic visual field inspections, calibrations and maintenance that may need to be conducted can introduce failure risk. There is some measure of risk from (and to) personnel who need to follow written procedures to conduct activities in the field and work with instruments that may need to be removed, transported, repaired, tested and reinstalled.

It has been stated by one of the world's largest chemical companies that "2% of every time we have human intervention, we create a problem." Another leading specialty chemical company conducted a study that concluded "4% of all devices (instruments) that are proof-tested get damaged during reinstallation." Reducing the need for personnel to physically touch a measurement subsystem offers designers an avenue to reduce systematic failure risk to a SIS.

IEC 61511 Edition 2 points to the need to specify in the safety requirements specification (SRS) the methods and procedures required for testing SIS diagnostics. SRS clause 10 states some of the requirements for proof-test procedures — including scope, duration, state of the tested device, procedures used to test the diagnostics, state of the process, detection of common cause failures, methods and prevention of errors.

Measurement subsystems from several instrument suppliers are now available with integral redundant self-testing diagnostics that can conduct continuous availability monitoring. This means a measurement subsystem may not only have high diagnostic coverage, but also redundancy — meaning the testing functions are redundant and continuously checking each other. This redundancy provides a number of benefits for the lifecycle management of instruments used in a SIS.

Extending proof-test intervals

Periodic proof-testing of the SIS and its measurement subsystems is required to confirm the continued operation of the required SIF, and to reduce the probability of dangerous undetected failures that are not covered by diagnostics. A proof-test procedure for a flowmeter or other measurement devices often requires removal of the instrument and its wiring, transportation to a testing facility, and reinstallation afterward. In some cases, modern instrumentation may provide the capability to conduct proof testing in-situ, thus eliminating the removal of equipment and risk of wiring, instrument or equipment damage.

Safety Integrity Level (SIL)-capable measurement subsystems typically have hardware and software assessments conducted during their development to determine failure mode effects and diagnostic analysis and to manage change processes according to IEC 61508-2, 3. The λdu and proof-test coverage values, among other safety parameters, are provided in a safety function manual and described in a certificate. Lower λdu values give system designers greater freedom when setting measurement subsystem proof-test intervals, because these intervals contribute a lower increase in PFD over time.

For example, some Coriolis flowmeters have λdu values in the range of 150 to 178 failure in time (FIT, where 1 FIT= 1 failure in a billion hours). Others, such as two-wire Coriolis flowmeters, have λdu values in the 73 to 89 FIT range. Vortex flowmeters with λdu in the 70 to 87 range are also available. If all other factors were equal, a measurement subsystem with half the FIT value could allow a doubling of the proof-test interval time (Figure 2).

Some measurement subsystems offer the capability to remotely invoke in-situ proof testing with a high degree of proof-test coverage to reduce the PFD subsystem contribution.

Given that external visual inspections are sufficient for at least some proof-test events, these measurement instruments might be proof-tested in-situ without the need to remove the instrument from service. Data from these proof-tests can be transmitted via 4–20-mA HART connections from the instrument to and through some safety control systems to a digital network, such as Ethernet/IP, where these data can be captured. In short, the proof-testing event can be invoked, and related data can be captured, managed and reported through safety control systems supporting these capabilities.

In-situ proof testing can create documented evidence that diagnostic checks have been carried out, and thereby fulfill the requirements for documentation of proof-testing, in accordance with IEC 61511-1, Section 16.3.3b, "Documentation of proof testing and inspections." When in-situ proof testing can be engineered into an SIS design, cost may be reduced compared to the expense of periodically removing the instrument from service to perform testing.

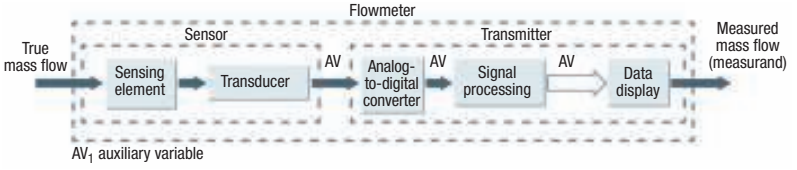

FIGURE 4. The diagram illustrates the relationship among the various subsystem elements of a flowmeter

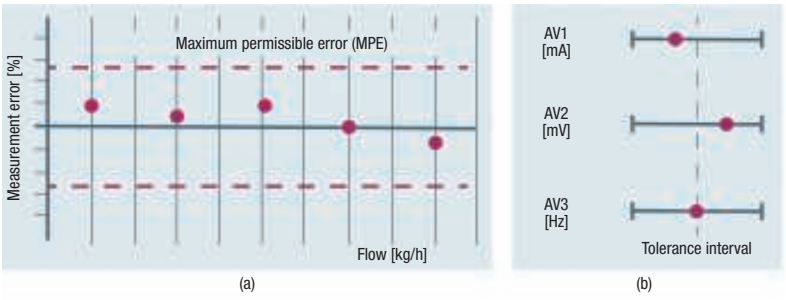

FIGURE 5. All measurements results from a particular instrument need to be within the band between the measuring error of the instrument and the maximum permissible error for the verification to be considered positive (AV = auxiliary variable)

Traceable calibration verification

Measurement subsystem proof-test procedures often require calibration verification of the measuring instrument. As operators seek to set proof-test intervals, they also need to set associated intervals for calibration verification.

Verification and documentation to prove that the SIS subsystem calibration is acceptable normally requires removal of the subsystem. This exposes the instrument to damage during removal, transport and reinstallation. There is also a risk introduced for unrealized damage or the introduction of an error due to process shutdowns, which are often required when an instrument is removed from service.

The measurement subsystem may need to be calibrated or verified with traceability to an international standard. If an organization is ISO 9001:2008-certified, it needs to address Clause 7.6a (Control of monitoring and measuring devices), which states: "Where necessary to ensure valid results, measuring equipment shall…be calibrated or verified at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards."

Some measurement instruments provide certified integral and redundant references that have been calibrated via accredited and traceable means, and can thus have their measurement calibration verified in-situ. This eliminates sources of risk and cost associated with removing instruments from service, while still meeting ISO 9001:2008 Clause 7.6a requirements.

Redundant references

Appointed with the task of coordinating the realization, improvement and comparability of worldwide measurement systems, the International Bureau of Weights and Measures

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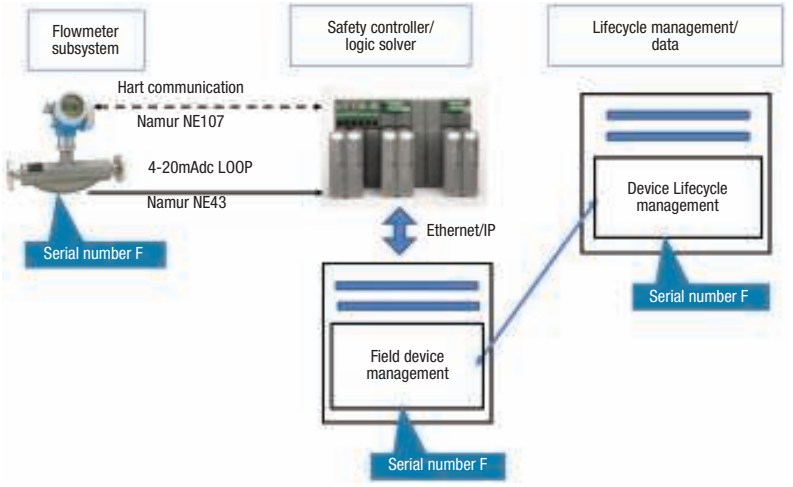

FIGURE 6. Cloud- or enterprise network-based lifecycle management tools can provide support documentation for specific instruments

(Sèvres, France; www.bipm.org) defines traceability as "the property of a measurement result to be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty." Figure 3 shows a traceability chain for a flowmeter.

The term "measurement result" can be used in two different ways to describe the metrological features of a measuring instrument:

1. Measurand (Process Value): Output signal representing the value of the primary process variable being measured (that is, mass flow).
2. Auxiliary variable: Signal(s) coming either from the instrument's sensor (transducer) or a certain element of the transmitter, such as an analog-to-digital (A/D) converter, amplifier, signal processing unit and so on. This variable is often used to transmit current, voltage, time, frequency, pulse and other information.

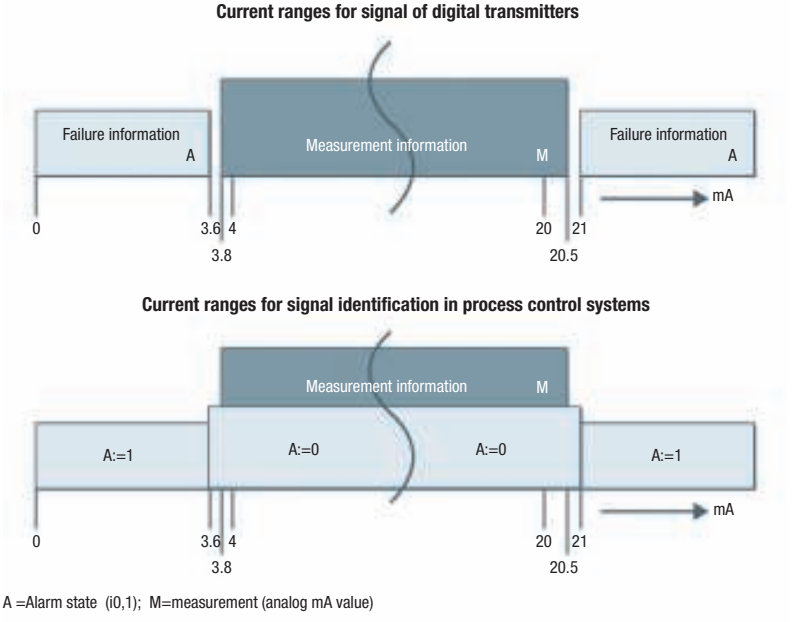

FIGURE 7. NAMUR NE43 recommendations for 4–20-mA d.c. transmitters (top) and process control systems (bottom) address the risk of mixing different vendor-specific current range signal levels

Figure 4 illustrates the basic concept and the relation among subsystem elements in a flowmeter.

During the lifecycle of any instrument, it is important to monitor measurement performance on a regular basis (ISO 9001:2008 Chapter 7.6.a), especially if the measurements from the instrument can significantly impact process quality.

For example, in Figure 4, the process value is defined as mass flow, and a traceable flow calibration system can be used to perform a proof test. Typically, the outcome of this test is seen in calibration certificates as a graph depicting the relative measuring error of the instrument and the maximum permissible error band. All of the measurement results are expected to be enclosed within this band for the verification to be considered positive (Figure 5a).

A second approach (Figure 5b) consists of assessing the functionality of an instrument by looking at one or more elements that can significantly impact the process value. In this case, verification can assist in assessing the instrument's functionality by observing the response of the process variable and the auxiliary variables. The auxiliary variables are compared to specific reference values to make sure they are within a tolerance interval established by the manufacturer.

Typically, proof testing requires the flowmeter to be removed from the process line and examined with specific equipment, such as a mobile calibration rig or a verification unit. This rig or unit needs to be maintained and calibrated by qualified personnel, thus introducing a costly and time-consuming procedure. The process has to be shut down to perform testing, often resulting in a loss of production. If removal and reinstallation of the flowmeter are carried out in a hazardous area, safety issues can arise.

Modern instruments, such as mass flowmeters, typically have in-situ proof testing built into the devices. While many instrument vendors have similar solutions, there are significant differences in how they work. In the cases where flowmeter

Status signal	Color	Symbol
Normal; valid output signal		
Maintenance required; still valid output signal		
Out of specification; signal out of the specified range		
Function check; temporary non-valid output signal		
Failure; non-valid output signal		

FIGURE 8. Five standard status states are specified by the NAMUR NE 107 recommendation

hardware and its associated software can conduct in-situ testing, the approach is often different as well. For example, the authors' company embeds the verification functionality in the device electronics of the flowmeter, so removal of the flowmeter is not required.

A key requirement for this type of verification method is high reliability. The internal references used to verify the auxiliary variables must remain stable and avoid drift during the service life of the instrument. And if drift does occur, it must be detected immediately. The stability of the references can be addressed with durable and high-quality components. Potential drift can be detected by the use of an additional, redundant reference, so that each can cross-check with the other. If one or both references drift out of tolerance, these cross-checks can trigger an alarm.

Redundancy of the references is achieved differently depending upon the measurement technology:

- Electromagnetic flowmeters use voltage references because the primary signal generated by the sensor is a voltage induced by the conductive fluid passing through a magnetic field
- Coriolis, vortex, and ultrasonic flowmeters use frequency generators (digital clocks) as references because the primary signals are measured either by a time period (the phase-shift in a mass flowmeter or the time-of-flight differential in an ultrasonic flowmeter), or by the frequency of an oscillation (such as the rate of capacitance swings by the differential switched capacitor sensor in vortex flowmeters)

In flowmeter models where redundant references are in place, observing both references drifting simultaneously in the same manner is very unlikely. On an installed base of 100,000 flowmeters, such an event is anticipated to occur just once every 148 years. Put another way, a device with a typical lifecycle of 20 years would have only a 0.007% probability of experiencing such a drift during its life.

Independent, third-party verification of a particular redundant-references approach can be obtained by organizations such as TÜV Rheinland AG (Cologne, Germany; www.tuv.com), and verification reports thus obtained can satisfy the need to document the approach.

In practice, a verification report from an independent, third-party or-

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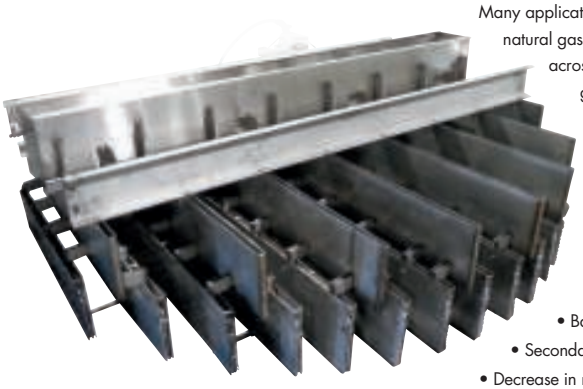

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ganization constitutes the front end of an unbroken, documented chain of traceability. Since the internal references remain valid over the lifetime of the instrument, their own factory calibration, performed in accredited facilities and documented, is the next link in this chain.

In addition, a traceable calibration of the instrument ensures that the integrity of the device has not deteriorated during assembly or handling in the plant. Calibration of the equipment used for calibration in the factory can then be traced back to national standards.

In-situ verification is therefore compliant with international standards for traceable verification.

Lifecycle management tools

ISA 84 and IEC 61511 — in particular, edition 2 clause 11 of the IEC document — require end users to collect reliability data to qualify or justify specification and design data. According to these documents, data quality and sources:

- Shall be credible, traceable, documented and justified
- Shall be based on the field feedback existing on similar devices used in similar operating environments
- Can use engineering judgment to assess missing reliability data or evaluate the impact on reliability data collected in a different operating environment

Collecting reliability data for SIS is costly, but lifecycle management tools are available to reduce the risk and required time for some of these activities. Several vendors offer lifecycle management tools that can work externally or through the safety system environment. They can also capture lifecycle events, such as systematic and probabilistic failures. If anomalies are detected, SIS components can be repaired or replaced. The right configurations can then be uploaded, reducing required time and risk of errors.

Field device management tools can work externally or through the safety system environment to invoke subsystem proof-testing and calibration verification, and to capture lifecycle events, such as systematic and probabilistic failures in the measurement subsystems. Subsystems can be repaired and replaced, and then the correct configurations can be uploaded, reducing time and risk of errors.

At least one field device management tool follows the Field Device Tool (FDT) standard from the FDT Group (Jodoigne, Belgium; www.fdtgroup.org), which provides a unified structure for accessing measurement subsystem parameters, configuring and operating them, and diagnosing problems. A logic solver with HART I/O and HART pass-through management capabilities can allow such a tool to work with the measurement subsystem to invoke in-situ proof testing and traceable calibration verification.

Some field-device-management tools can be used with device lifecycle management tools to aid in subsystem-related data support access and capture. These tools can also be integrated with overall lifecycle-management tools.

Several instrument suppliers provide, populate and maintain a real-time Cloud- or enterprise-based device lifecycle-management tool connection for individual device-specific support documentation, certificates, history, changes and calibration information.

For example, Figure 6 illustrates one possible configuration. In this case, information flows between a flowmeter subsystem through a logic solver (safety controller) to a field-device-management tool and device lifecycle-management software in the Cloud or on a local server.

In this example, the flowmeter and logic solver both use NAMUR NE 43-recommended current loop signal settings to reduce systematic risk from mixing the different vendor-specific current loop signal levels. Also, the flowmeter and logic solver both use standard HART Communication commands including the NAMUR NE 107 recommendation, which provides five clear actionable subsystem status indicators.

In the case of the author's employer, the FDT communicates though the logic solver with the flowmeter via 4–20-mA HART to monitor the device, to invoke in situ proof testing and calibration functions, and to diagnose problems. The field-device-management tool communicates via Ethernet/IP to a lifecycle management server installed within the user's network or the Cloud, where all flowmeter data are stored in accordance with ISA and IEC standards. The flowmeter data are synchronized and maintained from the flowmeter along with all associated data via its serial numbers.

The goal of this kind of field-device-management software is to enable plant operators to design a system that provides the following:

- Device power and wiring condition monitoring through the logic solver or safety controller
- Device primary current loop/secondary HART communication and status management through the logic solver
- Device repair/replace management through the logic solver
- Device proof testing management through the logic solver
- Device traceable verification of calibration management through the logic solver
- Capture and management of device proof testing, calibration, and other lifecycle data that may reduce risk and cost in SIS designs and lifecycle management

Detecting problems

A typical SIL-capable instrument, such as a flowmeter, connects to the logic solver or safety controller via 4–20-mA or 4–20-mA HART. These signals are also used to indicate problems.

Current signals per NAMUR NE 43 recommendations (Figure 7) convey measurement and failure information from the flowmeter to the safety controller via the 4–20-mA loop. Most every instrumentation and control system supplier offers options to support this standard. Essentially, any flowmeter and logic solver that follows the NAMUR NE 43 recommendation uses 4–20 mA for the measurement, and signals of less than 3.6 mA or greater than 20.5

mA to indicate failures. The benefit of following this practice is reducing the risk of mixing different instrument vendor-specific signal level variations with different safety controller signal level settings — something that could happen during a repair or replacement event.

Figure 8 shows the five standard status states specified by the NAMUR NE 107 recommendation. The NE 107 recommendation is now implemented within many HART-enabled devices for standard status communication. Under NE 107, problems are identified as normal, failure, out-of-specification, maintenance required and function check. The purpose of NE 107 is to alert systems and operations personnel in an actionable way if a problem exists. When the logic controller sees a NE 107 status indication change, it notifies the operator. Field-device-management tools can be used to provide additional diagnostic data to help identify specific problems.

Concluding remarks

Implementation of a SIS requires process risk protection to a targeted minimum while maintaining design and lifecycle costs at a reasonable level. Intelligent instruments and lifecycle management tools can help process plant personnel reduce risks and costs associated with a SIS system. They can also aid in capturing reliability data.

Instrumentation suppliers who serial-number their components are able to provide operators a realtime Cloud- or enterprise-based connection between the measurement device in the field and serial number-based support documentation, certificates, history, changes and calibration information. These data are maintained by the supplier for the user. Additional user data can be captured, including service history. This can help reduce the time required to obtain needed information, as well as reduce the risk of using the wrong information. ■

Edited by Scott Jenkins

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The Benefits Of Two-Stage Drying

Circular fluidized-bed dryers can boost the capacity, energy efficiency and product quality when used in conjunction with other primary dryers

James Schak and Sunny Nwadinma
Kason Corp.

Two-stage drying provides benefits from the standpoints of cost, energy savings, efficiency and product quality. This is especially the case when a circular, vibrating fluidized-bed dryer is employed as the auxiliary dryer positioned downstream of a spray dryer, or upstream or downstream of a rectangular fluidized-bed dryer, rotary dryer, belt dryer or other drying equipment.

Typical applications for two-stage drying include food products, such as flavors, yeast, starches, proteins, milk products and carbohydrates; organic products; agricultural chemicals; cellulose; fertilizers and other heat-sensitive products. In the milk industry, most spray dryers available today are two-stage dryers incorporating a fluidized bed dryer.

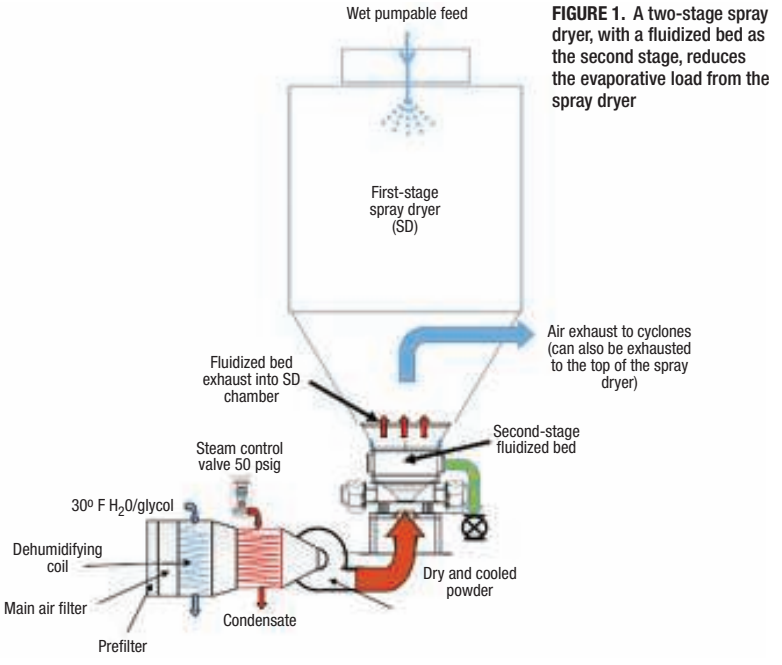


FIGURE 1. A two-stage spray dryer, with a fluidized bed as the second stage, reduces the evaporative load from the spray dryer

Spray dryer with 2nd stage

The most common application for adding a second-stage dryer is with a single-stage spray dryer. Spray drying is relatively expensive in terms of capital investment, operational costs, installation and construction. Not only can a two-stage dryer reduce costs, but often can produce a lower heat history and a higher quality product.

In Figure 1, a two-stage spray dryer with a circular fluidized bed as the second stage reduces the evaporative load from the more expensive and less energy-efficient spray dryer. The spray dryer dries the product to approximately 10 wt.% moisture (depending on the product), after which the circular fluidized-bed processor completes the drying and cooling.

Vibratory motion of the circular fluidized-bed dryer causes the material fed into the center of the fluidized bed chamber to flow outward to the discharge. Unlike static fluidized beds that rely on complete fluidization, the vibrating fluidized bed can handle a wide range of particle sizes, densities and shapes without rat-holing or excessive elutriation. The airflow can be adjusted to maximize drying efficiency without worrying about the degree of fluidization. Continuous vertical, uniform airflow maintains consistent product moisture and temperature.

Total drying time extended

Figure 2 shows how the second-stage fluidized bed optimizes the drying process as a longer drying time reduces the heat history. The longer retention time in the fluidized bed dryer provides the extended time needed in the final drying stage (falling rate drying zone). In a spray dryer, retention time is typically around 25 seconds, while in a fluidized bed, 5 to 10 minutes is not uncommon.

Spray dryers and fluidized bed dryers are both considered "air suspension dryers" wherein particles remain in contact with the air 100% of the time. Longer retention time in the fluidized bed permits lower

TABLE 1. OPERATING ADVANTAGES OF TWO-STAGE DRYING

Feed moisture: 70%
Product moistures: 10% between stages and 5% final

Example	1	2	3
One-stage air temperature, °F	300–170	500–230	900–280
Two-stage spray dryer air temperature, °F	300–145	500–300	900–245
Product gain, %	26	21	17
Heat saving, %	24	18	13

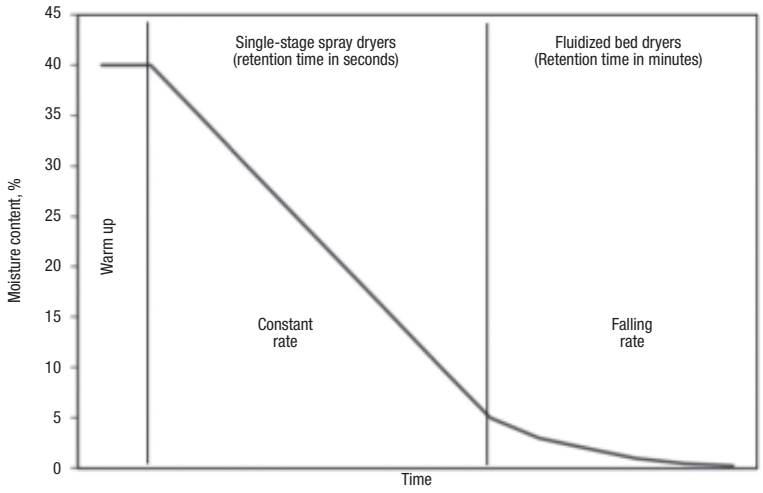


FIGURE 2. This typical drying curve helps to illustrate how a second-stage dryer can optimize the drying process

operating air temperatures, making drying more energy efficient than with spray drying alone, while reducing overall heat history.

Operating advantages

Table 1 shows the operating advantages of two-stage drying. The inefficiency of a direct dryer (that uses air to dry) is seen in the hot air exhausted. By reducing the temperature of the air exhausted or the amount of air consumed, energy consumption will be reduced. At the same time, a lower spray-dryer outlet temperature will increase the temperature difference (ΔT) and thus increase the evaporation capacity.

For Example 1, as mentioned in Table 1, the intermediate temperature of a two-stage dryer is 25 degrees lower than that of the single stage alone (170–145°F) starting with a spray-dryer inlet-air temperature of 300°F. The energy savings of the two-stage drying is 24%, while the productivity increase is 26%. At higher temperatures, as represented by Examples 2 and 3 in the table, the results are less dramatic, but still substantial.

Although the energy savings and productivity gains justify the cost of a second stage, so can the quality improvements, depending on the material being dried. Whereas a spray-dried product is greatly affected by the spray dryer's outlet air temperature due to evaporative cooling, the lower outlet air temperature of a second-stage fluidized bed results in a lower heat history of the product. A second cooling section can be added to the fluidized bed stage to further cushion heat sensitive products.

A spray dryer with an added circular fluidized bed will gain the following advantages:

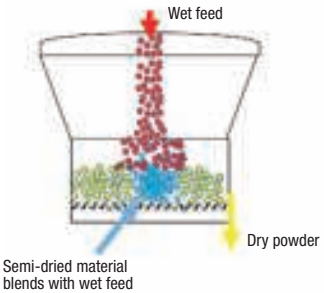
- Lower heat history and higher quality product
- Increased capacity
- Higher energy efficiency
- Less buildup of material
- Handle stickier products
- Controlled particle size
- Larger window of operation
- Lower cost
- Can add an agglomeration step
- More uniform drying of larger, difficult-to-dry, agglomerated particles

Additional advantages of a two-stage spray and fluidized-bed dryer combination include the following:

1. Direct top or bottom spray agglomeration capability in the circular fluidized-bed dryer
2. Dry larger particles via fines recirculation over the nozzle atomizer during spray agglomeration
3. Small footprint and plant space when using circular, instead of horizontal, fluidized bed as the second stage
4. Fluidized bed exhaust is recirculated into the spray dryer, gaining energy efficiency
5. Wider window of operation with cleaner spray-dryer chamber because of larger discharge port to the fluidized bed

A caveat is that two-stage drying may not be effective if the product undergoes a sticky stage or encounters flow issues at higher intermediate moisture levels.

Internal (circular fluidized beds):
- Wet feed is distributed (seeded to start)
- Good localized mixing gives consistent blended moisture
- Once-through design versus multiple passes with external backmix
- Deeper bed in center
- Vibrator can be adjusted for plug flow or backmix direction



External (rectangular fluidized bed):
- Hot dry product is discharged into a conveying system back into a paddle mixer that blends the sloppy feed with the dry product
- Some product may be redried more than once increasing the heat history
- Rectangular, vibrating fluidized bed requires external backmixing for too-wet feeds
- Shallow bed in inlet section
- Conveys in one direction

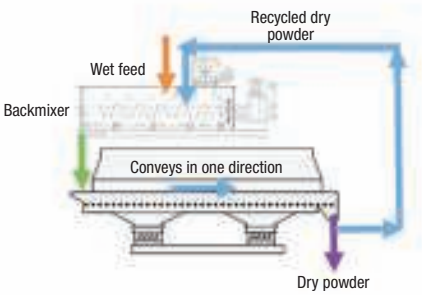


FIGURE 3. Some products may need re-drying and multiple back mixing passes, but internal back mixing, inherent in circular fluidized beds, accomplishes drying with minimal heat history to the product

Internal vs. external backmixing

The circular fluidized-bed dryer's internal backmixing, once-through design, as described in Figure 3, allows for a larger window of operation for difficult-to-handle feed materials. Other types of dryers use external backmixing, where some material may be re-dried more than once, increasing the heat history.

The circular vibrating fluidized-bed dryer, with internal backmixing, thus can handle a wetter feed than most other dryers. Internal

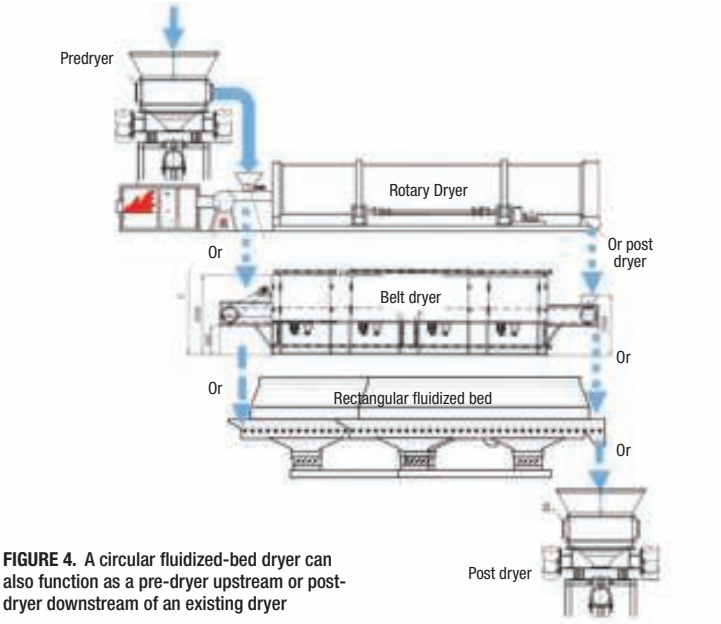


FIGURE 4. A circular fluidized-bed dryer can also function as a pre-dryer upstream or post-dryer downstream of an existing dryer

backmixing has been used successfully with deep-bed, static fluidized beds for many years. It has been further advanced with the circular vibrating fluidized-bed dryer, because internal backmixing allows handling of finer, non-free-flowing materials without requiring complete fluidization. The benefits of internal backmixing versus external backmixing are less heat history, less hardware, lower cost and smaller footprint.

Pre- or post-dryer

A circular fluidized-bed dryer can also function as a pre-dryer and pre-conditioner upstream or as a post-dryer and cooler downstream of an existing rectangular fluidized-bed dryer, rotary dryer, belt, flash or other dryer (Figure 4). Product buildup in the feed zone of these dryers can occur due to moisture fluctuations, lumps, stickiness, degradation and contaminants. Rather than replace the primary dryer, a circular fluidized-bed dryer can be added to pre-condition and pre-dry the material, greatly reducing moisture fluctuations that cause product buildup.

A pre- or post-dryer can also accomplish the following:

1. Increase capacity
2. Convert the cooling section of the dryer to a dryer zone and add cooling with a circular fluidized bed
3. Recirculate exhaust air to another stage for better energy efficiency
4. Add an agglomeration step to the circular fluidized bed, for example, spray liquid into the powdered material to form agglomerates as the material is fluidized and dried

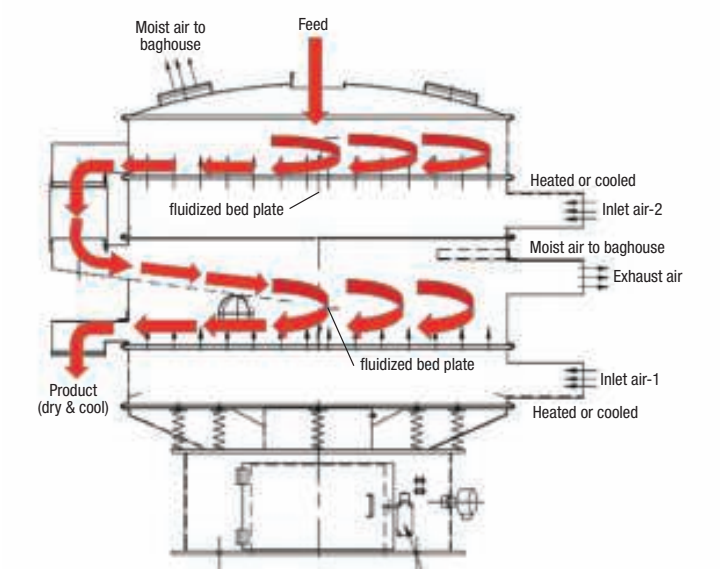


FIGURE 5. A new dryer design includes two separate air inlets and allows for drying and cooling in one unit

New dryer designs

New designs include a patent-pending one for vibrating circular fluidized beds as shown in Figure 5, which allows two separate stages for heat transfer. That is, drying and cooling, or drying and drying, or cooling and cooling, at different temperatures. The unit has two separate fresh air supplies each with its own temperature controls. ■

Edited by Dorothy Lozowski

Authors

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BULK SOLIDS HANDLING WORKSHOP

Best Practices for Challenges, Safety & Solutions

Preliminary Agenda

*A **Keynote** address by Herman Purutyan, CEO of Jenike and Johanson will kick off the workshop and the following sessions will follow:*

Bulk Solids Characterization
The design of successful bulk handling installations starts with an understanding of the properties of the materials involved. This lecture covers the proper sampling of bulk materials and the measurement of the three key parameters for flowability analysis – cohesive strength, bulk density, and wall friction. Flowability measurements for product quality control are also reviewed, as are the two most common particle size measurement techniques – laser diffraction and sieve analysis.
Presenter: Timothy A. Bell, P.E., Engineering Fellow and Group Technology Leader, DuPont Engineering Research and Technology

Flow of Solids
The field of bulk material handling is quite complex. Bulk solids theory has unique terminology, scientific flow principles that are not the same as fluid or gas flow behaviors, and often are not taught to engineers at the university level. Personnel responsible for designing, fabricating, installing, and operating bulk material handling equipment are often unaware of the complex flow behaviors that can occur with bulk solids. Dr. Orlando will be covering the basics of Bulk Solids Handling while discussing Common Flow Problems, Material Testing, Design Considerations and Design Tools to solve your solids flow issues.
Presenter: Andrés Orlando, Ph.D., Project Engineer, Jenike & Johanson

Combustible Dust Safety
Many powders will burn slowly or with difficulty as a layer on a surface, but can explode if dispersed as a cloud. In fact, the vast majority of powders can form explosible dust clouds if the particle size is small, moisture content is low, and the dust cloud concentration (measured in g/m3) is above the Minimum Explosible Concentration (MEC). This presentation will discuss a well-tried approach to identify, assess, and eliminate/control dust explosion hazards in facilities. This presentation will also include the "Dust Hazard Analysis (DHA)" requirements of the New National Fire Protection Association (NFPA) 652: Standard on Fundamentals of Combustible Dusts.
Presenter: Vahid Ebadat, Ph.D., Chief Technology Officer, Chilworth Technology

Feeders and Rotary Valves
Virtually all solids handling systems require the metering of solids from one part of the process to the next, often with precise rate control, and sometimes across gas pressure differentials. This lecture covers most common feeding devices, with a particular emphasis on screw feeders used in loss-in-weight applications. Applications of rotary valves as feeders and as air locks will also be discussed, as will the role of rotary valve leakage in pneumatic conveying operations.
Presenter: Timothy A. Bell

Pneumatic Conveying
Although many pneumatic conveying equipment advances have been made, costly problems – including wear, attrition, rate limitation and line plugging – continue to occur. Brian will cover the basic components of pneumatic conveying systems, as well as discussing the basic troubleshooting of systems to identify issues in your lines.
Presenter: Brian Pittenger, Senior Consultant, Jenike & Johanson

Register today at chemengonline.com/bulksolids.com

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Air-Pollution Control: Assessing the Options

Compliance with air-pollution regulations requires ongoing effort. Follow these recommendations to assess competing options and optimize system design while minimizing cost and risk

Thomas F. McGowan
TMTS Associates, Inc.

Tom McGowan

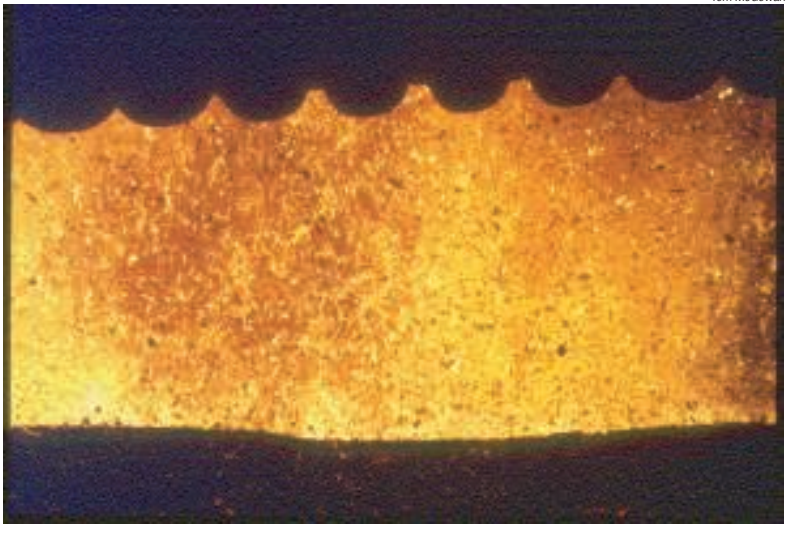

FIGURE 1. This wood-fired boiler furnace with a pneumatic spreader stoker shows lots of wood particles and burning embers above the grates

The goal of air-pollution control (APC) is to limit the amount of pollutants entering the environment. These include particulate matter (PM), acid gases, greenhouse gases, organic vapors such as hazardous air pollutants (HAPs), volatile organic compounds (VOCs), non-condensed gases (NCGs), aerosols, dioxins, oxides of nitrogen (NOx), metals and others. This article focuses on pollution from combustion sources, but the equipment discussed here can be applied to other applications, as well.

It has been said that a good engineer can build for a dime what any fool can build for a dollar. The same can be said for savvy plant managers. Smart chemical process industries (CPI) firms do their homework before installing air-pollution control systems [*1*]. They consider process changes (such as switching to the production of low-VOC coatings), plant-siting considerations (for instance, avoiding non-attainment areas, or those with complex terrain that may require tall stacks), and better capture systems (to reduce the volume of fume to be treated) before making a final decision on hardware. Nonetheless, other choices must be made — such as choosing a wet or dry system, and tradeoffs between cost of power versus capital — to optimize the final system's design.

Removal of particulate matter

Particle loading in the fluegas from any industrial process is measured in grains/dry std. ft^3 (grains/dscf) or mg/dry std. m^3 (mg/dscm) or mg/normal m^3. The particle loading in the gas will vary widely depending upon a number of factors, including the gas velocity, particle size, particle density and the nature of the upstream process and feedstock. The smaller the particle, the more easily it is carried by the fluegas, even at relatively low gas velocity. As the gas velocity increases, larger particles can be carried by the fluegas stream, and the number of particles of all sizes that can be carried increases (Figure 1).

U.S. federal and state regulations related to particulate matter vary with the process and the scale of the equipment. In the U.S., historic state and federal particulate limits (for example, the Resource Conservation and Recovery Act, or RCRA) were typically 0.08 grains/dscf (180 mg/dscm). By comparison, newer limits are generally at or below 0.02 grains/dscf (45 mg/dscm). This requires better, more-expensive controls, and better design, operation and maintenance strategies. Coal- and wood-fired boilers [*2*], and cement kilns are some examples of applications with high particulate levels upstream of the APC systems.

Dry-particle-removal systems. When it comes to removing dry particulate matter from fluegas streams,

Tom McGowan

FIGURE 2. The image at left shows two baghouses installed in parallel. On the right, the cage is inserted into filter bags, and pulse-jet pipes provide blowback to clean the dust off the filter

Bionomic Industries

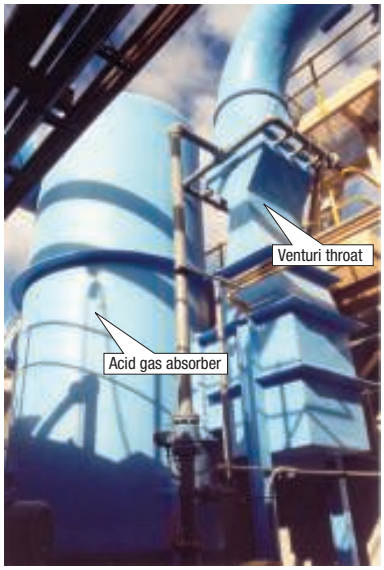

FIGURE 3. Shown here is a venturi scrubber and slinger tank/acid gas absorber with an internal mist-elimination system

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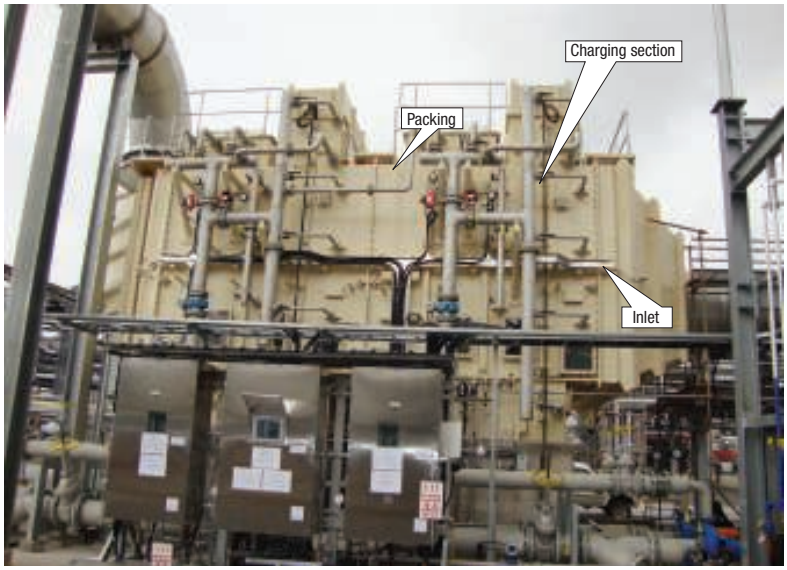

FIGURE 4. In this two-stage ionizing wet scrubber, particles are charged, then removed on grounded plates and on packing; a periodic wash flushes and cleans the plates and packing

the options include cyclones, fabric filters (Figure 2), and electrostatic precipitators (ESPs). If acid gases are present in the fluegas stream, these devices must be insulated to keep their shells above the acid dewpoint. The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and other sources publish charts, graphs and calculators to determine SO_2 and HCl dewpoints. If the wall temperatures of these pollution-control systems fall below the acid dewpoint temperature, acid vapors may condense on the metal surface and this will result in high rates of corrosion.

Wet-particle-removal and vapor-removal systems. When unwanted pollutants must be removed from the fluegas stream, the options include wet cyclones, venturis (Figure 3), wet electrostatic precipitators (WESP), and ionizing wet scrubbers (IWS; Figure 4). With regard to particulate emissions, venturis (Figure 3) tend to have limited ability to remove fine particles, and they experience exponentially higher pressure drops when forced to remove particulate matter. In recent years, with tighter U.S. Environmental Protection Agency (EPA) limits, the use of venturis as a standalone particulate-removal device has fallen out of favor.

Due to more stringent and complex regulations for multiple pollutants, different APC systems are frequently used in series. For instance, a venturi scrubber may be used to remove particulate matter, followed by a packed tower to remove acid gases, followed by a mist-elimination system to reduce droplets in the stack (Figure 3).

The wet-versus-dry decision is far from clear cut. Some industries tend to use dry systems (for example, the ESPs used in coal-fired power plants), while others prefer wet systems, such as an ionizing wet scrubber (Figure 4). Preferences change over time with more-stringent regulations. Disposal options for the removed particulate matter (that is, the resulting dry dust, wet sludge, or stabilized mixture that is formed during treatment) is another major factor in decision making. Cement kilns are an example, where baghouses are used to capture cement kiln dust (CKD), which is a salable product, while a wet capture system would form unsaleable (and system-fouling) cement solids.

For dry ESPs, the resistivity of the collected flyash is an issue, and changing the coal feed source can

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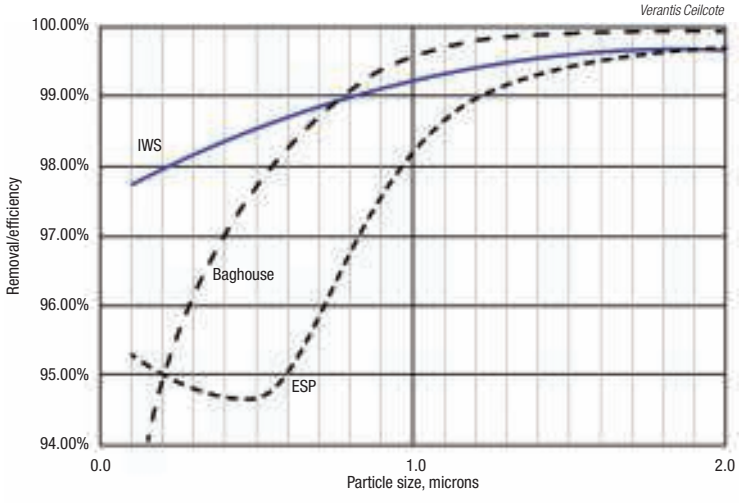

FIGURE 5. In this graph of particle size versus removal efficiency, three of the most commonly used APC devices experience a decline in collection efficiency as the particle size of the pollutants falls. This phenomenon is least pronounced for the ionizing wet scrubber (IWS)

change the resistivity and associated particulate-removal efficiency. Dust with high resistivity can be held too strongly to the grounded ESP plates, while low-resistivity dust may become re-entrained in the gas stream. By comparison, an IWS is immune to the effects of flyash resistivity.

Each of the devices mentioned here has its own characteristic operating curve. Figure 5 provides a comparison for an IWS, baghouse and dry ESP. Note that the collection efficiency for all of these devices begins to fall off for smaller particles, with the IWS having the least-rapid decay of its efficiency curve. IWS are frequently used in series with two or three in a row, in part, to maintain removal efficiency during their required periodic wash cycle; in this scenario, a downstream unit operates while the upstream unit is being washed down.

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Tom McGowan

FIGURE 6. Fouling of spray nozzle by lime solids requires periodic changeout or chemical treatment

Acid-gas removal

Combustion systems, chemical process operations, metals-recovery systems and incinerators produce acid gases, such as HCl and SO_2. Acid-gas removal can be accomplished using either a wet or dry system.

Wet systems. The wet system generally has a higher removal efficiency and uses more nearly stoichiometric amounts of a basic (alkaline) reagent compared to the dry system. In general, wet systems use a basic material such as lime or NaOH (caustic) to neutralize and remove the acid. For wet systems, blowdown must be handled (generally limited to 5% total dissolved and suspended solids), and operators should note that publicly owned treatment works (POTWs) and sewers may have limits on the salt content and temperature of accepted discharge streams.

Fouling of spray nozzles is to be expected over time (Figure 6). Good design allows for nozzles to be pulled from the outside of the unit for easier maintenance. It is a good practice to bench-test nozzles — both new and after cleaning — with water, to make sure the spray pattern is what is expected. Use of small amounts of sequestering agents, like hexametaphosphate for lime fouling, can significantly reduce nozzle plugging. In some CPI applications, an acid gas (such as HCl) can be captured during fluegas treatment, and then concentrated and reused in the process.

Dry systems. Dry systems typically

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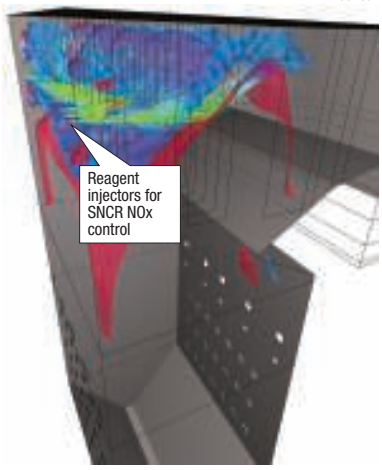

FIGURE 7. CFD modeling results are shown here for a large-scale boiler NOx-control application using a SNCR system. The colors are coded to show velocity. The green-yellow streams show the zones of NH_3 regent injection and mixing with fluegas

rely on one of two approaches — they inject powered lime or sodium-based reagents upstream of dry fabric filters or ESPs, or they spray a lime slurry into the spray-drying tower. These reagents adsorb and react with acid gases, removing them from the fluegas in the form of solid particles.

While not an acid gas, CO_2 produces greenhouse gas issues. For each pound of carbon burned in a CPI process, 3.67 lb of CO_2 is released. Using engineering principles to maximize fuel economy, maintain insulation, and carry out regular steam-trap maintenance can help to reduce the CO_2 burden. While EPA has put forth limits on utility power plants, in the CPI, CO_2 emissions are driven principally by longterm corporate goals rather than regulations.

Much has been said about CO_2 capture. However, this is a costly undertaking. And, parasitic power loss for associated utility operations has been estimated to be in the range of 30% for amine-based systems including the cost of CO_2 compression, and some consider burning 30% more fuel to capture CO_2 a questionable practice.

NOx control

EPA requires control of NOx, as NOx reacts with organic vapors in the presence of sunlight to produce ground-level ozone. The low-cost way to limit NOx is to do so upstream in the combustion process, for instance, via low-NOx burners, and low-oxygen firing systems [*3*]. This article focuses on the downstream or end-of-pipe methods that are most widely used.

The NOx levels resulting from any combustion operation are a function of a number of factors, including flame geometry, oxygen level, mixing, temperature, time and nitrogen level in the fuel. All conventional combustion systems produce "prompt NOx," and "thermal NOx." In addition, "fuel NOx" is created when the fuel contains nitrogen.

Some processes, such as cement and lime kilns, preheat air in the range of 2,000°F and operate at very high temperatures. NOx levels of 2,000 ppm are not unusual. "Normal" NOx levels from standard burners (for instance, those used in packaged boilers) are in the range of 100–200 ppm. So-called low-NOx burners typically produce less than 50 ppm of NOx, with ultra-low-NOx burners producing NOx at levels below 25 ppm. When preparing a permit application, use U.S. EPA AP-42 estimates [*4*] or conservative vendor quotes for NOx levels.

Fluegas recirculation is a popular NOx-reduction method for packaged boilers, both new and retrofit. With such a system, low-oxygen fluegas is injected into the burner along with fresh combustion air. When carried out properly, there is little change in efficiency and boiler output. However, it takes more sophisticated controls to maintain sufficient oxygen levels to ensure combustion while reducing overall oxygen levels with this system to minimize NOx formation.

Post-combustion control options to reduce NOx emissions consist of selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR), both of which involve the injection of a chemical reagent (ammonia or urea) into the fluegas stream. SCR processes typically operate at lower operating temperatures, ranging from 450 to 700°F. By comparison, SNCR processes operate at higher temperatures (just downstream from the furnace), ranging from 1,600 to 2,100°F. SCR systems are more efficient in NOx removal than SNCR systems, but have

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much higher capital costs. Computational fluid dynamics (CFD) modeling (Figure 7) is frequently done for SNCR systems, to help users to optimize injection points, enhance mixing and estimate NOx-removal efficiency. In general, CFD is not used as frequently for modeling SCRs, because such systems use a chamber to house the catalyst and the catalyst pressure drop helps to even out fluegas flow.

VOC control

The primary non-transportation sources of VOC emissions are chemical process operations (such as reactions); storage and transfer (such as pumping and working losses and tank-breathing losses); manufacturing (solvents); and surface coating (spray painting and dipping).

Three primary control technologies are used for VOC: thermal oxidation; adsorption via activated carbon or zeolites (or both); and condensation. Biofilters can also be used in some applications. Choosing the right control for each application involves knowing the following:

- Vent flowrate and concentration of VOC in the fume stream
- Chemical properties of the fume and oxygen content (especially the presence of chlorine or sulfur, as this produces acid gases when oxidized)
- The nature of the process (continuous, cyclical or variable)
- The ability to use waste heat generated by the control device
- State and federal regulations

The control system includes the hoods, ductwork, fans and controls needed to capture and deliver the VOCs to the control device, such as a refrigerated condenser unit, an activated-carbon adsorption unit, or more usually, a thermal oxidizer. Thermal oxidation devices convert VOCs to carbon dioxide and water vapor. The most widely used types of thermal oxidizers, in order of decreasing VOC concentration, are the following [*5, 6*]:

- Flare (Figure 8)
- Direct-fired oxidizer
- Recuperative oxidizer
- Catalytic recuperative oxidizer
- Regenerative thermal oxidizer (RTO) with hot-gas bypass
- RTO with 95% heat recuperation (Figure 9)
- Catalytic RTO

Space does not allow addressing every detail that must be considered in choosing the right oxidizer, but some considerations are presented:

- Flares are limited to gases above the lower explosion limit (LEL), but a fume can be boosted with natural gas if its heating value is marginal or variable
- An enclosed elevated flare, or elevated flare, has no test ports, and is not subject to VOC-control stack testing
- Direct thermal oxidizers can handle high particulate-matter loading, while recuperative, RTOs, catalytic and recuperative catalytic types do not fare well with it
- RTOs subject to cold-face buildup on the heat-exchange media from blue haze (aerosol liquids) from wood dryers and carryover from spray-paint coat-

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TABLE 1. CONTROL DEVICE PRESSURE DROP		
APC Device	**Emission**	**Pressure drop**
Direct thermal oxidizer	Organic vapors	1 in. water column (w.c.)
Regenerative thermal oxidizer (RTO)	Organic vapors	15 in. w.c.
Venturi scrubber	Particulate matter	10–80 in. w.c.
Acid gas absorber	Acid gases	2–6 in. w.c.
Coalescing mist eliminator	Submicron liquid aerosols	10 in. w.c.
Baghouse fabric filter	Particulate matter	4–8 in. w.c.
Dry electrostatic precipitator (ESP)	Particulate matter	1 in. w.c. per stage
IWS	Particulate matter	1 in. w.c. per stage

TABLE 2. POLLUTION CONTROL SYSTEM POWER AND ELECTRICAL COST				
Device	**Pressure Drop, in. w.c.**	**Particulate loading, gr/dscf**	**Motor horsepower**	**Annual electrical cost***
Venturi	10 in.	<0.08	75	$43,000
Venturi	60 in.	<0.02	400	$230,000
Baghouse	7 in.	<0.02	50	$ 30,000

*Based on $0.10/kWh x 8760 h/yr x 90% onstream x 0.746 kWh/hp

ings require a periodic bake out cycle to keep them clean; otherwise they may cause plugging or overheat when the buildup eventually catches fire

- Three-chamber RTOs (or rotary-valve RTOs, or those with puff chambers) should be considered for odor-control applications, to prevent the release of untreated gases during the small intervals when valves change the direction of gas flow
- Flashback-prevention devices (such as seal pots, flame arrestors and others) are required for some applications

Capturing VOCs is an issue, and EPA requires capture tests for some sources, to make sure that fugitive emissions do not exceed limits. Capture tests can be eliminated if a permanent total enclosure (PTE) is used to prevent VOC losses in a manufacturing environment. For tank farms, conservation vents reduce losses to the ductwork system [7].

Condensing systems return the vapor back into a usable liquid; however, they only work on vent streams with relatively high concentrations (for instance, 50 vol.% VOC). Carbon and zeolite adsorbers capture the VOCs temporarily, then release them when the adsorbent is heated with steam or hot air. Some of these systems can concentrate the material sufficiently for recovery while others send the concentrated vapors to thermal oxidizers.

Mercury and dioxins

Mercury and air toxics (MATS) regulations have impacted coal boilers in a big way. The usual approach to managing mercury is to inject powdered activated carbon (PAC) upstream of fabric filters and ESPs.

Circle 42 on p. 82 or go to adlinks.chemengonline.com/61498-42

John Zink

FIGURE 8. Shown here (above left and top) is a small, elevated enclosed flare that operates in a "smokeless," air- assisted type

Durr Environmental

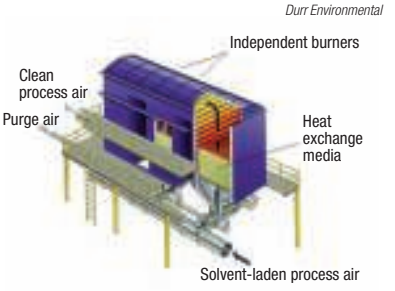

FIGURE 9. This three-chamber RTO, with 95% heat recuperation, has the ability to capture and treat fumes when the valve change over occurs to reverse the direction of flow

PAC producers have made major expansions over the past five years to keep up with demand. PAC is effective at temperatures up to 350°F. Higher than that, heat desorbs the mercury. Typical carbon-injection rates are 2 to 5 lb/million acf (actual cubic foot) of stack gas, varying with the amount of mercury in the coal and type of particulate filter.

Wet scrubbers can be used to remove elemental mercury if they are equipped with cooling towers to reduce stack exit temperatures to the required level. Meanwhile, dioxins are formed from organic chlorine in the feedstock, and even inorganic chlorine forms some HCl and Cl_2 in high-temperature combustion processes. The solution here is twofold — keep baghouse or ESP temperatures below 450°F to limit "de novo" formation from the chlorine in the stack gas, and use PAC or catalyst-coated filters to remove it.

Multi-pollutant control

While individual APC components can be placed in series to get the job done, single units with multiple capabilities also exist. An example are filters for PM removal, combined with urea or ammonia injection for NOx control and 1-in. thick catalytically treated filter walls. Temperatures of 400°F are preferred for dry-reagent injection for SO_2 removal (Figure 10). Yet another firm sells filter bags with a coating that removes dioxins. Activated carbon can be added for mercury and dioxin removal.

Auxiliary systems

Fans and blowers. These components are of prime importance because they move both the air into a combustor and the fluegas or process vent streams out of it. Combustion air is supplied by either a forced-draft fan, an induced-draft fan or both.

Fans may be driven by electric motors or in large sizes, steam turbines. The speed of the fan may be variable or fixed. Fixed-speed fans and blowers control air flow via a mechanical damper on the inlet to the fan, while variable-speed systems control air flow by changing the shaft speed. Variable-speed drives (VFDs) are popular, due to decreased power costs when compared to damper flow control. Gas temperature, fan alloy, resistance to corrosion, and sound level must be figured into the fan specifications.

Power required for the induced draft (ID) fan is equal to flow times pressure drop. In most applications, the flowrate of fume is fixed, however, pressure drop — and power consumption — varies widely with the control device. Table 1 provides some typical pressure drop values. As can be seen, venturis are not a good choice at high pressure drops, and even then, may struggle to remove very fine particles.

Mist and aerosol eliminators.

Tri-Mer

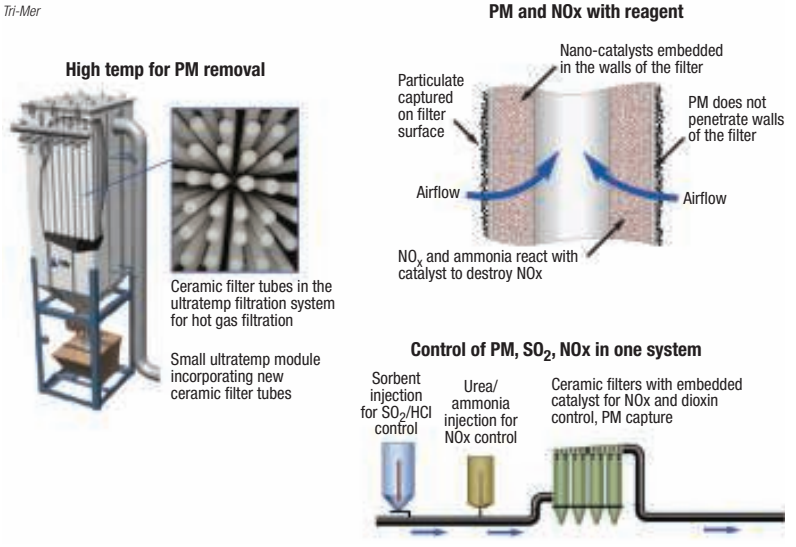

FIGURE 10. This example of an all-in-one, multi-pollutant-removal system uses reagent injection and catalytic bag filters

Gas leaving a wet scrubber or a condenser will contain mist and fog droplets. A mist-elimination unit or entrainment separator is used to remove them. Such devices typically use a wire or plastic mesh pad, or a series of baffle plates, which intercept the mist and allow them to coalesce into larger droplets, which then drain from the system.

Removal of very small aerosol droplets (less than 1-micron size), such as SO_3/H_2SO_4, require the use of coalescing mist-eliminator "candles" or mats made of a thick, dense packing, and this often results in correspondingly higher pressure drops and power requirements. An IWS can also remove submicron liquid aerosols and reduce stack opacity. Some states require (and some operating companies prefer) to have a clear stack (for example, a high-tech chip maker operating in the middle of a city). Wet scrubbers typically produce a white steam plume, and this can be eliminated by adding a heat exchanger or stack burner. Finally, in addition to the "front half catch" of hard, dry particulate matter in the front of an EPA test train, some permits require measurement of the "back half catch" of condensable liquids. Unfortunately, these include "pseudo particulates" that do not exist in the stack but rather are formed in the cooled test train impingers. The author has had success working out this issue with regulators when the failure was due to pseudo — not real — condensables.

Stacks. Predicted ground-level pollutant concentrations per dispersion models can be high and unacceptable if there is downwash due to nearby structures. Hence, we suggest stacks be at least 75 ft tall. Per codes, at a bare minimum, they must be 10 ft above nearby equipment and roof tops; this is to protect personnel and air intakes. Even if the current permit is not subject to dispersion, it may be subject to it in the future. Downdrafts can also trigger complaints from nearby neighbors by bringing emissions to ground level.

For testing, it is important to design in two test ports at 90 deg to each other, each with a minimum 3-in. dia., with stack clips to aid stack testers in their test work, with a minimum of 2 diameters upstream and a half diameter downstream of unobstructed straight run. Free-standing stacks, installed without the use of guywires, are preferred, in terms of test crew access and general site safety.

Energy efficiency and cost

Total APC costs include costs related to capital expenditures, operating costs, maintenance costs and compliance-related expenses. Costing of actual systems is beyond the scope of this article; however, it is worth discussing energy use and power costs via the example discussed next. A process produces a stack gas volume of 35,000 actual ft^3/min (acfm) at 60°F. The ex-

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isting APC system utilizes a venturi scrubber with 10–in. w.c. pressure drop to limit particulate-matter emissions to 0.08 grains/dry std. ft3 (gr/dscf). The fan that drives the system is equipped with a 75-hp motor. A higher particulate matter emission-removal efficiency is now required to limit emissions to 0.02 gr/dscf. Two options can be considered: Downsize the venturi throat and increase the pressure drop on the venturi system to 60–in. w.c. to improve particulate removal, or replace the venturi with a baghouse filter. Table 2 shows the power required for the current system, as well as the two options.

In this example, it is clear that the baghouse has significant power savings compared to the high-pressure drop venturi. The same would be the case for an IWS, should a wet system be desired.

What might have been the right choice years ago — a low-pressure drop venturi — is now the wrong choice, based on lowered particulate limits and energy cost for applications with high loading of fine particles. With proper bag selection and maintenance, many baghouses are capable of limiting stack emissions to 0.01–0.02 gr/dscf range, allowing for tighter regulations and for reduced total annual emissions.

Closing thoughts

When selecting new APC or upgrading old, look first at your regulatory limits, then factor in the characteristics of the fume, and all the pollutants that must be controlled. Then select candidate systems, and estimate capital and operating costs before making your final, well-informed choice. ■

Edited by Suzanne Shelley

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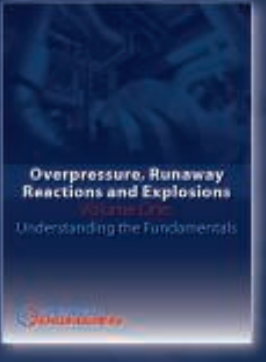
Overpressure, Runaway Reactions and Explosions

Volume: 1

Understanding the Fundamentals

This Chemical Engineering guidebook contains dozens of practical, how-to engineering articles to better help you do your job. It addresses engineering challenges and solutions related to the prevention of overpressure situations, runaway reactions, plant upsets and potentially explosive operating conditions.

These tutorial-style articles focus on monitoring pressure in the chemical process environment, selecting and operating pressure-relief valves. Also provided are engineering recommendations for safely handling and storing reactive chemicals, and the design and operation of explosion-protection devices and systems.



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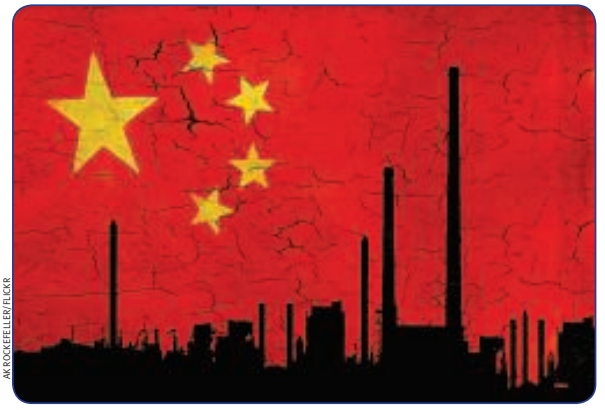
China: An economy in transformation

Despite slower growth in recent years, plenty of business opportunities remain for Western firms as China works to transform itself into a consumption-driven economy



AK ROCKEFELLER/FLICKR

Dawn of a new age? China's chemical process industries are a key force in the move towards a "new normal" economy

As China works to transform itself from an investment economy to one driven by domestic consumption, the phenomenal expansion of the last two decades has slowed considerably, and stock markets have been jittery. Yet, China is still growing at a rate most developed nations would envy: 6.9% according to the official figures for 2015, or 5% in the view of some more-sceptical economists. The slowdown could be a temporary slump; more likely, it is simply the beginning of a "new normal" for the Chinese economy.

The chemical process industries (CPI) remain a key driver for the country's prosperity. The shift towards a more conventional economy brings opportunities for Chinese businesses to consolidate and invest in the new technology they need to gain competitive advantage or meet tightening environmental standards, and the same is true of investors from the U.S., Europe, and Japan. Increasingly sophisticated projects thus give U.S. and European equipment vendors a chance to compete on performance against lower-cost Chinese suppliers.

That was certainly the view of several German experts in the run-up to AchemAsia 2016, which took place in Beijing in May. The three-yearly trade exhibition and conference is run by DECHEMA e.V. (dechema.de/en/; Frankfurt-am-Main). "Even with lower growth, business opportunities are still good", said Martin Wansleben, Chief Executive of the Association of German Chambers of Commerce and Industry (DIHK) in an interview with the *Neue Osnabrücker Zeitung* newspaper.

Sanjeev Gandhi, Head of BASF's operations in Greater China and Asia Pacific, told the *China Daily* that BASF was "very, very confident about the China market". And speaking to the Berlin newspaper *Tagesspiegel*, Axel Schweitzer, CEO of Alba Group, said: "The second-largest national economy in the world cannot grow continuously by six or seven percent." Schweitzer sees the slowdown as a healthy development, and Alba has recently invested massively in plants for recycling electronic scrap and urban waste in China.

Policy to stimulate innovation

Although China today has an outward appearance of rampant capitalism, the government remains committed to many of the habits of thought inspired by Communist doctrine. This raises questions about how the economy can be successfully managed without the openness and democratic controls most Western companies are accustomed to. On the other hand, central control allows the government to force the pace of change astonishingly quickly – and until recently the Chinese leadership has been dominated by scientists and engineers.

2006 saw the launch of a 15-year Medium to Long Term Science and Technology Development Program. Three years in the making, this ambitious plan recognized that *Continued on p73*

CTEF exhibition shows off technology for fine chemicals

The **8th China (Shanghai) International Chemical Technology & Equipment Fair** (CTEF) takes place 23–25 August at the Shanghai New International Expo Centre. This annual event, the largest of its kind in China, acts as an indicator of the state of the nation's chemical process industries.

Last year's CTEF occupied 35,000 m^2 of exhibition space and attracted 502 exibiting companies from 35 countries, including the U.S., Germany, the U.K., France, Italy, and Russia. This year, the focus will be on technology and equipment for the manufacture of fine chemicals, with the associated topics of energy efficiency, environmental protection, and security. China's average annual growth rate in fine and specialty chemicals and new materials is 5–6%, says exhibition organizer Guangzhou Zhenwei International Exhibition Co., Ltd., or around 2–3% higher than the rate for chemicals as a whole. Chemical engineering as applied to fine chemicals is also developing significantly faster than in the rest of the industry.

As a result, the Chinese government sets great store by this sector in its quest for sustainable growth. In a fiercely competitive market, companies who take advantage of up-to-date technology will be able to adjust their business strategies rapidly as market demand changes, and hence get the greatest profit from development trends.

Alongside the many Chinese companies exhibiting at CTEF, foreign visitors will find a number of familiar names from the West.

CTEF takes place at the Shanghai New International Expo Centre (pictured). The cover photo on p. 71 shows the Shanghai skyline.

www.ctef.net
www.zhenweiexpo.com

Inside:

Continued from p72

the existing drivers of the Chinese boom – cheap manufacturing, technology imports and foreign investment – would not carry the country through its next phase of growth in the face of challenges such as shortage of energy and resources, polluted air and water, and poor capacity for innovation. Even today, the great majority of Chinese companies do not own the key intellectual property on which their businesses depend.

The 2006 plan said that China should aim to be among the top five countries worldwide in terms of patents and scientific citations, with advances in science and technology eventually accounting for 60% of economic growth. "By the end of 2020… China will achieve more science and technological breakthroughs of great world influence, qualifying it to join the ranks of the world's most innovative countries," said President Hu Jintao at the launch. By 2013, China was second only to the U.S. in R&D spending, though this represented just 1.6% of GDP compared to 2.8% in the U.S.

"Made in China" for 2025

In May 2015, the State Council reinforced this trend through a new "Made in China 2025" strategy that aims to transform China in a leading manufacturing power. The focus is on innovation and the combination of manufacturing and services, with emphasis on digital technologies. The 13th Five Year Plan, published this year, pays great attention to reducing pollution and using alternative energy to cut carbon emissions.

Global operators must thus anticipate serious future competition from high-tech Chinese companies. On the other hand, many of the technologies needed to make "Made in China 2025" a reality are not yet available from domestic vendors. As a result, China's transformation will open up business opportunities for suppliers from all over the world, especially in process equipment, systems integration and automation. ■ *Charles Butcher*

Electric valve actuators for China

AUMA is a world leader in the global supply of electric actuators, controls and gearboxes

For over five decades, **AUMA** actuators have provided reliable and efficient service in an unequalled variety of chemical, petrochemical, water and power plants.

Regional representation is key to AUMA's international success, ensuring high-level and responsive local support worldwide. Recognizing the increasing importance of the Chinese market, the Germany-headquartered actuator supplier founded its local subsidiary AUMA China in 2004. In 2010, AUMA China moved to its new state-of-the-art production facilities in Taicang, Jiangsu, China. On a manufacturing site covering approximately 9,000 m^2, electric actuators and gearboxes for the Chinese market are produced following the highest AUMA quality standards. AUMA experts in eight regional offices located in Beijing, Shanghai, Xian, Chan Chun, Guanzhou, Chengdu, Urumqi, and Wuhan provide reliable consultancy services and fast on-site support all over the Middle Kingdom.

Major corporations turn to AUMA for tailored electric actuation solutions that meet the precise requirements and varying environmental conditions of each project.

AUMA is a leading supplier of electric valve actuators for the Chinese market

The comprehensive product range includes high-performance multi-turn, part-turn, linear, and lever actuators and gearboxes.

AUMA's modular SA multi-turn and SQ part-turn actuators with intelligent AC actuator controls adapt perfectly to any process requirements and offer extensive options for networking and diagnostics. These products have an outstanding reputation for easy handling, reliability, long life, low operating costs, and a design that simplifies retrofits. **www.auma.com**

Recent projects in China

July 8, 2016 — **BASF SE** (Ludwigshafen, Germany; www.basf.com) and **Xinjiang Markor Chemical Industry Co.** opened a new PolyTHF (polytetrahydrofuran) plant in Korla, Xinjiang Uygur autonomous region in northwest China. The plant has an annual capacity of 50,000 metric tons (m.t.) of PolyTHF, which is used elastomers and thermoplastic polyurethanes.

July 7, 2016 — With growing demand in Asia for performance coatings and adhesives, materials manufacturer **Covestro** AG (Leverkusen, Germany; www.covestro.com) has opened a 50,000 m.t./y plant for hexamethylene diisocyanate (HDI) in Shanghai.

June 17, 2016 — **Haldor Topsoe A/S** (Lyngby, Denmark; www.topsoe.com) officially opened an advanced automotive-catalysts plant in Tianjin Economic-Technological Development Area (TEDA) – an investment of RMB 600 million (more than $90 million). Topsoe has had an office in Beijing since 1984 and today employs 170 people in China.

June 16, 2016 — **PPG Industries, Inc.** (Pittsburgh, Pa.; www.ppg.com) marked the completion of a new $10 million coatings center of excellence at its existing complex in Tianjin. The new facility will serve regional customers in automotive plastics and decorative accessories. PPG built its first coatings plant in China at the Tianjin site in 1994.

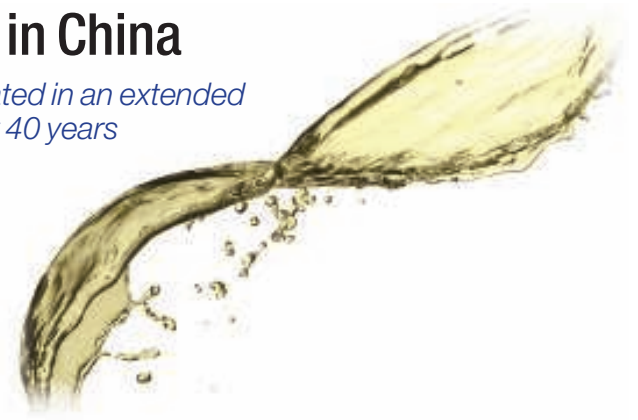
June 1, 2016 — **SABIC** (Riyadh, Saudi Arabia; www.sabic.com) has signed a project development agreement with **Shenhua Ningxia Coal Industry Group Co.** (SNCG), a subsidiary of Shenhua Group Corp., relating to a proposed greenfield petrochemical complex in the Ningxia Hui region of China. SNCG would supply coal for use as a feedstock.

June 1, 2016 — **KBR, Inc.** (Houston; www.kbr.com) has been awarded a license and basic engineering design contract by a confidential client for a grassroots Distill-Max stabilizer column in Shandong Province in China. KBR's Distill-Max dividing-wall technology cuts column costs by improving separation efficiency. ■

Original reporting by Scott Jenkins and Mary Page Bailey

Heat transfer fluid systems in China

Eastman has the "numbers," having participated in an extended period of high GDP growth in China for nearly 40 years



Since 1978, China has averaged nearly 10% per annum GDP growth. **Therminol** heat transfer fluids have been a trusted solution in China during this same period. And for more than 50 years, Therminol heat transfer fluids have been the products of choice in more than 15,000 heat transfer system installations worldwide.

With a broad product line having an operating range of –115°C to 400°C, and backed by Eastman's expertise in more than 120 different heat transfer and cooling applications – including renewable energy, oil and gas, chemicals, plastics, food/beverage manufacturing – Therminol fluids have demonstrated high performance and long life in nearly every operating condition and environment. In China, Therminol 66 and VP-1 have been products of choice for the PET, chemical, and concentrating solar power (CSP) industries due to the high-temperature performance of these products.

Thousands of design and operations engineers have relied on the Eastman TLC Total Lifecycle Care program, a collection of services and tools offered to extend the life of a heat transfer fluid system: design assistance, startup assistance, operational and safety training (seminars, webinars), flush fluid/refill assistance, calculators, and more.

As part of the TLC program, four global Eastman labs test and analyze a combined 5,000 customer in-service fluid samples each year, providing performance trends and insights for each Eastman customer to optimize their plant performance for the life of the system and avoid costly downtime and expense.

Eastman Therminol fluids are manufactured in four regional operational facilities, including the company's newest site in Newport, U.K., and a manufacturing site in Suzhou, China. The Suzhou manufacturing site provides the same high-quality, reliable Therminol products, available in stock for local purchase and also available globally. Inside China, Eastman has a dedicated team of Therminol heat transfer fluid sales and technical specialists ready to serve.

For a list of applications using Therminol heat transfer fluids in China, visit: http://www.szsolutia.com/yyzx_en.html. For more information, contact a Therminol fluid specialist in China by calling: +86-512-68258167.

To locate an Eastman sales or technical specialist outside China, visit www.therminol.com and click on the CONTACT US tab.

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Toxicity, reactivity, corrosivity, and instability are just a few of the everyday hazards the chemical industry faces. Add in business demands such as tight margins and feedstock cost pressure, and it is obvious why the twin imperatives of safety and efficiency are number one priorities, points out control and instrumentation supplier **Siemens**.

Process materials, temperatures and pressures can all affect the choice of components. With on-board maintenance and diagnostic functions, Sitrans devices translate data and alerts into timely and effective action. Advanced diagnostics and functions such as self-test, drag indication, partial stroke tests and multiple adjustable limit values are accessible at any time during operation. Safe upper and lower limits for items such as temperatures, pressures, flows and compositions are vital for plant safety and cost control.

Another important aspect in plant control and safety is the automation system. Openness and the support of industry standards are core features of seamless automation, and are thus the focus of process control right down to the device level. Many Sitrans field devices have features that cannot be directly integrated into an automation solution via established industry standards. This gap is being closed by the Sitrans Library. Offering device-specific faceplates, this engineering and operation tool offers plant owners a new degree of transparency, allowing easier operation and fast troubleshooting.

The Sitrans Library also aids the protection of assets. An example is valves, which depending on their size can represent large investments. This is why the Sipart PS2 electropneumatic valve positioner is equipped with additional functions to protect the valve and to cut maintenance costs. The Sipart PS2 faceplate shows the following information at a glance, and saves operators from having to create project-specific function blocks from scratch:

- valve opening and closing;
- switching from automatic to manual control of the valve;
- setting limit values;
- visualizes the binary inputs and outputs;
- trend curves; and
- alarm management.

With this interplay between the SIMATIC PCS 7 process control system and the Sitrans Library, operators can reap the benefits of the entire functional scope of their field devices. The result is a simpler and safer automation solution with less engineering overhead.

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Flexicon stand-alone equipment and automated plant-wide systems convey, discharge, condition, fill, dump and weigh batch bulk materials dust-free

Flexicon engineers and manufactures a broad range of equipment that handles virtually any bulk material, from large pellets to sub-micron powders, including free-flowing and non-free-flowing products that pack, cake, plug, smear, fluidize, or separate.

Individual bulk handling equipment includes: flexible screw conveyors, tubular cable conveyors, pneumatic conveying systems, bulk bag dischargers, bulk bag conditioners, bulk bag fillers, bag dump stations, drum/box/container dumpers, and weigh batching/blending systems. Each of these product groups encompasses a broad range of models that can be custom engineered for specialized applications, and integrated with new or existing upstream and downstream processes and storage vessels.

All equipment is available to food, dairy, pharmaceutical and industrial standards.

For large-scale bulk handling projects, Flexicon's separate Project Engineering Division provides dedicated Project Managers and engineering teams on four continents to handle projects from concept to completion. Working with each customer's preferred engineering firm or directly with their in-house team, Flexicon adheres strictly to the customer's unique standards, documentation requirements and timelines through a single point of contact, eliminating the risk of coordinating multiple suppliers. Flexicon's worldwide testing facilities simulate full-size customer equipment and systems.

In 2015 the company doubled the size of its manufacturing facility and world headquarters in Bethlehem, PA, and also operates manufacturing facilities in Kent, United Kingdom; QLD, Australia; and Port Elizabeth, South Africa.

Flexicon offers stand-alone bulk handling equipment as well as plant-wide systems integrated with new or existing processes

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Piping for a giant paper mill

In May 2015, **BUTTING China** acquired the biggest order in its history to date: pipework for a huge paper mill in Sumatra. Indonesian papermaker Asia Pulp & Paper is building the 2.6 million ton/y OKI mill, which will be the world's largest when it starts up later this year. The site is accessible only by boat.

The contract is worth around EUR 32 million."It comprises material deliveries, prefabrication of more than 20,000 piping components, transportation, assembly and on-site supervision," says Jens Ellermann, managing director of BUTTING China. "It's a mega-challenge!" To handle such a large job, BUTTING China took on 50 new staff members.

BUTTING China ordered EUR 4 million-worth of pipe made from Sandvik 254 SMO stainless steel from its parent company in Schwedt, Germany. Prefabrication took place at BUTTING's sites in Schwedt and Knesebeck.

Stefan Tietz (l) passes on his expertise to a colleague

So far, the project has consumed 150 km of pipe, with 2,500 tons in stainless steel and 1,000 tons in carbon steel, SMO, titanium and GRP, plus 2,000 tons of carbon steel brackets and 60,000 elbows, tees and reducers.

Contact Jens Ellermann, tel: +86 24 76219000, email jens.ellermann@butting.com.cn.

www.butting.com

Handling systems are key

Handling systems are one of the key factors in process economics, notes specialist supplier **Müller**. Whether in the pharmaceutical, chemical or food industry, cost-effective production depends on handling equipment that combines performance with safety and reliability. Müller has over 30 years of experience in this field: the company designs, develops and manufactures everything itself. As a result, customers can count on individual solutions of world-class quality to meet the most demanding needs, with full CE compliance. Customers worldwide appreciate the slender design of Müller's lifting columns, which ensures a good view of the drum or container. All lifters have electromechanical drives for all machine functions. This design has low maintenance requirements, and is cost-effective, safe, ergonomic and quiet. Typical tasks include feeding machines like tablet presses, capsule fillers and blister pack machines. Maximum repeatability for all travel positions makes Müller lifting columns the perfect choice, especially when working with split-valve systems. Customer can choose between relays or programmable logic controllers (PLCs), with optional peripherals such as metering butterfly valves and vibrators.

Slender lifting columns don't obstruct the view

www.muellersyshand.com/en

Rectification plant for the recovery of isopropyl alcohol

In just 14 months from contract to full production, GEA has supplied and commissioned an energy-saving distillation plant that needs no steam supply in normal operation

In June, **GEA** successfully commissioned a two-stage rectification plant for the recovery of isopropyl alcohol. The new plant is installed at a facility making xanthan gum at Jungbunzlauer Austria AG, which specializes in biodegradable ingredients of natural origin. The technical highlight is a unique GEA technology for saving energy, using columns designed for "super-efficient" heating by means of multiple mechanical vapor recompression (MVR). The concept allows energy savings of more than 50% compared to a conventional MVR-heated column system, GEA says. During normal operation, the system requires no external steam supply at all.

GEA delivered this innovative plant as a turnkey project within a very tight time frame. Within 14 months from award of contract, the plant reached full performance. This allowed:

- just five months for mechanical and electrical installation, with approximately 28,000 weld seams and 30 km of cabling; and
- only two months for commissioning and field checks.

Faced with such a demanding schedule, GEA used specifically adapted program modules to simulate the complete plant in real time. This allowed all communication checks to be made and step chains verified in advance. The plant's complex control algorithms and safety-related process steps were also thoroughly tested before installation. GEA thanks Jungbunzlauer AG for the opportunity to work on such an interesting challenge, and for their trust and support during all the phases of the project.

With over 17,000 employees, GEA is one of the largest suppliers of equipment and technology to the food processing industry and a wide range of other process industries. Consolidated revenues totaled approximately EUR 4.6 billion in 2015. More than 70% of this revenue comes the food sector, which is enjoying long-term sustainable growth. **www.gea.com**

GEA's innovative column design uses multiple vapor-recompression units to slash energy requirements

The right solution for every separation challenge

ANDRITZ SEPARATION's new service and repair center and product developments are also compatible with third-party products

As a company offering more separation technologies and services than anyone else in the world, **ANDRITZ SEPARATION** provides solutions for every customer, whatever their existing setup. The OEM for many of the world's leading brands employs 2,000 specialists in 40 countries worldwide. ANDRITZ SEPARATION solutions are found in oil and gas refineries, batch chemical processing plants, PVC production facilities, specialty chemical plants, and the plastics industries. The services and products are brought right to the customer's site, whether in an industrial complex or a remote plant far from any urban infrastructure.

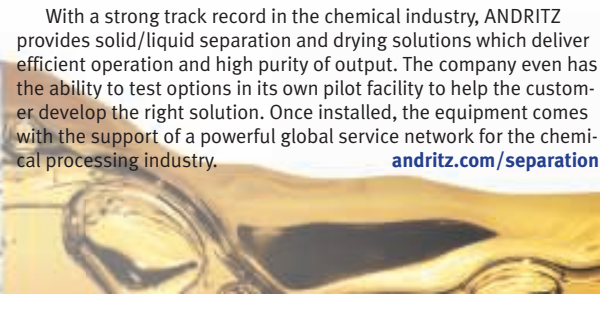
The separation solutions are based on the company's leading brands of screens, filters, drains, presses, thickeners, centrifuges, dryers and coolers. ANDRITZ SEPARATION also has a comprehensive service and support network that handles nearly all brands of separation equipment and systems.

ANDRITZ SEPARATION provides everything from initial consulting and service agreements, process optimization, and automation, through to training programs. Minimizing downtime, increasing predictability and driving up overall production efficiency are achieved through the fact that ANDRITZ SEPARATION is not only one of the world's largest OEMs, but also has a vast service network for spare parts, rentals, repairs, upgrades and modernization. The recently opened service and repair center in Krefeld, Germany, enhanced the service offerings for the Central European market – together with service teams in Cologne, Selb, Ravensburg, and Vierkirchen – even for customers using other manufacturer's products.

Gerd Reisner, the head of ANDRITZ SEPARATION Service, says: "Our service philosophy is simple: One phone call, one contact person, one dedicated team that speaks your language and knows your equipment and process. This is not an empty promise. It is backed by a network of 550 service specialists for solid/liquid separation equipment and systems as well as service centers all around the world."

Working with other products doesn't end with service – as seen in the new centrifuge control system launched this year. ANDRITZ CentriTune is a PLC (programmable logic controller)-based system that increases the performance and availability of new and existing decanter centrifuges, regardless of whether or not these are ANDRITZ machines.

With a strong track record in the chemical industry, ANDRITZ provides solid/liquid separation and drying solutions which deliver efficient operation and high purity of output. The company even has the ability to test options in its own pilot facility to help the customer develop the right solution. Once installed, the equipment comes with the support of a powerful global service network for the chemical processing industry. **andritz.com/separation**

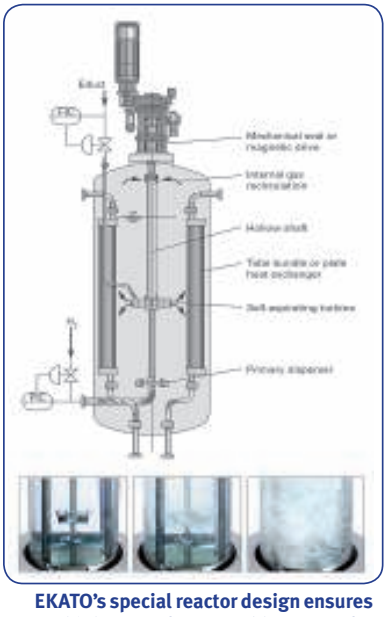


Hydrogenation plant technology

EKATO has the expertise to scale up from lab to plant

Hydrogenation reactions are challenging, as the solubility of hydrogen in most solvents is poor and the heat of reaction is often very high. **EKATO**'s high-performance hydrogenation reactors use a two-stage gassing system to overcome these issues. At the bottom of the reactor is a primary dispersing impeller, while a self-inducing turbine acts like an internal compressor to recirculate undissolved hydrogen. Internal heat exchangers, meanwhile, provide excellent cooling. The outstanding combination of mass and heat transfer allows short batch times with lower catalyst concentrations and fewer by-products.

Hydrogenation processes are also difficult to scale up from the lab to industrial size. The interaction between mass transfer, heat release, and catalyst concentration is complex, and requires iteration. EKATO supplies not only the reactor system itself, but also the know-how needed to design a complete hydrogenation plant, including catalyst handling systems and other equipment.



EKATO's special reactor design ensures high rates of mass and heat transfer

EKATO operates hydrogenation pilot plants of 5–60 liters, at pressures up to 100 bar and temperatures up to 250°C, in stainless steel and Hastelloy.

www.ekato.com

These pumps solve problems

By tackling difficult applications, specialist pumping solutions from Bungartz save both time and money

Frank Bungartz, the third generation of his family to run the company, with an MPCH DryRun model

Difficult liquids feeding tasks appear in nearly all branches of the chemical process industries, notes German pumping specialist **Paul Bungartz GmbH & Co. KG**. Bungartz centrifugal pumps, which are designed with high levels of intrinsic safety, are ideal for extreme assignments that are too demanding for others. The company specializes in pumps that are cavitation-free and self-regulating. Typical applications include problems with shaft seals, poor feed conditions, entrained gas, liquids close to their boiling points, and corrosive or abrasive media. The company's success is based on three pillars:

1. Sealing technology: Almost all Bungartz pumps combine a hydrodynamic primary shaft seal with a downstream secondary seal (a packed gland, mechanical seal or magnetic drive).
2. Special physics: Bungartz V-AN ("abnormal") centrifugal pumps adapt automatically to changing feed rates, and require zero NPSH.
3. Materials: These range from gray cast iron to stainless steel, titanium, zirconium, other special alloys, and even SiC.

Horizontal and vertical pumps are available in radial, axial and torque-flow designs, with non-contact hydrodynamic shaft seals or mechanical seals. Models suitable for dry running also include magnetically coupled pumps in horizontal, vertical and submerged designs.

www.bungartz.de

Measure extremely low flows

The new FLUXUS XLF clamp-on ultrasonic flowmeter from FLEXIM records flowrates down to 3.5 l/h and below

For the non-invasive measurement of extremely low flowrates, the FLUXUS XLF flowmeter from **FLEXIM** works down to below 3.5 l/h on pipe sizes from 6 to 50 mm. Its measurements are accurate, reproducible, and long-term stable. Since clamp-on ultrasonic transducers simply mount onto the outside of the pipe, the flowmeter can be installed without interrupting the process.

The FLUXUS XLF can be used on all pipe materials and with any pipe wall thickness. Measurements are also independent of the pressure in the pipe. Unlike flowmeters with wetted parts, the system is not subject to any mechanical stress or wear and tear from the process medium. This results in lower lifetime operating costs, and is significantly safer because there is no risk of leakage.

The high accuracy and reproducibility of the FLUXUS XLF, even at the lowest flowrates, is based on carefully paired ultrasonic transducers with internal temperature compensation to ANSI/ASME MFC 5.1–2011, highly sensitive electronics, intelligent signal processing, and accurate wet calibration that is traceable to national standards.

Clamp-on ultrasonic flowmeters are easy to install, and capable of high accuracy

The inherently sturdy measuring system is also available in a particularly durable stainless steel (316L /1.4404) design, sealed to IP66 for use under the most challenging conditions. The transmitter is certified for Zone 2 hazardous areas. Transducers for ATEX Zone 1 are available, as well as IP68 transducers for continuous operation while submerged.

www.flexim.com

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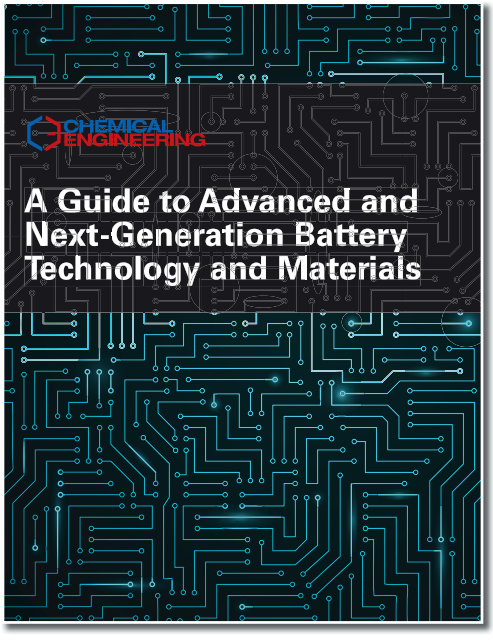
This comprehensive guidebook provides descriptions of the major battery technologies and materials in the advanced and next-generation battery markets, as well as information on many of the companies operating in the advanced and next-generation battery industries.

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



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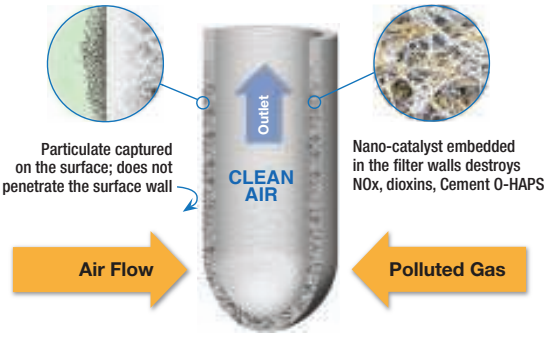

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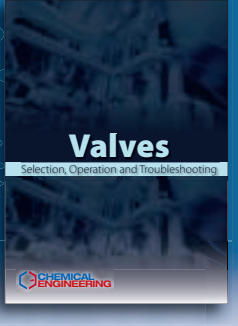

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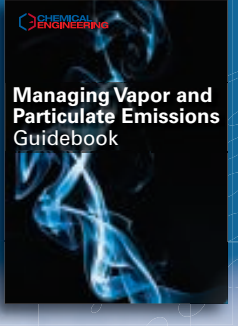
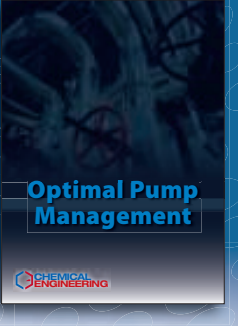


Optimal Pump Management



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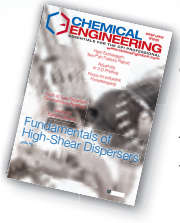
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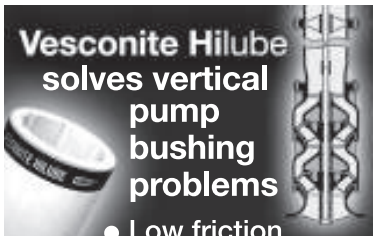
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Economic Indicators

2014 2015 2016

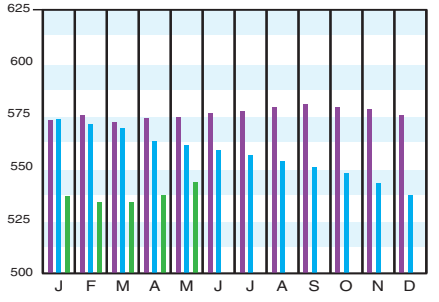
Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	May '16 Prelim.	Apr. '16 Final	May '15 Final
CE Index	543.5	537.5	560.5
Equipment	649.2	640.5	675.6
Heat exchangers & tanks	560.5	548.8	603.5
Process machinery	649.7	649.3	658.7
Pipe, valves & fittings	813.0	801.6	843.6
Process instruments	385.3	382.7	402.6
Pumps & compressors	970.4	970.5	958.0
Electrical equipment	508.7	508.2	513.0
Structural supports & misc	719.1	701.5	740.1
Construction labor	325.8	325.0	322.7
Buildings	543.5	540.8	542.7
Engineering & supervision	316.0	316.2	319.5

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

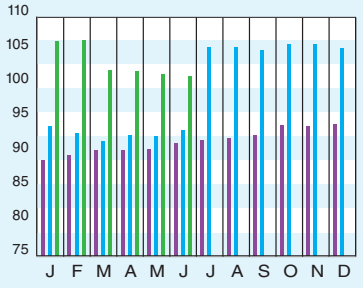
Annual Index:
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8



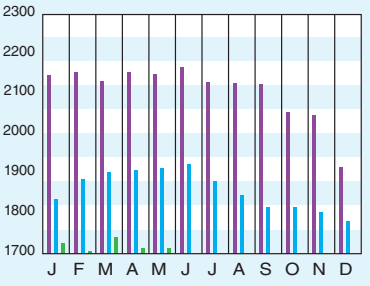
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS		YEAR AGO
CPI output index (2012 = 100)	Jun. '16 = 101.2	May '16 = 101.6	Apr. '16 = 101.5	Jun '15 = 101.3
CPI value of output, $ billions	May '16 = 1,713.3	Apr. '16 = 1,711.2	Mar. '16 = 1,702.4	May '15 = 1,864.2
CPI operating rate, %	Jun. '16 = 74.4	May '16 = 74.7	Apr. '16 = 74.6	Jun '15 = 74.9
Producer prices, industrial chemicals (1982 = 100)	Jun. '16 = 227.9	May '16 = 225.0	Apr. '16 = 221.6	Jun '15 = 251.2
Industrial Production in Manufacturing (2012=100)*	Jun. '16 = 103.2	May '16 = 102.8	Apr. '16 = 103.0	Jun '15 = 102.8
Hourly earnings index, chemical & allied products (1992 = 100)	Jun. '16 = 165.2	May '16 = 164.4	Apr. '16 = 161.4	Jun '15 = 157.6
Productivity index, chemicals & allied products (1992 = 100)	Jun. '16 = 101.3	May '16 = 101.6	Apr. '16 = 102.0	Jun '15 = 101.7

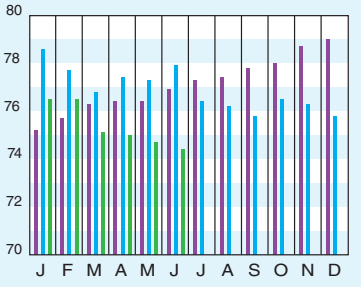
CPI OUTPUT INDEX (2000 = 100)†



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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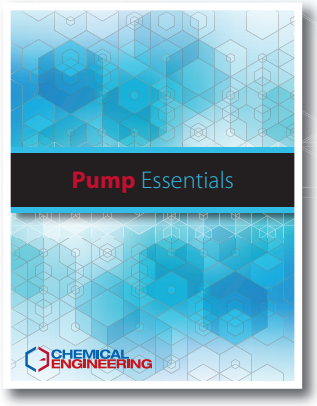
CURRENT TRENDS

The May 2016 preliminary value for the *CE* Plant Cost Index (CEPCI; top; the most recent available) is higher than the previous month, with the Equipment and Buildings indices rising by a significant amount. The preliminary May 2016 CEPCI value is 3.0% lower than the corresponding value from May last year. The year-over-year difference continues to decline as the values approach those from a year ago. Meanwhile, the latest Current Business Indicators (CBI; middle) for June 2016 showed a small decrease in the CPI output index compared to the previous month. Producer prices for industrial chemicals edged higher in June and the May number for the CPI value of output index also increased slightly from the previous month.

NOW AVAILABLE IN THE CHEMICAL ENGINEERING STORE

Pump Essentials



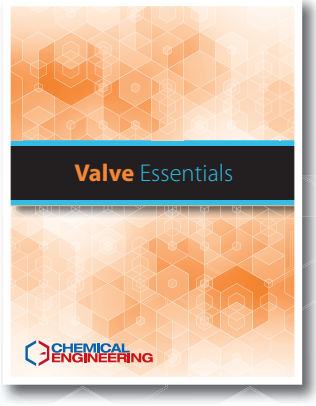
Most engineers would agree that pumps represent the workhorse component in any chemical process industries (CPI) facility. Every day, countless decisions must be made related to the proper selection and specification, sizing and installation, operation and maintenance, and troubleshooting of these critical machines.

This *Chemical Engineering* reference book provides a wealth of practical engineering guidance on the proper use and operation of several different types of pumps. Articles focus on the sizing and selection of centrifugal pumps, and tips for managing the impact of pumps whose operation deviates from the best efficiency point (BEP). Others provide engineering tips for understanding and optimizing magnetically driven and sealless pumps, and guidance for calculating net positive suction head (NPSH).

Included is detailed information on condition monitoring and maintenance of pumps, recommendations for designing and operating safe and accurate pressure-relief systems, and selecting variable frequency drives (VFD) for centrifugal pumps.

Text also encompasses data related to lifecycle cost analysis, construction-cost indices for CPI equipment, and budget considerations for capital-intensive CPI operations.

Valve Essentials



Engineers are routinely challenged when it comes to the proper selection, specification and sizing, and installation, operation and maintenance, and troubleshooting of valves to control fluid flow while ensuring overall reliability and safety.

This resource provides engineering articles which focus on the proper selection and operation of control valves and control valve positioners and sensors. Included is information provide sizing calculations for pressure-relief valves and related systems, plus tips for using pressure-relief valves with rupture disks.

Guidance is offered on reducing fugitive emissions and troubleshooting valves in the field, as well as engineering recommendations related to material selection, planning for plant revamps, improving operability, and managing challenges associated with hygienic operation.

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