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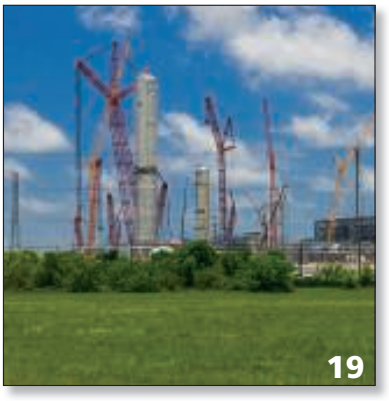

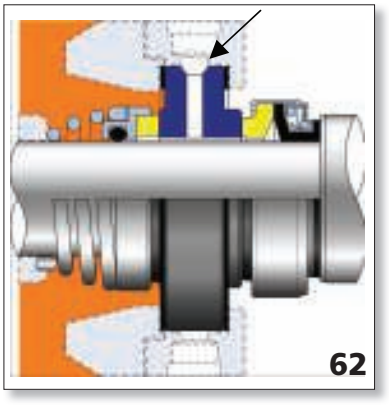

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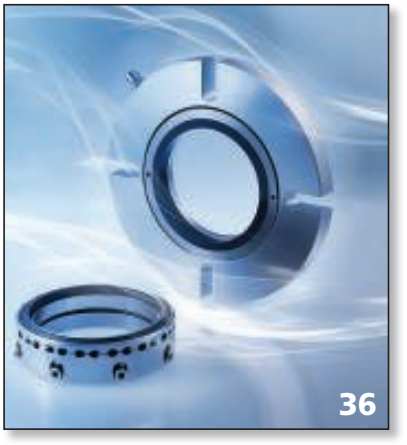

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BPA WORLDWIDE

Editor's Page

Making security a priority

It seems that more and more, security concerns — both physical and cyber — have become part of our daily lives both off and on the job. The all-too-frequent news stories on the topic as well as repetitive prompts, such as the "if you see something, say something" slogan, remind us to keep up our vigilance. This past year, security has been the subject of more than one Executive order that has resulted in stepped-up activity across numerous U.S. Government agencies.

In February, the National Institute of Standards and Technology (NIST; Gaithersburg, Md., www.nist.gov) unveiled its Cybersecurity Framework, which was developed in response to Executive Order 13636, titled "Improving Critical Infrastructure Cybersecurity," that was signed by President Obama one year earlier. The Framework was developed through a collaborative effort between industry and the government, and it gives guidance to owners and operators of critical infrastructure — of which the chemical process industries (CPI) are part — on how to manage cybersecurity-related risks. A description of the Framework and other cybersecurity-related resources relevant to the CPI can be found in our June issue (ICS Security: The Owner-Operator's Challenge, *Chem. Eng.*, pp. 30–35).

Executive Order 13650, "Improving Chemical Facility Safety and Security," was signed by the President in August 2013. The response to this order was the subject of much discussion at the recent Chemical Sector Security Summit (July 22–24, Baltimore, Md.; www.dhs.gov/2014-chemical-security-summit), now in its eighth year. An interagency working group released a report to the President titled "Actions to Improve Chemical Safety and Security — A Shared Commitment," in June. This report outlines action plans in response to the Executive order in five areas: Strengthening community planning and preparedness; enhancing Federal operational coordination; improving data management; modernizing policies and regulations; and incorporating stakeholder feedback and developing best practices. Presenters at the Security Summit commented that one of the more important outcomes of the Executive order is that a number of government agencies are now cooperating and communicating much more effectively about security in the CPI.

And it seems that CFATS (Chemical Facility Anti-Terrorism Standards) may finally have the strong support in Congress that could lead to longterm authorization, instead of the annual process that the program has undergone for the past seven years since its inception. In his presentation at the Security Summit, David Wulf, director of the Infrastructure Security Compliance Division (ISCD), Dept. of Homeland Security (DHS) called 2014 a transformative year for CFATS as he outlined the progress made in the program, including the approval of nearly 1,000 site security plans (for background, see CFATS and Chemical Plant Security, *Chem. Eng.*, Sept. 2009, pp. 21–23).

Worldwide interest in CPI security is also growing. It was suggested during international sessions at the Security Summit that U.S. approaches to security, such as (1) the combination of safety and security, and (2) public and private partnerships, could offer guidance to a broader international community.

Much groundwork has been laid and the key now is to make it a priority to incorporate security into our routine endeavors. ■

Dorothy Lozowski, Editor in Chief

Letters

In memory

It is with great sadness, that we learned of the passing of Jay Chowdhury, who was an editor with *Chemical Engineering* magazine for 20 years. Long-time readers of the magazine, and those that had the pleasure of knowing and working with Jay, will remember him as one of the kindest and wisest of human beings.

Gerald Ondrey
Senior Editor, *Chemical Engineering*

Founder of 'green chemistry' to receive 2014 Perkin Medal

The Society of Chemical Industry (SCI; London; www.soci.org) is presenting the 2014 Perkin Medal to John C. Warner, president and chief technology officer of the Warner Babcock Institute for Green Chemistry (Wilmington, Mass., www.warnerbabcock.com). The annual award recognizes outstanding work in applied chemistry in the U.S., and commemorates the discovery of the first synthetic dye by William Henry Perkin in 1856, who received the first Perkin Medal in 1906.

Warner holds a B.S. in chemistry from the University of Massachusetts at Boston and M.S. and Ph.D. degrees in organic chemistry from Princeton. After ten years with Polaroid Corp., Warner joined the University of Massachusetts at Boston, where he started a "green chemistry" doctoral program — said to be the first in the world. He went on to develop an efficient method of synthesis that requires fewer steps and generates less waste that is known as non-covalent derivatization (NCD) technology.

In 2004, Warner received the U.S. Presidential Award for Excellence in Science, Mathematics and Engineering Mentorship.

In 2007, Warner and Jim Babcock founded the Warner Babcock Institute for Green Chemistry, with a goal to create commercial technologies of superior performance that are also environmentally friendly.

The award is being presented at a dinner in Warner's honor in Philadelphia on September 16.

Postscripts, corrections

July 2014, "Finding the Balance in Packaging," p. 27. In the last paragraph on this page, a resin is incorrectly identified as Elite EPE. The correct name is Elite AT, and the sentence should read: As an example, for liquid, dry and frozen foods, Elite AT resins help reduce package thickness by up to 25% without sacrificing toughness or machinability.

August 2014, Who's Who, p. 70. The name of the company affiliation for Thomas Bartolomei was incorrectly stated as NAEL Corp. The correct name is NAES Corp.

August 2014, "Software for the Human Element," p. 25. The name Steve Elliott from Ventyx was misspelled as Elliot. The correct spelling is Elliott.

The corrected versions for the above full articles can be found at www.chemengonline.com.

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Bookshelf

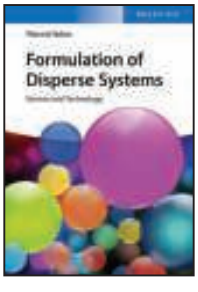
Bioenergy Research: Advances and Applications. By Vijai K. Gupta, Maria G. Tuohy, Christian Kubicek, Jack Saddler and Feng Xu. Elsevier Inc., 225 Wyman Street, Waltham, MA 02451. Web: elsevier.com. 2014. 500 pages. $149.95.

Non-equilibrium Thermodynamics: Transport and Rate Processes in Physical, Chemical and Biological Systems. 3rd ed. By Yasar Demirel. Elsevier Inc., 225 Wyman Street, Waltham, MA 02451. Web: elsevier.com. 2014. 786 pages. $249.95.

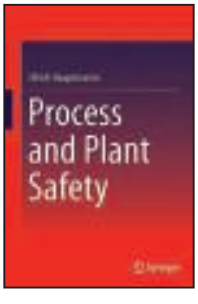
Black Liquor Gasification. By Pratima Bagpai. Elsevier Inc., 225 Wyman Street, Waltham, MA 02451. Web: elsevier.com. 2014. 130 pages. $69.95.

Industrial Wastewater Treatment, Recycling and Reuse. By Vivek Ranade and Vinay Bhandari, Butterworth-Heinemann, Elsevier Inc., 225 Wyman Street, Waltham, MA 02451. Web: elsevier.com. 2014. 576 pages. $140.00.

Process Modeling and Simulation in Chemical, Biochemical and Environmental Engineering. By Ashok Kumar Verma, Taylor and Francis Group LLC, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487. Web: crcpress.com. 2014. 440 pages. $139.95.



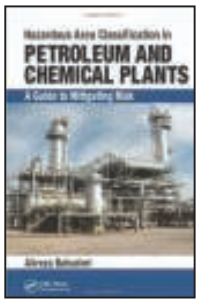
Formulation of Disperse Systems: Science and Technology. By Tharwat F. Tadros. John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, Web: wiley.com. 2014. 504 pages, $205.00.



Process and Plant Safety. By Ulrich Hauptmanns, Springer-Vieweg, Abraham Lincoln Strasse, 46, 65189, Weisbaden, Germany. Web: springer.com. 2014. 655 pages. $179.00.

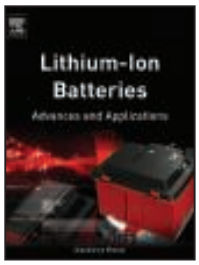
Editor's note: If you would like to contribute a book review for the Bookshelf column, please contact senior editor Scott Jenkins at sjenkins@chemengonline.com.

Thermodynamics and the Destruction of Resources. Edited by Bhavik Bakshi, Timothy Gutowski and Dusan Sekulic, Cambridge University Press, UPH, Shaftesbury Road, Cambridge CB2 8BS, U.K., Web: cambridge.org, 2014. 524 pages. $63.00.

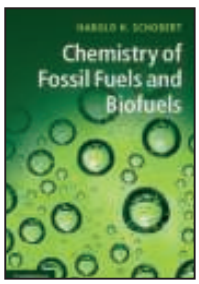


Hazardous Area Classification in Petroleum and Chemical Plants: A Guide to Mitigating Risk. By Alireza Bahadori, CRC Press, Taylor and Francis Group LLC, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487. Web: crcpress.com. 2013. 564 pages. $149.95.

IP Standard Test Methods for Analysis and Testing of Petroleum and Related Products, and British Standard 2000 Parts. By Institute of Petroleum. Energy Institute, 61 New Cavendish Street, London, W1G 7AR, U.K., Web: energyinst.org. 2014. electronic book, $800.00.



Lithium-Ion Batteries: Advances and Applications. By Gianfranco Pistoia. Elsevier Inc., 225 Wyman Street, Waltham, MA 02451. Web: elsevier.com. 2014. 660 pages. $235.00.



Chemistry of Fossil Fuels and Biofuels. By Harold Schobert, Cambridge University Press, UPH, Shaftesbury Road, Cambridge CB2 8BS, U.K., Web: cambridge.org, 2013. 497 pages. $118.00.

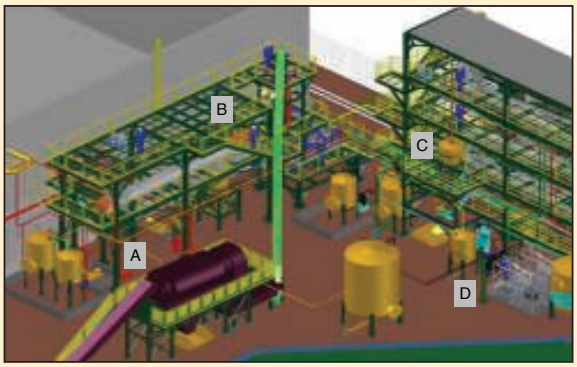
Advanced Materials Science and Engineering of Carbon. By Michio Inagaki, Feiyu Kang, Masahiro Toyoda and Hidetake Konno, Elsevier Inc., 225 Wyman Street, Waltham, MA 02451. Web: elsevier.com. 2014. 440 pages. $149.95.

Plant Equipment & Maintenance Engineering Handbook. By Duncan Richardson. McGraw-Hill Professional Publishing, 1221 Avenue of the Americas, 28th Floor, New York, NY 10020. Web: mcgraw-hill.com. 2014. 592 pages. $150.00. ■

Scott Jenkins

Demonstration plants for biomass-to-sugar technology under construction

Edeniq Inc. (Visalia, Calif.; www.edeniq.com) announced progress in building demonstration facilities in Brazil and China that feature the company's proprietary process for converting cellulosic biomass into industrial sugar for fermentation or catalytic conversion (diagram).



A. Pre-processing B. Pre-treatment C. Saccharification D. Separations and product recovery

In Brazil's São Paulo state, Edeniq is partnering with Usina Vale to build a 10-ton/d demonstration plant that will bolt onto an existing sugarcane-to-bioethanol production facility, allowing it to increase ethanol production by utilizing waste biomass. Meanwhile, in Jilin province, China, Edeniq is partnering with Global Bio-chem Group (Hong Kong, China) to build a commercial demonstration facility that will eventually produce 50,000 metric tons (m.t.) per year of sugar from corn stover at an attractive transfer price, the company says.

Both facilities feature Edeniq's patented continuous biomass-pretreatment technology, which hydrates the biomass, and mechanically grinds and mills the material. They also feature a closely integrated continuous saccharification process that depends on a proprietary reactor design to reduce residence times and increase enzyme-hydrolysis efficiency.

Among three types of mechanical shearing equipment deployed in the process, Edeniq's pre-treatment step features the Cellunator, which produces a homogenous, high-density slurry of biomass solids, while reducing average particle size to the several-hundred-micron range, explains Tom Griffin, chief technology officer at Edeniq. The comprehensive shearing and homogenization action gives enzymes enhanced access to biomass particles, which allows higher conversion rates to fermentable sugars. Further, the use of mechanical shearing obviates the need for high temperatures and corrosive chemicals in the pretreatment stage, he adds.

Edeniq has also developed a unique solid-liquid separation process that generates a solids-free sugar solution as a product, which is continually removed. The enzymes, additives and unreacted substrate are continuously recycled in the process. The separation step features a high-throughput tangential-flow filtration (TFF) system that has been customized for biomass. The Edeniq process also includes a step in which solid lignin is captured as a co-product; it can be used as a fuel to heat process boilers, or further developed into a livestock feed component.

Edeniq currently operates pilot facilities at its California headquarters and an Omaha, Neb. based business unit that utilizes the company's technology to enhance ethanol yields from corn. The Brazil plant has begun qualification testing of preprocessing unit operations, with construction completion planned for late 2014. The China plant will be constructed in late 2014, with Edeniq enhancements integrated in stages through 2015.

Mercury removal with modified aluminosilicate clay

The first commercial contract delivery was recently made for an emissions control product that removes mercury from fluegas without the use of activated carbon. The product, known as AS-HgX, is made by Novinda Corp. (Denver, Colo.; www.novinda.com), and will be used in the utility power-generation industry to help users meet limits on mercury emissions.

The product is a departure from the use of activated carbon to adsorb mercury from fluegas, as is done with conventional technology, and offers a host of advantages over the current approach. In power plants where activated carbon is used to remove mercury, the activated carbon often contaminates the flyash, rendering it useless as a replacement for ordinary Portland cement. Using flyash in concrete can reduce carbon emissions considerably and save significant money, notes Jim Butz, vice president of product management at Novinda. Butz further explains that a cradle-to-grave analysis of AS-HgX (manufacturing, transport, and so on) shows that its carbon footprint is one-tenth that of activated carbon. Another advantage of the product over activated carbon is its inertness. It does not present flammability and explosion risks, as activated carbon does.

Starting with an aluminosilicate clay, Novinda has developed a patented formula that infuses a proprietary metal

(*Continues on p. 12*)

CO_2-to-syngas . . .

Scientists from the University of Illinois at Chicago (www.uic.edu) have developed a catalytic system — molybdenum disulfide and an ionic liquid — to convert CO_2 into synthesis gas, (syngas; a mixture of CO and H_2 that is used for making liquid fuels and chemicals, such as methanol). Unlike alternative CO_2-reduction processes, which only generate CO, the new catalyst system enables the production of syngas directly. The catalyst is also said to be less expensive

(*Continues on p. 12*)

Note: For more information, circle the 3-digit number on p. 76, or use the website designation.

This process realizes large costs savings for manufacturing silicon wafers

Crystal Solar Inc. (Santa Clara, Calif.; www.xstalsolar.com) is preparing for high-volume production of silicon wafers using a process that forms the wafers directly from trichlorosilane (TCS) gas using a chemical vapor deposition (CVD) epitaxy process that can significantly lower the manufacturing costs for solar photovoltaic cells.

By eliminating several steps used in the traditional solar-wafer manufacturing process, including melting down polysilicon pieces, formation of a monocrystalline silicon ingot and slicing the wafers, Crystal Solar's "Direct-to-Wafer" technology allows for a 50% reduction in the wafer's production cost, which represents almost half of the cost of the final solar cell.

"Epitaxy has been well known for silicon production in the past," says T.S. Ravi, Crystal Solar co-founder and CEO, but the approach has not been economical for use in solar cell applications because growing the silicon layer has been too slow, and conversion rates from TCS to solid Si have been too low. "The key for us was to find good solutions to the problems of how can you grow the wafers faster and how can you achieve higher conversion rates?" Ravi says.

By using a vertical reactor concept, the company has been able to achieve 40% conversion rates of TCS to silicon, with the ability to make several hundred wafers at a time at atmospheric pressure. The reactor combines solar-grade TCS gas with hydrogen to deposit monocrystalline silicon on top of a porous silicon release layer.

Capital costs associated with this production method are said to be half what is required for traditional polysilicon plants. Another advantage of the Crystal Solar method is its amenability toward automation, Ravi notes. The technology was developed in part as a component of a National Renewable Energy Laboratory (Golden, Colo.; www.nrel.gov) program, and has garnered an R&D 100 award in 2014.

Crystal Solar has been making wafers in a pilot phase, and generating positive feedback in tests with cell manufacturers, Ravi says, and the company is gearing up to add capacity now.

This portable device measures Hg^{+2} in water samples

An ultra-sensitive, low-cost and portable system for detecting mercury in water has been developed by University of Adelaide (Australia; www.adelaide.edu.au) researchers, in collaboration with the Universitat Rovira i Virgili (Tarragona, Catalonia, Spain; www.urv.cat).

Project leader Abel Santos, of the Adelaide's School of Chemical Engineering, says there are systems capable of monitoring mercury at trace levels, but they are huge, expensive machines and are complicated to use. Also, samples require chemical treatment before analysis in such instruments. "Our system, on the other hand, is very cost-competitive, only as big as a mobile phone and easy to use," he says.

The researchers have engineered a nanoporous material, called nanoporous anodic alumina, to make a special structure called a rugate filter. The surface of the filter has been modified to make it selective to mercury ions. As water flows through the pores, the mercury ions become attached to the surface. Reflection spectroscopy measures the amount of mercury present.

The system has a linear working range from 1 to 100 µM of Hg^{+2}. Its low limit of detection is 1 µM of Hg^{+2} ions. Tests were successfully carried out at the River Torrens, demonstrating the suitability of the system for developing environmental point-of-analysis systems. The system also proved to be highly selective in a complex mixture of other metals and environmental samples.

MERCURY REMOVAL (*Continued from p. 11*)

sulfide material into the clay particles. After blending and milling processes, the AS-HgX product can be injected into fluegas streams, where it reacts with mercury to form mercuric sulfide, a very stable and insoluble compound, notes Butz. By altering the structure of the metal sulfide and the manufacturing process, Novinda can make related products using the same product platform. Novinda has partnered with several manufacturers of injection systems that work well because the dispersal of the material in the fluegas is a key factor in the product's effectiveness.

Novinda's product has been tested in full-scale coal power plants burning several types of coal in various locations, and has shown the ability to remove over 90% of mercury present in plant fluegas, Butz says. He adds that the tests suggested that AS-HgX is particularly effective in plants that use dry scrubbing to remove SO_2. In the future, AS-HgX may also be applied for mercury removal in fluegas from industrial boilers and cement kilns.

(*Continued from p. 11*)

than alternative reduction catalysts that are based on gold or silver. The results are described in the July 30 issue of *Nature Communications*.

. . . and CO_2-to-methanol

Meanwhile, a new catalytic system that directly converts CO_2 into methanol has been developed by scientists at the U.S. Dept. of Energy's Brookhaven National Laboratory (Upton, N.Y.; www.bnl.gov), in collaboration with researchers from the University of Seville (Spain; www.us.es) and the Central University of Venezuela (Caracas; www.ucv.ve). The catalyst is composed of copper and cerium oxide (ceria) nanoparticles.

The research team found that the interface of the two types of nanoparticles is critical to the reactivity of the catalyst system. Laboratory studies showed that the catalyst converts CO_2 to methanol more than 1,000 times faster than plain copper particles, and almost 90 times faster than a common copper/zinc-oxide catalyst currently used industrially. The results are described in the August 1, 2014 issue of *Science*.

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Commercial debut planned for an FCC process with enhanced olefins production

JX Nippon Oil & Energy Corp. (JX_NOE; Tokyo, Japan; www.noe.jx-group.co.jp) plans to construct the first commercial plant to utilize its high-severity fluid catalytic cracking (HS-FCC) technology, which has been demonstrated to generate higher ethylene and propylene yields compared to conventional FCC technology. The new plant, which could start operating as early as 2018 at the company's Kashima Refinery, will have a processing capacity of 24,000 bbl/d of crude oil, which is eight times larger than the semi-commercial demonstration plant JX_NOE has operated at its Mizushima Refinery since April 2011 (*Chem. Eng.*, August 2013, p. 10), and is equivalent to an ethylene capacity of 300,000 ton/d. JX_NOE will invest around $500–1,000 million for the project, which includes the construction of both the HS-FCC plant and the associated olefin-conversion unit.

JX_NOE currently supplies 1 million ton/yr of propylene to the petrochemical market, and aims to become the leading propylene supplier in Asia by boosting this to 1.8-million ton/yr, with 300,000 ton/yr from the new HS-FCC plant and the remaining 400,000–500,000 ton/yr from production plants outside Japan. The company believes the HS-FCC technology will help strengthen its petrochemicals production capacity.

The HS-FCC process features a downflow reactor that has the advantage of suppressing backmixing, and also results in shorter contact times (0.5–0.6 s) between the feed and the catalyst, which allows higher catalyst-to-oil ratios. The short contact times also enable the process to operate at higher (600°C) temperatures (For more process information, see *Chem. Eng.*, August 2009, p. 12).

(*Continues on p. 18*)

TSA for CCS advances

Last month, a post-combustion process capable of separating CO_2 from fluegas at one-third the cost of alternative separation processes moved a step closer to commercialization, as Inventys Thermal Technologies, Inc. (Burnaby, B.C., Canada; www.inventysinc.com) received additional funding from major investors, including Chevron Technology Ventures LLC, the venture-capital arm of Chevron Corp. (San Ramon, Calif.; www.chevron.com), and Chrysalix Energy Venture Capital. Inventys will use the additional financing to expand manufacturing and enable the deployment of full-scale systems using its VeloxoTherm gas-separation technology in late 2016. VeloxoTherm is based on a proprietary, low-pressure temperature-swing adsorption (TSA) technology that is said to achieve a carbon-capture cost of $15/m.t. — one third the cost of current post-combustion methods. (For more details about VeloxTherm, see *Chem. Eng.*, January 2011, p. 9). ❑

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A more direct route to ethyl acetate

Last June, Showa Denko K.K. (SDK; Tokyo, Japan; www.sdk.co.jp) started commercial operation of its new 100,000-ton/yr ethyl acetate plant at Oita Complex. The new plant is the first commercial facility in Japan to use the company's proprietary production-process technology. The process technology was first demonstrated in a 60,000-ton/yr plant in Indonesia.

SDK formerly produced ethyl acetate by a two-step process in which acetaldehyde is first made from ethylene, and then converted to ethyl acetate. In the new process, imported acetic acid is used as a feedstock, and reacts directly with ethylene using a solid heteropolyacid catalyst, which SDK developed in collaboration with professor Toshio Okuhara at Hokkaido University and Emeritus professor Makoto Misono at the University of Tokyo.

Ethyl acetate is an organic solvent used in a wide range of applications, including printing ink, paint, and adhesives for electronic devices. While global demand for the product is expected to continue growing, its business environment continues to be difficult due to the rise in raw material and fuel costs, and the increase in imports of inexpensive products that are mainly produced in China via a fermentation process.

Municipal water sludge-optimization technology poised for growth

A sludge-optimization technology for municipal water-treatment facilities is poised for rapid growth after the exclusive worldwide patent-licensing rights for the technology were acquired by CNP Technology Water and Biosolids Corp. (Kenosha, Wisc.; www.cnp-tec.com).

The technology, known as AirPrex, was initially developed at Berlin Water Works (Germany) in 2004, and was initially licensed to the German company PCS GmbH. AirPrex was subsequently implemented at three sites (two in Germany and one in the Netherlands from 2007 to 2012). Now, with the license transferred to CNP, orders to install the technology have been made for the Amsterdam West water-treatment plant in the Netherlands, as well as plants in Salzgitter and Uelzen, Germany. Several other projects are in the works in South Africa and in the U.S.

AirPrex uses a reactor with an aeration system to recover the high-phosphorus mineral struvite from sludge, thus avoiding the struvite precipitation that becomes a major maintenance nuisance for water-treatment

Monitoring pipeline deposits in realtime

The presence of scale depositions in pipelines can restrict flow, limit heat transfer and decrease efficiency. The ability to monitor pipelines for depositions helps avoid issues and optimize costs. The Deposition Watch system from Flowrox Inc. (Linthicum, Md; www.flowrox.us) presents a real-time, online predictive-monitoring solution for detecting scale-related issues in process pipelines that is based on the principles of electrical capacitance tomography (ECT; For more on ECT, see *Chem. Eng.*, October 1995, pp. 30–33).

ECT imaging techniques apply measured excitation signals to materials and monitor the output signals. Through an iterative mathematical model, these signals reveal information about the electrical properties of the measured material. The Deposition Watch system measures pipe volume and determines the electrical properties, including permittivity distribution and conductivity, of the process fluid and the unwanted deposition. Comparison of these materials' different electrical properties provides physical information about the behavior of the materials inside the pipe. For instance, estimated permittivity values shed light on deposition thickness and its distribution along pipe walls. Also, it is possible to evaluate deposition growth rate and available free pipe-volume percentage, allowing engineers to predict when maintenance or intervention will be required.

equipment. The technology simultaneously recovers a high-phosphorus byproduct that can be sold for use as slow-release fertilizer.

A key feature of AirPrex is that the struvite recovery for plants using biological phosphorus removal occurs after the anaerobic digestion of the biosolids, but before the dewatering step. This allows a reduction of energy and chemical additives, says Gerhard Forstner, president of CNP. In addition to eliminating the struvite buildup on process equipment, the removal of the mineral improves the efficiency of the sludge dewatering process. When present, struvite inhibits dewatering, leading to wetter cake solids and higher polymer consumption. Airprex realizes up to a five-percentage-point increase in dry solids in the cake, Forstner says, as well as lowering polymer consumption by up to 30% and reducing phosphorus-recycling load by up to 90% (For more on P-recovery, see *Chem. Eng.*, February 2013, pp. 17–22).

CNP is offering AirPrex as a technology provider, with the installation carried out by contractors. Forstner says the company works with engineering consultants to provide customized wastewater treatment systems that offer the best return on investment.

An inexpensive, sensitive device for detecting explosives

A microfluidic, paper-based analytical device (μPAD) — in conjunction with confirmation by a "lab-on-a-chip" analysis — was developed for detection of three explosives (trinitro aromatics) by a team from the University of Technology Sydney (Sydney, Australia; www.uts.edu.au), the University of Lausanne (Switzerland; www.unil.ch), and Florida International University (Miami; www.fiu.edu).

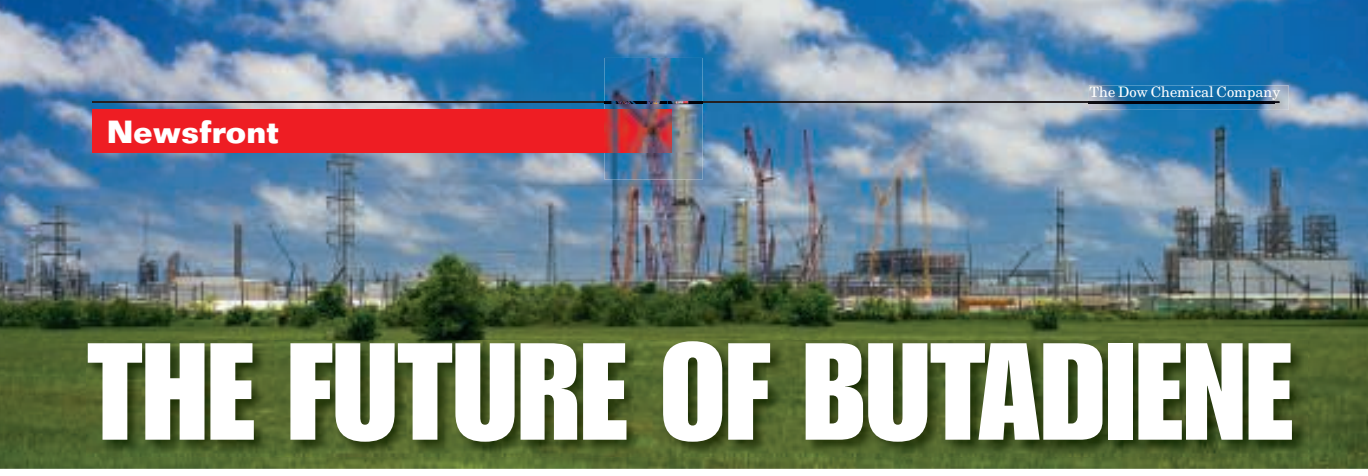
A wide range of analytical techniques have been developed for explosives detection, some of them offering high sensitivity and selectivity. However, their long analysis times, high costs and bulky instrumentation limit their use in strategic locations, such as airports or entrances to chemical and other secure facilities. Important advantages of μPADs are low cost, easy storage and disposal, and no requirements for pumps.

The fabrication of μPADs involves the construction of patterns of hydrophobic barriers on filter paper, using techniques such as photolithography, plotting, paper cutting, plasma oxidation, inkjet printing and laser treatment. The barriers allow controlled fluid movement that segregates chemical reactions. In the case of this particular application, the μPAD works by monitoring a color change as the nitro compounds react with a strong base. Color development following exposure of the base to trinitro explosives is observed immediately, but is measured after 10 min to ensure completion of the reaction.

The limits of detection of trinitrotoluene (TNT), trinitrobenzene (TNB) and trinitrophenylmethylnitramine (tetryl) on the μPAD were determined after application of 0.5 μL of each explosive at concentrations ranging from 1 to 200 ppm onto the active device, both visually and using a video spectral comparator (VSC6000) at 480-nm wavelength. The minimum levels detected visually (and with the VSC6000) were 30 ± 3 ng (7.5 ± 1.0 ng) for TNB, 50 ± 4 ng (12.5 ± 2.0 ng) for TNT and 70 ± 2ng (15.0 ± 2.0 ng) for tetryl. The technology can also be used for detecting black powder, smokeless powder and fertilizer-based explosives, such as ammonium nitrate. ■

FCC PROCESS (*Continued from p. 14*)

At the Mizushima Refinery 3,000-bbl/d demonstration plant, propylene yields have been found to be enhanced by 25 wt.% — much higher than the 4 wt.% yield achieved in the existing FCC unit. The butenes yield was also enhanced by 6% to 20 wt.%. Although the gasoline yield is reduced by 60% to 29 wt.%, the yield of high-octane gasoline is increased, says the company.



The Dow Chemical Company

THE FUTURE OF BUTADIENE

Butadiene scarcity imposed by the shift toward ethane cracking provides opportunities for the development of new technologies

The chemical process industries (CPI) have experienced many benefits from the so-called shale-gas boom — recent years have seen an unprecedented rise in construction and expansion activity in the petrochemicals sector. Shown in Figure 1 is construction at the Freeport, Tex. facility of The Dow Chemical Company (Dow; Midland, Mich.; www.dow.com). Dow is just one of many companies to initiate large petrochemical projects on the U.S. Gulf Coast in the wake of increased shale-gas availability.

"We are in the midst of unprecedented growth due to the abundance of natural gas liquids," explains Bob Maughon, Dow's global R&D director for performance plastics and feedstocks. "The use of natural-gas liquids took hold in 2009. In 2011 and 2012, the abundance of ethane compelled the industry to flex strongly toward natural-gas feedstocks and away from petroleum-derived naphtha."

Since this shift, though, the changing feedstock landscape in petroleum refineries has led to shortages for many co-products, including 1,3-butadiene (butadiene; Figure 2), an important building block for synthetic rubber and nylon. Says Maughon: "As naphtha cracking has waned and ethane cracking increases, cracker co-product production drops. The slate of products that have been affected include propylene, butadiene, isoprene, benzene and others. It isn't that the industry doesn't want to produce these chemicals. The economics of ethane-only cracking have become so compelling that naphtha cracking has been squeezed. Production is driven to the lighter feedstocks and co-product production is lost."

Figure 3 shows the variation in production from naphtha-cracking operations versus the cracking of lighter feedstocks. The shale-gas-imposed scarcity for chemicals like butadiene presents opportunities for new technologies to arise. This article covers some actions that companies are taking in response to butadiene shortages, including the development of on-purpose production methods and the use of bio-based feedstocks.

Oxidative dehydrogenation

TPC Group Inc. (Houston; www.tpcgrp.com), has been commercially operating its OXO-D butadiene process technology for over 40 years. TPC's OXO-D technology converts butylenes into butadiene through oxidative dehydrogenation. In June 2014, TPC announced a partnership with Honeywell's UOP LLC (Des Plains, Ill.; www.uop.com) to further develop and globally license this technology in the wake of increased demand for on-purpose butadiene. There will be research and development teams and pilot plants at both companies' facilities to jointly develop process advancements. Also, through this agreement, UOP acquires the worldwide exclusive licensing rights of the TPC OXO-D process.

Jim Rekoske, petrochemicals global business director for UOP, describes what attracted UOP to this partnership, saying "A key distinguishing feature of the OXO-D process is the more than 40 years of operating experience. This operating experience allows TPC and UOP to understand and position on-purpose butadiene technology for our licensing customers." Rekoske goes on to emphasize that timing is key for this collaboration, stating that "This is not a technology that needs a long development period or a long market incubation period — the opportunities are now."

Both companies stress the importance of on-purpose butadiene production going forward — demand for butadiene-based products, such as tires, is rising, as traditional feedstocks are becoming less readily available. "Lighter feedstock slate means, on average, fewer kilograms of butadiene produced per metric ton of ethylene produced. On-purpose butadiene technologies will be needed to fill this gap," explains Rekoske.

With the ongoing flurry of activities in the shale-gas sector, TPC Group sees global potential for the licensing of the OXO-D process. Miguel Desdin, senior vice president and chief financial officer of

FIGURE 1. New construction (like that at Dow's Freeport complex) is rampant as the industry takes advantage of the shale-gas boom

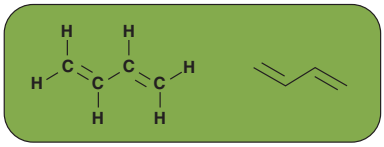


FIGURE 2. 1,3-butadiene is a major co-product from naphtha cracking, and is experiencing shortages due to the newfound dependence on lighter refining feedstocks

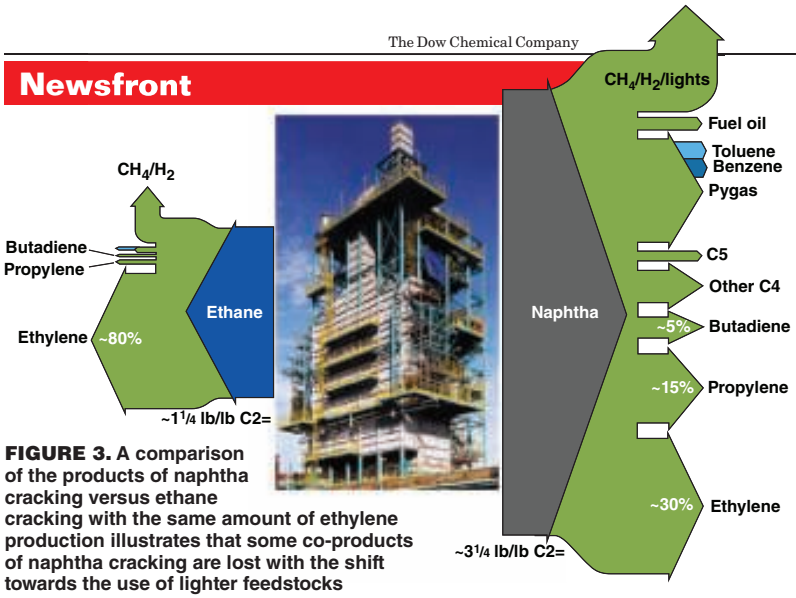


FIGURE 3. A comparison of the products of naphtha cracking versus ethane cracking with the same amount of ethylene production illustrates that some co-products of naphtha cracking are lost with the shift towards the use of lighter feedstocks

TPC Group states that "The global market will need on-purpose butadiene to meet future demand, and in order to satisfy that demand, multiple on-purpose butadiene plants in various regions of the world will be required." Desdin goes on to say, "Since the announcement, there has been a significant amount of interest in the technology. UOP is currently in the process of creating a licensing package for the OXO-D technology, which will be available to prospective licensees in the fourth quarter of 2014."

In the earlier stages of development is another technology partnership focused on butadiene, also announced in June 2014, by The Linde Group (Pullach, Germany; www.linde.com) and BASF SE (Ludwigshafen, Germany; www.basf.com). The two companies are collaborating on the development and licensing of an on-purpose route from butane to butadiene via butenes. For butene synthesis from butane, BASF is contributing a high-yield monolithic catalyst. In the presence of a metal-oxide catalyst, those butenes are then subsequently converted via an oxydehydrogenation step into butadiene. Although the process is still quite new, progress to commercialization is moving ahead, with developments occurring at both kilogram-scale and pilot-plant-scale operations in Ludwigshafen (*Chem. Eng.*, July 2014, p. 14).

Last year, Wison Engineering Ltd. (Shanghai; www.wison.com) introduced its own on-purpose butadiene technique, also based on oxidative dehydrogenation principles (*Chem. Eng.*, June 2013, p. 15). With a proprietary high-yield catalyst in its arsenal and a process-design package completed, Wison expects to announce a license agreement for commercial deployment of the technology in the coming months.

Another on-purpose technology developed in response to the prevalence of lighter cracking feedstocks and the associated reduction in butadiene supply is the butene-to-crude-butadiene process (abbreviated BTcB), which was introduced by Mitsubishi Chemical Corp. (MCC; Tokyo, Japan; www.m-kagaku.co.jp) at the 2014 American Institute of Chemical Engineers (AIChE) Spring Meeting. The BTcB process (Figure 4) involves the oxidative dehydrogenation of a C4 mixture to produce 1,3-butadiene in the presence of air, steam and a very selective catalyst. Yields are estimated to be 10–25% higher than past butadiene-production technologies, per MCC's evaluations. Also, the catalyst achieves a very long operational life without the need for regeneration, says the company. The reaction runs at ambient pressure, and operating temperatures are typically between 300 and 400°C. MCC also estimates that this process involves up to 80% less wastewater than past butadiene technologies, decreasing the environmental impact of operations.

The process is flexible enough that all industrial C4 mixtures, in-

cluding *n*-butenes and C4 streams from naphtha cracking and fluid-catalytic-cracking (FCC) operations can be processed to produce butadiene. The feedstock versatility of this process makes it feasible to retrofit into an existing facility or construct new-build plants. Testing at a demonstration plant with a capacity of 200 metric tons per year (m.t./yr) and development of a process design package were both completed in 2013, and technology licensing activity commenced in 2014. Currently, feasibility studies for commercial plants are being executed with potential customers.

Bio-based butadiene

While many groups are investigating on-purpose butadiene solutions that utilize existing chemical streams (like butene or butane) as feedstock, others are investing in bio-based routes to alleviate concerns associated with butadiene availability. Last fall, a bio-based butanediol process technology from Genomatica (San Diego, Calif.; www.genomatica.com) was awarded the Kirkpatrick Chemical Engineering Achievement Award (*Chem. Eng.*, November 2013, pp. 15–19). In the months since winning the Kirkpatrick Award, Genomatica has announced multiple milestones in developing its next bio-based process technology focused on the production of bio-based butadiene. They have announced two high-profile partnerships with Braskem S.A. (São Paulo, Brazil; www.braskem.com.br) and Eni S.p.A.'s (Rome; www.eni.com) chemical subsidiary Versalis.

The combination of these strategic collaborations gives Genomatica global reach for the licensing of its bio-butadiene technology. Under a December 2013 agreement, Genomatica and Braskem will together develop and commercialize a process to make butadiene from renewable raw materials. With this agreement, Braskem gains exclusive licensing rights to use the technology in the Americas. The Versalis partnership is targeted on licensing activities for bio-butadiene production in Europe, Asia and Africa,

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and will specifically focus on using non-food lignocellulosic biomass as a raw material.

Genomatica sees global viability for bio-butadiene, citing shifting refinery feeds and an increased awareness of product sustainability. The company says that the butadiene development program is off to a fast start, with $100 million in industry investment and strategic partners with commercialization intent.

Genomatica's butadiene platform employs proprietary microorganisms that convert biological feedstocks into butadiene directly or via an intermediate. All of the steps in these metabolic pathways have demonstrated functional expression. A patent was granted in November 2013 covering a method for the direct production of butadiene. According to the company, the process involves all aspects of separation and purification to deliver a chemical product that will work in existing applications without requiring changes by downstream users. This versatility, along with the use of renewable feedstocks, are the main aspects that have drawn commercial interest in the process.

Another company seeking a renewable pathway to butadiene is Cobalt Technologies (Mountain View, Calif; www.cobalttech.com), which has developed a fermentation platform that takes sugars sourced from cellulosic biomass and converts them into *n*-butanol, which can subsequently be reacted to form many other chemicals, including butadiene. The ability to leverage the flexibility of *n*-butanol as a chemical starting point is a huge benefit, says Andy Meyer, president of Cobalt Technologies. "*N*-butanol is an incredible building block into other renewable chemicals and fuels. Given our cost position in the production of *n*-butanol, and given the impact of shale gas on C4 molecules, it became a natural fit to pursue butadiene as a product platform."

According to the company, Cobalt is finalizing a joint-development agreement with strategic partners in Asia, which will complete the work required to scale the remaining elements of the technology. "Upon successful completion, we plan to move forward with commercialization with our Asia partners and further monetize the technology globally through other licensing and partnership arrangements," says Meyer. Cobalt is also in the preliminary stages of pursuing various opportunities in the U.S.

Cobalt and Genomatica are just two of the many companies at the forefront of bio-based butadiene technology. Several other notable developments have been announced in the past year, including the BioButterfly project, a research partnership between Axens (Rueil-Malmaison, France; www.axens.net), IFP Energies Nouvellas (Rueil-Malmaison, France; www.ifpenergiesnouvelles.com) and Michelin (Clermont-Ferrand, France; www.michelin.com) to create and market a process for producing bio-sourced butadiene. Scoped for eight years, the project is focused on the need for alternative raw-material sources for the synthetic rubbers industry, and, with €52 million in backing, the partners hope that it will be a major step toward a more environmentally friendly rubber industry.

Additionally, Global Bioenergies (Evry, France; www.global-bioenergies.com) was granted a patent in April 2014 for production of bio-butadiene via enzymatic dehydration. Further development of this process is the scope of a partnership with Synthos Group S.A. (Oswiecim, Poland; www.synthosgroup.com). Also investigating enzymatic technology for butadiene production is Arzeda Corp. (Seattle, Wash.; www.arzeda.com), which has designed specific enzymatic pathways to convert biomass into butadiene. For the process development of this technology, Arzeda has collaborated with Invista (Wichita, Kan.; www.invista.com), citing butadiene price volatility as one of the main drivers behind this partnership.

Utilizing waste gas

A novel technology developed by LanzaTech (Skokie, Ill.; www.lanzatech.com) aims to create

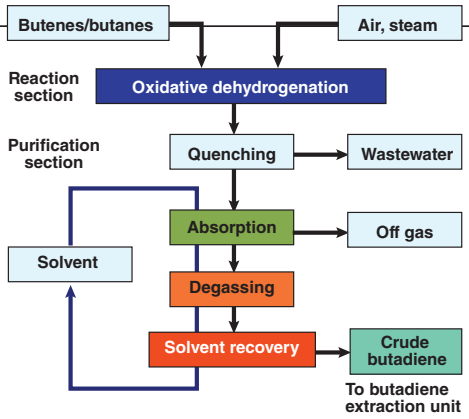

FIGURE 4. MCC's on-purpose butadiene process is designed to be compatible with a variety of C4 feedstocks

a platform for butadiene synthesis from waste-gas feedstocks. The feed gases for LanzaTech's process can come from a variety of sources, both industrial and biological, including offgases from steel mills and CPI plants, and syngas generated from municipal solid waste or agricultural waste.

Together with SK Innovation, (SKI; Seoul, South Korea; www.sk.com) in a partnership announced in late 2013, LanzaTech plans to commercialize a two-step platform to create butadiene from waste gases that contain carbon monoxide (CO). First, through a patented fermentation process, an acetogenic microbe converts the CO from the feed gas into 2,3-butanediol and ethanol. Via downstream catalytic technology provided by SKI, the 2,3-butanediol fermentation intermediate undergoes double dehydration to form 1,3-butadiene.

The biochemical pathway used in LanzaTech's process (called the Wood-Ljungdahl pathway) for fermentation to 2,3-butanediol is shown in Figure 5. A hallmark of this process technology is its ability to run continuously rather than in batches. "Syngas can be constantly processed and butanediol can continuously pass to the catalysis step," says Alice Havill, senior process engineer and separations lead at LanzaTech. With advanced lab-scale testing underway at both companies, a pilot demonstration of this technology is planned for the first quarter of 2015 at SKI's research facility in Daejeon, Korea, with an eventual goal of making the platform available for licensing.

Another benefit of this process is its versatility. As seen in Figure 5, either CO or CO_2 can be used as a raw material to synthesize butadiene. LanzaTech has partnered with Invista on further development of processes utilizing a CO_2/H_2 feedstock, targeting the nylon 6 and 6,6 product chain as a potential application for the butadiene product. Commercialization for this project is expected in 2018.

Commercial interest has been piqued, especially in the areas of polymers, synthetic rubbers and industrial solvents, with companies requesting samples of fermentation-based butadiene as a "drop-in" replacement for butadiene produced via traditional methods. LanzaTech touts the technology's unique feedstock as a driver for commercial success, citing price fluctuations as a crucial factor in the development of new butadiene-production techniques, not only in the case of crude oil, but also in the sugar-based feedstocks that are used for many bio-based routes, which can experience similar price volatility. According to Havill, "LanzaTech has developed an innovative platform that recycles carbon-rich waste gases and residues and converts these local, highly abundant waste and low-cost resources into sustainable, valuable commodities." She continues, saying "The need for new butadiene sources will only be exacerbated by the rising global demand for butadiene-based products. This will especially be evident in the growing consumption of rubber in emerging markets — the commercial reach is global."

Eliminating butadiene

The use of alternative raw materials can also allow companies to decrease their reliance on butadiene. At the 2013 PCI American Nylon Symposium, Rennovia, Inc. (Menlo Park, Calif.; www.rennovia.com) announced the demonstration of a continuous bio-based pathway to hexamethylenediamine (HMD) that utilizes widely available, renewable feedstocks. Traditionally, HMD, an

important component in the production of nylons and polyurethanes, is produced from a butadiene hydrocyanation reaction forming adiponitrile, which is then hydrogenated to HMD. Rennovia's new process uses glucose as a raw material for a two-step catalytic conversion to HMD — no butadiene is required. The process has been demonstrated to run continuously, and the construction of a mini-plant is planned for 2015. In February 2014, Archer Daniels Midland Co. (ADM; Decatur, Ill.; www.adm.com) invested $25 million for the advancement of Rennovia's renewable technologies. Subsequently, Genomatica announced in August 2014 that they would begin developing bio-based routes to various nylon intermediates, including HMD, caprolactum and adipic acid.

Others are searching for alternative products altogether. In addition to their butadiene partnership with Genomatica, Versalis has joined forces with agricultural biomaterials company Yulex Corp. (Phoenix, Ariz.; www.yulex.com) for the manufacture of biorubber materials using guayule, a renewable, non-food crop, as a raw material. Plans for an industrial production facility in Europe are underway, where the biorubber will be a supplementary product to Versalis' traditional butadiene-based synthetic rubber. Once again, forecasted scarcity and price volatility of butadiene are among the factors driving this partnership.

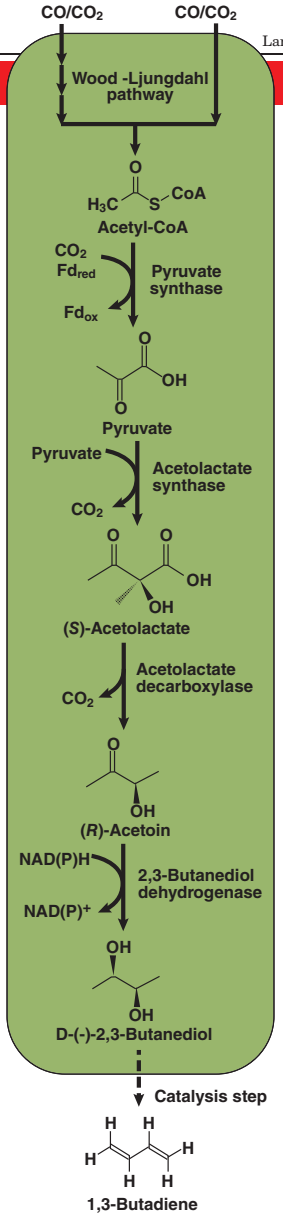

FIGURE 5. LanzaTech's fermentation/catalysis platform follows this biochemical pathway

On-purpose chemistry's future

In the case of butadiene, it is clear that on-purpose and bio-based technologies are not merely a fad. Companies are investing and showing confidence in the commercial potential of these processes. On the future of on-purpose technologies in the CPI, Dow's Bob Maughon remains optimistic about the industry's willingness to adapt, saying, "In general, we were forced into the co-product ecosystem and we learned to love it. I am convinced that we will learn to love the on-purpose world even more." He also emphasizes one major positive aspect of an on-purpose economy: companies can apply capital to make precisely the product they want. There are obviously great opportunities in the field of on-demand production technologies for byproducts of crude-refining processes. Beyond butadiene, speaking about the next on-purpose trend on the horizon, Maughon explains that cyclopentadiene, like butadiene, is a cracker co-product with many uses. However, there are no on-demand routes to it currently. Also among the chemicals affected by the move toward ethane-only cracking are isoprene and piperylene, as well as aromatics like benzene, toluene and xylene. It seems likely that companies will continue investigating advanced butadiene process technologies, and perhaps they will follow suit for cyclopentadiene and other chemicals. ■

Mary Page Bailey

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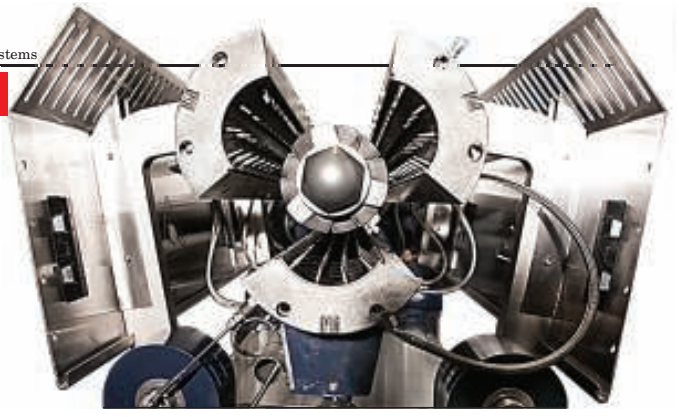

FIGURE 1. The TriVolution offers twelve pin-flight intermeshing zones in the cross section, versus two for a typical twin-screw extruder or three for a typical continuous kneader

A changing marketplace necessitates the need for extrusion equipment with more flexibility and greater efficiency

Whether the application is reactive extrusion, pharmaceutical manufacturing, compounding or plastics processing, finding the sweet spot where increased efficiency, flexibility and lower capital expenditures are well balanced is the holy grail of today's extruder operations.

Most industries that employ extrusion are facing a very different market than what existed just a few years ago. This new marketplace is fraught with process challenges, including the development of new materials with different characteristics, more varieties of materials being run on one line, frequent changeovers from one product to the next and fierce market competition from overseas.

Unfortunately, many processors have large production machines that were not designed for the rigors of the current marketplace. Older machines were created to be efficient when making continuous runs for days and weeks at a time, says Adam Dreiblatt, director of process technology at Century Extrusion (Traverse City, Mich.; www.centuryextrusion.com), but now they are running for only hours before they are stopped and changed over to accommodate the next product, and again turned on for just a few hours before they are stopped and changed over yet again.

"Because of the diversity of products required in today's market and because of the make-to-order world we now live in, the companies that make these materials face severe challenges when it comes to making their products in a cost effective way," Dreiblatt says. "Their cost margins and productivity are being squeezed because of the way the global world is evolving."

For example, in the compounding industry, he says, manufacturers of resins that are used to make articles like cell-phone cases and automotive parts, are often charged with finding new materials for better performance. "It might be necessary to create a new blend of plastics, additives and rubbers for a new product, such as a bumper and then another new resin for something like a valve cover and still another material for radio knobs," says Dreiblatt. "As a result, manufacturers of the resins and compounds are rapidly expanding their portfolio of products. However, they can't just make a bunch and keep it on a shelf in their warehouse because it costs too much to inventory and they run the risk of making more than their customers will want. Because of these factors, compounders require production equipment that is capable of not only producing a variety of materials, but also changing over quickly from one run to the next."

"The good news is that the equipment is now evolving to meet the challenges presented by the demands of this new marketplace," Dreiblatt says. "New machines are being designed for faster turnarounds and changeovers. High-performance screw and barrel materials are being developed to reduce wear and tear on the equipment to reduce downtime. Some extruders are being designed with lower costs in mind. And some are being designed for greater efficiency and throughput."

And, no matter what the industry or application, efficiency, flexibility and lower costs are the most requested items on the extrusion wish list.

Increased efficiency

"While products and materials are being innovated, the equipment tends to be developed more slowly, which leaves many users of extrusion technology running new processes on old equipment or, sometimes, new equipment that operates on the same principle that has existed for the past 40 years," says Michael Lazorchak, global product manager, mixing systems with B&P Process Equipment and Systems (Saginaw, Mich.; www.bpprocess.com). "This is not conducive to efficiency and reliability for today's processors."

However, equipment providers such as B&P are finally beginning to address the need for increased ef-

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FIGURE 2. The BCG extruder offers a monoblock design that features no dead spaces or connections, which makes installation and cleaning easy

ficiency from the machine's process zone, rather than through power capabilities alone. For newer applications, such as reactive extrusion and devolatilization, as well as traditional chemical industry applications, such as processing catalysts, mastics, graphite and carbon-based materials, and in plastics compounding, B&P's TriVolution kneader (Figure 1) offers a non-traditional operating principle in an effort to increase efficiency.

The kneader leverages elongational mixing to stretch and disperse viscous materials. Elongational mixing imparts a high degree of particle droplet deformation and breakup to finely disperse materials without excessive shear or heat generation. The TriVolution offers twelve pin-flight intermeshing zones in the cross section versus two for a typical twin-screw extruder or three for a typical continuous kneader. The key to improved efficiency lies in these twelve zones, where elongational flow action occurs, says Lazorchak.

Several aspects of the design enable efficient extrusion, especially in devolatilization and reactive extrusion. Smaller channels and quick multiplication of flow splitting for a given throughput result in thinner material thicknesses. This creates shorter diffusion paths for volatiles to escape from the melt. Larger free volume for a given screw diameter offers longer residence times. And, says Lazorchak, narrow residence-time distribution, coupled with excellent surface-area renewal, promote efficient temperature control of the melt. Volatile byproducts can be efficiently removed and a greater number of molecular chains are exposed for higher reaction rates.

In industries such as pharmaceuticals, where there may be frequent changeovers and contamination is a risk, efficiency in changeover and cleaning the equipment, in addition to better controls for more efficient throughput, are high priorities. For this reason, L.B. Bohle Maschinen + Verfahren GmbH (Enningerloh, Ger-

FIGURE 3. A configurable rotary-wheel extrusion blow molder allows for high outputs of a range of bottle sizes used in beverage, dairy and household products on a single platform

many; www.lbbohle.de) introduced a newly designed GMP-compliant twin-screw extruder, supplied by a continuous mass-controlled powder dosing unit and a continuous liquid dosing unit (Figure 2). The BCG extruder offers a monoblock design that features no dead spaces or connections, which makes installation and cleaning easy. The "real" torque measurement — on each screw individually — allows for tighter control of the process, says Andreas Altmeyer, head the service center at L.B. Bohle.

Finding flexibility

Sometimes increased efficiency also comes in the form of greater flexibility. Handling a variety of materials and frequent product changes means there are often changeovers, which amounts to a lot of downtime. This is especially true when extruding plastics, says David Schroeder, president and CEO of Graham Engineering (York, Pa.; www.grahamengineering.com). "Downtime or loss of production and material due to changeover is expensive and time consuming. Product quality can also suffer, resulting in scrap, until optimal production is achieved," explains Schroeder. "In addition, equipment is a significant capital investment. A single line or machine capable of producing a variety of parts or products helps leverage that investment."

For this reason, Graham Engineering offers rapid in-line color change via its accumulator heads. While many competitive heads can take as much as 8 to 12 h to purge from one color to another, Graham heads can generally change from one color to another in 30 to 60 min, using only simple hand tools. After removing some bolts, the hydraulic cylinders on the head are used to lift the diverter and plunger out of the head body. The diverter plunger and head body can then be cleaned using a brass scraper. When finished, the diverter and plunger

are lowered and fastened back into the head. Quality parts with a new color can be manufactured within a few shots.

When it comes to extrusion blow molding, Graham has also developed a configurable version of its rotary-wheel extrusion blow molder for high outputs of bottles (Figure 3). "It is now configurable to accommodate a range of bottle sizes used in beverage, dairy and household products on a single platform," says Schroeder.

And, the American Kuhne brand (a part of the Graham Group; www.americankuhne.com), offers a modular extruder. "Interchangeable extruders, the barrel, screw and feed section, are available on one common, stationary base," says Schroeder. "This allows one extruder to swing into place, rapidly replacing the other, enabling offline purging or service, while another extruder can be preheated and aligned, minimizing downtime."

Flexibility is equally important in the compounding industry, says Paul Lloyd, business unit director with Farrel Pomini (Ansonia, Conn.; www.farrel-pomini.com). "In the compounding industry, the ability to adapt in markets that are constantly changing is important. There are frequent formulation changes based on the development of new additives, new customer requirements or new market opportunities," he says. "So the ability to have an asset that is flexible is desirable because extrusion equipment is expensive and traditionally difficult to change out."

To help provide flexibility, Farrel Pomini offers a two-stage machine with a mixer at the top and an extruder underneath, which allows the production of quality compounds in the mixing section and the pressurization in the extrusion section. In traditional extruders, these two processes are combined, explains Lloyd. Providing a two-stage process with a mixer and extruder that are separate from each other allows additional process variables to be employed, which allows flexibility to be achieved through the control system rather than making mechanical changes as you would on a traditional extruder. "This allows a single machine to process a range of materials without any mechanical changes to the equipment," he says.

The company's latest CP4000 Compact Processor (Figure 4) allows more flexibility in variables such as throughput rate, rotor speed, temperature and discharge-gate position to improve or change mixing parameters. "Because of the ability to make changes via programming the necessary process changes into the recipe on the control system, the machine is inherently more flexible than a traditional extruder,

Farrel Pomini

FIGURE 4. The CP4000 Compact Processor allows more flexibility in variables such as throughput rate, rotor speed, temperature and discharge-gate position to improve or change mixing parameters

which typically requires the use of tools and additional components for changeover of products."

Also operating on a new premise to increase flexibility when compounding and injecting product-specific formulations, the injection molding compounder (IMC) from KraussMaffei (Munich, Germany; www.kraussmafei.com) links the continuous extrusion process with the discontinuous injection-molding process in a single-stage process. This set up protects the material by processing at one temperature. The process starts with individual materials being metered by mass. The plasticized and homogenized material moves from the extruder into the barrel of the injection unit via a heated runner. In the injection and holding pressure phase, the extruder continuously supplies the material through a buffer to ensure consistent formulation quality. The material is shaped in the twin-plated clamping unit on one of the standard injection molding machines offered by the company. The IMC makes it possible to purchase less expensive raw materials, initiate compounding tailored to the application and run small production series. It also provides an increase in flexibility in the way users can process and create new combinations of a vast assortment of materials, from blends to real reinforcing agents to fillers.

Reduced costs

While efficiency and flexibility help reduce operating costs, the capital investment of the equipment itself is often a deterrent when it comes to updating equipment to suit the demands of this globally competitive marketplace. And, with many compounders moving overseas, there's been an abundance of extrusion equipment suppliers cropping up in China and other Asian countries, offering machines at deeply reduced

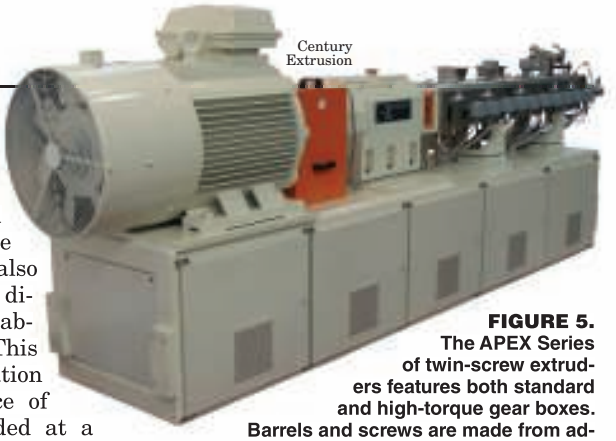


FIGURE 5. The APEX Series of twin-screw extruders features both standard and high-torque gear boxes. Barrels and screws are made from advanced materials and wear technology

prices. However, many of these machines are not designed and crafted with the same quality parts found in European- and American-made machines. But, some European and American suppliers are partnering with selected Asian companies so that the critical parts are made in Europe or the U.S. and the non-critical parts hail from China, where the assembly is also done under the direction of the established firms. "This results in the creation of a quality piece of equipment provided at a lower cost," says Dreiblatt. "This is important in today's economy because in any application, there's a lot of cost pressure to get down to the lowest capital cost possible, yet the company purchasing the equipment still needs high productivity. But unless the supplier has partnered with an established expert, the machines coming out of China are not high-quality, high-performance machines."

He says his own company has established a partnership to provide machines of this "hybrid" nature. For example, the Century Extrusion APEX Series of twin-screw extruders (Figure 5) is engineered to provide optimal value to compounders around the world. Engineering teams from both Century Extrusion and Ruiya Extrusion in China worked closely to integrate the best design features and materials into three flexible extruder models, allowing the equipment to deliver high performance, flexibility and reduced cost of ownership. The series features both standard and high-torque gear boxes that are designed and manufactured in Europe, and the machines are available with Century's cold-formed, high-torque shaft technology, as well as barrels and screws that are made from Century's advanced materials and wear technology.

Obviously, more extrusion equipment providers are beginning to understand the changing world in which their customers are currently operating and are working hard to create lower cost machines that provide higher efficiencies and more flexibility to meet the needs of processors in this fast-paced, changing marketplace. ■

Joy LePree

FOCUS ON

Valves

Tideflex Technologies

Hayward Flow Control

Dresser-Rand

Thermoplastic butterfly valve enables many stopping positions

With its advanced, one-piece thermoplastic design and construction, the patent-pending BYV Series Butterfly Valve (photo) offers a variety of design advances, including a hand lever that features a 72-spline interlock mechanism that allows for 19 stopping positions (every 5 deg). Pneumatic or electric actuators are available. Available in a variety of thermoplastic materials (for the body, disc and liner), in sizes from 2 to 12 in. (DN50–300), these butterfly valves have a stem-bearing and seal-retainer design that enables accurate stem positioning and retention, says the firm. — *Hayward Flow Control, Clemmons, N.C.*

www.haywardflowcontrol.com

Valve handles high-molecular-weight fluids in compressors

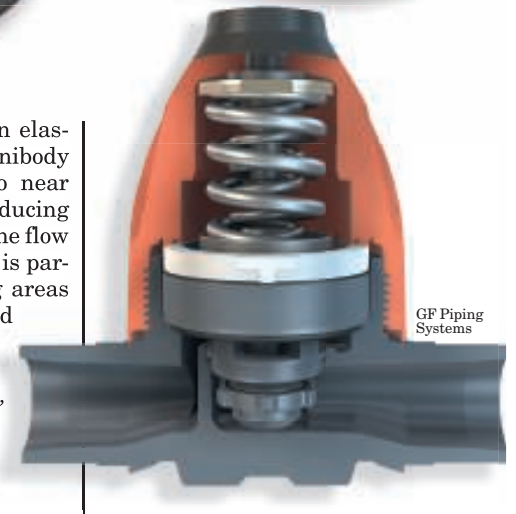
The Magnum HammerHead valve (photo) is a versatile valve that can be applied to all brands of reciprocating compressors, and is specifically designed for applications involving high-molecular-weight fluids at both low and high compressor speeds. This valve's design has been re-engineered using computational fluid dynamics and finite element analysis, improving the valve flow area by 60% compared to standard Magnum valves. Its new streamlined flow path (with optimized seat, guard and lift areas), not only maximizes the valve flow area but provides greater tolerance to particles and liquids in the gas, says the company, and allows it to be applied at higher compressor speeds compared to other poppet valves. — *Dresser-Rand, Houston*

www.dresser-rand.com

Check valve prevents backflow and odor at discharge points

The CheckMate Inline Check Valve (photo)is ideal for backflow prevention and odor mitigation from outfalls, stormwater, oceans, rivers and interceptors. The valve, available in sizes from 4 to 72 in., has an elastomer, fabric-reinforced unibody construction. It can open to near full pipe diameter, thereby reducing head loss while maximizing the flow capacity of the outfall, which is particularly helpful in low-lying areas where limited driving head is available, says the company. — *Tideflex Technologies, a Div. of Red Valve Co., Carnegie, Pa.*

www.tideflex.com



GF Piping Systems

Full plastic construction provides a range of advantages

Traditional plastic regulating valves (PRV) — which involve top and bottom plastic elements held together by metal screws — are susceptible to leakage due to differential expansion coefficients of the component materials, and require regular retorquing of the metal screws during maintenance intervals. By comparison, this firm's fully plastic PRV (photo) has consistent temperature expansion coefficients, so it provides stable, long-term setpoint behavior without the need for regular adjustment, says the firm. Its compact design enables the valve to fit in confined spaces. It is available in several polymers to ensure fluid compatibility, at a range of standard- and low-pressure options. Online support is available to assist with proper sizing. — *GF Piping Systems Ltd., Schaffhausen, Switzerland*

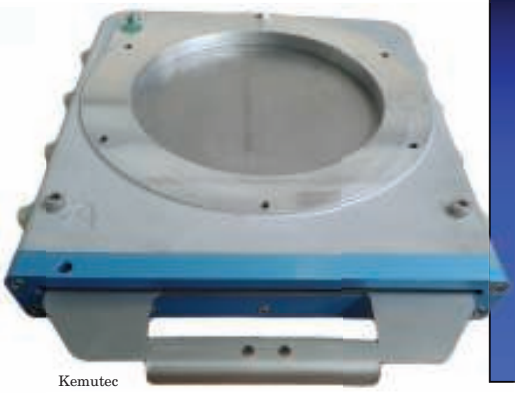
www.georgfischer.com

A family of forged valves for severe operating conditions

The new Pacific Forged line of high-pressure gate, globe and check valves is available for use in power, oil-and-gas and chemical markets. These forged components are designed for applications that are likely to encounter high stress and high thermal cycling. A countoured

Note: For more information, circle the 3-digit number on p. 76, or use the website designation.

Assured Automation


Kemutec


Conval

shape and proprietary hard-face overlay process makes these valves resistant to cracks and delamination, reducing maintenance and downtime, says the company. Multi-stage ultrasonic testing is standard on all forgings and finished valves to ensure that they are suitable for use under severe process conditions. — *Crane ChemPharma & Energy, Houston*
www.cranecpe.com

This family of block valves is designed to ensure fire safety

The FM Fire-Safe Thermal and Electro-Thermal Shutoff Valves (photo) are used as emergency block valves for fire safety applications. They are available in three types of assembly (ball valve, flanged ball valve and butterfly valve). These valves, with a body made from carbon steel or stainless steel, are available in a range of sizes and end-connection styles. A variety of fusible links, designed to withstand different temperature thresholds, are available. The company's Configurator tool helps specifying engineers design their assembly, and generate part numbers and quotes. — *Assured Automation, Clark, N.J.*
www.assuredautomation.com

Double-flange, slide-gate valve isolates gravity-fed solids

The Mucon DSV Double Flange Slide Gate Valve (photo) provides an in-line option to help isolate gravity-fed, free-flowing powders and granules, especially for applications that require a flange connection at the outlet. It has a slim, lightweight alloy design. A stainless-steel slide gate provides standard, tamper-proof locking, so that the user can lock or tag the valve in the closed positions. The device also provides grounding points for applications in which static charge may be a problem. A lightweight pneumatic actuator assembly can be added as a simple retrofit and easily removed to return the unit to basic hand operation. — *Kemutec, Bristol, Pa.*
www.kemutecusa.com

Valve designs are available for high-pressure urea service

This company's Swivldisc Gate Valves (photo) are available in sizes ranging from 0.5 to 4 in. The wedge gate design uses a flexible disk, which permits the seating surface to achieve optimal alignment and thus a tighter seal than is possible with standard wedge gates, says the company. They are available in ASME/ANSI pressure classes through #4500. They are available in a range

Samson Controls

of standard and specialty materials, and options include bypass, air or motor actuators. — *Conval, Somers, Conn.*
www.conval.com

Positioner provides fast response for large valves
This control-valve positioner package (photo) ensures precise positioning with fast response times over the entire operating range, for applications with strokes of 60 mm or greater. The package consists of a positioner and a connection to several volume boosters with different air-output capacities. Closing and opening times of less than two seconds can be achieved over the entire positioning range. This device is especially useful for compress or bypass valves (anti-surge valves). — *Samson Controls, Surrey, U.K.*
www.samsoncontrols.co.uk

Ball valves help users meet lead-elimination requirements
The Pro-Press family of lead-free ball valves, available in sizes from 0.5 to 2 in. and made from a proprietary silicon-bronze alloy, is specifically designed for press systems. Multiple configurations and multiple thread or connector options are available. The valve stem is available in Eco Brass or Type 316 stainless steel. — *Viega, Wichita, Kan.*
www.viega.us

Portable valve-actuator device can service multiple valves
The EasiDrive portable valve actuator is a versatile tool for use with valves that require a large number of turns or that are otherwise difficult to operate because of high torque or harsh climate conditions. Using this tool, an operator can easily drive multiple valves, and it is designed to prevent both the application of excessive torque and torque kickback, thereby reducing operator fatigue and the risk of injury. This device is adaptable to any type or size of valves, and provides a low-cost alternative to permanent actuators with no permanent power supply required, says the company. It is said to be ideal for moving tight or partially seized valves. — *Smith Flow Control, Erlanger, Ky.*
www.smithflowcontrol.com

Select or design the valve you need for any fluid service
This firm offers a broad array of engineered valves to manage hydraulic fluid oil, air, refrigerants, water, chemicals, fuel and gases in a variety of industrial applications. Material options include steel, stainless steel, brass, aluminum and Monel, and all forms of fittings are available. Custom engineering and manufacturing helps to reduce costs, assembly time and potential leak points. — *Fluid Line Products, Willoughby, Ohio*
www.fluidline.com

These digital valve controllers can be mounted remotely
The Fieldvue DVC6200p series of digital valve controllers are designed for applications in which accessibility, extreme temperatures (up to 120°C or 250°F), extreme vibration or confined space makes integral mounting impractical. With the remote-mount version of DVC6200p, only the valve-position feedback is mounted on the control valve; the remainder of the digital controller can be mounted more than 300 ft away (in a preferable environment). With no linkages to wear, loosen or corrode, the feedback unit can withstand extreme operating conditions. — *Emerson Process Management, Marshalltown, Ia.*
www.fieldvue.com ■

Suzanne Shelley

SEPTEMBER New Products

EagleBurgmann

BBA Pumps

Mass Flow Online

Berthold Technologies

A new line of electrically driven solids-handling pumps

These-auto prime pumps (photo) have a capacity of 100 to a maximum of 6,500 m^3/h. The BA diesel-driven pumps have been actively used on the market for many years. Now, with the development of a new standard norm block construction (NMC) the company offers a modular and compact electrically driven pump design. Using high-efficiency pumps and IE2 electric motors, the pumps offer maximum performance at minimal cost. In addition to a standard control box and soft starter, the pump sets can also be provided with a frequency converter; which ensures maximum control over the pumping process, not just by using the automatic start/stop but also by increasing or decreasing the speed of the electric motor. These pumps can be deployed in sewage or dewatering applications. — *BBA Pumps B.V., Doetinchem, the Netherlands*
www.bbapumps.com

Level detectors approved for SIL2 and SIL3 applications

The radiometric gauge SENSseries LB 480 (photo) has been awarded SIL2/SIL3 certification, making this company the first supplier providing SIL-certified radiometric systems for both level (point level or continuous level) and density measurements. The high level of availability and operational safety of the SENSseries LB 480 detectors was intensively tested and approved by TÜV Süd according to IEC 61508:2010. In redundancy installations (one out of two; 1oo2) SIL3 can also be achieved. Unlike other instrumentation available on the market that require frequent recalibration, this company's patented stabilization methods correct for temperature and aging effects. — *Berthold Technologies GmbH & Co. KG, Bad Wildbad, Germany*
www.berthold.com

Intelligent and robust fuel flowmeters and readout units

Fuel-View (photo) is a compact, lightweight and cost-effective solution for measuring the fuel consumption and operating time of vehicles, tractors, river vessels or any mobile or fixed installations with diesel engines. The device can be used for protecting and preventing theft of fuel, preventing overstatement of readings and intervention and the patented method of measuring different engine operating times. New are models for measuring diesel, gasoline, fuel oil, biofuel or other viscous liquids up to 500 L/h. Special differential meters are now available with two integrated measuring chambers, one for measuring the supply line and one for measuring the return line to calculate fuel consumption in realtime. — *Mass Flow Online B.V., Apeldoorn, the Netherlands*
www.massflow-online.com

A new generation of dry running agitator seals

This company has launched a new generation of dry-running shaft seals for agitators. In addition to the known benefits of this type of mechanical seal, the new SeccoMix1 (photo) is also silent running and has been prototype-tested for use in ATEX category 1 (zone 0). These shaft seals are used in mixers, agitators, dryers and filter strainers. Dry-running SeccoMix seals need no supply system, so they have a significant advantage over liquid or gas-lubricated seals. Given this

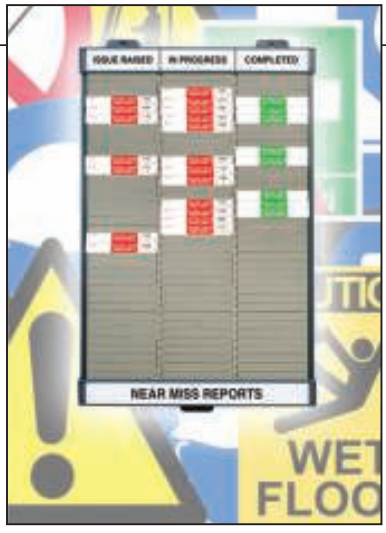
Note: For more information, circle the 3-digit number on p. 76, or use the website designation.

New Products

saving on the purchase and operation of a seal-supply system, the investment costs for a dry-running single seal are as little as 30% of those for an equivalent liquid-lubricated seal, says the company. — *EagleBurgmann GmbH & Co. KG, Wolfratshausen, Germany*
www.eagleburgmann.com

Get the message across about workplace hazards

Providing information to, and communicating with, staff and colleagues in the workplace is essential, particularly when hazards, incidents or near-misses occur that may impact on others. An effective, low-cost solution to "getting the message across" is the Near Miss/Incident Reporting System (photo), which is an easy way to manage and document health and safety issues. The standard display board is available in a three-column format with standard 50 or 30 cards deep and measures 409 mm wide and is supplied fully assembled, complete with headings and 200 Incident T Cards. There is also the option to have the system made to a bespoke format. — *T Cards Direct, Kent, U.K.*
www.tcardsdirect.com



Uraca

This control system now has enhanced alarm functions

The newly released Centum VP R5.04 (photo, p. 39) is an enhanced version of this company's flagship integrated production control system. This new Centum release features enhanced alarm and batch

Yokogawa

functions. With the Centum system, a prominently colored tag mark is displayed on the HMI screen next to any measurement reading that falls outside the normal range. With Centum VP R5.04, these colored tag marks now come in a variety of easily recognizable shapes that indicate the importance of a measurement item and the severity of an anomaly (critical, high-risk, medium-risk, low-risk and so on). New audible alarms have also been added to provide information on the severity and equipment location of an anomaly. Through the use of color, shape and sound, operators can quickly and intuitively recognize the significance of a specific alarm, thereby allowing for improved operational safety. — *Yokogawa Corp. of America, Newnan, Ga.*
www.yokogawa.com/us

Tank cleaning in explosion-proof zones

By means of high-pressure water, various incrustations can be removed inside of autoclaves, reactors, spray towers and vessels. The pump unit discharges high-pressure water (up to 1,600 bars) through the company's Tank Cleaning Head Nozzles (photo). The water jet cuts through the deposits, removing hard incrustations by means of precise rotating movement, thus reaching the inner surfaces in an optimal way. Thanks to their examination certificate according to EC directive 94/9/EC for category 1, the tank-cleaning heads series TWK are permitted to be used in explosion-proof areas zone 0 and zone 20. Optimized displacement circle diameter allows the use of cleaning heads even with small access openings. — *Uraca GmbH & Co. KG, Bad Urach, Germany*
www.uraca.com

This valve controller is suited for hostile environments

The Fisher Fieldview DVC6200p series of digital valve controllers is an ideal solution for applications in which accessibility, extreme temperatures (up to 120°C), extreme vibration or confined space make integral mounting difficult or impractical. Industries such as pulp and paper, and metal and mining have typically preferred to isolate valve-mounted instruments from harsh environments. With the remote-mount version of DVC6200p, only the valve position feedback is mounted on the control valve, while the remainder of the digital valve controller can be mounted over 90 m away in a less severe or more accessible environment. — *Emerson Process Management, Marshalltown, Iowa*
www.emersonprocess.com

New Products

These dry vacuum pumps have a high throughput

The adixen vacuum dry pump (photo) is said to meet current and future challenges of cutting-edge procedures in the coatings industry (LED/OLED, flat/touch panel and solar). The multistage roots vacuum pumps of the ADH series are designed for challenging processes where lots of dust accumulates, corrosive gases are pumped and high temperatures are present. These vacuum pumps distinguish themselves with their high gas throughput and a pumping speed of 600 to 4,500 m^3/h. The pumping speed for the light gases that are particularly important in innovative coating processes is especially high. A monitoring system monitors the pumps in the process. The strongly reduced energy and water consumption result in low operating costs. Their silent operation (<65 dBA) makes them ideal even for serial installations. — *Pfeiffer Vacuum GmbH, Aßlar, Germany*

www.pfeiffer-vacuum.com

This horizontal-paddle vacuum dryer has a concentric agitator

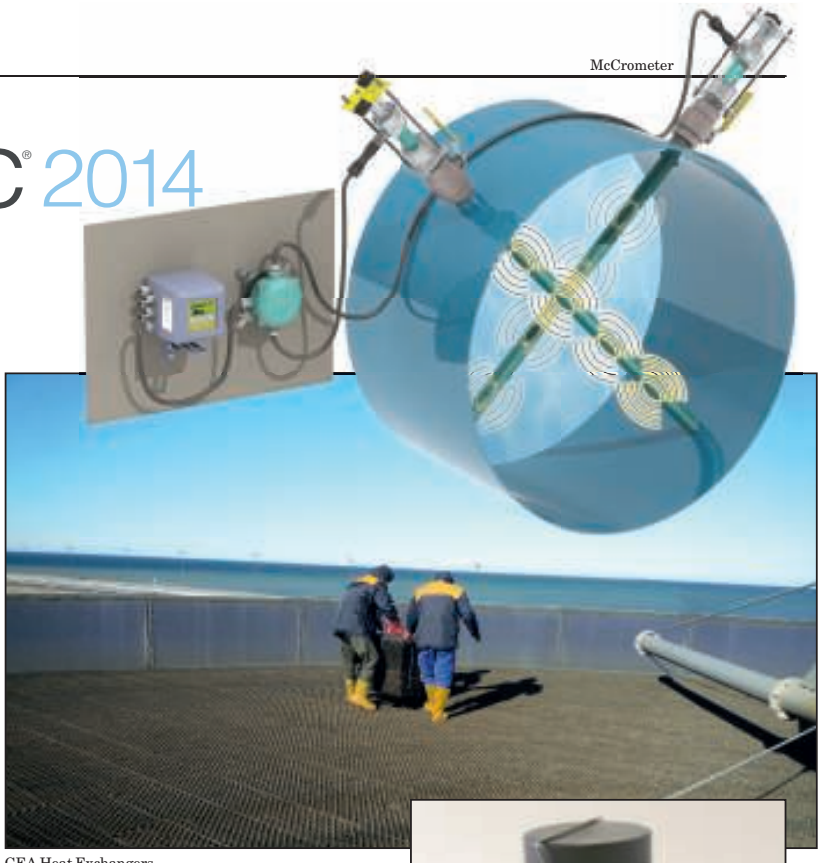
Maximum ease of cleaning, maintenance and internal inspection are the qualities that make the CosmoDry System suitable for multiproduct applications. The CosmoDry System consists of a horizontal cylindrical chamber, equipped with a concentric agitator, fitted with a heated shaft that is dismountable in sections — a feature that sets it apart from conventional paddle vacuum dryers. The peculiar configuration of the agitator enables continuous stirring of the product and facilitates its thermal exchange, reducing drying time. Moreover, it was designed to limit mechanical and thermal stresses, thus allowing the treatment of thermo-sensitive products. The CosmoDry System is manufactured in volumes ranging from 150 to 4,400 L, and the loading capacity can vary from 30 to 80% of the chamber's volume. — *Italvacuum S.r.l., Turin, Italy*

www.italvacuum.com ■

Gerald Ondrey

weftec® 2014
the water quality event

Neptune Chemical Pump



GEA Heat Exchangers

Universal Flow Monitors

The Water Environment Federation (Alexandria, Va.; www.wef.org) is holding its annual Weftec exhibition and conference from Sept. 27–Oct. 1, 2014 at the Ernest N. Morial Convention Center in New Orleans, La. The event will feature numerous technical sessions and committee meetings, as well as a host of exhibitors showcasing new products and services for the water and wastewater industries. This show preview highlights a small selection of the products that will be on display at this year's Weftec exhibit hall.

Install this flowmeter in areas of extreme flow conditions

The FPI-X dual-sensor electromagnetic flowmeter (photo) provides accurate and repeatable measurements under extreme flow conditions, including environments with swirl and other flow disturbances in the line. Designed for use in close proximity to cascading or multiple-pump arrays, the FPI-X mag meter delivers ±0.5% accuracy. Even when installed in areas where establishing a symmetrical velocity-flow profile is extremely difficult, such as near pumps, valves, elbows or headers, the FPI-X performs to specification. Booth 6737 — *McCrometer, Inc., Hemet, Calif.*
www.mccrometer.com

These diaphragm pumps feature a simple valve and head design

This company's Series 7000 mechanically actuated diaphragm pumps (photo) simplify operations by eliminating the use of contour plates on the liquid side of the diaphragm. Designed with water and wastewater applications in mind, the pumps' straight-through valve and head design allows for improved flow characteristics. Self-priming Series 7000 pumps feature a maximum flow capacity of up to 1,135 L/h at 150 psi, with suction lift exceeding 20 ft on water-like chemicals. Additionally, Series 7000 pumps can handle viscosities as high as 5,000 cP. Booth 1529 — *Neptune Chemical Pump Co., North Wales, Pa.*
www.neptune1.com

Polypropylene filter media resists erosion and buckling

BIOdek polypropylene (PP) trickling filter media provides an alternative to traditional polyvinyl chloride (PVC) media used in biological wastewater-treatment processes. BIOdek filter media can accommodate many process requirements, types of flow patterns and channel sizes for a variety of trickling applications. Since PP is not as stiff as PVC, the filter media can be more easily inspected without fear of damage to the media — personnel can walk on top of the media (photo) for inspection without the requirement of a protective walking grate. Also, PP media is more resistant against erosion and buckling due to its lower density when compared with PVC. Booth 2939 — *GEA Heat Exchangers, Bochum, Germany*
www.gea-heatexchangers.com

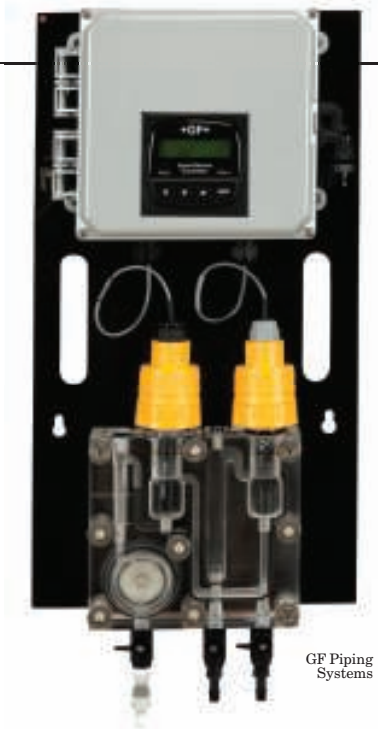
These PVC flowmeters are built with no moving parts

The P-420 line of vortex-shredding flowmeters (photo) are intended for use in process water, brine, corrosive fluids and chemical-treatment applications. These flowmeters are constructed of conventional PVC or chlorinated PVC, without moving parts that can stick, bind or coat. Electronic output is from a 4–20-

Note: For more information, circle the 3-digit number on p. 76, or use the website designation.

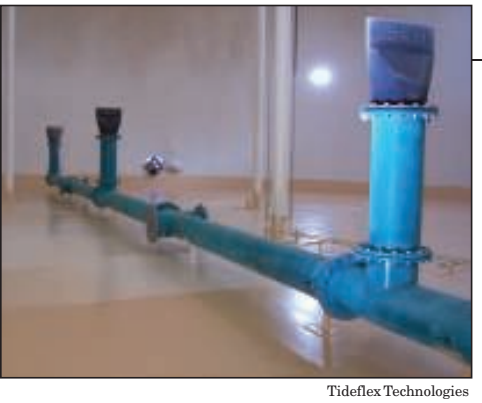
mA two-wire transmitter with no local display. It is rated as intrinsically safe when used with barriers. The electronics package is totally potted and not vulnerable to the installed environment. Booth 7711 — *Universal Flow Monitors, Inc., Hazel Park, Mich.*
www.flowmeters.com

Continuously monitor free chlorine without using reagents
The Signet 4630 Free-Chlorine Analyzer System (photo) provides a turnkey solution for measuring free chlorine in water. Designed with amperomatic sensing technology, the system incorporates a clear flow cell, flow regulators, sensors, filter and rotameter all in one compact unit. With this system, continuous, realtime monitoring of chlorine is achieved without the use of reagents, thus lowering maintenance and calibration requirements associated with chlorine-monitoring activities. The ability to accomodate manual or continuous pH compensation further increases accuracy in the Signet 4630's free-chlorine readings. The built-in flow regulator automatically controls flow across the sensor's membrane, reducing bubbles, and allowing for a wide range of inlet pressures ranging from 1 to 8 bars. The unit's flow cell can be easily opened for thorough cleaning and removal of algae or hard-water deposit buildup. Booth 7209 — *GF Piping Systems, Tustin, Calif.*
www.gfps.com



GF Piping Systems

Eliminate stagnation in finished-water storage tanks
This company's TMS mixing system (photo, p. 43) consists of a combination of patented check-valve technology and a piping manifold that separates the inlet and outlet. Designed to improve the quality of water in finished-water storage reservoirs, the TMS can be installed for new or existing water-storage tanks of all shapes and sizes to eliminate stagnation and short-circuiting. Operating with intrinsic differen-



Tideflex Technologies

Watson-Marlow Pumps Group

tial pressure, the TMS requires low energy input. The system's built-in check valve is constructed of elastomers and demands very little maintenance. Booth 2331 — *Tideflex Technologies, Carnegie, Pa.*
www.tideflex.com

This metering pump provides single-component maintenance
The Qdos 60 peristaltic metering pump (photo) is designed to reduce chemical metering costs when compared to conventional solenoid or stepper-driven, diaphragm metering pumps. Qdos pumps eliminate the need for ancillaries, boost productivity and cut chemical waste due to accurate, linear and repeatable metering. Also, simple installation and maintenance lower total cost of ownership. Maintenance tasks are expedited due to the pumps' patented single-component, contained tool-free technology. Qdos 60 pumps are suited for numerous applications, including disinfection, pH adjustment and flocculation of drinking water, wastewater and industrial process water, as well as reagent dosing and metering in mineral-processing tasks. Booth 3207 — *Watson-Marlow Pumps Group, Wilmington, Mass.*
www.watson-marlow.com

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www.fluiddynamics1.com ■

Mary Page Bailey

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Safe Sampling of Heat-Transfer Fluids

Collecting representative samples of heat-transfer fluid for routine quality checks falls short of the goal if safety or the environment is compromised. While users should consider their systems' unique design features in consultation with their safety and health experts, incorporating the tips below can help to avoid common potential safety concerns associated with sampling these fluids, which may be at extreme temperatures. Understanding these safety issues is the first step in planning a safely conducted task.

Ergonomics

Safe access to heat-transfer-fluid sample ports is a key part of an ergonomically designed station. Important aspects of a well-designed sampling station include the following:

- Clear standing area with unobstructed path of egress
- Height of sample port below chest-high, to avoid upper body splash
- Limited extent of reach required to avoid body strain
- Space beneath sample port to allow hands-free placement of a properly labelled flush bucket
- Non-slip, solid floor surfaces to prevent drips to a lower level
- Globe valves in sample port are preferred for the best control of flowrate

Extreme temperatures

Representative samples are best collected during operation, when the fluid is uniformly mixed throughout the system. Heat-transfer fluids routinely reach temperatures that can present thermal burn hazards. The following tips are for sampling hot streams:

- Review safety data sheets (SDS) for the personal protective equipment (PPE) that is required for the fluid being sampled, as well as its physical and chemical properties, and hazard information
- Use a sample cooler to reduce fluid temperature to below 93°C (200°F) to protect sample composition integrity
- Wear gloves that provide chemical and thermal protection, as well as a splash apron, eye goggles and a face shield
- Inspect the port area for uninsulated contact points to avoid
- Avoid drips which may occur before, during or after collection
- Do not remove PPE until the port and sample bottle are secured

Splashes and spray

Even with the proper PPE in use, initiating flow from the sample port is a transient operation that can result in splatter or spray, and efforts should be made to limit the splash potential. Since the fluid may be hot, it is important to take precautions against accidental hot-fluid contact to avoid thermal burns. Thermal burns are the single greatest safety concern to personnel working with high-temperature fluids and equipment. Use of a globe valve can provide better flow control when opening the sample port.

Think ahead to plan what actions will be taken in the event of an unexpected spray. Anticipate pressure on the line when opening the port valve, and open the valve gradually. Stand to the side so that any spray will be directed away from potential physical contact. One technique to better control the sample stream is to install a short length of small-diameter tubing on the sample valve outlet, which steadies the stream and also permits easy insertion into the neck of sample bottles.

When flushing the sample port prior to collecting the "good" sample, direct the stream into a dry bucket. Any moisture in the flush bucket can result in violent splatter of the hot heat-transfer fluid into the vicinity, if the sample stream is above the boiling point of water.

Take the time needed to sample the fluid safely. Rushing to perform this task can pose unnecessary safety risks for those collecting the fluid samples.

Spills

By expecting the unexpected, we can prepare adequately to avoid potential spills and their consequences, or minimize their extent and impact. A well-placed sample port will be at ground level with little exposure to sewers or floor drains. A small, curbed area can help keep small releases contained. Above all, efforts should be taken to keep potential releases of organic heat-transfer fluids from drains and waterways. If a storm drain is in the area, it should be adequately covered or otherwise blocked during sample collection.

High-temperature heat-transfer fluids are commonly organic liquids, and suitable dry, absorbent media should be available in the area for response to stabilize and aid in clean-up. These fluids are also likely to be combustible, and clean-up should be performed promptly.

Some heat-transfer fluids may have unique spill clean-up and disposal methods that are directed by their manufacturers, so refer to the product SDS for specific guidance.

Finally, any fluid residues will also create a hazard by making walking surfaces, handrails, or coated structures slippery. To avoid slips and falls, and to avoid fueling a fire, these residues should also be cleaned. Oil-absorbent cloths and socks can also be used to help keep the areas clean. Additional clean-up may be done with appropriate detergents or chemical cleaners.

Inhalation

Each heat-transfer fluid chemistry can be different, so learn about the unique requirements of each one from the supplier's literature. Key concepts to avoid unnecessary exposure to fluid vapors are the following:

- Cooler fluid has lower vapor pressure, and provides less exposure
- Stand upwind of the sample port during flushing and sampling
- Place a lid over the sample port flush bucket when finished
- Promptly cap and seal the sample bottle once filled

For products containing components that have established airborne-exposure limits, consult with an industrial hygiene technician about the need for respiratory protection. In many cases, proper job planning and sample cooling may eliminate the need for respiratory protection.

Finishing the job well

Now that the sample has been collected, it is ready for packaging and shipment to the laboratory for analysis. While most organic heat-transfer fluids are not regulated for transport by the U.S. Dept. of Transportation (Washington, D.C.; www.dot.gov) for sample quantities, the bottle should be packed properly so that it remains leak- and damage-free until it arrives at its destination.

Bottles should be protected against breakage. Metal containers offer the greatest resistance, and glass containers will require adequate packing materials. Precautions against container leakage can include the following actions:

- Ensure all seals are properly in place in the neck and mouth of the bottle
- Do not use substitute parts for liquid seals
- Apply tape to the outside of the tightly-sealed container cap
- Place the bottle within a chemically compatible bag, which is then closed to prevent liquid escape into the outer package
- Foam packing (pre-formed, or "peanuts") can be placed around the sample container to protect it against sharp blows
- Properly dispose of fluid collected in the sample-port flush bucket

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Editor's note: The content for this column was provided by Eastman Chemical Co. (Kingsport, Tenn.; www.eastman.com).

Technology Profile

1,4-Butanediol from Bio-Succinic Acid

By Intratec Solutions

The compound 1,4-butanediol (BDO) is a versatile intermediate for the chemical industry. Its largest derivative product is tetrahydrofuran (THF), which is used to make spandex fibers, resins, solvents and printing inks. The second largest product is polybutylene terephthalate (PBT), which is used to make high-performance materials, electronics and automotive equipment.

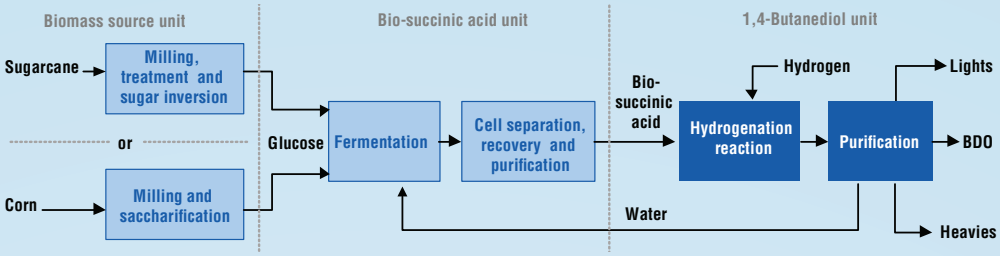

FIGURE 2. It is possible to integrate 1,4-butanediol and bio-succinic-acid production units

BDO can be produced from different technologies and raw materials. The conventional method for manufacturing BDO is the Reppe process, starting from acetylene. Other processes use propylene oxide, maleic anhydride, 1,3-butadiene or *n*-butane as starting points. The newest technologies being developed for BDO are bio-based pathways, which mostly rely on bio-based succinic acid derived from biomass or a sugar substrate.

Succinic acid is a platform chemical that can be used to produce many products. However, its high cost of production from petroleum raw sources limits its use to specific applications (such as pharmaceuticals and food additives). According to the U.S. Dept. of Energy (DOE), bio-succinic acid is a renewable building-block chemical with great potential for the future.

The process

The process depicted in Figure 1 was compiled based on a U.S. patent published by BioAmber Inc. (Montreal, Canada; www.bio-amber.com; U.S. patent no. 2011/0245515). The patent discloses details about the initial reaction, while the separation process was conceived by Intratec and is based on well-known practices.

Hydrogenation reaction. A solution of bio-succinic acid in water is pre-heated and sent to the fixed-bed hydrogenation reactor. Hydrogen is compressed and also fed in excess to the reactor. The process uses a bimetallic catalyst consisting of metals (including ruthenium, rhenium, tin and others) on a carbon support.

The exothermic reaction product is mostly BDO (selectivities to BDO of more than 90% are reported in literature). Side products include THF, *gamma*-butyrolactone (GBL), and linear alcohols (*n*-butanol, *n*-propanol). The amount of each product depends on the catalyst and operational conditions used.

The bio-succinic acid is totally reacted, and the unreacted hydrogen is compressed and recycled back to the reactor. The product stream is cooled and sent to flash vessels to recover unreacted hydrogen and eliminate volatile materials.

Purification. The product from the flash vessels is sent to a series of distillation columns to separate BDO from side products. In the first column, BDO, GBL and water are removed from the bottoms and then sent to the drying column, where most of the water is removed. The column's top fraction is sent to a lights column, to recover side-products as fuel.

The recovered water is sent to a tank for further disposal or to be recycled to an integrated bio-succinic acid production unit (see Figure 2). The drying column's bottoms are sent to a BDO recovery column and further to a heavies column, where a stream of 99.5 wt.% BDO is finally achieved.

Economic performance

An economic evaluation of the process was conducted based on data from the fourth quarter of 2013. The following assumptions were taken into consideration.

- A 55,000-ton/yr BDO production unit (the process equipment is represented in Figure 1)
- Storage capacity equal to 20 days of operation for BDO and no storage for bio-succinic acid

The estimated capital investment (including total fixed investment, working capital and other capital expenses) to build a plant would be $100 million in the U.S. Gulf Coast region and $140 million in Brazil.

Process perspective

It may be an interesting consideration to control the entire supply chain through the integration of a bio-succinic-acid production unit with a BDO unit (see Figure 2). Also, the bio-BDO produced must include a premium price over its petrochemical counterpart. Both measures are important to make the venture economically feasible.

In addition, it is also an important research-and-development goal to find hydrogenation catalysts that have the following qualities:

- Improved tolerance to impurities generated in the fermentation process (that produces bio-succinic acid). This can help reduce the costs of bio-succinic acid purification
- Increased selectivity of bio-succinic acid to BDO, reducing the formation of side products and the costs with BDO purification

Both achievements can reduce investment and production costs. ■

Editor's Note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented herein are prepared on the basis of publicly available and non-confidential information. The information and analysis are the opinions of Intratec and do not represent the point of view of any third parties. More information about the methodology for preparing this type of analysis can be found, along with terms of use, at www.intratec.us/che.

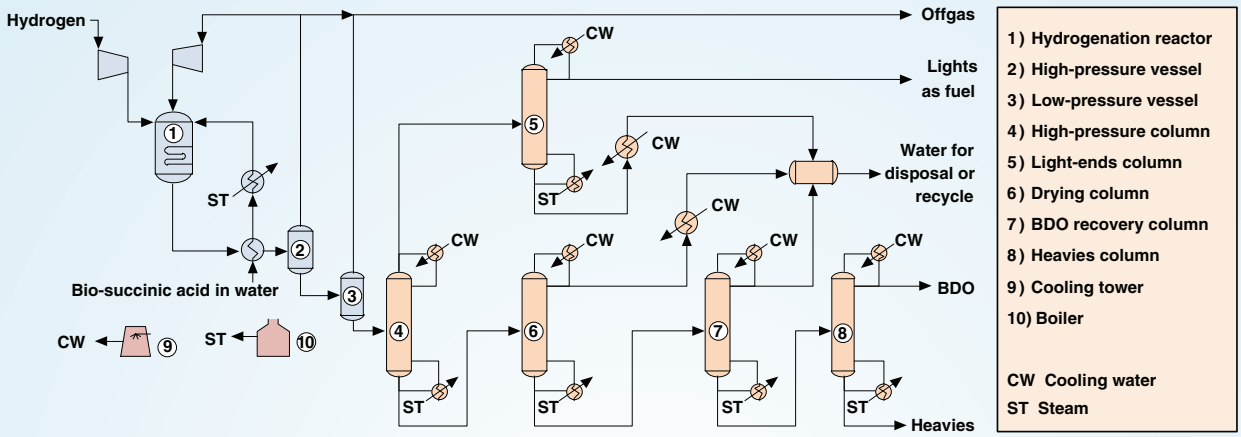

FIGURE 1. The 1,4-butanediol process from bio-succinic acid that is shown here is based on patent disclosures from BioAmber and well-known practices

Modern Water-Treatment Challenges

LNG and other facilities that are expanding due to the shale-gas boom face specific challenges when it comes to ensuring the purity of the inlet and outlet water

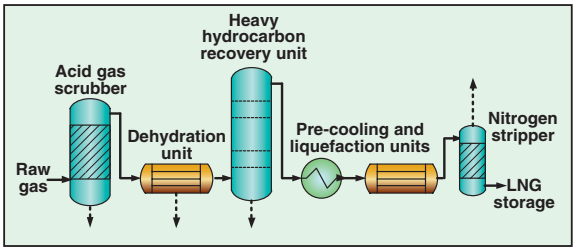

FIGURE 1. The major unit operations involved in the treatment of natural gas for conversion to LNG are shown here. In order, the processes remove acid gases and sulfur, water, heavy hydrocarbons and nitrogen

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Kiewit Power Engineers

Water and wastewater treatment are extremely important at liquefied natural gas (LNG) facilities and other industries that are blossoming due to the shale-gas boom. Engineering concerns are similar to those of other industrial water-treatment and power-generation systems, but with the added issue of adequate treatment for entrained hydrocarbons. With proper system design and operation, plant personnel can plan for, and react to, issues that could otherwise cause unit shutdown, environmental hazards or safety problems.

The enormous growth in shale-gas production has led to an expansion in the number of LNG distribution facilities in the U.S. These facilities require power and steam to compress and cool incoming natural gas, and also to scrub the gas of impurities that would otherwise interfere with the liquefaction process. Economically, it is often logical to use a portion of the incoming natural gas as a source of energy for onsite combined-cycle power and steam generation.

However, a number of specific engineering challenges confront personnel who must work with makeup water, process water and wastewater treatment for such complex and integrated facilities. Many of the water-treatment processes discussed in this article are also applicable to other industries that are benefitting from the shale gas boom, such as production facilities for ammonia and urea, ethylene and other petrochemicals.

Processing natural gas

Natural gas is primarily composed of methane (CH_4), but the methane content is never 100%. Rather, impurities typically exist in most natural gas supplies (Table 1).

Ethane, heavier hydrocarbons and impurities must be removed to ensure successful production and delivery of the required end product. The impurities will negatively impact the liquefaction process, and some may cause corrosion in the equipment. Figure 1 shows many of the fundamental unit processes that are used to treat natural gas prior to LNG production.

The acid-gas scrubber typically uses an aqueous amine solution to remove carbon dioxide and sulfur compounds. This is followed by dehydration to remove water that would otherwise freeze during liquefaction. Next is a heavy-hydrocarbon-recovery unit (HRU), which extracts ethane and other higher hydrocarbons (these are recovered for further processing). It should be noted that ethane is becoming an increasingly popular feedstock for ethylene production, with a new technology — "oxidative dehydrogenation" — gaining interest as an alternative to standard cracking [*2*]. The remaining steps in LNG preparation are liquefaction and nitrogen stripping to produce the final liquid product for storage.

The waste- and product-recovery streams from the LNG-production facility are typically treated in various heat exchangers and other unit operations. Among the several water and wastewater streams around the plant, the following are very likely:

- High-purity makeup water for the power- and steam-production units. A water-cooled thermal oxidizer may also be present to destroy some organics
- Makeup water for the amine solution for acid-gas scrubbing
- Recovered water from the dehydration unit
- Returned condensate from other unit processes, including heavy-hydrocarbon recovery
- Makeup water for a possible cooling tower

Treating each of these streams presents new challenges beyond those of standard water purification.

Makeup water treatment. Common for new LNG plants and related facilities, such as petroleum refineries and petrochemical plants, is high-pressure steam generation, often with auxiliary power production. Ensuring proper makeup water treatment for this process is critical [*3*]. For high-pressure steam

TABLE 1. CONSTITUENTS IN NATURAL GAS SUPPLIES, %*

	Source (State)				
Components	**PA**	**SC**	**OH**	**LA**	**OK**
Methane	83.4	84.0	93.3	90.0	84.1
Ethane	15.8	14.8	—	5.0	6.7
Carbon dioxide	—	0.7	0.2	—	0.8
Nitrogen	0.8	0.5	3.4	5.0	8.4
Hydrogen sulfide	—	—	0.2	—	—

*Abridged from original table in Ref. 1

TABLE 2. MAKEUP WATER REQUIREMENTS FOR HRSGS

Constituent or measurement	Normal limit
Chloride	3 parts-per-billion (ppb)
Silica	10 ppb
Sodium	3 ppb
Specific conductivity	0.1 µS/cm
Sulfate	3 ppb
Total organic carbon (TOC)	300 ppb

Source: Reference 4

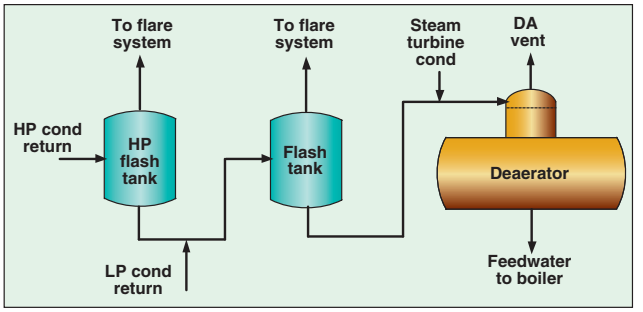

FIGURE 2. Shown here is one possible treatment scheme to remove impurities from the LNG-condensate return. The process removes combustible materials from the condensate return followed by any excessive dissolved oxygen that may exist. Ideally, the boiler feedwater should contain a small dissolved oxygen residual concentration of 5 to 10 ppb to inhibit flow-accelerated corrosion

generation, high-purity makeup water must be supplied to the unit. Even slight concentrations of impurities can cause major corrosion and fouling problems within a steam generator, due to the high temperatures and pressures. As an example, the Electric Power Research Inst. (EPRI) has established guidelines (shown in Table 2) for makeup to combined-cycle heat recovery steam generators (HRSGs).

To produce water with such high purity, a step-wise process must be employed. Following the removal of large solids via settling, screens, or both, many industrial applications now also carry out micro- or ultra-filtration (MF and UF, respectively), followed by two-pass reverse osmosis (RO), with final polishing carried out by either mixed-bed ion exchange or electrodeionization (EDI). Additional details on these processes may be found in Ref. *3*.

Heavy industrial plants typically require a large volume of water for cooling and makeup water production. Often, the amount of water needed for steam production is small compared to cooling water needs. This is particularly true if a large percentage of the steam is recovered as condensate and returned to the boilers. For low-volume needs, a freshwater source may be available for makeup. However, makeup for industrial cooling towers typically requires flowrates of several thousand gal/min or more, most of which leaves the towers as evaporation. To meet this demand, facilities are increasingly being mandated to use less-than-pristine supplies for such high-volume inlet water.

These sources include reclaim water from municipal wastewater-treatment plants and groundwater with high dissolved-solids content. For the former source, problem constituents that may arise include elevated levels of ammonia, phosphorus and suspended solids, all of which can be problematic in cooling towers. Excessive suspended solids increase the potential for deposition in cooling tower fill and other locations in the cooling system. Ammonia reacts irreversibly with chlorine, making chlorine-based biocide programs less effective. Microbiological fouling can create a range of problems within cooling systems.

Meanwhile, phosphorus in the makeup stream presents multiple problems. For decades, a common cooling-tower treatment method has been based upon a core chemistry of inorganic and organic phosphates, with minor additions of other chemicals to manage corrosion and scale. However, excess phosphorus in the makeup water can throw such programs completely out of range. And another emerging problem is overshadowing this issue in many areas of the country. The issue is "phosphorous impairment" (a condition recognized by the U.S. Geological Survey) of receiving bodies of water. More and more frequently, phosphorus discharges are being limited or banned due to their potential to promote toxic algae blooms [*5*]. In fact, this issue had led to the development of, and demand for, non-phosphorus, cooling-water-treatment programs, in which only polymers are utilized for scale control [*6*].

Condensate return. In a typical power plant arrangement, virtually all of the steam that passes through the turbine is recovered and returned to the steam generator. Losses due to minor leaks and evaporation may consume one or two percent of the stream, but the vast bulk of purified water is continually recovered. At chemical process plants, much of the steam serves process heat exchangers and reaction vessels. Thus, there is substantial opportunity for the condensate to become contaminated.

Per the nature of this article, we will focus on organic contamination and start with an illustrative case example. A number of years ago, author Buecker and a colleague were called to an organic chemicals plant that produced phenol derivatives. At the time of the visit, the plant had four 550-psig boilers with superheat. Plant personnel had to regularly replace the superheater of each boiler every 1.5 to 2 years due to extensive solids deposition and subsequent tube overheating.

An initial visual inspection showed foam in the boiler drum sample lines. Subsequent research indicated frequent high concentrations of organic carbon in the condensate return, sometimes as great as 200 parts-per-million (ppm). AMSE industrial boiler guidelines [*7*] recommend a total organic carbon (TOC) limit of 0.5 ppm for steam generators of this pressure. Although this

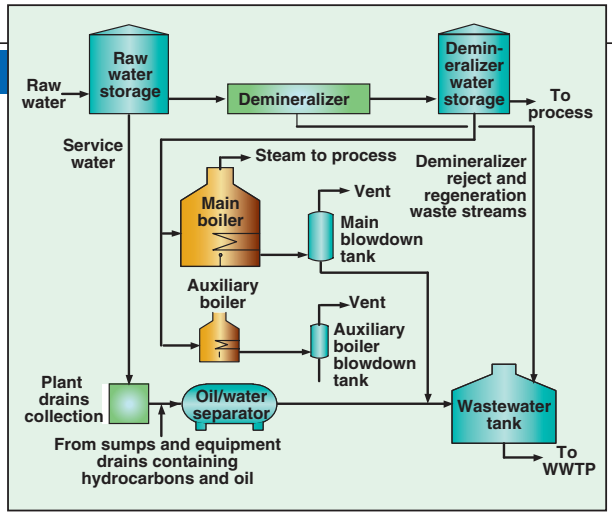

FIGURE 3. Shown here is a generalized water-treatment schematic (excluding the cooling tower) for an LNG-production facility. A common demineralizer arrangement is reverse osmosis to remove >99% of dissolved ions, followed by ion exchange polishing to remove residual ions. Pre-treatment to remove suspended solids is not shown

case example may seem extreme, the point is that organic contamination can create a host of problems. For high-pressure steam generators of 2,000 psig or greater, the recommended TOC limit in the condensate is 200 ppb. This guideline aims to reduce the transport of organics to the boiler and carryover to the steam, particularly in high-pressure units, since this results in decomposition of these materials to small-chain organic acids. The acids may cause corrosion in steam turbines and condensate systems.

For LNG facilities (Figure 1), the potential impurities that can enter the condensate include residual amine from the acid-gas scrubber, and hydrocarbons from HRU and from fuel gas heaters that are not shown on the figure. One configuration that has been developed for volatile-compound removal is shown generically in Figure 2.

The process relies on flash tanks and conventional deaeration to remove the volatile impurities that may be in the condensate. Some streams from the amine-scrubbing system are at high pressure, and these are treated in the HP flash tank. Other, low-pressure (LP) streams, including condensate from heavy-hydrocarbon heat exchangers, enter the main flash tank. This stream combines with condensate recovered from the power plant steam turbine for final conditioning in the deaerator. This particular process relies on the volatility of the impurities. At other facilities where heavier hydrocarbons and oil could be in the condensate, other techniques — such as steam-driven stripping or condensate polishing using activated carbon or adsorbent resin — may be required.

Another concern regarding condensate return is the potential transport of piping corrosion products to the steam generator. Straightforward particulate matter filtration might be the answer in some cases, but in others, the use of powdered-resin condensate polishing may be appropriate to achieve greater removal of particulates.

Cooling water. The authors and many others have discussed cooling-water treatment methods in numerous publications. But, there are several cutting-edge aspects of cooling water that bear further examination. Perhaps most important to future system design are the pending 316b regulations from the U.S. Environmental Protection Agency (Washington, D.C.). These guidelines have been developed to protect aquatic creatures at plant intakes. The ultimate effect of the guidelines is to eliminate once-through cooling. As discussed in Ref. 8, to meet these requirements, cooling towers, and to a lesser extent air-cooled condensers (ACC), are now the choice for new facilities. As we have previously commented, cooling tower chemistry is becoming more complex, particularly at plants that either accept less-than-fresh makeup water or have tough restrictions on cooling-tower discharge.

The list that follows outlines potential treatment and control technologies that can be used to deal with difficult makeup streams for cooling tower systems.

- For systems where phosphate/phosphonate chemistry is presently used or is desired, selection of reclaim water for makeup might require installation of a clarifier to remove incoming phosphorus compounds. Iron and aluminum coagulants will precipitate phosphate. Jar testing and pilot testing are a must for developing the proper treatment scheme
- Ammonia in makeup water can be removed by breakpoint chlorination, but for high-volume flows (such as cooling towers), this scenario may be a cost-prohibitive technique. Ammonia stripping may be a necessary option
- Some plants now have makeup water coming from deep wells. This water often contains high concentrations of hardness, bicarbonate alkalinity, chloride, silica and others. To remove hardness ions and alkalinity, lime and soda ash softening may be required, with possible supplemental magnesium feed for silica reduction. Chlorides can wreak havoc on stainless steels, so more exotic materials may be needed for heat exchangers
- Cooling-tower-sidestream filtration is always beneficial in reducing the suspended-solids concentration in the circulating water. Cooling towers are also effective air scrubbers, capturing particulate matter that may enter from the atmosphere, and particulate matter that enter via the makeup stream. Typically, a sidestream filter is designed to treat from 3–10% of the total circulating water flow
- Use of substandard makeup water requires very careful selection of the biocide treatment system. Microbiological fouling can occur very rapidly in a cooling system, with severe consequences. In fact, cooling towers have been known to collapse due to the weight of microbiological deposits. Chlorine will be immediately consumed by ammonia and organics in the water, and this can plague systems using reclaim water. Becoming more popular for reclaim-water

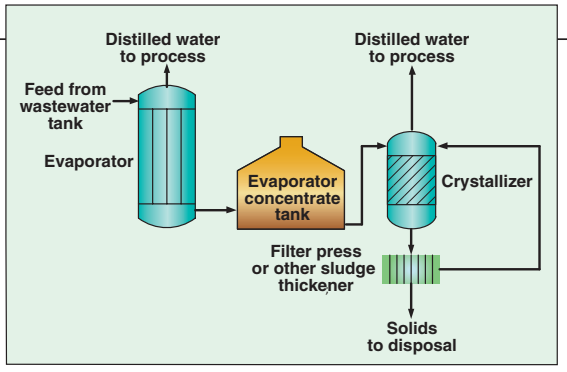

FIGURE 4. Shown here is an evaporator-crystallizer schematic for wastewater treatment. This process, or variations thereof, allow the plant to operate with zero liquid discharge

microbiological treatment is chlorine dioxide (ClO_2). This product must be generated on-site and is more expensive than bleach, but it does not react with ammonia and is not consumed by standard organics

Even with these technologies in place, the wastewater produced during LNG production still needs proper treatment.

Wastewater. Cooling-tower blowdown is often the largest wastewater stream at heavy industrial facilities, and at LNG plants, petroleum refineries, petrochemical plants and similar facilities. At many plants, the blowdown is released to a receiving body of water, provided the discharge meets the plant's National Pollutant Discharge Elimination System (NPDES) guidelines. However, this option is becoming more limited for many process operators [*8*].

Excluding the cooling tower, a generic water balance at an LNG facility with power generation might closely resemble Figure 3. The unit operations are not shown in elaborate detail in Figure 3, but the objective is to provide a system overview. The process shown is similar to that of a typical natural-gas-fired, combined-cycle plant, with a few exceptions. The large bulk of the makeup water goes toward production of steam for process use and as a source of demineralized feed to the process. The aqueous amine used for acid-gas scrubbing needs regular replenishment. As seen in this particular design, plant and process drains are treated in an oil-water separator (OWS) prior to further treatment. The OWS stream combines with boiler blowdown and demineralizer waste in the wastewater tank, from which the liquid is forwarded for further processing.

One possibility for wastewater treatment is to remove non-volatile impurities as solids and recycle the distillate, as shown in Figure 4.

Evaporator-crystallizers are commonly used in the chemical process industries, with proven success. A deaerator is typically installed up-

stream of the evaporator-crystallizer, and as previously discussed, will remove some hydrocarbons, although miscible compounds such as glycols would probably not come out of the water phase as easily as nonpolar materials. The same considerations mentioned earlier regarding hydrocarbon carryover from the liquefaction process apply to wastewater treatment, and become even more critical as the wastewater becomes more concentrated.

One drawback to evaporator-crystallizers is the significant energy that is required for evaporating large quantities of water. An alternative possibility — see Ref. 8 — is a process that combines filtration, softening and reverse osmosis, which can reduce the discharge volume to be treated by 90%. This leaves a relatively small stream to be further processed by a crystallizer or other method. ■

Edited by Suzanne Shelley

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Challenges of Drying Sticky Wastewater Sludge

In wastewater-sludge drying and dewatering operations, many issues arise from the sticky properties of the sludge. Here are some insights to address them

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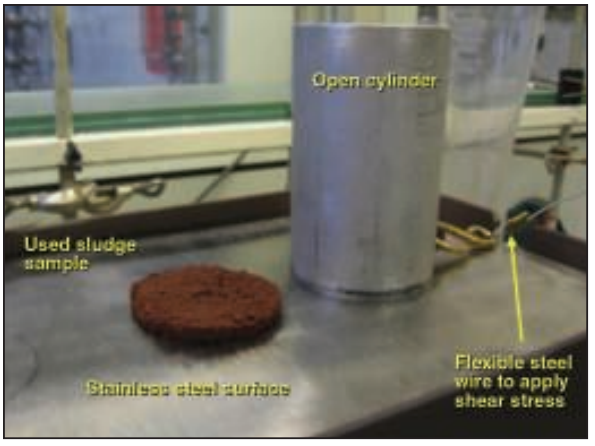

FIGURE 1. A rather simple laboratory protocol can be used to map the sticky phase of waste sludge (see Ref. 7)

Operators and engineers in the chemical process industries (CPI) who are responsible for the daily operations associated with sludge dewatering and drying equipment are undoubtedly aware that wastewater-sludge drying is not an easy task. A large number of the problems that arise during these operations are due to the sticky phase of sludge, which makes the drying of sludge as much an art as a science. Although insight into the sticky behavior of sludge during drying processes is critical for successfully drying sludge in practice, the sticky phase of sludge is not a common topic in the standard engineering curriculum at universities and colleges, whereas topics such as the theoretical design of dryers typically are. Also, most research papers and reference works on sludge drying tend to emphasize the different types of sludge dewatering and drying technologies [*1,2*], rather than the physical property changes that the sludge undergoes while being reduced in volume due to water removal. The sludge's sticky character is typically mentioned in just a few lines, without elucidating the reasons behind its existence. Reference 3, (a paper with the appropriate title "Can You Handle Sticky Cakes?,") concludes that "difficulties in solid-liquid separations usually arise because conventional design optimizes only the unit operations and takes no account of the nature of the thickened product or possible handling problems" [*3*]. This assessment applies well to the case of sludge dewatering and drying. Providing more insight into the peculiar sticky phenomenon of sludge is the aim of this article. Further, an overview of applied strategies to tackle the operational issues related to the sludge's "glueyness" will be provided.

Growing mountains of sludge

Increasingly stringent environmental regulations over time have resulted in enhanced industrial and domestic wastewater treatment (see, for example, *Chem. Eng.* Oct. 2005 and Oct. 2013 issues [*4,5*]). The improved wastewater treatment has resulted, in turn, in increased volumes of waste activated sludge. In a recent review paper on the application of wastewater-sludge drying, some data are presented on the quantities of generated municipal sewage sludge, illustrating these increasing "mountains" of sludge. In China, more than 9 million tons of dry solid sludge were produced in 2009. In the European Union and the United States, this number amounted to about 12 and 8 million tons in 2010, respectively [*6*].

To lower the sludge volumes (in order to decrease costs for further downstream processing, including transport, storage and incineration costs), mechanical dewatering and thermal drying of sludge are important onsite unit operations in CPI wastewater treatment plants (WWTPs). Sludge management in industrial sludge-handling installations is, and will continue to be, a challenge, and sticky phase of sludge is an issue common to all.

The sticky phase of sludge

When sludge is partially dewatered, it behaves as a sticky, paste-like substance. In that state, it literally glues onto the surface of the dewatering and drying equipment. In order to gain insight into the stickiness of sludge, the authors of this article developed a laboratory

protocol that allows its visualization. For details on the protocol, see Ref. 7. In short, a rather simple laboratory device (Figure 1) measures the shear stress necessary for letting pre-consolidated sludge (with a certain composition) start moving over a steel surface. A higher shear stress requirement indicates that the sludge is stickier [*7,8*]. By plotting the shear stress as a function of the sludge dry-solid percentage (%DS), one obtains a map of the sticky behavior. In Figure 1, a sludge sample is shown after it was tested, along with the cylinder where this sludge sample was contained during the shear test.

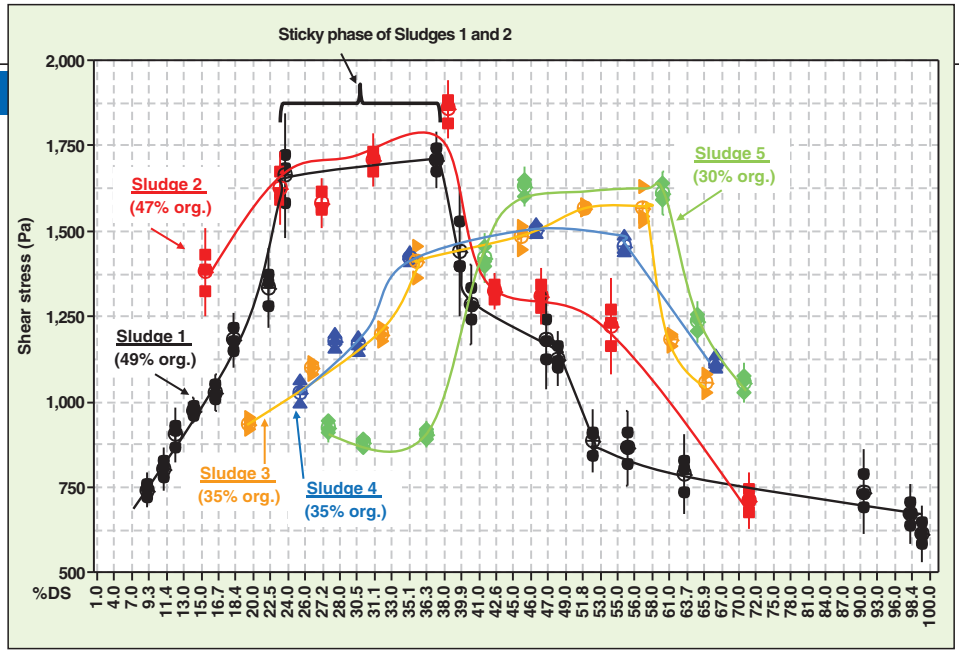

FIGURE 2. The sticky behavior of sludges depends on dryness and organic content (org.). There are three repeats of the shear stress test at every %DS, and bars are the 95% confidence interval (lines are to guide the eye). Data from Sludges 1 and 5 are adapted from Refs. *7* and *10*, respectively

The mapping of the stickiness is shown in Figure 2 for five different sludges from the Monsanto WWTP in Antwerp, Belgium. The organic contents vary from 49% for sludge 1 to 30% for Sludge 5 (the organic fraction was analyzed according to the standard methods [*9*]). The data depicted in Figure 2 suggest that the sludge's sticky character depends on both the sludge's dryness and its organic content. Considering Sludges 1 and 2, samples behave most sticky in the dryness range from 25–40% DS. Therefore, this dryness region is called the sticky phase of sludges 1 and 2 [*7*]. Likewise, the sticky phase of Sludges 3 and 4 is in the dryness region from 35–60%DS. For Sludge 5, the sticky phase reaches from about 45–60% DS.

These data support the concept that the sticky phase appears in a particular dryness region (often cited in literature sources), but that the exact location of the sticky region depends on the characteristics of the sludge, as exemplified by the different curves in Figure 2.

Some room for error is thus very much justified in the interpretation of the data provided in literature sources. Moreover, instead of using this information, engineers might do better to take the plunge and map the sticky phase for the sludge in their own facilities.

The reason why the sticky phase occurs at higher dryness for sludge with a lower organic content will become clear after we have explained the (proposed) mechanism for the sticky phenomenon of sludge [*10*].

An understanding of why sludge should behave in such a sticky manner during the course of drying begins with a look at activated sludge as a matrix of long biopolymers (such as extracellular polymeric substances — EPS) wherein the microorganisms are entrapped [*11,12*]. In other words, in the context of explaining the physical property changes of drying sludge, we think of sludge as a kind of "biopolymer matrix" whereby the biopolymers glue together the microorganisms of the sludge. The central role of the EPS in the sludge floc structure was also highlighted in *Chemical Engineering* [*13*]. During dewatering and drying, the gluing biopolymers become more and more concentrated and a sticky mixture develops. Keeping in mind the concept of a biopolymer solution, the stickiness curves for each of the five individual sludges represented in Figure 2 (which, in general, can be qualitatively summarized by the curve depicted in Figure 3) is explained as follows [*10*]:

1. At low sludge dryness (high water content), the wet sludge does not behave as a sticky substance because at that stage, it is a biopolymer solution with low concentration. The sludge makes loose contact with the surfaces of the dewatering and drying equipment (to be compared with aquaplaning)
2. When the sludge's dryness increases (and water content decreases), the biopolymer solution becomes more and more concentrated — and becomes more and more sticky — until it reaches the dryness region, wherein it behaves with most stickiness (this is its sludge-specific sticky phase)
3. The quite abrupt decrease in sludge stickiness at higher dryness, just beyond the sticky phase, is attributed to the cavities that develop at the contact surface between the sludge and dryer equipment. These cavities are a result of the further concentration of the biopolymer solution to such a critical extent that the biopolymers will not spread out any more on the dryer wall to the same extent that they did at a somewhat lower dryness. At this point, the adhesiveness of the drying sludge decreases spectacularly with only small increases in dryness.

Figure 3 presents a summarizing scheme of the sludge consistency

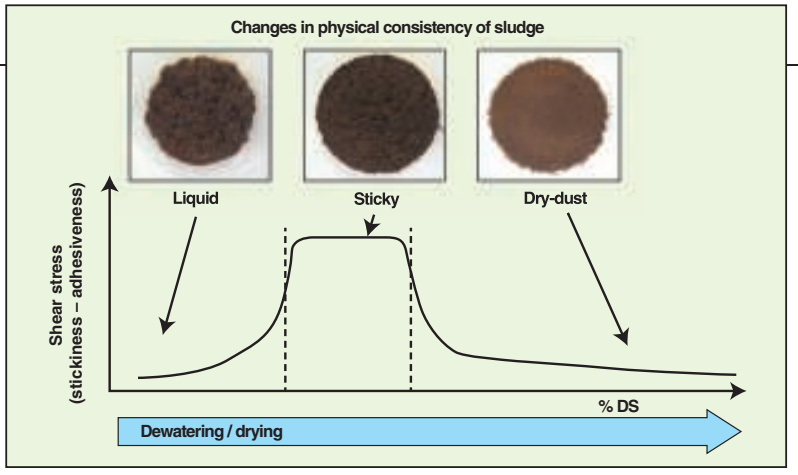

FIGURE 3. The changes in physical consistency of waste sludge during the course of dewatering and drying are summarized here

during its course of dewatering and drying. For a conceptual representation of the sludge sticky behavior, see Ref. 10.

This brings us back to the question raised above — that is, why does sludge with a lower organic content have its sticky phase at higher dryness levels? Lower organic content of the sludge (as a result of a temporarily higher amount of precipitated $CaCO_3$ salts in the sludge floc because of changing wastewater composition, for example [*14*]) implies a lower EPS content per unit mass of sludge. Again keeping in mind the above described biopolymer matrix of sludge, the lower EPS concentration at the start will require a more extended dewatering or drying of the sludge (or lower water content) before the sludge will exhibit the same viscoplastic behavior compared to sludge with a higher EPS concentration. The latter sludge will already attain its maximum stickiness at lower dryness.

Sticky-phase strategies

The negative effects of the sticky phase on dewatering and drying installations include, but are not limited to, higher torque requirements in both decanter centrifuges [*10, 15, 16*] and sludge paddle dryers [*17–19*], and sludge buildup on dryer surfaces [*20, 21*], potentially causing equipment damage.

To prevent these issues, strategies applied in industry are threefold. Two strategies aim at controlling the sludge %DS at the beginning of the drying stage, by either increasing or decreasing the %DS, and the third is an innovative approach triggered by the biopolymer matrix concept explained above:

1. A well-established method employs back-mixing of finally dried material into the raw (mechanically dewatered) sludge feed stream of the dryer. By doing so, the average %DS in the blended feed to the dryer is increased beyond the sticky phase of the sludge [2, 8, 22]. As a result, the sludge mixture becomes crumbly before being introduced into the dryer, and it becomes easier to handle. For Sludge 1 (in Figure 2), an increase of the solids dryness to 45% DS would suffice, as illustrated in the upper part of Figure 4, whereas for sludge 5, backmixing of dried material would be needed to achieve about 65% DS in the feed to the dryer
2. A less established technique involves combined mechanical dewatering and flash-drying systems [20, 21]. By lowering the sludge %DS after the mechanically dewatering stage (that is, at the beginning of the thermal drying stage), one postpones the timing and place in the flash dryer where the sludge goes through its sticky phase. By applying this strategy

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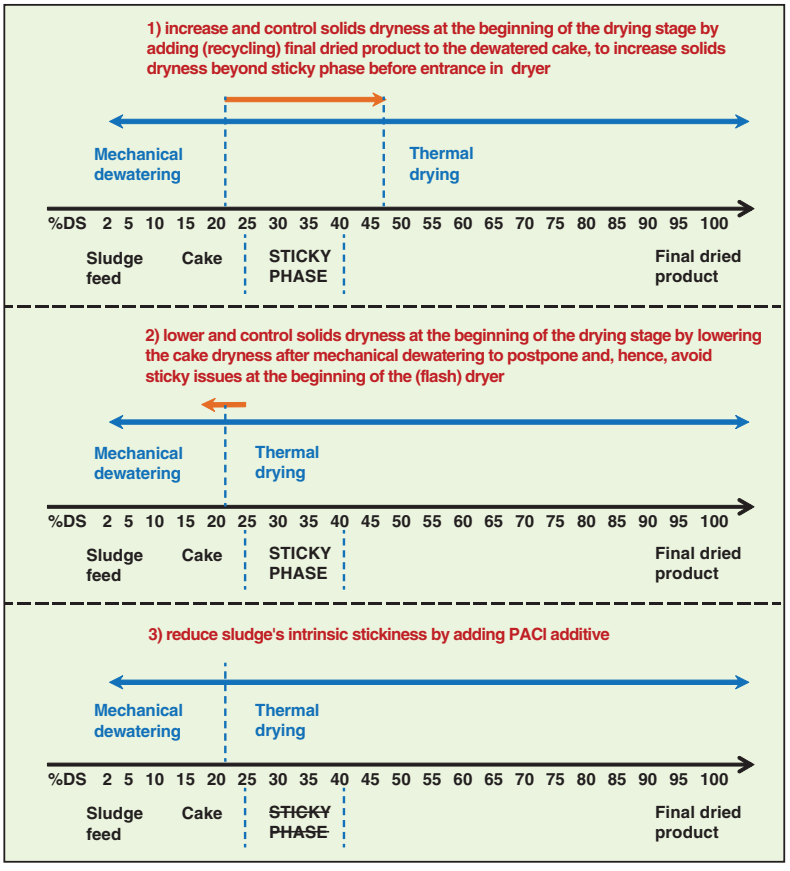

FIGURE 4. Practical control strategies to tackle sticky issues during the course of sludge drying

(depicted in the middle of Figure 4), the drying sludge behaves as a sticky paste only at a less critical place in the dryer, such that no operational issues are encountered

3. Finally, an additive can be introduced into the raw sludge feed to mitigate, or even almost completely eliminate the stickiness of the sludge (conceptually presented at the lower part of Figure 4). This can be accomplished by adding polyaluminium chloride (PACl) — a technique thoroughly tested and validated by the authors [10, 15, 20]. The addition of rather small amounts of PACl to the raw sludge feed of a combined centrifuge-dryer system (only 10–20 L on a volumetric sludge flow of 7 m^3) has become common practice at the Monsanto WWTP in Antwerp for more than four years. The beneficial effect of PACl conditioning of waste sludge is explained by the bound hydration water associated with the super-aluminium structures of PACl solutions, attached to the exterior of the sludge flocs upon dosing of PACl to sludge. These shields of hydration water act as a type of lubrication (aquaplaning) and guide the underlying sticky biopolymers through the dryness range, where they otherwise would cause the sticky issues of partially dried sludge [10]. Also lime addition pretreatment of sludge would reduce the sludge buildup on dryer walls, based on recent laboratory results of Li and others [23].

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Magnetically Driven Pumps: An overview

Understanding sealless pump technologies and their potential applications

Richard Tym
ITT Goulds Pumps

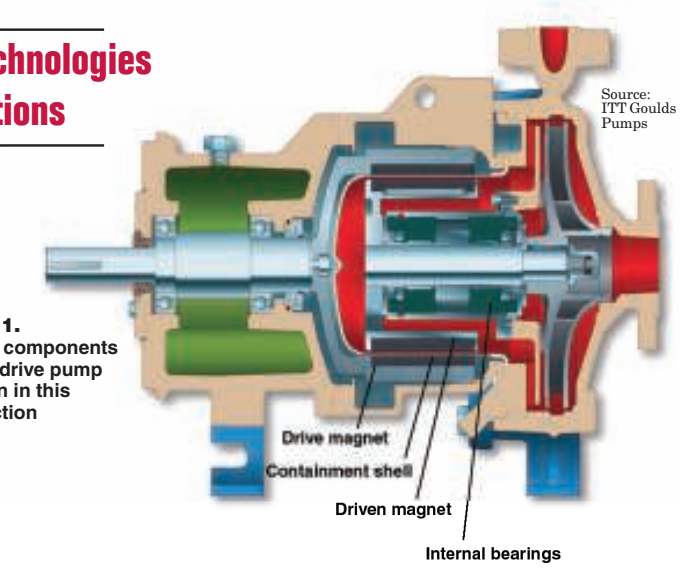


FIGURE 1. The main components of a mag-drive pump are shown in this cross section

Magnetically driven (mag drive) centrifugal pumps have been in use since 1947 when the first mag-drive pump was developed. Mag drives have always been the workhorse pump in applications with corrosive and often toxic fluid applications, and particularly over the last 20 years they've become more common in the chemical process industries (CPI).

A typical mag-drive pump is comprised of a magnetically coupled rotor-and-drive assembly separated by a containment shell that hermetically seals pumpage from the atmosphere (Figure 1). The mag-drive pump's key feature is a sealless design, which eliminates a mode of failure. This often makes it a strong solution for pumping applications with mechanical seal problems. The mag drive is commonly used to pump hazardous and high intrinsic value pumpage where the process cannot or should not be diluted by flush media (typical in a traditional mechanical-seal pump). Mag drives have many growing applications in global industries, such as petrochemicals in petroleum refineries, pharmaceutical applications, and pulp-and-paper mills, which employ caustic, acid and solvent services during production. However, this type of pump is somewhat underutilized in many of these industries due to common misconceptions about the technology.

Mag-drive fundamentals

Magnetically driven pumps have several design features that extend pump life, especially in common CPI applications with hazardous scenarios. The mag drive's key design feature is the absence of a traditional rotating mechanical seal (compare Figure 1 and Figure 2). Instead, a full hermetic seal with no rotating component reduces the risk of leaks. This sealless design is the most well-known feature of mag drives and is a primary reason why they are often used for hazardous or valuable fluids. Another advantage is avoidance of mechanical seal maintenance and flush plan maintenance.

Mag-drive pumps are available in either ANSI or ISO dimensional standards. They are available in most metallurgies, as well as non-metallic designs, such as with a polymer lining. A polymer design offers improved corrosion resistance, utilizing polymer coatings such as EFTE (ethylene tetrafluoroethylene). All mag drives, whether metal or lined, have very limited solids handling capability. The nature of the mag-drive design has circuits that facilitate process lubrication of internal bearings, and these passageways are typically very small. If solids are introduced, the circuits can easily get blocked, leading to pump damage. The passage ways are sometimes so small that it will take only a minute amount of very small solids to erode the components of a mag-drive pump.

Design and usage

In addition to the sealless advantages, there are some key considerations when deciding whether to use a mag-drive pump. Because they utilize magnets to transfer power and torque from the drive assembly to the driven rotor assembly, it's important to recognize that there are temperature limitations for magnet's materials. When exposed to temperatures above their threshold they can begin to lose their magnetism. Over time,

Source: ITT Goulds Pumps

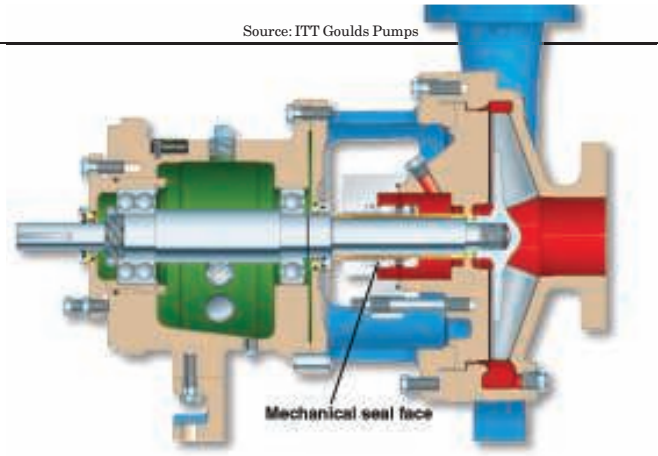


FIGURE 2. One advantage of mag-drive pumps is the absence of a mechanical seal (shown here), which reduces the risk of leaks

Source: ITT Goulds Pumps

FIGURE 3. Unlike earlier designs, today's mag-drive pumps are simpler and have fewer components

this loss of magnetism results in pump failure due to degradation of the magnetic coupling between the drive and the driven component. Therefore temperature characteristics of the application are a critical factor when considering application of a mag-drive pump.

Another factor to weigh is the torque limitation due to the magnetic coupling of the drive and components. It's important to make sure that the magnets are sized correctly so magnetic-coupling breakaway torque is not exceeded during unit startup or steady-state operation. If breakaway torque is exceeded, the magnetic coupling between the drive and the driven assemblies is lost, and the impeller will cease to spin, which means the pump must be shut down to allow the magnets to recouple. If there are numerous instances of magnet decoupling due to improper magnet selection or other circumstances, such as clogging or process upset, magnets will degrade over time to the point where the pump will no longer operate properly.

In metallic mag-drive pumps, eddy currents can also affect performance. Eddy currents are electrical currents generated by the motion of the magnets moving past an electrically conductive containment shell. The inner workings of a metallic mag-drive pump have a drive magnet and a driven assembly separated by a metal barrier. As the magnets start rotating around this barrier, eddy currents form and generate heat. The design of a mag-drive pump must take into account the removal of this heat to avoid boiling and possible flashing or vaporizing of process lubricants, which will cause pump failure through bearing damage. Furthermore, there is a loss of horsepower due to eddy currents. Eddy-current effects can be mitigated by correct sizing of the magnets and the motor.

A final consideration when utilizing mag-drive pumps is to be aware that they are extremely sensitive to dry-run and dead-head conditions. In the case of dry run, a loss of liquid in the pump system can cause the process lubricated bearings to overheat and crack, leading to pump failure. Dead head occurs when running the pump against a closed valve or a blockage in the line results in the loss of fluid circulation. This results in a buildup of heat and excessive thrust loading that can cause unit failure.

Overview of mag-drive designs

A common misconception about mag-drive pumps is that their designs are complicated. These misconceptions are based on older mag-drive designs that commonly had a large number of component parts, including individual heat-shrunk bearings, spacers and various O-rings. More than a dozen components were typically involved and assembling and disassembling required longer maintenance time. However, the industry has made great strides in recent years, resulting in newer, significantly simpler technologies (Figure 3). Improvements to bearing-cartridge designs reduce and consolidate components, such as bearings and spacers, making for easier maintenance, reduced downtime and less inventory.

Operationally, there are several fundamental components in a mag-drive pump design. There are two separate rotating assemblies (drive and driven) connected by a magnetic coupling. The motor transfers power through the drive magnet assembly to the driven magnet assembly, which is connected to the impeller and ultimately moves the fluid in the pump system. Between the two assemblies is a containment shell that keeps all of the fluid within the pump and serves to maintain pressure, acting as a hermetic seal that prevents fluids and vapors from escaping to the atmosphere. The magnets interact through magnetic flux lines that are translated across the containment shell. Within these two assemblies are alternating rings of north and south magnets, which both attract and oppose each other based on positioning, preventing slippage from occurring. This type of design is known as a coaxial synchronous magnetic drive, and ensures that both the pump and motor will spin at the same rate.

Some high-temperature mag-drive designs (>500°F) use a slightly different design to alleviate demagnetization effects. The drive magnet assembly outside the containment shell is typically the same as a standard design. However, the driven assembly consists of a metallic torque ring that couples with the drive magnet to spin the impeller (Figure 4). This design protects against excessive temperatures by removing driven magnets from immersion in high-temperature media, and is often used in heat-transfer-

media applications, as well as many other high-temperature chemical, oil-and-gas and general industry applications. This design allows for a small amount of slippage due to the use of the drive metallic torque ring, but it typically does not experience issues with decoupling, although a slight loss of efficiency (when compared to traditional mag-drive designs) may result.

Finally, the rare earth materials from which magnets are made are important to understand. The most common is neodymium iron boron (NdFeB), which has a high magnetic field strength per volume, but cannot withstand high temperatures. Other materials commonly used in mag drives are samarium cobalt (SmCo) and aluminum nickel cobalt (Alnico). SmCo has slightly lower magnetic strength than NdFeB, but can withstand higher temperatures. Alnico can handle much higher temperatures than both NdFeB and SmCo, however it lacks strength and cannot handle the torque present in some of the more demanding pumping applications. Magnet material selection is therefore critical when specifying mag-drive pumps.

Typical applications

Hazardous and regulated services are the most common applications for mag drives as they are well-suited for pumping liquids that may pose threats to people and the environment. The mag-drive design offers heightened safety for workers and better protection for the environment by eliminating leaks of hazardous fluids (see boxes on p. 58 and 59). Sealed pumps applied to these types of services may leak over time, or require complex double seals to prevent hazardous liquids and vapors from escaping to the atmosphere, which can lead to safety hazards, downtime and increased maintenance requirements.

Some examples of primary mag-drive applications are liquid pumping of strong acids, strong bases, and solvents, such as acetone, hydrochloric acid, sulfuric acid and sodium hydroxide. Many of these would pose a serious health risk to plant personnel if there is a fluid or vapor leak. Some materials can even auto-ignite when exposed to the atmosphere.

In these situations, a mechanically sealed unit can be riskier and more expensive than a mag drive. Typically a traditional mechanically sealed pump in a hazardous application process would utilize complex double-seal systems that are a significant capital investment. They also require much more maintenance and additional monitoring.

Other mag-drive applications can be where liquid is hard to seal with a traditional mechanical seal. For example, pulp-and-paper mills employ sodium hydroxide applications where pumpage can crystallize on seal faces, which then can cause seal failure. To avoid this, a flush must be run to the seal that can increase installation, maintenance, plant water and energy consumption costs.

The need for environmental regulation adherence in the marketplace has also driven awareness of mag-drive pumps. The U.S. Environmental Protection Agency (EPA) regulates emissions and waste, and instituted the Clean Air Act of 1990, which requires certain chemicals or services to utilize a sealless pump. Furthermore, many chemical plants have implemented their own set of guidelines based on internal hazard classifications.

Valuable pumpage, such as mercury and printer ink, along with other industry services where downtime brings significant costs, can also be viable candidates for mag-drive usage. Single seals leak fluid upon failure, and once a pump leaks, the fluid is not usually recoverable. This results in lost money and environmental cleanup time. A double seal is an expensive and higher-maintenance solution. Magnetically driven pumps can protect precious pumpage and eliminate risk of leakage due to their hermetically sealed design and limited maintenance needs.

Finally, remote locations are scenarios that often call for sealless mag-drive pumps. As plants expand, sometimes over miles of land, some services are located remotely and are not conducive to routine monitoring and maintenance. Examples include wastewater-treatment facilities where pH correction is needed because water is going to be introduced back into a system or a nearby river or lake. This requires technology to eliminate potential leaks and limit maintenance needs. Another example would be a sealed pump in a remote area that would require flushing. This may require running a significant length of flush line to the pump's location

REDUCING ENVIRONMENTAL CONCERNS AT PAPER MILLS

Pulp-and-paper mills are now able to drastically reduce environmental concerns by eliminating a primary potential point of failure by replacing sealed pumps with sealless mag drives. The latest mag-drive designs and technologies feature fewer parts and are robust enough to withstand the caustic chemicals commonly used in paper mills, including sodium hydroxide, sulfuric acid, sodium hypochlorite, chlorine dioxide, and hydrogen peroxide. Any of these chemicals may cause damage to and leakage through the seal faces, ultimately damaging pumps and posing safety and health risks to workers. Plant operators can streamline maintenance requirements and utilize mag-drive pumps to handle hazardous sulfuric acid services commonly found in almost any paper mill, minimizing potential environmental hazards and saving time and money. ❑

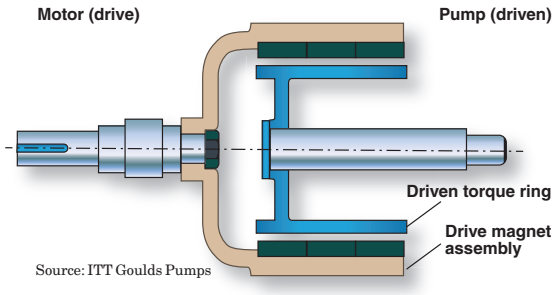
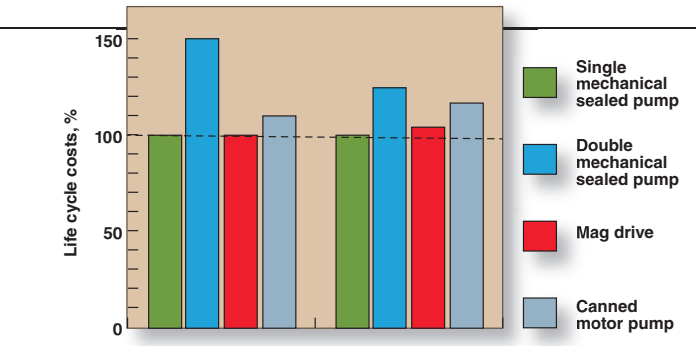


FIGURE 4. This high-temperature (>500°F) mag-drive design uses a metallic torque ring instead of a drive-magnet assembly to couple with the drive magnet. Removing magnets from the high-temperature pumpage eliminates the possibility of driven magnet demagnetization

Source: ITT Goulds Pumps



Pump size		50-32-160	85-50-200
Discharge	Q =	10 m^3/h	40 m^3/h
Head	H =	28 m	41 m
Speed	n =	2,900 rpm	2,900 rpm
Power	P =	1.5 kW	7.0 kW

Source: Infractor DEGUSSA-Hüls

FIGURE 5. This chart compares the lifecycle costs for centrifugal pumps using various sealing options

SAFER WORK ENVIRONMENT FOR ALUMINUM MANUFACTURER

A North American architectural aluminum store-front and door manufacturer used several anodizing tanks to treat and color its aluminum products. Each tank contained 17% sulfuric acid that needed to be maintained at 70°F for optimal results. During the course of the anodizing process, heat was generated as the sulfuric acid reacted with the aluminum products, and the acid was pumped out of the tanks through chillers. Each of the pumps was a mechanically sealed ANSI pump with a large sheet of Plexiglas leaning up against the pump unit, effectively acting as a "spray shield." A fine mist of sulfuric acid would emit from each pump seal, barely noticed by plant personnel. This hazardous condition resulted in workers finding multiple holes in work clothing where the acid had splashed during the workday. Needless to say, a change was needed in order to increase worker safety. Initially, the plant agreed to install one non-metallic magnetically driven pump as a test on one of these tanks. The mag-drive pump cut maintenance, increased safety and reduced downtime. The replacement was such a success that mag-drive pumps replaced all mechanically sealed ANSI pumps, providing a safer and more efficient work environment for plant personnel. ❑

and also carries high water-usage costs. Introducing a sealless pump to a remote location eliminates the need for seal checks and flushing, and provides a reliable system with minimal maintenance.

By taking the seal out of the system, a major failure point is eliminated and reliability is enhanced. Eliminating bearings is a second feature mag-drive pumps offer that improves reliability. Close-coupled mag-drive designs eliminate the power end, removing the possibility of oil-lubricated bearing failure, coupling misalignment, and in most cases, the need for a baseplate.

Comparison to other seal options

A mag-drive pump is comparable in cost to single-sealed and canned-motor pump designs, and is less costly than double-sealed pumps that utilize barrier-fluid systems. There is no replacement of seals and no running of flush lines, leading to reduced maintenance and downtime. When evaluating different pump sizes and duty points one must look at total lifecycle costs. The chart shown in Figure 5 provides a breakdown across the various pump designs. Canned-motor pumps require more maintenance time and dollars, as they are generally very difficult to work on, and require a specialized maintenance shop on site. Also, operators may need to send the motor out for service if there is a breach of the primary barrier to the internal motor windings. Double-sealed pumps have higher costs across pump sizes compared to mag drives. Mag drives also deliver optimal performance, with metallic mag-drive efficiencies often equivalent to that of metal-sealed ANSI pumps. Also worth noting is that non-metallic (lined) mag-drive pumps can be up to 30% more efficient than metallic sealless pumps.

Lined versus metallic

Lined mag-drive designs (Figure 6) protect the metal casing from corrosion that is common in chemical applications. Some common linings are PTFE (polytetrafluoroethylene), PFA (perfluoroalkoxy alkanes), ETFA (ethylene tetrafluoroethylene) and PVDF (polyvinylidene fluoride). All offer corrosion resistance from chemicals; however, they are not universally resistant to all media, which is why various coating options exist. Some components can also be fiber reinforced with carbon or glass. For example, the impeller can often be reinforced with these materials to provide greater protection from hydraulic erosion. In a lined mag-drive pump there is no eddy-current heat buildup or potential power loss from currents as the containment shell is typically fiberglass-reinforced plastic (FRP) that is coated with one of the linings listed above.

One thing to consider with lined mag-drive pumps is that they are generally limited in the areas of temperature and pressure. The linings can only accommodate temperatures in the mid-200°F range, with various casings typically capable of sustaining design pressures in the mid to upper 200 psi range. Overall, lined mag-drive pumps are very good for working with various acids or bases as long as they are below certain temperature and pressure thresholds.

A metallic mag-drive-pump design (Figure 7) is capable of withstanding higher pressure and temperatures limits. These pumps are well suited for solvents, heat-transfer fluids and other non-conductive fluids that typically run hotter. Some metallic mag drives can easily handle over 500°F for liquid-service temperatures. Metallic mag-drive pumps also are strong solutions for pumping non-conductive fluids, such as benzene, that can build up an electrostatic discharge, which can be an issue for designs employing an FRP polymer-lined containment shell. When using an FRP-lined shell design, the electrostatic discharge can "arc" through the nonmetal containment shell, causing a pinhole leak that will cause complete pump failure over time, as well as introduce environmental and personnel hazards that may be difficult to observe at their onset. In a metallic mag-drive pump this arcing charge will not penetrate the alloy containment shell.

Finally, metallic mag-drive designs have better solids-handling

Source: ITT Goulds Pumps

FIGURE 6. Mag-drive pumps can be supplied with polymer linings for corosion protection

Source: ITT Goulds Pumps

FIGURE 7. Metallic mag-drive pumps are more suited for higher temperature and pressure applications

capabilities compared to their lined counterparts. Metal is more resilient to solids erosion than a lined pump, although only up to a point. Also, with metal-mag-drive designs there are typically options for providing additional internal bearing flush since concerns over breaching and compromising polymer linings are eliminated. Metal mag drives also offer more options for monitoring and controls. Instrumentation devices, such as thermocouples, resistance temperature detectors (RTDs), level switches and temperature switches are all more readily available to use on a metallic mag drive, once again because concerns about breaching lined components are eliminated.

Avoiding failure modes

When using mag drives, one can encounter failure modes not present with a sealed-pump application. The most common mag-drive failure mode is dry run. Simply put, dry run occurs when a pump is run without fluid. Mag-drive designs employ process lubricated bearings often made of carbon or silicon-carbide material. During dry run, the lack of fluid in the system causes the bearings to lose lubrication, which can result in cracking, fracture and eventual failure due to the nature of the bearing material. Another cause of dry run is when fluid overheats, boils and flashes off in the lubrication circuit, effectively removing process lubrication. This can lead to chipping, cracking and increased temperatures that can melt plastic linings and lead to a pump seizing.

Some solutions to avoid dry run are to attach a power monitor to the pump, which can alert the operator or control system of the condition, or just automatically shut the pump down after a short period of time. There are also specialized methods of treating or coating rotating and stationary silicon-carbide component surfaces that reduce their coefficient of friction and can, for a short time, minimize the effects of dry run.

The other common failure mode of mag-drive pumps is dead heading, which can occur by running the pump against a closed discharge valve. Fluid temperatures begin to rise quickly because of energy buildup of impeller rotation in a closed system, leading to boiling, cavitation and bearing damage. Dead heading can be avoided by flow and temperature monitoring and controls.

Processing solids can also provide a set of challenges due to erosion or clogging. Mag-drive pumps are not made to handle solids. Introducing solids will cause accelerated erosion, especially within lined mag-drive pumps. Solids can also collect in low-pressure areas in the bearing circuits, typically at the rear corners of the containment shell, causing accelerated erosion. Clogging of process lubrication and recirculation circuits can also occur where the bearings can lose lubrication and fail. A primary solution in metallic mag drives is a bearing flush where added pressure is introduced to a pump system and can help to keep solids from building up in these circuits. Improved pump designs in both lined and metallic mag drives can also lead to more fluid movement (and thus easier solids removal from "problem areas"), achieved by introducing more channels or adding pumping actuators in the lubrication circuit.

A final important consideration is magnetic decoupling. In mag-drive pumps, the magnetic field between the magnets spins the impeller. The magnetic coupling has a torque limit, so the pump must be properly sized, and designs must take into consideration the proper magnetic materials as well as sizing. If magnet materials and size are not properly specified, the torque limit is exceeded and the magnetic coupling connection can be broken, resulting in downtime and possible unit failure. Some common causes of magnetic decoupling are hard starts with higher rates of start-up torque than seen during steady operation, wet end clogging due to an unexpected high shear or fibrous fluid, or a process upset, such as encountering colder temperatures than anticipated, which causes a spike in fluid viscosity. Employing a power monitor can detect magnet decoupling and mitigate these effects.

Final remarks

CPI plant operators continue to gain a deeper understanding of the latest magnetically driven pump technologies, which offer simpler and more efficient fluid-process solutions. Using magnetically driven pumps can yield significant benefits by improving safety, reducing plant downtime, slashing maintenance time and associated costs, cutting onsite parts inventory and eliminating potential failure points through a hermetic sealless design. Today's mag-drive pumps have ideal processing applications in industries that handle hazardous fluids. Mag-drive pump designs offer distinct advantages over traditional sealed models when used in the proper environments and appropriately specified. ■

Edited by Gerald Ondrey

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Mechanical Seals Update:
Pharmaceutical and Food Applications

For applications that require cleanliness, be sure your centrifugal pumps have the proper seals

Heinz P. Bloch
Consultant

Second only to electric motors, centrifugal pumps are the most common machine used in the chemical process industries (CPI). Pumps are serving in every conceivable fluid application. They move all manner of fluids from wastewater to paper pulp, from ultra-clean and purest pharmaceutical liquids to crude oils laden with a great variety of contaminants. Hundreds of millions of these pumps are fitted with mechanical seals at the point where shafts protrude through the pump casing. And some of these seals must satisfy very special requirements; the prevention of contamination is among them.

Appropriately, process pumps in the pharmaceutical and food-and-beverage industries are subjected to stringent hygiene and cleaning requirements. These include clean-in-place (CIP), and steam-in-place (SIP). Industry and its regulatory agencies seek to reduce, and hopefully eliminate, the possibility of bacteria and micro-organism growth. Cleanliness is especially important on surfaces that are in contact with, or "wetted" by, the processed media. Needless to say, such contamination is detrimental to the finished processed product; therefore, considerable efforts are made by plant operators, engineers and managers to avoid contamination.

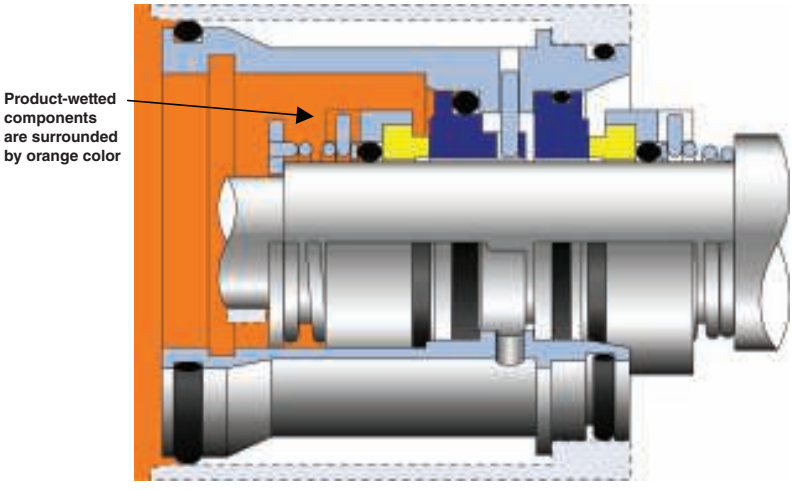

FIGURE 1. This cutaway shows a traditional component-style mechanical seal. A buffer fluid is introduced into the space between inside and external seals

But how thorough are the prevailing cleaning routines, and how successful are even the most diligent efforts around the restricted and confined spaces of the all-important mechanical seal? Clearly, the answer to this question depends on the design of the mechanical seal and the seal housing. More specifically, cleaning effectiveness is influenced by the geometry of sealing components contacted by the process fluid.

Seal design considerations

The three main causes of pump process-fluid contamination in hygienic applications are easily recognized, as follows:

1. Microorganisms can enter the process fluid from the atmospheric side of the mechanical seal and may pass through the seal fluid film.
2. Process fluid could pass through the sealing fluid film to the non-process fluid side, which may lead to microorganism growth in the residues. These microorganisms could then move back across the seal fluid film into the process fluid where they could cause contamination.
3. Process fluid could stick to the process-wetted components of the seal or seal cavity. In that case, it would be difficult to properly clean the seal region after processing each batch. This could lead to microorganism growth and contamination.

The issue is of concern to the European Hygienic Engineering and Design Group (EHEDG), an international body which helps industry focus on best-practices guidelines for mechanical seal designs. Among the considerations spelled out by EHEDG for hygienic and aseptic applications, we find a classification of hygienic equipment into the following three groups:

1. Aseptic
2. Hygienic Equipment Class I
3. Hygienic Equipment Class II

Across all groups or categories, the EHEDG stipulates that the sealing

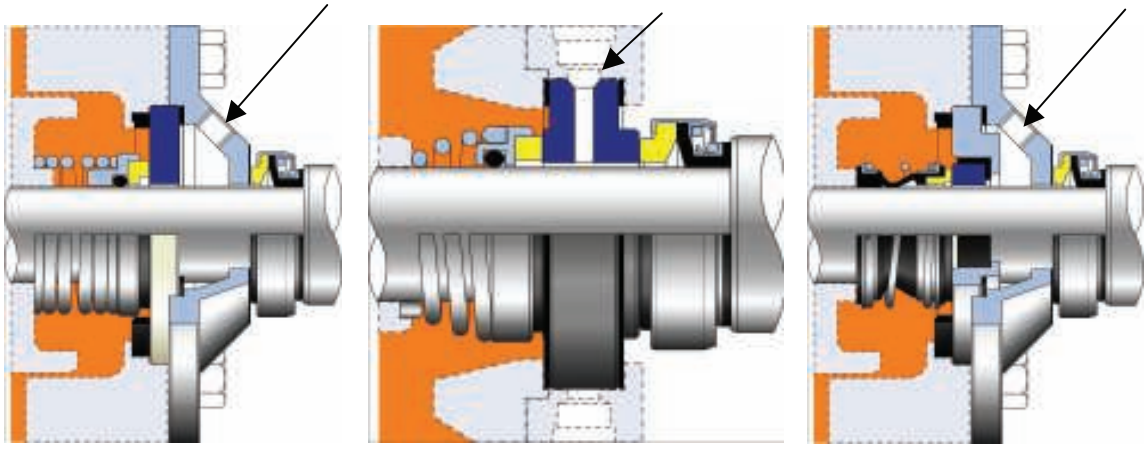

FIGURE 2. Shown here is range of traditional, risky, external and internal component seal designs. These are still found in hygienic applications. Internal components are wetted by process fluid, shown in orange. Arrows point to locations where buffer fluid is injected

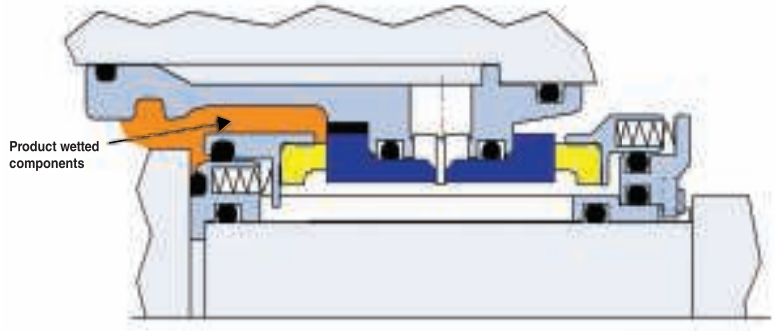

FIGURE 3. Shown here is a cartridge seal design for use in hygienic applications. Buffer fluid is introduced into the space between the product-wetted seal on the left, and the external seal on the right side

device should protect the process fluid from being contaminated by the fluid environment. It should be easy to clean the sealing region to reduce the risk of microorganism growth. It is intuitively evident that equipment that is difficult to clean will result in an inferior processed product. Flawed product quality may result in a rejected product batch, incur additional reprocessing cost, force product recalls and represent a real danger for human consumption or use.

Within the three equipment groups or categories, Class I and Aseptic equipment requirements detail the use of an external seal to create a buffer region (seal cavity). This buffer region can be continually flushed with an appropriate fluid. A dual-seal arrangement is intended to reduce the possibility of cross-contamination and issues arising from process fluid traveling across the seal fluid film of the inboard seal faces.

EHEDG also stipulates that all unavoidable gaps must be sited at the non-process fluid side of the seal and the components in contact with the process fluid must be smooth and free of crevices. Again, this guideline is intended to reduce the potential for bacteria and microorganism growth. It would serve no-one's best interests to have process fluids stick to any part of a pump. Contamination risks are even greater when changing batch composition, or with time elapsing between successive batches.

Reality versus best practice

Informal surveys show that many seals presently found in the food, beverage and pharmaceutical industries are not representing best-available designs. Single-coil spring "component seal" designs of the 1970s and 1980s (Figure 1) are still dominant and in common use. Note that Figure 1 depicts an old-style dual (inboard versus external "face to face") component mechanical seal used in certain hygienic applications.

However, on the process side, the fluid (shown in orange in Figure 1) is in direct contact with multiple seal crevices and cavities. It will be impractical, if not impossible, to thoroughly clean these regions. As an aside, practically every best-practice seal-design guideline has been ignored in this particular geometry. Regrettably, this is not an isolated issue.

Figure 2 illustrates another family of similarly unsuitable or outdated designs. All three are internal/external component-seal designs with buffer fluid. These seals find extensive use in the food-and-beverage industry. But these and similar designs have significant bacteria and microorganism growth potential around the components wetted by the process fluid. While the issue is entirely design-related,

it can, and has been, successfully avoided by the intelligent redesign depicted in Figure 3.

Using the seal in Figure 3 for new and existing pumps in hygienic services allows plant engineers to avoid substantial risk. This mechanical seal is not only easier to clean, but fully harmonizes with international best practice guidelines. The design is uncomplicated and very cost-effective. Most important: It fits in the space shown earlier in Figure 1 and represents true state-of-the-art technology.

Note also that the component seals in Figures 1 and 2 will require careful dismantling and reassembly. In contrast, the recommended state-of-the-art "slip-in" design of Figure 3 can be fully assembled at the factory, which reduces field work and potential errors. Moreover, the possibility of process-fluid contamination is greatly lessened by incorporating only smoothly contoured wetted parts. Common sense convinces us that components with smooth surface finishes facilitate cleaning and sterilization. Eliminating crevices and cavities makes it much more difficult for microorganisms and bacteria to adhere to surfaces. In the state-of-the-art seal of Figure 3, springs and drive mechanisms cannot be contacted by the process fluid.

So, while single-spring component seals may appear to be low-cost sealing solutions, they do have many shortcomings. Best-practices companies recognize the hidden costs and contamination risks associated with outdated designs. Risk-averse users increasingly make innovative seal manufacturers one of their technology resources. As business partners, both manufacturers and users demand what best practices guidelines require. Not all mechanical seal designs are the same. Reliability-focused engineers look at both the "big picture" and the details of the best available seal designs. ■

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All three figures courtesy of AESSEAL plc, (Rotherham, U.K. and Rockford, Tenn.)

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The practical side of R&D

With 38 years of experience, Mike Resetarits consults on distillation, absorption and extraction processes. Each month, Mike shares his first-hand experiences with *CE* readers

William Banholzer gave an opening keynote address at the AIChE Spring Meeting (New Orleans, La.; March 31) that was interesting, fun — and brave. It reminded me of the "Six Sigma for Research and Development [R&D]" training that UOP provided to me many years ago. The following principles regarding R&D were taught in that training: the goal is profit, not data; new apparatuses do not necessarily lead to new products; there must be a market for any new product and that product must be manufacturable at a reasonable cost; and the new product must be protectable (such as via patents).

Banholzer's presentation, entitled "The World Needs Engineering Judgment," contained some similar themes directed at commodity chemicals. R&D should be regarded as a privilege and not a right. In today's companies, new products provide only about 8% of their profits. Invention is not enough. The new product must be desirable and affordable.

Banholzer gave some micro and macro examples of new technologies. He was skeptical regarding all of the following: the conversion of greenhouse gases into biodegradable plastics; the conversion of algae to crude oil; the use of graphene nanotubes for desalination; the use of sugar to create ethanol and then ethylene and then polyethylene for softdrink "bio-bottles." "Overall, bio has under-delivered," he stated. He also said that "distillation works" and that there are hurdles to replacing it. On the other hand, heat integrations of distillation units have been successful. He recommended asking questions like the following regarding new processes: How much energy is in the starting material? How much energy is required for conversions? How much energy is in the final products?

Banholzer also gave examples of research work that has truly yielded appreciable dividends. The production costs of low-density polyethylene are now at about 10% of those in the 1950s. Shale gas is producing seven times more energy than what is required to isolate it. Mechanical hurdles have been overcome to allow the construction of larger, more-efficient plants.

Surveys have shown that consumers and buyers are extremely hesitant to "pay for green." This places an extra burden on the people who do research work on new products and processes. At the same time, new chemical processes usually require about 20 years to show profits. Large companies and small companies need to be very careful not to initiate research projects that might be doomed, especially if they fail to analyze the realistic costs and benefits of the new processes. Banholzer seemed to purposely avoid the Federal Government's role in funding energy and chemical projects that might waste taxpayer money.

Banholzer started and finished his presentation with some very good news for the more than 2,000 attendees at his presentation: "the skills of chemical engineers are needed now more than ever." Hopefully, not too many of them will be working on almost-hopeless research projects. ■

Mike Resetarits

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Water in mining: from liability to valuable resource

In the mining industry, the perception of water has changed: from a waste product to be treated, to a valuable resource needing proper management, says Outotec

Water management in the mining and minerals industries needs to include optimizing usage across the mine or concentrator site, minimizing fresh water use, minimizing waste from water treatment, and practices for water reuse and recycling.

To succeed, companies offering water management solutions for the mining industry must have a deep understanding of mining and mineral processes. Just being good at water treatment technologies is not enough. **Outotec**'s Industrial Water Treatment offering combines mineral processing know-how built up over several decades with water treatment expertise to develop tailor-made and optimized solutions for customers.

Water in the mining industry is complex and site-specific, since the composition of impurities depends on the ore itself and how it is processed. Typical impurities in wastewater are metals, arsenic, sulfate, chloride and cyanide, often at toxic concentrations.

Water treatment processes must meet two targets. First, the treated water should be of high enough quality so that it can be recycled to the mineral processing plant, thus reducing fresh water consumption. Secondly, the process must be efficient and reliable so that the mining company can meet the requirements of its environmental permits.

Outotec has developed several processes that meet these targets. They combine proprietary and patented process technology with Outotec's equipment offerings in reactors and dewatering, plus high-quality engineering and automation systems.

A deep understanding of the mining sector gives Outotec a head start in designing specialist water treatment processes

An example is Outotec's Ettringite process for managing sulfate, which is a common and growing challenge in the industry. This two- or three-step process precipitates sulfate and calcium, lowering the scaling potential and total dissolved solids (TDS) content of the treated water while also removing many other impurities such as metals. **www.outotec.com**

A single solution for drinking water analysis

The Type 8905 Online Analysis System replaces a range of individual analyzers

Bürkert Fluid Control Systems presents a modular end-to-end system that can be expanded at any time

The continuous analysis of water parameters can be costly, usually requiring several different systems with separate displays, controls and sensors. The Type 8905 Online Analysis System from **Bürkert**, on the other hand, combines all the measurements relevant to drinking water analysis in a single compact and modular unit.

The basic version of the Online Analysis System includes standalone analysis cubes for five measurement parameters: pH, redox (ORP), conductivity, free chlorine and turbidity. All measurements have upper and lower alarm thresholds. The measured values are stored internally, and also optionally sent to a remote system.

Additional sensor types and system functions are available to expand the performance of the modular system step by step. Retrofits are possible at any time. The next steps up are on one side to add sensor cubes for more sophisticated parameters and on the other side to extend the range of control modules and enhance the software to more control capabilities.

The analysis modules combine leading micro-technologies with chemical, physical and optical measuring principles. Modules are hot-swappable and can be combined as needed for customized applications.

The compact design of the platform provides a range of savings opportunities for users. For example, the new device requires less space than previous standard systems, has lower energy consumption, and requires less wiring. It also needs less maintenance, since the platform combines the functions of numerous separate sensors and all the units can be purchased from a single source. It can easily be integrated into existing systems, or quickly installed in the field.

The functional scope of the Online Analysis System is initially optimized for municipal waterworks. By supporting drinking water treatment specialists in their daily work, the unit can contribute to cost-effective and safe drinking water production through optimization of individual process steps. **www.burkert.com**

Compact, smaller, and better value

GEMÜ valves represent a milestone in industrial plastic piping systems, saving space and weight yet out-performing metal valves in corrosive environments

In plant engineering there is a great demand for application-specific components with a wide range of functions that save space and weight, and are easy to install. Compact, lightweight plastic diaphragm valves fall into this category, offering cost-effective alternatives to conventional valve designs.

The new R690 pneumatic and R677 manual plastic diaphragm valves from **GEMÜ**, the premier engineering specialists for valves, measurement and control systems, check all the boxes for most applications: They are small and compact, lightweight, and designed so that combinations of several nominal sizes can be installed on the same mounting height plane. For installation, the valves are supplied in all standard connections for the different international standards.

Despite their compact size and smaller dimensions, the new flow-optimized valve bodies provide the same high flowrates as the previous models. In some cases, flowrates are even higher. Depending on the valve design, they are reliable at temperatures from –20°C to +80°C, and at pressures up to 10 bar (150 PSI).

The product line comprises nominal sizes from ½ –4 in. In the course of redesigning its products, GEMÜ has also succeeded in reducing the control air consumption of the type R690 pneumatic actuated version.

In addition to the standard optical position indicators, options such as electrical position indicators, positioners or process controllers, pilot valves, seal adjusters and stroke limiters are available. Valve bodies are available in a variety of plastics (PVC-U, PP, ABS, PVDF, etc.) and with a range of seal materials (EPDM, PTFE, FPM, NBR).

These compact plastic diaphragm valves are suitable for use in chemical process plants, for plant solutions in surface finishing, coating and electroplating, municipal and industrial water treatment, fluid handling in technologies such as reverse osmosis, neutralization, and microfiltration, and for chemical processes with aggressive and corrosive media, such as electronics manufacturing, fertilizers, and detergents. **www.gemu.com**

Lightweight yet capable: GEMÜ's R690 pneumatic diaphragm valve series

World-class overpressure protection solutions

Fike manufactures a wide range of rupture discs, both standard and custom, to protect equipment against excessive pressure

From hygienic processes to wastewater treatment, Fike offers peace of mind

Since 1945, **Fike Corp.** has provided world-class overpressure protection solutions, and is the industry leader in delivering reliable yet innovative products that exceed customer expectations. From safeguarding critical manufacturing processes to protecting pressure relief valves (PRVs), Fike products are part of the critical path to lowering costs and helping companies achieve higher profitability.

A rupture disc is designed to provide a leak-tight seal within a pipe or vessel until the internal pressure rises to a predetermined level. At that point the disc bursts, preventing damage to the equipment from overpressure. Liquid-full systems create a number of processing challenges, the solution to many of which lies in rupture disc technology. The typical rupture disc begins to respond to pressure in excess of the burst pressure in less than 1 millisecond. This means that a short-duration pressure spike that is not detectable by normal process instrumentation will activate the rupture disc, saving the process vessel from overpressure.

In addition to a full line of standard products, Fike also manufactures custom engineered rupture discs tailored to the application. Fike engineers and application specialists consider many important factors such as type of application, operating conditions, inlet/outlet configurations, rupture disc specifications, and special process requirements.

To support this work, Fike has an on-site flow laboratory and a metallurgy lab. The Fike Flow Laboratory is a general-purpose flow characterization laboratory for quantifying the performance of rupture discs, rupture disc/relief valve combinations, and any other device whose flow capacity or resistance to flow must be determined. Test equipment for diameters of ¼–4 in. (DN6 to DN100) allows a wide range of disc sizes and installations to be tested. Specific applications are simulated to check that custom solutions provided by Fike engineers will perform as specified.

The Fike Metallurgy Lab is used to gain understanding of the behavior of materials necessary for different applications. Fike is a single-source supplier giving full service for fire, explosion protection and pressure relief. From product development to customer support, Fike provides quality solutions. **www.fike.com**

This compact mixer boasts big performance

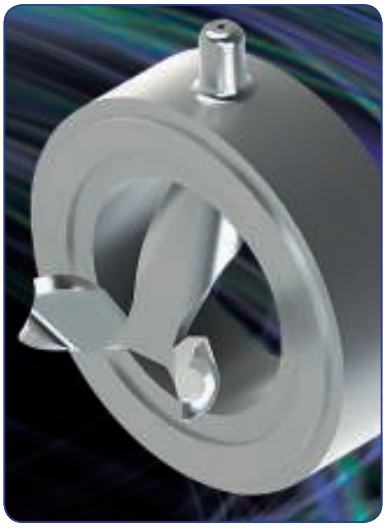
The Kenics UltraTab Static Mixer from Chemineer is designed for turbulent flow applications in pipe diameters ranging up to 60 in. and above

Chemineer is offering the Kenics UltraTab static mixer designed for turbulent flow applications where a high degree of mixing is required in a compact space.

The Kenics UltraTab provides a combination of advantages, including its compact installation space requirement, its complete blending in short distances downstream of the mixer, and the low pressure drop through the mixing element.

Some of the key features and benefits of the Kenics UltraTab static mixer include:

- integral wall injector upstream of the mixing element that forces flow stream additives through the high energy dissipation region created by the mixing element which provides superior mixing efficiency;
- low pressure drop through the UltraTab element enhances process energy efficiency and saves pump energy;
- compact design and short mixing length minimizes pipe lengths and optimizes the efficiency of the plant layout.



An integral injector simplifies the dosing of additives into the fluid stream

Product specifications of the Kenics UltraTab static mixer include:

- size range 2–60+ in.;
- NPT or flanged injectors;
- materials available include carbon steel, stainless steel, coated carbon steel or 316 stainless steel, FRP, and high alloys;
- housing options include between-flange tab and spool piece designs.

Chemineer is a brand of National Oilwell Varco. Chemineer's mixing expertise includes high-flow, low-shear liquid-liquid/solids blending, gas dispersion, high-shear blending and viscous mixing. Chemineer has operations in Dayton, Ohio; North Andover, Mass.; Derby, England; Mexico, D.F.; Singapore, and China.

With its headquarters in Houston, Tex., National Oilwell Varco has over 170 years' experience providing products and services to the international oil and gas industry. It has more than 100 subsidiaries and over 60,000 employees at over 1,000 sites around the world, plus annual revenues in excess of $20 billion. **www.chemineer.com**

Technologies for wastewater treatment and reuse

Innovative Dow wastewater treatment technologies offer reduced energy use, less fouling and better performance

As water becomes increasingly precious, industries and municipalities worldwide are turning to innovative water treatment and reuse technologies to help meet demand. **Dow Water & Process Solutions** (DW&PS) offers a broad range of component technologies to help water-intensive industries and municipalities make the most of every drop of water available.

Focused on advanced separation technologies for wastewater treatment, DW&PS is committed to maximizing the vast potential in the world's reusable water, and working with industries and communities to recover water, energy, nutrients and other valuable components of wastewater streams.

Known for its industry-leading DOW FILMTEC elements, DW&PS has developed an innovative XFR fouling-resistant technology and optimized spacer design for challenging water treatment. Applying this technology to its highest-rejection and lowest-energy membranes, DW&PS offers a range of 8-in. products tailored specifically for industrial and municipal wastewater treatment. Lower energy consumption, higher fluxes, fewer cleanings, and greater rejection of contaminants significantly improve sustainability and better enable water reuse – even in challenging applications.

Applying the same science and quality that have made DOW FILMTEC elements so successful worldwide, DOW IntegraFlo ultrafiltration modules have established a new global standard. IntegraFlo modules feature an outside-in configuration for higher solids loading. The PVDF membrane material and very narrow pore size distribution make the modules an excellent choice for wastewater treatment and offer high removal of suspended solids, bacteria, viruses and organics.

In addition, the innovative TEQUATIC PLUS fine particle filter combines the power of continuously cleaning, cross-flow filtration with centrifugal separation and solids collection into one device.

For municipalities and industries such as chemical, petrochemical, pulp and paper, textile, steel, and food and beverage, DW&PS technology is helping to turn wastewater streams into a valuable resource by allowing the specific removal of pollutants and re-use of treated wastewater in industrial processes, boilers, cooling and utilities. **dowwaterandprocess.com**

Dow membranes and filter systems aid the re-use of precious water

Keeping supplies of fresh water flowing

Eastman Therminol heat transfer fluids play a key role in the efficient and reliable operation of thermal desalination plants

According to www.unwater.org, by 2025, two-thirds of the world's population could be under freshwater stress conditions. Current estimates indicate only 0.5% of the global water supply is available as fresh water. An additional 2.5% is frozen water at the poles or in glaciers, and the remaining 97% is undrinkable seawater.

To sustain a growing global population with safe and dependable supplies of fresh water, recycling of wastewater or desalination of seawater is critical. Several desalination technologies exist; those based on distillation may use heat transfer fluids.

Eastman Therminol heat transfer fluids are available to support desalination process needs, whether the energy source is from concentrating solar or fuel-fired heaters. Thermal stability ensures long life for the fluid, resistance to fouling, and excellent fluid-side heat transfer coefficients for consistent and reliable service. Additionally, CSP (concentrating solar power) hybrid applications, combining CSP and desalination, are a new development in alternative energy and water recycling technologies. Again, Therminol heat transfer fluids can help.

- Therminol 66 is the world's most popular high-temperature, liquid-phase heat transfer fluid. Therminol 66 is pumpable at low temperatures, and offers high-temperature thermal stability.
- Therminol 59 is a synthetic fluid with excellent low-temperature pumping characteristics and thermal stability.
- Therminol XP heat transfer fluid is an extremely pure white mineral oil which provides reliable heat transfer.
- Therminol 55 is a synthetic fluid used in moderate-temperature applications. Therminol 55 fluid is designed for use in non-pressurized /low-pressure, indirect heating systems. It delivers efficient, dependable, uniform process heat with no need for high pressures.
- Therminol VP-1 heat transfer fluid is an ultra-high-temperature synthetic fluid designed to meet demanding requirements in vapor-phase or liquid-phase systems. It is an excellent option for CSP/desalination hybrid systems.

Desalination: a key technology for expanding future fresh water supplies

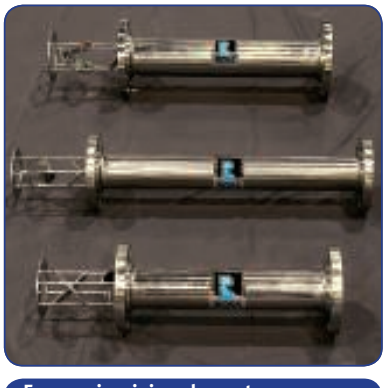
Eastman's TLC Total Lifecycle Care Program is designed to support Therminol customers throughout their systems' lifecycle. This comprehensive program includes system design support, start up assistance, training, sample analysis, flush and refill fluids and more.

www.therminol.com

Static mixers with low pressure drop

Ross LPD Low Pressure Drop Static Mixers are ideal for effective fluid mixing in water and wastewater treatment processes

The **Ross** Low Pressure Drop (LPD) Static Mixer enables more efficient dosing of flocculants, disinfectants, neutralizing agents and pH conditioners into a water stream. This simple-to-install heavy-duty device completely mixes treatment chemicals within a short length of pipe. When used in conjunction with automated instrumentation, the LPD delivers predictable quality control based on a virtually maintenance-free operation.



Four or six mixing elements are usually more than sufficient for effective mixing under turbulent flow conditions, Ross says. Diameters range from 1 in. through 48 in.

The LPD Static Mixer consists of a series of baffles or "elements" discriminately positioned in series. Each element comprises a pair of semi-elliptical plates set 90 degrees to each other. The next element is rotated 90 degrees about the central axis with respect to the previous baffle set, and so on. For even lower pressure drop, an LLPD model is also available, in which the plates of each element are oriented at 120 degrees relative to each other.

As the fluid moves through each LPD or LLPD element, flow is continuously split into layers and rotated in alternating clockwise and counterclockwise directions. This method of subdividing the stream and generating striations leads to highly efficient and repeatable mixing with minimal pressure loss. During turbulent flow, the baffles enhance the random motion of molecules and the formation of eddies. In most water and wastewater processes, four or six elements are more than sufficient to completely disperse treatment chemicals and create a very uniform solution or suspension.

Small LPD/LLPD mixers of 1 in. through 2.5 in. in diameter are welded to a central rod, while larger elements are welded to four outside support rods for maximum rigidity and stability. Available in a wide range of sizes up to 48 in. in diameter, these mixers can be supplied as pipe inserts or as complete modules with housing and injection ports.

In addition to Static Mixers, Ross also manufactures High Shear Mixers and Multi-Shaft Mixers used in the production of water treatment chemicals. The company offers no-charge mixer testing services and an extensive trial/rental program.

www.mixers.com

Building valve solutions for water treatment

Inline Industries has a proud tradition as a vertical manufacturer, designing and building a wide range of high-quality valves

Inline Industries' 334 valve with pneumatic actuator

Inline Industries is a pioneer in building valve solutions for OEM equipment and water treatment plant operations.

Inline Industries has been providing innovative valve solutions to the treatment industry for over 21 years. From manually operated valves and automated valve assemblies to high-performance control valves, Inline has built a strong reputation for manufacturing high quality, consistent and reliable products.

Inline has been able to achieve this by designing and building its own valve products as a vertically integrated manufacturer. The company pours its own castings, machines, then assembles and tests each valve to exacting industry standards.

Valves are cast to applicable ASTM material standards and designed and tested to ASME B16.34 specifications to assure buyers that the products will perform at the pressures and temperatures for which they are designed. Each casting is heat stamped and documented through an ISO 9001:2008 quality control process to provide consistency and complete product traceability.

Inline offers a wide range of valve styles including valves with compression ends for chemical injection tubing systems; two-way, full and standard port valves with threaded, grooved or flanged ends in economical low-pressure and high-pressure versions; and three-way diverter and multi-port valves for bypass, tank farm and filtration applications.

Inline also offers a spring return – normally closed – handle allowing the lab to take samples at various points in the treatment process, as well as valves capable of pressures to 4,000 PSI for the most demanding applications. Inline can provide actuated packages complete with accessories such as direct mount electric or pneumatic actuators; limit switches; solenoids; and digital or pneumatic positioners – all factory mounted and tested.

At the heart of Inline's success over the years has been its ability to deliver. Inline's headquarters, located in Rosemead, Calif., houses an extensive multimillion dollar inventory, machine shop, and automation center, enabling the company to ship 95% of all orders complete in 48 hours.

Inline is supported by a select network of distributors that are highly trained in helping provide customers with valve solutions.

www.ballvalve.com

Methanol metering for wastewater denitrification

An innovative metering pump from Fluid Metering boasts excellent performance when dosing methanol into processes for removing nitrate from wastewater

Nitrate, an end-product of the bacterial degradation of ammonia, is present in high levels in untreated wastewater. The release of effluent containing high concentrations of nitrate into bays and watersheds can have a devastating effect on water ecosystems. Through a process known as denitrification, water treatment facilities therefore convert excess nitrate into harmless nitrogen gas.

The anaerobic bacterial process that breaks down nitrate is accelerated by adding methanol to the wastewater. The CeramPump QDX Hazardous Duty Metering Pump from **Fluid Metering** has proven to be an excellent choice for methanol metering in wastewater denitrification, thanks to its unique valveless design. This is especially true in small to mid-size treatment facilities, where methanol flowrates are extremely low; this often causes valved pump designs to become air-bound and lose prime, the company says.

The CeramPump has only one moving part in contact with the process fluid: a rotating and reciprocating ceramic piston. As with a conventional piston pump, the piston's reciprocating motion performs the pumping function. However, this is where the similarity to conventional piston pumps ends.

Small but tough: the CeramPump

During the pumping cycle the CeramPump piston simultaneously rotates, alternately opening and closing the inlet and outlet ports of the pump, and hence effectively functioning as a valve. At no point are the inlet and out ports interconnected, thus eliminating the need for check valves. The pump drive is FMI's QDX Hazardous Duty Drive, typically required for pumping methanol.

Fluid Metering, Inc. patented the first rotating and reciprocating valveless pump and has been providing fluid control solutions for medical, analytical, chemical, and industrial applications for over 50 years. In each of these markets FMI pumps can be found from the laboratory to the production floor, incorporated into OEM equipment and instrumentation, as well as process control and field installations.

Flowrates range from 2.5 µl/dispense to 4.6 l/min, with pressures to 200 psig. FMI pumps will dispense and meter fluids for millions of cycles with a drift-free accuracy of better than ±1%. **fluidmetering.com**

Polypropylene makes the difference

GEA BIOdek trickling filter media made from polypropylene are stronger and more environment-friendly than their PVC equivalents

Tough stuff: Trickling filter media made from polypropylene need no protective grating to prevent damage during inspection

Trickling filter media made of polypropylene (PP) have gained growing acceptance in recent decades, notes **GEA Heat Exchangers**, because they have valuable features that make them attractive substitutes for commonly used PVC fills.

Simple though plastic trickling filter media might appear, they have to meet many criteria if the biological treatment process is to be successful. They should provide a large surface for the biofilm to grow. Sufficient air circulation is necessary to provide the required oxygen. The biofilm should have the appropriate thickness, and the water should flow through slowly and evenly. The result is a balanced three-phase system in which water, air, and biosolids share the void space within the fill medium.

Achieving this balance is a challenge for the design engineer. BIOdek fills from GEA Heat Exchangers are available in a selection of media types to accommodate the process requirements with any desired type of flow pattern and a variety of channel sizes.

As well as meeting the process requirements, the medium must be self-supporting and rigid enough to withstand the weight of the biofilm and captured water. It must retain its shape for decades, and must be environment-friendly in manufacture and disposal. Here PP has several advantages over PVC:

- PP is less brittle than PVC, so during inspections an operator can walk on top of a PP bed without damaging it. PVC filters require a separate PVC grating to prevent breakage.
- PP is less dense than PVC, so PP sheets are much thicker than PVC sheets of the same weight. This provides greater resistance to erosion and media buckling, which is the most common cause of failure when a filter collapses.
- GEA BIOdek PP media are thermo-welded, eliminating the solvent emissions associated with manufacturing PVC products.
- PP media can be recycled at the end of their working lives.

www.gea-heatexchangers.com

Plastic control valves handle corrosive chemicals

Collins 2-in. valves and actuators are specially designed to handle corrosive fluids – acids, bleaches, chlorine, pH control – and aggressive environments

Collins Instrument Company's line of economical 2-in. flanged plastic control valves handle corrosive liquids including hydrochloric acid, caustic, sulfuric acid, and many others. With bodies of either PVDF or polypropylene, these highly-responsive control valves are specifically designed for use with corrosive media and/or corrosive atmospheres.

Suitable for applications in numerous industries, including chemical, petrochemical, pulp and paper, and municipal, these valves are extremely corrosion-resistant, and feature fast-acting positioning (stroke rate approximately ½ in./s). They are available with a wide selection of trim sizes, in globe, angle, and corner configurations.

The differential-area piston eliminates the necessity for auxiliary loading regulators. All actuator parts apart from the integral positioner are molded of glass-filled, UV-inhibited polypropylene. Before shipment, the aluminum positioner and a portion of the cylinder are immersed in Dip Seal to provide atmospheric protection.

Plastic valves and actuators from Collins

The integral positioner eliminates the need for external linkages which are subject to corrosion and malfunctioning. Valves may also be furnished without a positioner for on/off applications.

Collins also offers a plastic pneumatic actuator. The combination of a plastic actuator and a plastic valve body provides an effective way to handle both corrosive materials flowing through the valve, and harsh environments that can attack the outside of the valve and actuator. Collins plastic control valve packages withstand salty marine atmospheres as well as industrial environments that are too corrosive for metal valves and actuators.

Collins actuators incorporate a unique internal locking ring to attach the cylinder to the yoke. A semicircular groove is machined inside the lower edge of the cylinder, and a matching groove cut in the yoke. When the yoke and cylinder are assembled, a flexible polypropylene rod is inserted into the groove through a slot in the side of the cylinder, securing the two sections together.

Along with its corrosion resistance the Collins control valve features a stem packing arrangement that virtually eliminates the problem of fugitive emissions, thereby protecting the environment.

Located on the Texas Gulf Coast in the town of Angleton, Collins Instrument Company has been serving the chemical and petrochemical industry for over 65 years. **www.collinsinst.com**

Not all scale inhibitors are created equally

Polymer chemistries from BWA Water Additives give a one-two punch against scales, where traditional phosphonates or very low molecular weight polymers fail

BWA Water Additives is a technology-led specialty chemicals company that focuses on providing sustainable solutions in water treatment challenges. Whether it is scale control, corrosion inhibition, microbiological control or desalination, BWA has unique chemistries providing solutions in increasingly extreme environments.

Scale inhibition is a concern for any process that uses water, from industrial treatment, though cooling towers and geothermal energy, to oil and gas production. These environments can have water chemistries that rapidly change, as well as physical characteristics such as temperature that can fluctuate greatly in mere hours. Traditional scale inhibitors, based in phosphonates or very low molecular weight polymers, are prone to failure in such applications because of the types of inhibitory mechanisms they depend on.

In particular, scaling caused by barium sulfate can be difficult to control. Once nucleation has begun, it can very rapidly seize up a pipe, resulting in a significant loss of money in terms of both system downtime and maintenance efforts. The resulting scale is not easily removed, and often results in the need to either drill out the blockage or simply replace the pipe. In a low-pH environment the problem seems to be compounded by standard scale inhibitors, which fail at an even faster rate. BWA's Bellasol S50, on the other hand, has proven itself time and again in these types of environments as a cost-effective water treatment.

Poorly controlled scale can quickly block pipes so badly that replacement may be the only practical option

A growing concern that needs to be acknowledged is that scale inhibition products must now be able not only to protect and maintain the functionality of a system, but to do so in an environmentally-friendly, biodegradable fashion. BWA Water Additives' Belclene 810 has strong antiscalant properties in calcium carbonate, barium sulfate and even mixed scales, while scoring high in the OECD 302B biodegradation test.

BWA Water Additives scale inhibition polymers work where phosphonates can fail because they block crystal growth and provide threshold inhibition, while having great thermal stability properties over a wide pH spectrum. BWA's polymeric scale inhibitors can provide the needed solution to common scales such as calcium carbonate, barium sulfate, harder-to-treat silica scales, and even heavy metals.

www.wateradditives.com

An intelligent approach to measurement

OTEK Corp. manufactures panel instruments that combine traditional visibility with modern digital accuracy and reliability

Manufacturers rely on digital process instruments to maintain accuracy and consistency in their processes. For many processes, including water treatment, even a small inaccuracy in a variable can have a significant effect on the desired product. Variations in temperature, flow, proportion, and other parameters must be carefully monitored and controlled.

OTEK Corp., a leading designer and manufacturer of digital instrumentation, knows that accuracy is required to maximize its customers' profitability and ensure quality and safety. Its instruments are manufactured with the latest technology to ensure accurate and reliable performance, and durable products.

The NTM series is the latest in digital panel meters from OTEK. The series includes 19 different models available with loop, signal or external power. The use of high-efficiency components allows OTEK to produce a product with lower power consumption than the current industry average. A lower power requirement permits the display to maintain an even intensity at both the high and low end of the 4–20 mA range. Units are equipped with an LED digital display and a tri-color bar graph to ensure visibility. The bar graph also shows the current setpoints in color.

OTEK offers a signal failure detection feature in all of its units. If a sensor fails or a cable breaks, the display will flash the message "INPT FAIL" for approximately 20 s to alert the user. It then transmits a failure notification to the supervisory control system, before going dark.

The innovative designs incorporate flexible firmware for improved customization. Depending on the model and the input selection, the NTM series offers a wide variety of options. For instance, one channel's setpoint can be used to control another channel's function. Isolated serial I/O is available, and there is a choice of USB, RS485, Ethernet or IRDA. Added benefits include remote display for SCADA/DCS, improved response time, and self-diagnostics.

A combination of digital and bar graph displays provides maximum information

The series offers replacements for virtually all existing analog and digital meters. Easy pin-for-pin replacement means no rewiring and no need to run additional power to the unit. NTM meters have no moving parts so there is no longer a need for recalibration and maintenance.

OTEK Corp. backs all its instruments with a lifetime warranty that is unique to the industry. **www.otekcorp.com**

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Specialty chemicals producer **Lanxess** (Cologne, Germany) names *Matthias Zachert* chairman of the board, and promotes *Jorge Nogueira* to head of the Performance Butadiene Rubbers business unit.

The Sensors Div. of **Honeywell Life Safety** (Morris Township, N.J.) appoints *Sean Clay* general manager and *Alexandre Naef* sales leader.

Finder Pompe S.p.A. (Merate, Italy), which recently became part of Dover Corp.'s Pump Solutions Group (Oakbrook Terrace, Ill.), names *Lorenzo Barbieri* CEO.

Victor Ferris becomes president and CEO of **HRST, Inc.** (Eden Prairie, Minn.), a provider of products and services to power plants and industrial facilities. *Andrew Kubly* is now the company's chief financial officer.

Siluria Technologies (San Francisco, Calif.), a developer of commercial processes for producing fuels and chemicals from natural gas, names *Karl Kurz* chairman of the board.

Dan Kieny joins **Black & Veatch** (Overland Park, Kan.) as chief information officer and senior vice president.

Vimal Kapur becomes CEO of **Honeywell Process Solutions** (Morris Township, N.J.), which supplies process automation, control and instrumentation solutions.

Gary McArthur joins **CH2M Hill** (Denver, Colo.) as executive vice president and chief financial officer. ■

Suzanne Shelley

BUSINESS NEWS

PLANT WATCH

Jacobs awarded contract for ExxonMobil projects in Baytown and Mont Belvieu
August 12, 2014 — Jacobs Engineering Group Inc. (Pasadena, Calif.; www.jacobs.com) was awarded a contract from ExxonMobil Chemical Co. to provide engineering, procurement and construction services as part of an ethane-cracker project in ExxonMobil's Baytown, Tex. complex, and associated premium product facilities in Mont Belvieu, Tex. Company officials did not disclose the contract value.

Clariant plans to build new masterbatches plant in Australia
August 12, 2014 — Clariant AG (Muttenz, Switzerland; www.clariant.com) plans to build a new masterbatches plant in Sydney, Australia. The new plant will mainly serve the Australian market. Construction on the plant is currently underway, with commissioning scheduled for the fourth quarter 2014.

Ashland to expand capacity for hydroxyethylcellulose capacity Nanjing
August 4, 2014 — Ashland Inc. (Covington, Ky.; www.ashland.com) plans to expand capacity at its hydroxyethylcellulose production facility in the Nanjing Chemical Industrial Park by 4,000 metric tons (m.t.), or approximately 40%, over the next 18 months. The additional capacity will come online in two phases. The first 2,000 m.t. will be available in early 2015 and the second 2,000 m.t. will be available in late 2015.

Polyamide 6 plant commissioned for Hangzhou Hangding Nylon Tech.
August 1, 2014 — Uhde Inventa-Fischer GmbH (Berlin, Germany; www.uhde-inventa-fischer.com) and Hangzhou Hangding Nylon Tech. Co. have commissioned a plant for the production of high-performance polyamide 6 for textile-grade applications. The plant is located in Hangzhou City in Zhejiang Province, China and has a production capacity of 47,000 m.t./yr.

Arkema starts up methyl acrylate plant in Clear Lake, Tex.
July 28, 2014 — Arkema (Colombes, France; www.arkema.com) has started up a new plant for the production of methyl acrylate at its Clear Lake, Tex. site, representing the last phase of a $110-million investment plan. The new methyl acrylate plant has a capacity of 45,000 m.t./yr.

Tesoro announces plans for xylenes production in the U.S.
July 22, 2014 — Tesoro Corp. (San Antonio, Tex.; www.tsocorp.com) intends to gather intermediate feedstock, primarily reformate, from its West Coast refining system for xylene extraction at Anacortes, Wash. The initial investment is estimated to be around $400 million. Startup of the new facilities is expected in 2017, subject to permitting and approval processes.

Evonik invests in new plant in Brazil for the production of precipitated silicas
July 21, 2014 — Evonik Industries AG (Essen, Germany; www.evonik.com) plans to build a plant to produce precipitated silicas in São Paulo, Brazil. The plant is scheduled to go onstream in 2016. This is said to be the first production plant for highly dispersible silica in South America.

Topsøe opens new sulfuric-acid-catalyst production plant in Bayport, Tex.
July 18, 2014 — Haldor Topsøe A/S (Lyngby, Denmark; www.topsoe.com) opened a new plant at its production site in Bayport, Tex. The plant is devoted to producing Topsøe's VK portfolio of extruded catalysts, which are used for the production of sulfuric acid.

MERGERS AND ACQUISITIONS

Borealis takes full ownership of specialty polymers JV
August 7, 2014 — Borealis AG (Vienna, Austria: www.borealisgroup.com) will take full ownership of the Specialty Polymers Antwerp N.V. joint venture (JV) by purchasing a 67% share from DuPont Holding Netherlands B.V. The transaction is subject to approval by the relevant authorities.

Yara acquires majority position in Brazilian fertilizer company Galvani
August 5, 2014 — Yara International ASA (Oslo, Norway; www.yara.com) has acquired a 60% stake in Galvani Indústria, Comércio e Serviços S/A for an enterprise value of $318 million. Galvani is an independent, privately held fertilizer company engaged in phosphate mining, production and distribution of fertilizers in Brazil.

Mexichem acquires German PVC specialist Vestolit
August 5, 2014 — Mexichem S.A.B. de C.V. (Tlalnepantla, Mexico; www.mexichem.com) has signed a definitive agreement to acquire polyvinyl chloride (PVC) producer Vestolit GmbH (Marl, Germany; www.vestolit.de) from Strategic Value Partners LLC. The acquisition is subject to regulatory approvals and is expected to close in the fourth quarter of 2014.

Solvay to sell its Eco Services sulfuric-acid business for $890 million
July 31, 2014 — Solvay S.A. (Brussels, Belgium; www.solvay.com) has agreed to sell its Eco Services business, which specliazes in sulfuric-acid virgin production and regeneration, to affiliates of CCMP Capital Advisors, LLC for an enterprise value of $890 million. Completion of the transaction is expected in the fourth quarter of 2014.

Showa Denko to acquire high-purity chlorine business from Air Products
July 31, 2014 — Showa Denko K.K. (Tokyo, Japan; www.sdk.co.jp) subsidiary Taiwan Showa Chemicals Manufacturing Co. has come to an agreement with Air Products San Fu Co. (APSF), a subsidiary of Air Products and Chemicals Inc. (Lehigh Valley, Pa.; www.airproducts.com), to acquire APSF's high-purity chlorine business, including its production facility in Kaohsiung, Taiwan.

Outotec acquires the business of Kalogeo Anlagenbau
July 28, 2014 — Outotec Oyj (Espoo, Finland; www.outotec.com) has purchased the assets of Kalogeo Anlagenbau GmbH (Leobersdorf, Austria). Kalogeo provides solutions for biomass, sludge and wastewater-treatment and has designed, built and operated several mid-size thermal sludge-treatment plants based on fluidized-bed technology. Outotec plans to expand the acquired business's annual sales to approximately €15–20 million beginning in 2016.

Albemarle to acquire Rockwood Holdings for $6.2 billion
July 15, 2014 — Albemarle Corp. (Baton Rouge, La.; www.albemarle.com) and Rockwood Holdings, Inc. have entered into a definitive agreement under which Albemarle will acquire all outstanding shares of Rockwood in a transaction valued at approximately $6.2 billion. This combination creates a company with positions across the lithium, catalysts, bromine and surface-treatment sectors. The transaction is expected to close in the first quarter of 2015. ■

Mary Page Bailey

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

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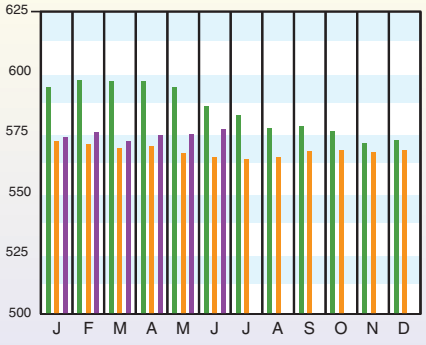
(1957–59 = 100)	June '14 Prelim.	May '14 Final	June '13 Final
***CE* Index**	576.2	574.3	564.8
Equipment	700.1	697.0	684.1
Heat exchangers & tanks	638.1	635.1	626.7
Process machinery	673.8	665.0	654.4
Pipes, valves & fittings	880.3	876.2	859.3
Process instruments	411.0	410.8	410.1
Pumps & compressors	938.2	938.6	919.2
Electrical equipment	515.3	515.3	512.7
Structural supports & misc	770.0	767.4	730.9
Construction labor	319.7	320.5	317.3
Buildings	543.4	543.2	530.7
Engineering & supervision	321.1	321.0	323.9

Annual Index:

2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3

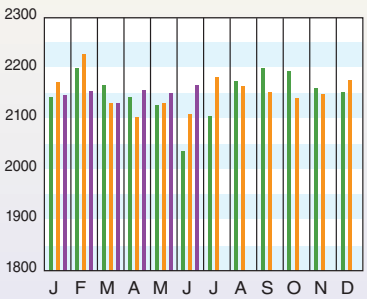


CURRENT BUSINESS INDICATORS*

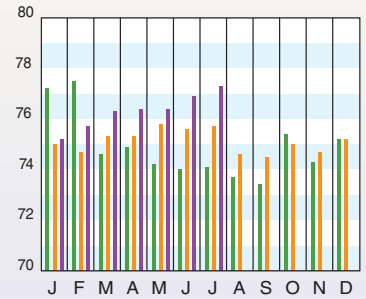
	LATEST			PREVIOUS			YEAR AGO		
CPI output index (2007 = 100)	Jul.'14	=	91.9	Jun.'14	=	91.4	May '14	=	90.6	Jul.'13	=	88.9
CPI value of output, $ billions	Jun.'14	=	2,167.0	May '14	=	2,150.6	Apr.'14	=	2,156.4	Jun.'13	=	2,109.4
CPI operating rate, %	Jul.'14	=	77.3	Jun.'14	=	76.9	May '14	=	76.4	Jul.'13	=	75.7
Producer prices, industrial chemicals (1982 = 100)	Jul.'14	=	293.2	Jun.'14	=	288.9	May '14	=	288.4	Jul.'13	=	299.8
Industrial Production in Manufacturing (2007 = 100)	Jul.'14	=	100.7	Jun.'14	=	99.8	May '14	=	99.5	Jul.'13	=	96.0
Hourly earnings index, chemical & allied products (1992 = 100)	Jul.'14	=	157.4	Jun.'14	=	156.8	May '14	=	155.2	Jul.'13	=	156.8
Productivity index, chemicals & allied products (1992 = 100)	Jul.'14	=	108.5	Jun.'14	=	107.6	May '14	=	107.4	Jul.'13	=	106.0

CPI OUTPUT INDEX (2007 = 100)

CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Current Business Indicators provided by IHS Global Insight, Inc., Lexington, Mass.

HIGHLIGHTS FROM RECENT ACC ECONOMIC DATA

The July Chemical Activity Barometer (CAB), a leading economic indicator created by the American Chemistry Council (ACC; Washington, D.C.; www.americanchemistry.com) posted a 0.4% increase over June, as measured on a three-month moving average (3MMA) basis. Look for updated CAB information on our website (www.chemengonline.com). The pace of growth was consistent with earlier growth logged in the second quarter. Year-over-year growth now stands at a 4.4% increase. Uncertainty in global energy markets kept the non-adjusted barometer at a slow 0.1% gain in June, but provisional data suggest there is room for further expansion in coming months, the ACC said.

In one of its recent Weekly Chemistry and Economic Reports, ACC noted that exports of chemicals from the U.S. rose 3.2% in June to $16.7 billion, while imports were down 2.4% to $16.4 billion. Excluding pharmaceuticals, chemical exports were up 0.8% to $12.0 billion, and imports were down 3.8% to $8.5 billion. "The trade balance moved from deficit to surplus in June," the report said, adding, "Excluding pharmaceuticals, the [U.S.] chemical industry continues to post a large trade surplus."

In another recent report, ACC said the Global Chemical Production Regional Index (Global CPRI) was flat for the second month in a row in June, on a 3MMA basis. This indicates that growth stalled in the second quarter of 2014, with activity only slightly higher than the first quarter, the report said.

Meanwhile, the U.S. CPRI rose 0.3% in June, with chemical output higher in all geographic regions, the ACC said. The June gain follows a 0.5% rise in May. ❑

CURRENT TRENDS

The preliminary value for the June *CE* Plant Cost Index (CEPCI; top; the most recent available) rose 0.3% from the final May value, after gains the previous two months. Subcategories of the equipment index generally saw small increases, or were relatively flat. The most significant increase came in the Process Machinery subindex. The Construction Labor index declined slightly in the June preliminary numbers, while the Buildings and Engineering & Supervision subindexes rose slightly. The overall June PCI value stands at 2.0% higher than its value from June 2013. Meanwhile, updated values for the Current Business Indicators (CBI) from IHS Global Insight (middle) saw small increases in all CBI categories. ❑

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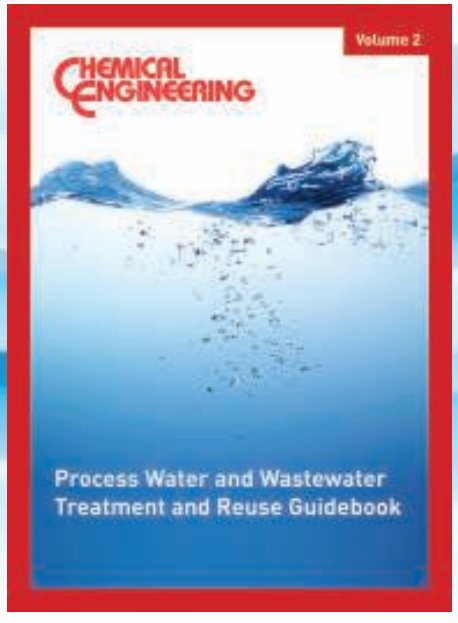

This guidebook contains how-to engineering articles formerly published in *Chemical Engineering*. The articles in Volume 2 provide practical engineering recommendations for process operators faced with the challenge of treating inlet water for process use, and treating industrial wastewater to make it suitable for discharge or reuse.

There is a focus on the importance of closed-loop or zero-discharge plant design, as well as the selection, operation and maintenance of membrane-based treatment systems; treating water for use in recirculated-water cooling systems; managing water treatment to ensure trouble-free steam service; designing stripping columns for water treatment; and more.

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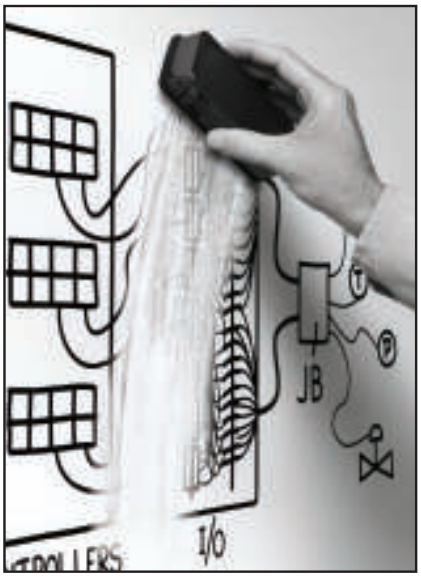

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