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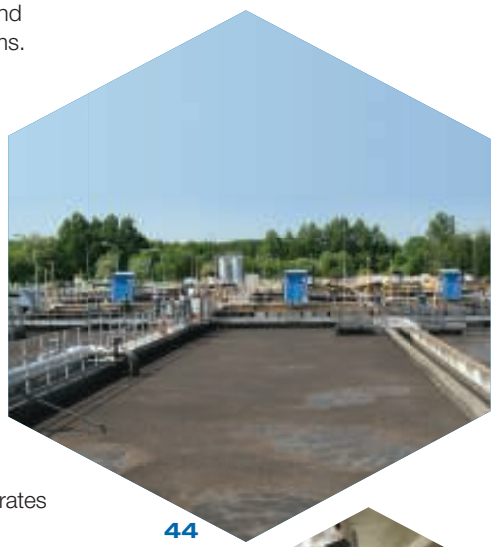

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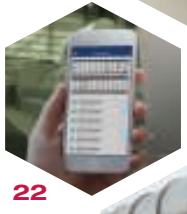

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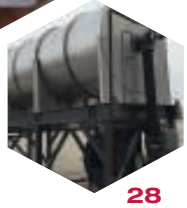

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BPA

Editor's Page

Targeting clean energy

Last month, New York Governor Andrew Cuomo announced the approval of New York's Clean Energy Standard, which according to the governor's office is "the most comprehensive and ambitious clean energy mandate in the state's history, to fight climate change, reduce harmful air pollution, and ensure a diverse and reliable energy supply." With the trends in climate change, such as the recent news that July of this year was the warmest month on earth ever recorded, the arguments to reduce carbon emissions and support renewable energy grow stronger.

The new standard will require 50% of New York's electricity to come from renewable sources, such as wind and solar, by 2030. This mandate is considered to be critical in reducing the state's greenhouse gas emissions. According to the American Wind Energy Association (AWEA; www.awea.org), four other states — Oregon, Hawaii, California and Vermont — also have a goal to reach 50% or more of their electricity needs from renewable sources.

In addition to environmental advantages, renewable energy standards are also seen as having a positive economic impact. According to the AWEA, growing wind energy in New York has already attracted $3.4 billion in capital investments, and wind power supports up to 2,000 jobs. And in nearby Pennsylvania, over 8,800 jobs are attributed to renewable energy due to growth in the wind, solar and low-impact hydroelectric industries, according to the report, "Clean Jobs in Pennsylvania," which was released in July by Environmental Entrepreneurs (E2) and The Keystone Energy Efficiency Alliance (KEEA).

The CPI and renewable energy

The growing movement toward renewable energy has caused some of the chemical process industries (CPI) to rethink their portfolios. Traditional oil-and-gas companies, and others, are incorporating technologies related to renewable energy into their plans. For example, Total S.A. (Paris; www.total.com), a leading oil-and-gas company, recently acquired Saft (Bagnolet, France; www.saftbatteries.com), a high-technology battery manufacturer, for around €950 million. Total had already proven its commitment to renewable energy with its strategic relationship with Sunpower (San Jose, Calif.; www.us.sunpower.com), formed in 2011.

One of the biggest challenges in renewable energy is the ability to store electric energy and make it available as needed on demand. In announcing Total's intent to acquire Saft this spring, Total's chairman and CEO, Patrick Pouyanné recognized electricity storage solutions as "a key component of the future growth of renewable energy."

Work on storage technologies is a fast-growing area where chemical engineers, chemists and other scientists are making great strides. A look at the informative Newsfront in this issue, "Redox Flow Batteries Charge Forward," p.14, gives an impression of the breadth of work going on in this area.

In this issue

This issue's wide array of topics includes a two-part cover story on wastewater treatment, a two-part feature on pumps, news stories on industrial mobile applications and on advances in drying equipment, an article on design of experiments, a preview of the Weftec show and much more. As always, we hope you enjoy reading. ■

Dorothy Lozowski, Editor in Chief

Communicating in acronyms

I finally got around to reading the May 2016 issue of *Chemical Engineering*. I was fascinated with the editorial [p.5].

I have been an engineer since 1968 and in the EH&S (environmental, health and safety) field since the mid 1970s. We engineers and scientists, always looking for a better way to do things, came up with using acronyms. To say the least, it has gotten out of hand.

In the mid-1980s, I was tasked by my employer with developing a list of acronyms for those working in environmental. It quickly expanded to EH&S. In the late 1990s, as keeper of the list, I decided to expand it into the energy field and then engineering in general. After I left my employer and set up my own business. I continued to maintain the list and have expanded it further. Most of my inputs come from people to whom I send the list. I make the list and updates available to anyone who requests them at no charge.

Keep up the excellent work. It is a real pleasure to read *Chemical Engineering*.

Arnold Feldman
JJDS Environmental, Doylestown, Pa., (jjdsenv@att.net)

TABLE 1. TUNED COEFFICIENTS USED IN EQUATIONS (3–6)

Coefficient	Value	Coefficient	Value
A_1	$-2.60209064 \times 10^{-1}$	A_3	$3.5995496368 \times 10^{4}$
B_1	$-4.64712011 \times 10^{-6}$	B_3	-1.5920349698
C_1	$-3.17817228 \times 10^{-9}$	C_3	$-2.224437123 \times 10^{-3}$
D_1	$2.88726660 \times 10^{-13}$	D_3	$1.8214824677 \times 10^{-7}$
A_2	$-1.145969902 \times 10^{2}$	A_4	$-2.930937692 \times 10^{6}$
B_2	$4.810244580 \times 10^{-3}$	B_4	$2.32398913631 \times 10^{2}$
C_2	$4.902744144 \times 10^{-6}$	C_4	$3.17489914017 \times 10^{-1}$
D_2	$-4.240021674 \times 10^{-10}$	D_4	$-2.428258824 \times 10^{-5}$

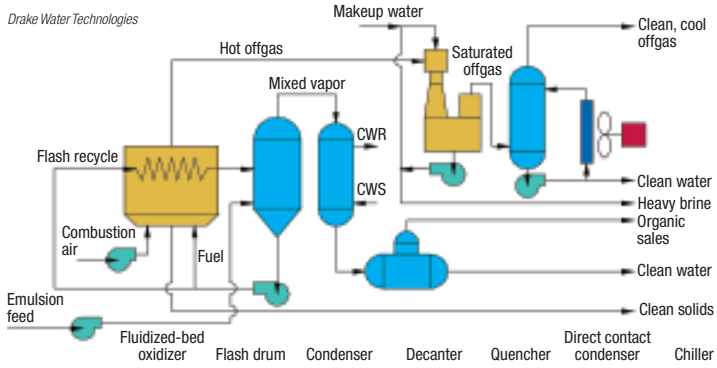
Postscripts, corrections

June, 2016, "Rapid Prediction of Prandtl Number of Compressed Air", pp. 52–59. The coefficients in Table 1 on p. 53 were missing the exponent multipliers. The corrected Table 1 is given above, and in the online version of the article. Thanks to Jesse Williams at Johnson Matthey Inc. for finding this error.

Also on p. 53, the following sentences are missing a citation, which is included below.

"Unlike the Reynolds and Grashof numbers, the Prandtl number contains no length scale in its definition, so Pr is dependent only on the fluid involved and the state of the fluid. As such, Prandtl numbers are often found in property tables alongside other properties such as viscosity and thermal conductivity." (Wikipedia, en.wikipedia.org/wiki/Prandtl_number, accessed June, 2016)

A process to treat tight emulsions and intractable oily wastes



Spent invert drilling fluids, slop oil, rag layers, and tank bottoms often present as very tight emulsions having high brine and solids fractions that render them difficult and economically unfeasible to break and separate by traditional means, says Ron Drake, CEO at Drake Water Technologies, Inc. (DWT; Helena, Mont.; www.drakewater.com). Conventional demulsification schemes using heater-treaters, demulsifying chemicals, electrostatic grids, centrifuges, and so on often exhibit limited separation efficiency and merely produce a more concentrated and intractable residue requiring stabilization, transport and landfill disposal, explains Drake. Likewise, high moisture and solids content of tight emulsions greatly reduces throughput and organic recovery when they are subject to thermal desorption, he adds. To overcome these problems, DWT has developed a single-load, high-throughput, mobile treatment system to provide complete, on-site, resource recovery and disposal of pumpable emulsions and oily wastes.

In the process (flowsheet), a recirculating stream of feed emulsion is heated at moderate pressure (15–30 psig) and flashed to produce a mixed vapor stream of light organic compounds and water. The mixed vapor stream is condensed and separated using a coalescing decanter to produce merchantable streams of dry, solids-free oil and clean water.

Energy for heating the feed emulsion is provided by a low-temperature (800°C) fluidized-bed (FB) catalytic oxidizer that is fueled using a side stream of the flash-drum bottoms — negligible amounts of oxides of nitrogen (NOx) and CO are produced at this low temperature. Off-gas from the oxidizer is quenched in a high-temperature (80°C), high-energy scrubber, producing a low-volume dense-brine blowdown stream that can be sold or injected. Solids discharged from the oxidizer are dry and free of organic contaminants. Saturated, warm off-gas from the quencher is chilled to produce water with low (less than 100 parts per million) total dissolved solids (TDS), and a clean, cooled, offgas.

The FB catalytic oxidizer has been demonstrated at commercial scale for thermal desorption applications, says Drake. Pilot testing of the emulsion flash system on spent invert drilling fluid (21 wt.% solids, 48 wt.% moisture and 31 wt.% organic content) yielded recovery of about 70% of the organic material as merchantable oil. The balance (30%) of the organic fraction was designated as fuel for the FB catalytic oxidizer. Based on pilot-test results, the commercial unit is expected to produce about 97 barrels per day (bbl/d) of light (specific gravity = 0.84) oil plus 81 bbl/d of low-TDS water, while processing 325 bbl/d of emulsion feed, he says.

CO_2 in biomass pre-treatment

Ionic liquids are being investigated as a way to break down cellulosic plant material in biofuels-production processes. A significant hurdle to their use is the fact that ionic liquids are toxic to the microbes used in biofuel production.

Researchers from Lawrence Berkeley and Sandia National Laboratories, working at the Joint Bioenergy Institute (JBEI; Emeryville, Calif.; www.jbei.org), have found that adding CO_2 during the pretreatment step can neutralize the toxicity of the ionic liquids by adjusting the alkaline pH. Because the use of CO_2 as a reversible method to adjust pH could eliminate the need to separate and purify the biomass after pretreatment, the researchers say the CO_2-enhanced process could reduce costs by 50% or more compared to traditional biomass-pretreatment techniques.

Edited by:
Gerald Ondrey

Li-ION BATTERIES

Over the course of several battery charge/discharge cycles, microscopic fibers of lithium, called dendrites, sprout from the surface of the lithium electrode and spread across the electrolyte until they reach the other electrode. An electrical current passing through those dendrites can short-circuit the battery, causing it to rapidly overheat and even catch fire.

In an effort to suppress dendrite formation, scientists from CSIRO (Melbourne; www.csiro.au), in collaboration with RMIT University (Melbourne; www.rmit.edu.au) and Queensland University of Technology (Brisbane; all Australia; www.qut.edu.au), believe they have solved the problem with a new pretreatment process.

The pre-treatment involves immersing lithium metal electrodes into an electrolytic bath containing a mixture of ionic liquids and lithium salts prior to the battery's assembly. This creates a durable and lithium-ion-permeable, solid-electrolyte interphase that allows safe charge/discharge cycling of commercial Li/electrolyte/$LiFePO_4$ batteries for 1,000 cycles with coulombic efficiencies better than 99.5%.

The interphase is prepared using a variety of electrolytes based on the N-propyl-N-methylpyrrolidinium bis(fluorosulfonyl)imide room-temperature, ionic liquid containing lithium salts (LiFSI, $LiPF_6$, and $LiAsF_6$). When optimized, it prevents dendrite formation and consumption of electrolyte during cycling. As an added benefit, batteries that have undergone the process can spend up to one year on the shelf without loss of performance, say the scientists. They are now developing batteries

(Continues on p. 8)

Note: For more information, circle the 56-digit number on p. 98, or use the website designation.

based on their pre-treatment process, and are looking for partners to help bring those batteries to market.

SOLID Li-ION BATTERY

Researchers at ETH Zurich (Switzerland; www.ethz.ch) have developed a Li-ion battery that contains neither liquids nor gels. The battery cannot ignite, even at very high temperatures, giving it a safety advantage over conventional batteries. In most conventional batteries, charges move between the electrodes through a liquid or gel electrolyte, which can swell or ignite if overheated. ETH researchers developed an improved electrode-electrolyte interface, consisting of lithium garnet — one of the highest known conductors of Li^+ ions.

Although the all-solid batteries operate at room temperature, they actually work better at 95°C — a feature that makes them especially suitable for energy-storage applications, in which waste heat from power plants could be used to warm the batteries. The technology could also enable the production of thin-film batteries for mobile and computer applications.

BIOMASS POWER

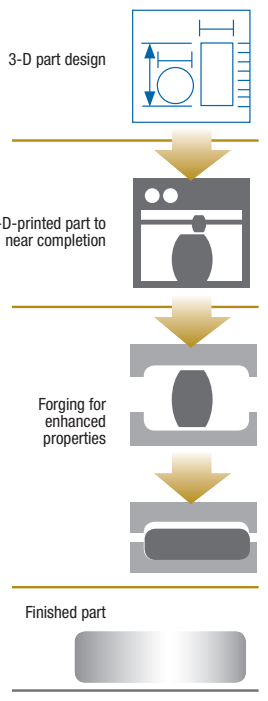
Last month, Taiheiyo Cement Corp. (Tokyo, Japan; www.taiheiyo-cement.co.jp) and Erex Co. (both Tokyo, Japan; www.erex.co.jp) established a new joint-venture (JV) company that will produce and market electricity generated from woody biomass. The JV, named Oofunato Power Generation Co., will be located within Taiheiyo Cement's Oofunato Factory. Construction has started on a 75-MW power generation plant that will use a circulating fluidized-bed boiler and "reheat-type" steam turbine when it starts operation in the fall of 2019. The power plant will be fueled by a mixture of coal (10 wt.%) and biomass (90 wt.%), with the biomass predominantly made up of palm kernel shells (PKS), suplemented by the palm's empty fruit bunches (EFB).

(Continues on p. 10)

Hybrid 3-D-printing process optimizes performance, cost for aerospace parts

Alcoa Inc. (Pittsburgh, Pa.; www.alcoa.com) has developed a hybrid technique, called Ampliforge (diagram), that combines additive manufacturing (3-D printing) and advanced forging techniques to improve the performance and reduce the cost of metal aerospace components. The company has produced prototype metal components for several aerospace applications.

"Alcoa is taking a comprehensive approach to 3-D printing, including direct and indirect processes," says Ed Colvin, vice president for new product development at Alcoa. "We understand that one standalone process may not give us the very best part. The hybrid Ampliforge process allows us to combines technologies to optimize performance and cost."



In addition, Colvin says the 3-D printing aspect of the Ampliforge process allows the production of parts with unique geometries that are not cost effective with traditional manufacturing processes alone.

Ampliforge involves building a part using 3-D printing, followed by a forging step and a metal-finishing step. The process reduces the amount of material inputs, as well as the number of processing operations, compared to traditional manufacturing approaches. It also improves critical mechanical properties of the resulting parts compared to parts made with additive manufacturing alone.

Alcoa is piloting the Ampliforge process at facilities in Cleveland, Ohio, and Sheffield, U.K., as well as at the recently expanded Alcoa Technology Center near Pittsburgh.

Environmentally safe oil-sands extraction

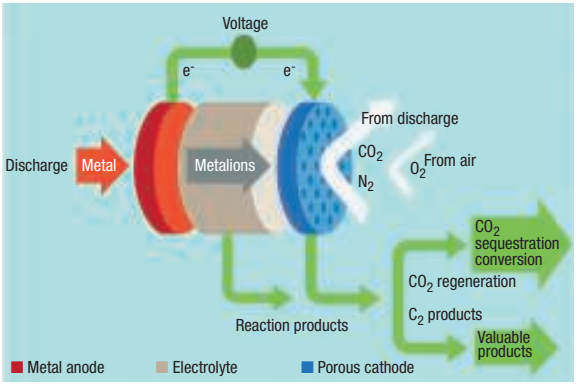
Processing oil sands is a mechanically intense process that involves pumping steam underground to emulsify crude petroleum. The procedure presents what MCW Energy Group (Toronto, Ont.; www.mcwenergygroup.com) CEO and former Exxon executive Jerry Bailey calls an "environmental nightmare." Among the main problems is the generation of large tailings ponds containing incompletely separated material. A process developed by MCW could be used to remediate tailings, as well as to extract hydrocarbons from oil sands in an environmentally safe manner in areas where the oil sands are close to the surface. Also, the technology uses no water, an advantage over conventional processes, where water consumption has been a problem.

The MCW technology is a continuous, solvent-based extraction process that removes 99% of the hydrocarbon content from the oil sands and recycles 99% of the solvent. After a preparatory crushing process, oil-sands ore is delivered via conveyor to MCW's patented liquid fluidized-bed reactor tower. There, the ore is mixed with a proprietary blend of common hydrophilic and hydrophobic solvents at temperatures of 50–60°C. The extracted hydrocarbons are separated from the solvent mix with a distillation process, and the solvents are returned to the tower for further extraction. Purified sand can be safely returned to the ground with no negative environmental impact.

MCW's Bailey explains that his company's oil-sands extraction process was adapted from technology invented by Russian scientists for soil remediation. MCW bought the patents for the process. The company CTO Vladamir Podlipskiy, an expert on benign solvents, further developed the final process. "Before this process was developed, no one had found the correct mix of solvents to perform the extraction of oil from oil-sand ore in an environmentally safe manner," Bailey says.

MCW has built a proof-of-concept plant that produces 250 barrels of oil per day (bbl/d) in Eastern Utah, where abundant oil sands exist close to the surface. The heavy (22 API gravity) oil produced by MCW is being sold to refiners looking to blend heavy oils with the lighter crude oil typically produced from shale deposits. MCW plans both to enter into joint ventures worldwide for building production plants, and to license the technology for oil production and remediation, Bailey says.

This electrochemical cell sequesters CO_2 and generates electricity



Researchers from Cornell University (Ithaca, N.Y.; www.cornell.edu) have developed an oxygen-assisted, Al/CO_2 electrochemical cell that converts CO_2 into a useful product while producing electricity. This represents a possible paradigm shift from most current carbon-capture models, says Lynden Archer, the James A. Friend Family Distinguished Professor of Engineering. Traditional carbon-capture methods, such as scrubbing CO_2 from fluegas with amines or other solvents, require energy to regenerate the absorbent — as much as 25% of the energy output of the power plant, says Archer.

The laboratory-scale cell (diagram) is based on a room-temperature ionic-liquid electrolyte — 1-ethyl-3-methylimidazolium chloride ([EMIm]Cl)/aluminum chloride ($AlCl_3$) melt, as an alternative to alkaline and saline electrolytes, which suffer from parasitic corrosion and hydrogen evolution problems. Aluminum is used as the anode and a mixed stream of CO_2 and O_2 is the active ingredient of the porous-carbon cathode. This cell design effectively captures CO_2, converts it to a C2 oxalate (without the need for a catalyst or high temperatures), and generates 13,000 mA·h per gram of porous carbon at a discharge potential of around 1.4 V. The energy produced by the cell is comparable to that produced by the highest energy-density battery systems, according to the researchers.

The aluminum oxalate product, $Al_2(C_2O_4)_3$, can be converted to oxalic acid, which is used as a bleaching agent in the pharmaceutical and fibers industries, as a cleaning agent, and as a precipitant in metal smelting.

Another key finding of the study, which was published in the July 20 issue of *Science Advances*, is that the main electrochemical process in the cell is the reduction of O_2 into superoxide intermediates, which then reacts with the normally inert CO_2 to form the oxalate, which falls out as aluminum oxalate.

One drawback of this technology is that the electrolyte is extremely sensitive to water. Ongoing research is addressing the performance of the electrochemical systems and the use of electrolytes that are less sensitive to water.

Both EFB and PKS are waste products from the production of palm oil, and have been simply discarded in the past.

'CIRCULAR' HDPE

Last month, Total Refining & Chemicals (Brussels, Belgium; www.totalrefiningchemicals.com), a division of Total S.A. (Paris, France; www.total.com), introduced a new range of high-density polyethylene (HDPE) circular compounds with high levels of recycled content for packaging applications. The new product range is said to have a performance equal to, or exceeding that of virgin resins, says the company. The range consists of HDPE polymer products, in natural color, that cover all the manufacturing needs for blow-molded bottles and heavy-duty containers for household and industrial liquids with a guarantee of 25% or 50% minimum of post-consumer recyclate (PCR). Total's initial production capacity of HDPE circular compounds amounts to 20,000 ton/yr, coming fully on stream during the course of 2017.

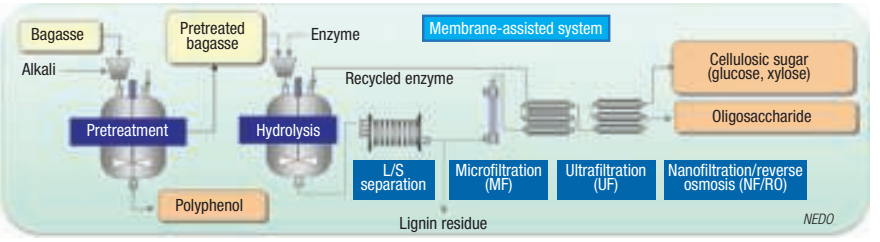
The recycled content of these circular compounds originates from post-consumer household waste collected in Western European countries and is recycled by selected partners. In its Antwerp plant, Total applies a last deep decontamination step, which transforms the PCR into a fragrance-free resin. Then, the PCR is compounded in Total's plant with HDPE virgin products, specifically designed and produced as intermediate resins in order to overcompensate for any lack of performance and consistency of the PCR.

BIO GASOLINE ADDITIVES

Global Bioenergies GmbH, the German subsidiary of Global Bioenergies (Evry, France; www.global-bioenergies.com) has been awarded a €400,000 grant from the German Federal Ministry for Research and Education (BMBF; Bonn) for a 14-month project aimed at producing renewable gasoline additives. A pilot plant has been installed at the Fraunhofer Center for Chemical-Biotechnological Processes (CBP; Leuna, Germany; www.cbp.fraunhofer.de) for producing two gasoline additives — isooctane and ETBE (ethyl-*tert*-butyl ether) — from 100% renewable, bioethanol and bioisobutene. In a 5,000-L fermenter, bacteria will convert biomass-derived sugars into isobutene. Then, using the hydrothermal reactor units available at CBP, the isobutene will be converted into ETBE. Samples of the additives will then be sent to Audi for testing. The pilot plant is planned to start up this fall.

(Continues on p. 11)

Recover chemicals from sugarcane bagasse using the half the energy



Last month, the New Energy and Industrial Technology Development Organization (NEDO; Kawasaki, Japan; www.nedo.go.jp) signed a Memorandum of Understanding (MOU) with the National Innovation Agency (NIA; Bangkok, Thailand; www.nai.or.th) to work jointly on a project to demonstrate a manufacturing system to produce chemicals that can be converted into raw materials for bioethanol and high value-added products from the fibrous waste material (bagasse) remaining after sugarcane has been squeezed.

The project will utilize a polymer membrane technology (diagram) developed in Japan, and aims to achieve more than 50% reduction in energy consumption compared to conventional distillation techniques. This is the first attempt to apply Japan's polymer membrane technology in the biomass field in Thailand.

The project will demonstrate the effectiveness of the technology in a pilot plant that can process 5,000 ton/yr of dried bagasse into 1,400 ton/yr of cellulosic sugars (glucose/xylose), which will produce 700,000 L/yr of bioethanol when converted. The project, which includes planned contractors Toray Industries, Inc., Mitsui Sugar Co. and Mitsui & Co., Ltd., will run through 2022.

New process for cyclohexasilane offers lower cost and improved safety

A newly developed process for manufacturing cyclohexasilane (CHS; Si_6H_{12}) offers a lower-cost and safer pathway to a material whose molecular architecture allows a wider range of material possibilities than alternative starting materials for several important silicon-based products. CHS can be used to make silicon-based films (such as polysilicon, silicon nitride, silicon carbide and others), as well as silicon nanowires and quantum dots. CHS also has the potential to be used to make novel materials for semiconductors, printable electronics and hybrid silicon-carbon anodes in next-generation lithium-ion batteries, among others.

Making such materials with CHS, rather than SiH_4 or cyclopentasilane, for example, has advantages, explains Doug Freitag, CEO of 3DIcon Corp. (Tulsa, Okla.; www.3dicon.net). Freitag's company is completing a merger with Coretec Industries LLC (Fargo, N.D.; www.coretecindustries.com), the licensee of the technology. One advantage is easier transport and handling. CHS exists as a liquid at room temperature and while it will burn, it will not explode similar to other silane chemistries, Freitag explains. CHS also has the advantage of being suitable for liquid-, as well as vapor-deposition processes (CHS converts to the gas phase above 400°F), he adds, and it's more stable and less expensive than cyclopentasilane.

Philip Boudjouk and his research team developed the process in his laboratory at North Dakota State University (Fargo, N.D.; www.ndsu.edu). In this process, trichlorosilane is reacted with a tertiary polyamine compound to generate tetradecachlorocyclohexasilane dianion. That compound is then chemically reduced to liquid CHS. Boudjouk has produced CHS at high yields (60% or higher) in the laboratory and has achieved 99.999%-pure CHS, with higher purities expected in the future, Freitag says. Coretec is lining up industry partners to scale up the process and launch the product in 2017.

A smart adhesive that 'turns on' at body temperature

Scientists from the Korea Institute of Science and Technology (Seoul; www.kist.re.kr) and Ulsan National Institute of Science and Technology (UNIST; Ulsan, both Sout Korea; www.unist.ac.kr), led by UNIST's professor Hyunhyub Ko, have developed smart adhesive pads — in the form of flexible pressure sensors — inspired by the suction cups of octopus' tentacles.

The scientists said building adhesives usually requires laborious transfer of nano- and micro-ribbons of inorganic semiconductor materials onto polymer sheets. They were therefore searching for an easier way to produce those adhesives and octopus suction cups gave them the idea.

Each suction cup in the octopus' tentacles contains a cavity whose pressure is controlled by surrounding muscles, allowing for suction and release as desired. The scientists used the rubbery material polydimethylsiloxane (PDMS) to create an array of microscale "suckers." The suckers include pores that are coated with a thermally responsive polymer. The scientists discovered that the best way to mimic the functioning of octopus suction cups was by means of applied heat. The material's microcavity pads enable excellent switchable adhesion in response to thermal stimuli. At room temperature, the cavity walls are in an open state, but when heated to 32°C, the walls contract, creating suction. The adhesive strength nearly triples (from 32 kPa to 94 kPa) at the higher temperature.

To test the adhesives, the scientists made indium-gallium-arsenide transistors placed on a flexible substrate and reported that the adhesives worked as expected. They anticipate their smart adhesive pads can be used as a substrate for adhesive bandages or sensors that stick to the human skin at normal body temperatures but fall off when rinsed under cold water. ■

WOODEN WINDOWS?

Engineers at the A. James Clark School of Engineering at the University of Maryland (UMD; College Park; www.eng.umd.edu) have demonstrated that windows made of transparent wood could provide more even and consistent natural lighting and better energy efficiency than glass. In a paper published in *Advanced Energy Materials*, the team, headed by Liangbing Hu of UMD's Dept. of Materials Science and Engineering and the Energy Research Center describe research showing that their transparent wood provides better thermal insulation and lets in nearly as much light as glass.

The research team recently patented their process for making transparent wood. The process starts with bleaching all of the lignin, which is a component in the wood that makes it both brown and strong. The wood is then soaked in epoxy, which adds strength, and makes the wood clearer and waterproof. The transparent wood lets through just a little bit less light than glass, but a lot less heat, says Tian Li, the lead author of the new study. The channels in the wood transmit visible light, but block the wavelengths that carry mostly heat, says Li. ❑

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Plant Watch

Cepsa to build new *m*-xylene unit under supply agreement with Indorama

August 9, 2016 — Following a supply agreement with Indorama Ventures Public Ltd. (IVL; Bangkok, Thailand; www.indorama.net), Compañía Española de Petróleos S.A.U. (Cepsa; Madrid, Spain; www.cepsa.com) will construct its second *m*-xylene unit for exclusive supply to IVL. The new unit will have a capacity of up to 70,000 metric tons per year (m.t./yr). The additional supply is expected to come onstream in 2018.

Sekisui Plastics establishes manufacturing base in Mexico

August 8, 2016 — Sekisui Plastics Co. (Osaka, Japan; www.sekisuiplastics.com) has established a new corporation in Mexico, Sekisui Plastics Mexico, S.A. de C.V., and opened a $7-million manufacturing facility in Valle de Santiago. The new plant has a molding capacity of approximately 60 m.t. per month and will initially mold products from hybrid foam resin.

Evonik completes sodium methylate capacity expansion in Ala.

August 4, 2016 — Evonik Industries AG (Essen, Germany; www.evonik.com) has recently completed a significant capacity expansion at its sodium methylate plant in Mobile, Ala. The expansion project brings the production capacity of the site to 72,000 m.t./yr.

LyondellBasell to build HDPE plant on U.S. Gulf Coast

August 1, 2016 — LyondellBasell (Rotterdam, the Netherlands; www.lyondellbasell.com) will build a 500,000-m.t./yr high-density polyethylene (HDPE) plant on the U.S. Gulf Coast. The plant will be the first to employ LyondellBasell's proprietary Hyperzone PE technology. Startup is planned for 2019.

Amec Foster Wheeler wins FEED contract from Thai Oil

August 1, 2016 — Amec Foster Wheeler (London; U.K.; www.amecfw.com) was awarded a front-end engineering design (FEED) contract by Thai Oil Public Co. for expanding the Sriracha petroleum refinery in Thailand. The project will expand crude distillation capacity from 275,000 barrels per stream day (bpsd) to 410,000 bpsd.

Mitsui Chemicals to increase production capacity of olefinic elastomers

August 1, 2016 — Mitsui Chemicals Inc. (MCI; Tokyo; www.mitsuichem.com) announced a one-line production augmentation totaling 5,000 m.t./yr for olefinic elastomers at its wholly owned domestic subsidiary, Sun Alloys Co. Construction for the production increase will commence in February 2017, with a planned completion date of June 2017. MCI expects commercial operations to begin in October 2017.

ExxonMobil to expand specialty elastomers plant in Wales

July 21, 2016 — ExxonMobil Corp. (Houston; www.exxonmobil.com) announced plans to expand its specialty elastomers plant in Newport, Wales. The company says the project, expected to be completed in late 2017, will result in a 25% increase in its global capacity to manufacture high-performance elastomers used for automotive, industrial and consumer applications.

Sumitomo Chemical to build polyethersulfone plant in Japan

July 21, 2016 — Sumitomo Chemical Co. (Tokyo; www.sumitomo-chem.co.jp) will construct a new production facility for polyethersulfone (PES) in Ichihara City, Chiba, Japan. The new facility will have a production capacity of 3,000 m.t./yr and is scheduled to start commercial-scale production in 2018. When the facility becomes fully operational, Sumitomo Chemical's total production capacity of PES will double.

Mergers & Acquisitions

Yara acquires Tata Chemicals' urea business in India

August 11, 2016 — Yara International ASA (Oslo, Norway; www.yara.com) has agreed to acquire Tata Chemicals Ltd.'s (Mumbai, India; www.tatachemicals.com) Babrala urea plant and distribution business in Uttar Pradesh, India for $400 million. The plant has a production capacity of 0.7 million m.t./yr of ammonia and 1.2 million m.t./yr of urea.

Johnson Matthey and 3M enter license agreement for LIB cathode materials

August 8, 2016 — Johnson Matthey (London, U.K.; www.matthey.com) and 3M (St. Paul, Minn.; www.3m.com) have entered into a patent license agreement that aims at further expanding the use of nickel-manganese-cobalt (NMC) cathode materials in lithium-ion batteries (LIB) for automotive applications.

Zeon and Sumitomo investigating merger of S-SBR businesses

August 5, 2016 — Zeon Corp. (Tokyo, Japan; www.zeon.co.jp) and Sumitomo Chemical will commence a joint study on the consolidation of both companies' solution styrene butadiene rubber (S-SBR) businesses. The signing of definitive agreements is expected by the end of December 2016.

Innospec to purchase Huntsman's European surfactants business
August 3, 2016 — Innospec Inc. (Littleton, Colo.; www.innospecinc.com) has committed to purchase Huntsman Corp.'s (The Woodlands, Tex.; www.huntsman.com) European surfactants business. Under the terms of the $225-million transaction, Innospec would acquire manufacturing facilities in France, Italy and Spain.

Solvay to divest chlorine and peroxide derivatives site in Italy
August 3, 2016 — Solvay S.A. (Brussels, Belgium; www.solvay.com) has agreed to divest its chlorine and peroxide derivatives site in Bussi sul Tirino, Italy to Caffaro Industrie (Torviscosa, Italy; www.caffaroindustrie.com). Caffaro aims to further develop the site, which is mainly dedicated to chlorine and its derivatives.

Emerson announces trio of divestments worth over $5 billion
August 3, 2016 — Emerson (St. Louis, Mo.; www.emerson.com) announced the divestment of three of its business units. Emerson will sell Network Power to Platinum Equity in a transaction valued at $4 billion. The company has also agreed to sell its Leroy-Somer and Control Techniques business units to Nidec Corp. in a transaction valued at $1.2 billion. Both transactions are expected to close by year-end 2016.

Ineos acquires producer of sulfur dioxide and sodium derivatives
August 3, 2016 — Ineos (Rolle, Switzerland; www.ineos.com) has acquired Calabrian Holdings Corp., a technology and market leader of sulfur dioxide and sodium derivatives in North America. The company has a production base located in Texas, and is currently building a facility in Ontario, Canada. The Ontario site will add 35,000 m.t. of capacity once completed at the end of 2016.

AkzoNobel takes full ownership of Egypt powder coatings business
July 27, 2016 — AkzoNobel N.V. (Amsterdam, the Netherlands; www.akzonobel.com) has raised its stake in AkzoNobel Powder Coatings SAE in Egypt from 60 to 100%. The transaction forms part of the company's accelerated growth strategy for Egypt and the wider North Africa region.

Sandvik to divest Mining Systems operations
July 19, 2016 — Sandvik AB (Stockholm, Sweden; www.sandvik.com) has signed an agreement to divest its Mining Systems operations. The closing of the transaction is expected during the fourth quarter of 2016, and Sandvik will maintain ownership of ongoing projects that are close to finalization.

Arkema acquires sealants producer Den Braven
July 20, 2016 — Arkema (Colombes, France; www.arkema.com) announced the planned acquisition by its specialty adhesives business line, Bostik, of Den Braven, a European provider of sealants for insulation and construction. The acquisition has an enterprise value of €485 million. Closing is expected to take place in late 2016. ■

Mary Page Bailey

Redox Flow Batteries Charge Forward

Developments in redox flow batteries are moving at a tremendous pace to meet the growing need for large-scale energy-storage systems, which are used for stabilizing electric power distribution

IN BRIEF

The global energy-storage market is expected to double, from 1.4 GWh added in 2015 to 2.9 GWh this year, according a report published in July by IHS Markit (London, U.K.; www.ihsmarkit.com). Global grid-connected energy-storage capacity will surge to 21 GWh by 2025, says IHS Markit. Although lithium-ion batteries are expected to dominate the market — accounting for 80% of global installations by 2025, IHS Markit projects — next generation batteries, including advanced redox-flow batteries (RFBs), will also grow in importance.

According to Navigant Research (Boulder, Colo.; www.navigantresearch.com), flow batteries' market share (in power capacity and revenue) of stationary energy storage across utility, commercial and industrial, and residential sectors, will rise from 145 MW in 2016 ($151 million) to 5.77 GW ($2.92 billion) in 2025. In contrast, Li-ion batteries' share will grow from 1.06 GW ($789 million) in 2016, to 19.28 GW ($6.36 billion) in 2025. Navigant Research forecasts that new, next-generation flow batteries will begin to penetrate the market in 2019, but vanadium redox will likely remain a significant player within the flow-battery spectrum through 2025, says William Tokash, senior research analyst at Navigant Research. Key drivers for commercial, advanced flow battery technologies to penetrate the market are reduction in costs for raw-materials, manufacturing scale and enhanced safety profiles, says Tokash.

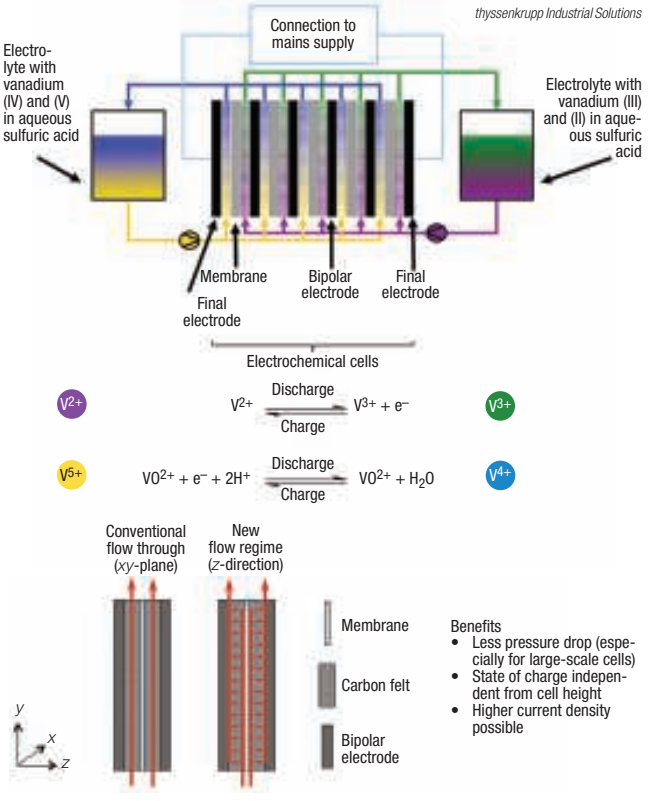

FIGURE 1. This soon-to-be commercialized all-vanadium RFB technology features a patented flow design to enable scaleup to multimegawatt sizes

Hoping to tap into this rapidly growing, and important market, extraordinary efforts are underway to bring down the costs of RFBs — the main hurdle in widespread adoption — in order to exploit the advantages this technology offers compared to leading, solid-state Li-ion technology.

In the last 2–3 years, there have been more publications about RFBs than there have been in the previous 30 years combined, says Mike Perry, project leader, Electrochemical Systems, United Technologies

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TABLE 1. RECENT LARGE-SCALE* VANADIUM-BASED RFB PROJECTS				
Location	**Power, energy**	**Technology developer**	**Application**	**Startup**
Minami Hayakita Substation, Japan	15 MW, 60 MWh	Sumitomo Electric Industries (Japan)	Integrating photovoltaic solar into grid	2015
Avista Utilities, Pullman, Wash.	1 MW, 4 MWh	UET (U.S.)	Load shifting, frequency regulation	2015
St. Johns, Antigua and Barbuda	3 MW, 12 MWh	Sun2live (Switzerland)	PV solar	2015
Zhangbei Project, China	2 MW, 8 MWh	VanSpar (Canada)	Integrates wind, solar, storage and smart grid	2016
RedoxWind, Germany	2 MW, 20 MWh	Fraunhofer ICT (Germany)	Integrated wind farm, microgrid	2017
Ontario IESO, Canada	5 MW, 20 MWh	Imergy (Canada)	Smooth power flow from wind and solar	2017
Milton-IESO, Canada	2 MW, 8 MWh	Glidemeister (Austria)	Realtime grid balancing	2018
Dalian VTF, China	10x20 MW, 800 MWh	UET (U.S.) and Rongke Power (China)	Peak shaving, grid stabilization	2020

Source: U.S. Dept. of Energy's Global Energy Storage Database (www.energystorageexchange.org) and industry sources
*Power ≥ 1 MW

Research Center (UTRC; Hartford, Conn.; www.utrc.utc.com). We see a much steeper decline in costs for RFBs compared to Li-ion technology because there are so many areas where improvements can be made, he says. "With RFBs, we are just starting to gather watermelons off the ground, whereas Li-ion technology needs a much higher ladder to 'pick the low-lying fruit,'" says Perry.

RFB technology today

Redox flow batteries were first invented in Germany in 1949, and the first wave of efforts to commercialize the technology occurred during the U.S. oil crisis of the 1970s. Today, the dominant RFB technology is based on vanadium chemistry (Figure 1). One reason for this is because vanadium is less toxic and easier to handle other multivalent metals, such as chromium.

According to the U.S. Dept. of Energy's (DOE; Washington, D.C.; www.energy.gov) Global Energy Storage Database (www.energystorageexchange.org), RFBs account for only 102 of the 1,591 energy-storage projects listed in the database. Of these 102 projects, 59 are vanadium RFBs (VRFBs; 90 MW of power), followed by zinc-bromine (31 projects, 59 MW), iron-chromium (1 project) and others (HBr, zinc-nickel oxide, and zinc iron). Some of the more recent, large-scale VRFB projects are shown in Table 1. One of the largest operating systems, and one of the longest operating VRFBs is a 3-MW system installed at Sumitomo Denseto Office in Osaka Japan, which started up in 2000. This system, which uses 60 50-kW modules, was developed by Sumitomo Electric Industries, Ltd. (Osaka, Japan; www.global-sei.com).

Long life, as demonstrated by the Sumitomo project, is one of the main advantages of RFBs over traditional batteries, such as lead acid and Li-ion. In conventional batteries, the electrodes are continuously degrading over time, explains UTRC's Perry. In contrast, the electrodes in RFBs are not inherently required to undergo physiochemical changes during the charge/discharge cycles, he says. As a result, RFB manufacturers are able to deliver systems with lifetimes of at least 20–25 yr. In contrast, major components of Li-ion and other batteries need replacing after about 7–10 yr.

RFBs also have the advantage of being able to decouple the power (the rate of electricity flow, in Watts) from the batteries capacity (total amount of energy stored, in Watt-hours), explains, Bill Sproull, vice president of Business Development and Marketing at Energy Storage Systems, Inc. (ESS; Portland, Ore.; www.essinc.com). This feature makes flow batteries much more economical for long-duration energy-storage applications, says Sproull.

UTRC's Perry agrees. If you want 6 h of discharge, conventional batteries will not work because the electrode required would be too thick, so multiple sets of batteries would be required. With RFBs, you just need to add more chemicals (bigger storage tanks), he says.

Improved designs

Recent RFB breakthroughs have enabled operation with 4–5 times higher current densities than in the past, says Perry, which means one can reduce the size of the membranes required. Based on many years experience with fuel cells, UTRC developed its IDFF (interdigitated flow field) technology, in which the fluids are more evenly and intimately directed across the membranes. The technology is said to generate a much higher power density (2x) compared to traditional flow-through and flow-by designs, according to Vionx Energy Corp. (Woburn, Mass.; www.vionxenergy.com), which is commercializing UTRC's technology. The company offers a patented battery stack design in its VNX1000 modules based on 1-MW power and 1 MWh building blocks. Vionx is currently installing two 500-kW, 3-MWh systems under DOE-funded projects in Massachusetts, one integrating a photovoltaic (PV) array into the grid in Everett, and a second integrating a wind turbine into the grid in Worcester.

Integration of wind generation with a microgrid is also the goal of the RedoxWind project at the Fraunhofer Institute for Chemical Technology (ICT; Pfinztal, Germany; www.ict.fraunhofer.de). With construction underway (Figure 2), this pilot project, funded by the state of Baden-Württemberg and the Federal Ministry of Education and Research, will have a power and storage capacity of 2 MW, 20 MWh when it starts up next year.

Meanwhile, thyssenkrupp Industrial Solutions AG (Essen, Germany; www.thyssenkrupp-industrial-solutions.com) is applying its know-how for building chlor-alkali plants in order to take advantage of economy-of-scale for large all-vanadium RFBs (see *Chem. Eng.*, August 2015, p. 9). The company developed a new and unique flow regime. Instead of electrolyte flowing in the *xy*-plane, as in conventional flow-through designs, the electrolyte is first fed perpen-

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FIGURE 2. Shown here is the installation of the storage tanks that will hold acidic vanadium solutions for the 3-MW RedoxWind project in Pfinztal, Germany

dicular to the electrodes (*z* direction) through a number of channels (Figure 1, bottom). This feature results in a lower pressure drop, and a state-of-charge (SOC; remaining capacity in a battery) that is independent of the cell height, as well as the ability to operate at higher current densities, says Niels Bredemeyer, senior chemist at the company's Process Technology business unit.

The patented design is being developed in a pilot system with cell areas of 0.6 m^2 at thyssenkrupp's R&D center in Ennigerloh, Germany. The technology will be commercially available in full size — with cell areas of 2.5 m^2 — in 2017.

Anticipating the need for larger and affordable components, the companies thyssenkrupp, Centroplast Engineering Plastics GmbH and Eisenhuth GmbH & Co. KG (www.eisenhuth.de), along with two research institutes, launched a joint R&D project in January. The aim of the three-year project — with €3.9-million funding from Germany's Ministry for Economic Affairs and Energy (BMWi) — is to develop a new, low-cost process to manufacture bipolar plates with surface areas in the square meter range. The new technology will substantially reduce the unit manufacturing costs of RFBs, and is expected to be marketed by thyssenkrupp from 2018.

Meanwhile, Volterion GmbH (Dortmund, Germany: www.volterion.de) has been working — since its formation in 2015 — to commercialize the completely welded stack design developed at the Fraunhofer Institute Umsicht (Oberhausen, Germany; www.umsicht.fraunhofer.de). The design eliminates the problems associated with seals. The company is currently conducting field tests, and plans to introduce compact-size VRFBs for private homes in 2017.

Enhanced chemistries

Because RFBs need pumps, they do not have the same efficiencies as Li-ion batteries. More importantly, the energy density of RFBs is lower, too. To overcome these disadvantages, thereby allowing smaller storage tanks for the electrolytes, improvements are being made by enhanced chemistries. For example, the vanadium technology that Pacific Northwest National Laboratory (PNNL; Richland, Wash.; www.pnnl.gov) introduced in 2011 is said to increase storage capacity by 70%. Three companies have since licensed that technology, including UniEnergy LLC (UET; Mukilteo, Wash. www.uetechnologies.com) and WattJoule Corp. (Lowell, Mass. www.wattjoule.com).

In June, UET announced that its strategic partner Dalian Rongke Power (Dalian, China; www.rongkepower.com) will deploy the world's largest battery, rated at 800 MWh. The two companies have been working together since 2012 to develop vanadium RFBs. The battery arrays will be made up of ten 20-MW VRFB systems to be installed on the Dalian peninsula, where extreme weather events have caused stress on the electricity grid. When commissioned in 2020, the VRFB battery will be able to peak-shave approximately 8% of Dalian's expected load.

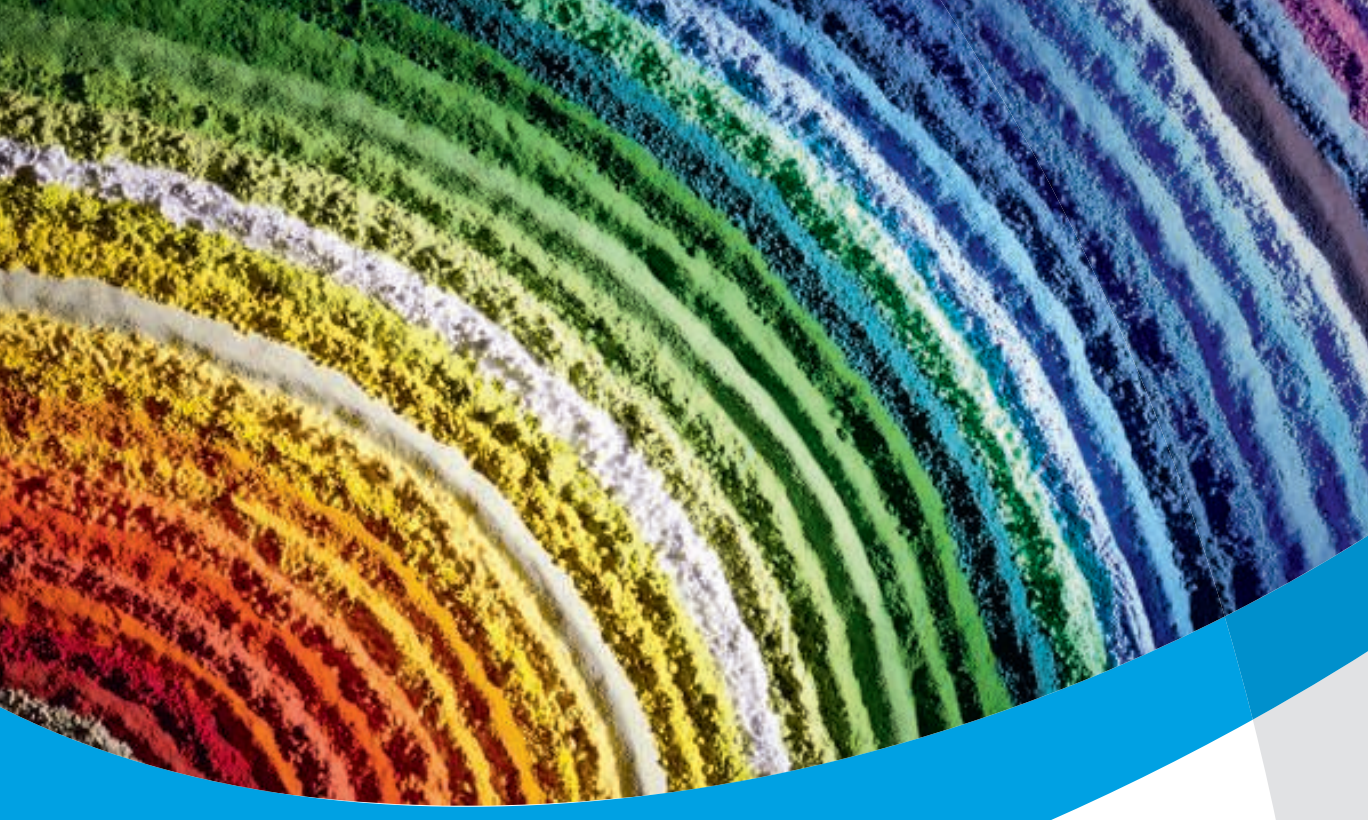
The battery will be built at Rongke Power's new GigaFactory, which opens this fall, with phase 1 capacity of 300 MW of VFB electrode stacks, phase 2 capacity of 1 GW, and phase 3 capacity of 3 GW.

Rongke — founded in 2008 by Dalian Bolong Holding Group and the Dalian Institute of Chemical Physics, Chinese academy of Sciences (DICP; www.dicp.cas.cn) — has deployed nearly 30 energy-storage projects, including those for integrating renewable energy, microgrids and isolated power systems. UET was established in 2012, and its founders led the core technology development at PNNL. The company already has almost 20 MW/80 MWh of energy-storage systems deployed, ordered or awarded.

UET has commercialized two products. The Uni.System is packaged in five 20-ft containers, and delivers 600 kW of power with maximum energy of 2.2 MWh. The ReFlex, launched in January, is rated at 100 kW with up to 5-h duration (500 kWh), and is especially suited for commercial and industrial, microgrid and utility applications, says the company. It comes packaged in a single, stackable 20-ft container. Both systems are said to have a 20-year life with no degradation. In July, UET announced that the ReFlex system will be used in a utility grid modernization project in Chattanooga, Tenn., in a project involving the utility EPB and three U.S. national laboratories.

Next-generation chemistries

As efforts continue to improve VRFBs, another R&D front is to find cheaper, more environmentally friendly chemistries than vanadium, which also requires sulfuric acid with the costs associated with corrosion-resistant materials-of-construction



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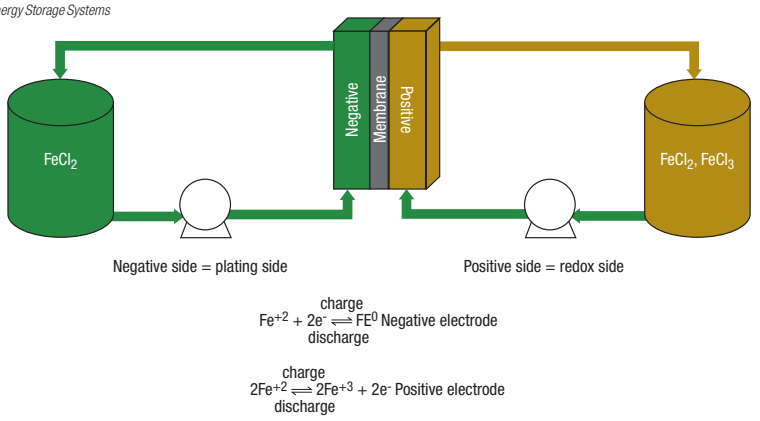

FIGURE 3. The all-iron RFB commercialized by ESS Inc. uses an inexpensive, abundant electrolyte

and equipment.

For example, ESS Inc. has developed and is producing its All-Iron Flow Battery (IFB) systems. This system (Figure 3) is a hybrid RFB that utilizes a low-cost common electrolyte on both sides of the battery composed of iron, salt and water, explains ESS's Sproull. During charging, the system electroplates iron to the negative side of the battery and has a redox reaction on the positive side. During discharge, the iron is de-plated back into solution and the chemistry returns to the same ionic state on both sides. The process is repeatable without any degradation in performance over 20,000+ cycles, says Sproull.

ESS has integrated the cells into battery stacks and developed a complete turnkey energy-storage system in 40-ft ISO shipping containers. The power container has the battery stacks, control electronics and a.c.-power conversion system. The energy container has the positive and negative electrolyte tanks and the pump systems. Combined, these two 40-ft containers deliver 100 kW of power and store 8 h of energy (800 kWh).

The primary key feature of the IFB is its low levelized cost of storage (LCOS) over 20–25 year project lifetimes, says Sproull. With low capital, operating and maintenance costs, combined with the ability to cycle multiple times a day without degradation, in an application like smoothing and time-shifting renewable energy, the LCOS of an IFB system can get down to $0.10/kWh, says Sproull. The first commercial system — a 10-kW, 60-kWh unit installed in a microgrid application at Stone Edge Farm (Sonoma, Calif.) — started up in April.

Meanwhile, JenaBatteries GmbH (www.jenabatteries.com) is working to commercialize the all-polymer-based RFB technology that was developed by researchers led by professor Ulrich Schubert at the Friedrich Schiller University (both Jena, Germany; www.uni-jena.de). This water- and polymer-based RFB eliminates the need for vanadium or other metal compounds (which must be very pure), as well as the expensive materials of construction needed for handling the strong acids they are dissolved in, says Schubert. Instead, organic polymers are used as the charge-storage material and an aqueous sodium chloride solution is used instead of sulfuric acid. Because the polymer is a macromolecule, it is much larger than vanadium ions, so an inexpensive cellulose dialysis membrane can be used to separate the cathode from the anode. VRFBs require an ion-selective membrane — typically Nafion — to prevent the metal ions from passing through. This can account for more than 30% of the cost of the reaction cell, says Schubert. The polymer can be made by a standard free-radical polymerization procedure, and is easily upscalable, he says.

JenaBatteries plans to introduce its first series by mid-2017.

Researchers from PNNL have also recently developed an organic aqueous flow battery. When fully developed, the organic RFB is expected to cost 60% less than today's standard flow batteries, again because the technology enables the used of a simple, inexpensive porous membrane. Storage costs are expected to fall to $189/kWh once the technology is fully developed, says PNNL.

Others are actively looking for new electrolyte materials that are based on organic compounds or organometallic complexes, such as iron with ligands, to eliminate the need for ion-selective membranes. For example, in July, researchers at the John A. Paulson School of Engineering and Applied Sciences, Harvard University (Cambridge, Mass.; www.harvard.edu), published a study that identified a new class of organic molecules, inspired by vitamin B2, that can safely store electricity. The easy-to-synthesize compound (an alloxazine) is highly soluble in alkaline solution. Previously (in 2014), Harvard scientists had developed RFBs that replace metal ions in acidic solutions with quinones, followed by (in 2015) an alkaline RFB based on quinones and ferrocyanide (a common food additive).

New membrane technology

Researchers at the Leibniz Institute for Interactive Materials e.V. (DWI), RWTH Aachen University (Germany;www.dwi.rwth-aachen.de) and Hanyan University (Seoul, South Korea; www.hanyang.ac.kr) have discovered a hydrophobic membrane with nanopores that may be a less expensive alternative to ion-exchange membranes used in vanadium RFBs. These membranes contain tiny (less than 2 nm) water-filled pores and channels that allow protons to quickly pass through, but block the passage of the larger vanadium ions. At all current densities tested (between 1 and 40 mA/cm^2), an energy efficiency of 85% was observed, compared to 76% achieved by conventional systems, which suffer from vanadium-ion crossover.

Meanwhile, the Energy Storage Division at DICP has developed porous, non-fluorinated membranes with ultra-high selectivity and stability. When used in a single VRFB cell an energy efficiency of over 90% is achieved at a current density of 80 mA/cm^2. ■

Gerald Ondrey

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Mobile Apps for Increasing Process Efficiency

Industrial mobile apps help chemical processors overcome process, maintenance and inventory issues

IN BRIEF

Due to the portability and propagation of smartphones and tablets, mobility is all around us. Plugging in on the fly has become second nature in our personal lives thanks to mobile applications (apps) that allow users to take pictures and post directly to multiple social media sites in a split second, apps that create personal playlists based upon our musical preferences and a host of other apps that provide modern day conveniences. So, it makes sense that the intersection of mobile apps and the industrial world quickly followed suit. As a result, there's been a proliferation of industrial mobile apps that conveniently assist with process engineering and maintenance activities, inventory and logistics and even simulations. And, because of the existing comfort level with mobility, chemical processors are quickly and easily embracing these mobile apps as useful tools that help ensure reliability of equipment, process and product quality.

Endress+Hauser

FIGURE 1. CompuCal calibration management solution is a Web-based platform for managing process information, designed upon a scalable architecture and can start as a cloud-based version or scale up to an enterprise deployment. The enterprise version interfaces with mobile platforms and integrates seamlessly into users' IT infrastructures

Process and engineering management

Reliability of process is the "Holy Grail" of the chemical process industries (CPI) and, as such, apps designed to assist with managing processes are being eagerly employed.

For example, Honeywell Pulse from Honeywell Process Solutions (Houston; www.honeywellprocess.com) remotely connects plant managers, supervisors and engineering staff to customized, realtime plant performance notifications so that users can easily and quickly collaborate to resolve plant-productivity issues. Honeywell Pulse is designed to monitor the process and proactively seek and analyze trends and upset conditions. It can tag events for future reference and add them to a watch list. The app can also send alerts from multiple data sources based upon user-defined conditions and present data in realtime, easy-to-read formats. But, perhaps the biggest benefit of this mobile app is that it allows users to take action on the events. "The ability to collaborate with subject matter experts around the globe in the same way we all use threaded conversations on Twitter or Facebook helps bring resolution to any problems, faster," says Rohit Robinson, director, portfolio innovation with Honeywell Process Solutions. "There is also a feature that allows one person to take ownership, which means one person alerts others on the thread that they are taking over and fixing the issue, so time to resolve is optimized."

Similarly, Seeq Corp., (Seattle, Wash.; www.seeq.com) released Seeq R12, an application for engineers and operations analysts in the process industries that provides insights into asset and operations data. The software and application tools provide data visualization, collaboration and knowledge-capture features. For engineers investigating or trying to improve yield, quality, margin or

Emerson Process Management

FIGURE 2. The ATG View application provides mobile access to critical asset health information from Emerson's CSI 6500 ATG machinery protection and prediction monitoring system. Users can scan a quick-response code located on the cabinet and view the status and health of all cards and measurements from the associated rack on their mobile device

safety issues, the tool allows them to obtain and use data without the need for programming by connecting them directly to process information stored in any historian.

"Seeq features include advanced trending and data visualization, Google-like search functions and document sharing and data cleansing and contextualization," says Michael Risse, vice president and CMO with Seeq. "This gives engineers the expertise, incentive and responsibility to analyze and improve production outcomes without burdening them with new hiring requirements, IT [information technology] overhead or a long learning curve. Seeq, on first use and within minutes, gives engineers hours of their day back that were previously spent on data wrangling, report writing and manual spreadsheet manipulation."

While it is focused on mining information from data loggers, the HOBOmobile app from Onset (Bourne, Mass.; www.onsetcomp.com) is also a tool used to monitor quality of a chemical process, according to Jessica Frackelton, senior manager of product marketing with Onset. The app allows users to configure MX Series dataloggers and manage the collected data. Directly from a mobile

Seek Thermal

FIGURE 3. The CompactPRO plugs directly into a smartphone device, giving the user instant connect-and-detect convenience and versatility, turning the smartphone into a thermal-imaging camera and combining it with an app that maximizes heat-sensing technologies to prevent damage, increase productivity and visually image the necessary details within heat signatures

phone or tablet, users can view data in graphs, check the operational status of loggers, share data files and graph images for analysis in Excel, Numbers and other applications, and store data in the cloud. HOBOmobile also allows for the creation of audible alarm notifications so users are immediately notified of problems.

"These tools can be used to ensure that processes are staying in [specification] and, because the app is portable, users can apply it to various points of the process that need to be more closely monitored without interruption of the process to read the data," says Frackelton. "It also improves product quality because it can be used to monitor the temperature and humidity of materials, ensuring that they are kept at proper levels as they move through the process, become finished product and move into storage."

Maintenance management

Industrial mobile apps also have a large presence in the management of maintenance activities.

For example, Endress+Hauser (E+H; Greenwood, Ind.; www.us.endress.com) released the CompuCal calibration management solution (Figure 1), which is a Web-based platform for managing process instrumentation, according to Matthew Dornan, sales director with E+H. The calibration-management solution portfolio is designed upon a scalable architecture and can be deployed as a cloud-based version or scaled up to an enterprise deployment. This software interfaces with mobile platforms and integrates seamlessly into users' IT infrastructures, such as SAP. Both cloud-based and enterprise solutions can integrate with the E+H Web Asset Management architecture. The solution provides a full time-and-date stamped audit trail, reverse traceability, history and key process indicators (KPIs) and the system is fully compliant with 21 CFR Part 11 and validated with protocols and reports with no need for extra validation resources. Users can access safe and secure data from anywhere using just a browser, with no IT required.

"This means they can view, from anywhere, all the instruments and all the details associated with these instruments, including work instructions," explains Dornan. "We can also manage plant equipment in the system and provide automated planning and scheduling information. Another key feature of the system is that we can manage things like deviations, so that if a deviation is detected and recorded, it sends an automated notification to the proper plant personnel so the problem can be corrected and production can continue without affecting quality."

Similarly, Fluke Corp. (Everett, Wash.; www.fluke.com) offers Fluke Connect Assets, a cloud-based wireless system of software and test tools that gives maintenance managers a comprehensive view of all critical equipment — including baseline, historical and current test tool measurement data, current status and past inspection data — enabling them to set up and sustain a preventive maintenance or condition-based maintenance system easily and with minimal investment.

"The app features the industry's only wireless one-step measurement transfer from more than 40 Fluke Connect wireless test tools, eliminating manual recording of measurements so maintenance managers can be confident that the equipment history is accurate," says John Neeley, product manager, mobility solutions, with Fluke.

He adds that maintenance teams can capture and share data via their smartphones, regardless of their location to automatically record measurements from Fluke Connect wireless test tools, upload the data to Fluke Cloud storage and then assign it to a specific asset for sharing and analysis. "Technicians can collaborate with their colleagues to discuss problems while sharing data and images in real time, speeding up problem solving, decision making and approvals," he says.

And, Emerson Process' (Knoxville, Tenn.; www.emersonprocess.com) new ATG View application provides mobile access to critical asset health information from Emerson's CSI 6500 ATG machinery protection and prediction monitoring system (Figure 2). With mobile devices, app users can scan a quick response code located on the CSI 6500 ATG cabinet and immediately view the status and health of all cards and measurements from the associated rack on their mobile devices, enabling faster maintenance rounds and reducing unnecessary trips to the control room, increasing productivity and improving response time.

"The key reason a user of the CSI 6500 ATG should have the app is to improve the reliability, availability and safety of their critical assets and process itself," says Björn Müller, product manager at Emerson. "Knowing the state of critical assets at anytime will help users manage those assets more effectively and make decisions quickly. Higher uptime of critical assets means higher reliability and availability and better safety."

And for thermal imaging activities, the Seek Thermal (Santa Barbara, Calif.; www.thermal.com) mobile app serves as the primary interface for the Seek CompactPRO thermal imaging camera (Figure 3). "This is the world's first thermal imager, built for a smartphone, to feature 76,800 infrared measurement pixels from a thermal sensor array of 320x240," says Tracy Benson, CMO/VP of marketing for Seek Thermal.

"With a professional-grade product built for the industrial market, we redesigned the features in the app to maximize heat-sensing technologies that can prevent costly damage, increase productivity and visually image the necessary details within heat signatures," she says. The features include the ability to capture and document both photos and video, choose between nine different visual color palettes on demand, as well as lock into a narrowed range of thermal measurement. The app also features advanced benefits, such as thermal span and level, emissivity compensation and raw thermal data capture for post analysis.

"Because the CompactPRO plugs directly into a smart phone device, it gives the user instant connect-and-detect convenience and versatility," says Benson. "This allows users to pull it out, plug it in to the device already in their pocket and turn a smartphone into a thermal-smart device."

And, if lubricant analysis is needed, there's an app for that too. ExxonMobil is launching Mobil Serv Lubricant Analysis, a new mobile-enabled used oil analysis (UOA) service, complete with a mobile app.

"Conducting UOA is one of the best ways to monitor and enhance equipment performance," says Juan Martinez, Americas marketing advisor — services, with ExxonMobil Fuels and Lubricants (Spring, Texas; www.mobilindustrial.com). "Successful UOA programs and services will provide maintenance personnel with critical insights that help identify any potential performance issues at the earliest stages, before they result in unplanned downtime. What users like most about Mobil Serv is that it is an intuitive and user-friendly approach to streamlining UOA. It eliminates time-consuming and error-prone paperwork by replacing the hand-written labeling process with a mobile platform."

Inventory and logistics

Mobile apps also lend themselves well to inventory and logistics management. For example, Bin Master (Lincoln, Neb.; www.binmaster.com) provides BinCom modules to monitor bin levels and manage inventory because they allow continuous or point level sensors to send data to the BinView Web application, providing instant access to bin level data on any device with an Internet connection. A smartphone, tablet or PC can be used to get timely, remote data access to all level measurements from local and corporate-wide locations.

"The small, cellular devices allow us to take the data from any of our sensors, and will also connect to

Elemica

FIGURE 4. Elemica Track provides visibility into shipments transacting through Elemica's Enhanced Transport Visibility solution. Via the app, users can monitor shipments from anywhere, identifying where they are in the execution process with access to detailed information for shipments that need attention

anyone else's sensors, and send data to the cloud, allowing the data to be displayed on BinView. This makes the rates for viewing and seeing inventory and level data very economical, which means it is a simple and cost effective means of making sure there is always enough to material available."

MSDSonline, the VelocityEHS Chemical Management product, (Chicago, Ill.; www.msdsonline.com) recently enhanced its Chemical Inventory Scanner app, making it easier for users to scan and search barcodes for improved access to container details, safety data sheets and other chemical inventory information.

"With better visibility of the chemical and quantities at a specific location, the app helps users meet a variety of regulatory reporting requirements for the Environmental Protection Agency (EPA), Occupational Health and Safety Administration (OSHA) and other agencies," says John Colon, business product analyst with VelocityEHS. "The app was created for workers where safety and compliance tasks include managing safety data sheets for chemicals and tracking containers of the chemicals. It is also suitable for employees who need in-the-field access to information about the chemicals in their inventory. Users of the app benefit from getting instant access to the most up-to-date information wherever an Internet connection is available and from the convenience of a mobile device."

And, for reliability of logistics, there's Elemica Track from Elemica (Wayne, Pa.; www.elemica.com), a supply-chain operating network for the process industries. The mobile app provides visibility into shipments transacting through Elemica's Enhanced Transport Visibility solution (Figure 4). Users can monitor the shipments from anywhere, identifying where they are in the execution process with access to detailed information for shipments that need attention. "The mobile app frees up the user from having to be in the office at their computer. By getting the information this way, shippers can react more quickly to shipments in trouble and be more proactive about telling their customers of expected delays, thereby improving customer satisfaction," says Cindi Hane, vice president of logistics management.

Engineering simulation

In addition to apps making an appearance in the process, maintenance and inventory aspects of the CPI, there is also use in engineering simulation applications.

"Simulation apps allow users without any previous experience using simulation software to run the apps for their specific purpose," says Ed Fontes, CTO with Comsol, Inc., (Burlington, Mass.; www.comsol.com) which offers LiveLink for SolidWorks and an application builder that allows users to build apps based upon Comsol models created from a SolidWorks software geometry.

Fontes describes the company's mixer app and how it could be of assistance in the CPI. He says, a typical mixer consists of two physical components, a vessel with or without baffles and an impeller structure. Process developers may use such an app to select parameters such as impeller type, dimensions of the impellers, number of impellers and the size and specifications for the electric motor that drives the impellers, in addition to the type of tank and the number of baffles. "The result could be an optimized set of impellers and tanks for a specific type of synthesis process or mixing process. For synthesis, the reactor can be designed for a minimum of side-reactions and also with highly controlled and reproducible results, which result in uniform quality of the product."

He says the benefit of having an app available on a mobile device is that, as a process developer, you are able to follow the status of the simulations when you are outside the laboratory, at a pilot plant or at the plant. "You can also easily show the simulation results to the process engineers and demonstrate the implications of different results directly at the site," says Fontes.

And, Schaffner EMC (Edison, N.J.; www.schaffner.com) offers its PQS, a power quality simulation tool, which allows planners, consultants and application engineers to accurately model and simulate low-voltage, three-phase network topologies. The app allows users to select medium- and low-voltage transformer parameters, including voltage, power, short circuit current and impedance, specify cable and then add loads and harmonic filters.

"In app format, it is ideal for quick, hands-on preliminary engineering and makes it very flexible to change parameters and confirm most beneficial power-system schemes and harmonic solution designs," says Chuck Gougler, director of power quality with Schaffner. ■

Joy LePree

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Emerging Applications for Traditional Dryers

Traditional classes of drying equipment are being adapted for use in a growing number of applications, and more complex analysis and process control are helping to optimize processes

IN BRIEF

The chemical process industries (CPI) are full of processes in which a volatile substance, often water, must be separated from one or more nonvolatile species. These drying processes are well established and well understood, but the processes and associated equipment continue to be optimized to improve performance and lower costs while complying with regulations on solids handling, such as those for dust control. At the same time, the portfolio of established drying methods, including rotary dryers, fluidized-bed dryers, spray dryers and others, are being used in an increasing number of applications. Several examples of new applications to which drying technology is being applied involve the wider effort to make better use of waste streams by recycling materials. Other examples include the adaptation of existing dryers to applications that require sanitary handling of materials.

Meanwhile, advancements in analysis technologies, process control and simulation software are giving CPI engineers a clearer picture of their process and providing guidance in equipment selection. There are, and will continue to be, drying applications that call for every type of dryer, and CPI engineers will be challenged to make equipment selections based on the particular requirements of the process, including the characteristics of the feed material and the operating costs.

Drying trends

"In general, all classes of dryers will continue to be used [in the CPI]," says Joe Bevacqua, president of Wyssmont Inc. (Fort Lee, N.J.; www.wyssmont.com), a maker of custom-designed drying equipment. "But those same general classes of dryers are being adapted for new and different applications," he says.

Georgios Raouzeos, a consultant at the firm 4E Engineering GmbH (Basel, Switzerland; www.4e-eng.ch) agrees, having observed a significant amount of optimization of existing dryers, rather than the development of new drying approaches in recent years.

Witte Co.

FIGURE 1. Control hardware is being constantly updated, and is instrumental for drying equipment, allowing improved automation for processors

Drying tends to be an energy-intense and expensive unit operation, so processors are continuously looking for ways to match the energy input to the requirements of the product. "Careful consideration of the end-use of the solid product is key," explains Bevacqua. For example, electrode materials must be dried to very low moisture levels to be effectively used in batteries. "You always want to produce a quality product without overheating," Bevacqua remarks.

To lower costs and optimize the effectiveness of given technologies, many processors are turning to multiple dryer types to achieve more efficient overall removal of moisture. "Multi-stage drying is a growing segment of the industry," Bevacqua notes. "In many cases, two separate drying stages may be more effective than a single technology."

Over the past couple of decades, dryers have improved greatly in the way they manage energy, comments Tom Schroeder, of ALMO Process Solutions (West Chester, Ohio; www.almoprocess.com), with the advent of PLC (programmable logic control) controls, and improved instrumentation for detecting moisture. That evolution will con-

tinue, especially with the added current challenges of drying solids with smaller particle sizes.

"The most significant technological changes to our dryers in recent years have been the level of controls to allow better equipment automation for plant operators," agrees Tyson Witte, president of Witte Co. Inc. (Washington, N.J.; www.witte.com; Figure 1). "Witte fully understands the importance of having centralized control and monitoring ability in today's modern production plant, so we do everything we can to be sure our equipment fits into this. Control hardware is constantly being updated, Witte Co. understands the importance of supporting the most relevant and up-to-date control products."

Energy efficiency is also a constant concern in drying, which requires significant energy input. "In recent years, energy costs have made customers more aware of drying efficiency," says Witte, and the company has worked on technologies to reduce energy requirements by recycling a portion of the exhaust air for heat recovery, either directly from a dust collector or through an air-to-air heat exchanger.

Other strategies likely to see increased use in drying include the use of vacuum to help evaporate volatile components with high boiling point — particularly when the solid material is temperature-sensitive, and the technique of introducing a portion of already dried product back into the drying process to help avoid a transition of the material to a particularly sticky, pasty or highly viscous phase, 4E Engineering's Raouzeos says. Also, regarding equipment selection, there has been a lot of activity in quick laboratory tests and simulation programs for drying to aid in equipment selection, Raouzeos says.

Materials recycling

Across a broad range of industries, companies are looking to make better use of waste materials, either by converting them into saleable products or by using them to generate energy. That effort is creating new opportunities for makers of drying equipment.

"The recycling industry is a really hot focus for drying right now," says Tom Schroeder of ALMO Process Solutions (Cinncinnati, Ohio; www.almoprocess.com), and there has been a lot of innovation surrounding solutions for handling and drying recycled materials. One example is in the area of refuse-derived fuel (RDF), which is produced by shredding and dehydrating municipal solid waste. ALMO recently developed a patented rolling-bed dryer that combines fluidized-bed technology with a rotary drum dryer. The machine can be used for homogenizing and drying RDF or wood waste. The dryer helps reduce the risk of fire that can occur when drying, and can be heated with waste heat from a downstream torrefaction process, ALMO says.

Wyssmont has also been active in recycling-related materials, using its Turbo Dryer, which uses a stack of slowly rotating circular trays to uniformly dry solid materials (Figure 2). Wyssmont's Bevacqua says the company has adapted the Turbo Dryer for the pyrolysis and drying of recycled automobile and truck tires. In the oxygen-free pyrolysis, the used rubber is separated into oils and carbon, both of which can be sold. Bevacqua says his company is also involved in a project using the Turbo Dryer in a wood torrefaction process to make bio-coal for fuel. The Turbo Dryer's close temperature control and unique seal system make it well-suited to these recycling applications.

Other drying equipment companies are also seeing interest in utilizing waste organic matter and bio-solids. Rich Klein, account manager at Tarmac International Inc. (Lee's Summit, Mo.; www.tarmacinc.com) says "We've seen a recent increase in interest in the drying of organic matter."

For that task, Tarmac has developed an air-heater system designed to reduce the risk of the dried organic material burning or exploding (Figure 3). Tarmac's system lowers air temperature at the point where the feed is introduced to the rotary dryer by using a secondary fan that introduces ambient air, Klein says.

Witte Co. has also seen a recent uptick in applications involving bio-solids drying, where sugarcane waste, coconut husks, corn byproducts and wood waste are dried for use as fuel or as components of livestock feed.

Wyssmont

FIGURE 2: The stacked, circular trays of the Turbo Dryer have been used for several applications in drying recycled material

Sanitary applications

While drying grows in "green" waste applications, it continues to be prevalent in the food and pharmaceutical industries, where sanitary handling of solid materials is a critical component of the processes. There, dryers are seeing adaptation as well.

4E Engineering's Raouzeos explains an ongoing industry trend in the area of sanitary drying: "Many companies in Europe have taken technologies originally designed for chemical applications, and adapted them for pharmaceutical applications." They are attracted by the smaller volumes of solids in that area and the higher-margin products. "Drying equipment has, in many cases, been modified to fit pharmaceutical applications, including polishing to help avoid deposits of material that could lead to cross contamination. All types of drying equipment have been adapted in this way; not only one, Raouzeos notes.

Filter dryers are among those being adapted for pharmaceutical applications. According to Dirk Ramsbrock, product manager for Comber drying products (part of Heinkel Drying and Separation Group; Besigheim, Germany; www.heinkel.com), there is a trend in sanitary applications (including drying operations) toward contained handling. Because of its ability for containment, filter drying is gaining attractiveness for pharmaceutical

Tarmac International

FIGURE 3: An increased demand for drying organic matter has led to a number of innovations in adapting drying equipment

processors, he says. Also, processors are looking to increase the available surface area for heating, so they are using more heated agitators, which raise the amount of contact area to heat the product, Ramsbrock says.

Heinkel/Comber has introduced drying equipment to fulfill those wishes, including Comber's Pressofiltro filter dryer, its ConDry dryer and its PharmaDry system. These filter dryers are equipped with the company's unique heel-break system, in which a manifold introduces bursts of gaseous nitrogen from underneath the filter cloth. "With this heel-break system, the nozzles blowing the gas do not touch product, eliminating them as a source of cross-contamination," Ramsbrock says.

Dust control and air quality

The nature of several drying processes, including spray drying and fluidized-bed drying, involve the production of powders, and the mixing of those powders with air. The combination creates the risk of dust explosions, and forces both drying equipment vendors and processors alike to address the risks and comply with relevant standards and regulations.

With regard to addressing dust explosion hazards, the drying community represents only a part of the wider bulk-solids-handling industry that must be concerned with these hazards, according to remarks from Witte Co. "Of primary importance are the new National Fire Protection Association (NFPA; Quincy, Mass.; www.nfpa.org) standards 652 and 654, which address the hazards associated with, and regulations pertaining to, preventing dust explosions," Witte says. "We work closely with our customers, as well as explosion protection leaders like Fike Corp. (Blue Springs, Mo.; www.fike.com) to provide the safest equipment possible," Witte says.

"In the case of the newest revision of NFPA 654, there are materials that now require an explosion-suppression system or venting device for materials that in the past have not been considered explosion risks," Witte says. "While we understand the intent of these regulations, we hope it does not have an adverse effect on materials processing here in the U.S."

In addition to dust explosions, dryer vendors and drying-equipment users also have to contend with air-quality regulations from the U.S. Environmental Protection Agency. Witte manufactures a fluidized-bed dryer with a highly efficient dust filter directly over the bed. This allows particles as fine as 5 µm to be dried without being carried to a remote dust collector, the company says. "The exhaust air is totally clean and can be discharged into the atmosphere or into the plant directly from the dryer. This also allows higher fluidization velocities without the concern of entrainment thus providing higher efficiency," Witte says.

Spray-drying analysis

Process monitoring is a key component of drying processes. Spray-drying provides an illustrative example of how processors are exerting greater control over product properties by analyzing drying parameters in real-time, including those parameters that go beyond traditional measures, like temperature and feedrate. A more detailed understanding of the physical phenomena of spray drying is giving users opportunities to increase product yields and improve control of product properties, including particle size and shape. The fluidity of spray-dried powders is influenced greatly by their particle size distribution, particle shape and moisture content.

"In spray drying, moisture loss occurs very quickly, but is in fact just one of the parameters monitored to control the drying process, granule formation and the properties of the finished product," explains Daisuke Sasakura, a product specialist at Malvern Instruments (Malvern, U.K.; www.malvern.com). Parameters such as dryer temperature, atomization rate and feedrate of the incoming slurry are monitored routinely, but Sasakura says spray-dryer equipment makers are developing ways to also monitor particle size along with the traditional parameters in an effort to obtain further control over their processes and products.

For example, the speed of vaporization (rate of moisture loss) has a large impact on the size of the granules formed, Sasakura says. When the speed of vaporization is too high, droplets can explode, resulting in the formation of fine particles in too great a proportion. "There is increasing awareness in the industry that the direct impact of these control parameters can be monitored in real-time using particle-sizing techniques (usually based on light scattering or particle velocimetry), Sasakura adds. "In- and online particle-sizing systems provide direct feedback for manual or automated process control. The realtime monitoring and feedback they provide leads to higher product yields and enhanced process efficiency," he remarks.

Beyond particle size, there is also growing interest in particle shape and how this too may be controlled by manipulating process parameters, according to Sasakura. Spray-dried particles are typically prized for their highly spherical shape, which, for example, tends to enhance flowability. Automated imaging technology makes it possible to rapidly and efficiently generate statistically relevant particle-shape distribution data that can be used to tailor a product to a specific application, Sasakura says.

Further, spray-dried granules contain air pockets that help determine the final particles' mechanical properties. "As a result, there is increasing interest in characterizing the internal structure of spray-dried granule products," Sasakura says. A working hypothesis is that a greater proportion of granules with a high level of internal voids will lead to lower-density products with lower mechanical strength. Such particles may be more likely to break under compaction. ■

Scott Jenkins

Performance Additives and Specialty Materials

Waterborne polyurethane brings functionality to textiles

Waterborne polyurethane coatings (photo) bring a range of functionalities, effects, finishes and color to textile materials for textile applications ranging from fashion and sportswear to automotive upholstery and protective gloves. This company's family of waterborne polyurethane coatings and services (available under its brands Impranil, Imprafix, Impraperm and Insinq), help the textile industry to create waterproof, polyurethane-coated textiles that combine both decorative and functional attributes. One example is Imprafix 2784, a crosslinker that activates at very low temperatures, enabling its use even on temperature-sensitive substrates such as polyamide-based knitwear. Another family of products, Impranil eco, consists of a series of bio-based polyurethane dispersions (PUD) that contain up to 65% renewable carbon; it is said to be an environmentally friendly option that can match the performance levels of the conventional PUD with minimal reformulation. The company works with textile manufacturers to develop advanced processes, helping them to expand the range of applications that can benefit from these functional coatings. — *Covestro LLC, Pittsburgh, Pa.*
www.covestro.com

This exterior nickel coating protects glass-lined parts

This company's exterior nickel coating technology (photo) provides corrosion protection comparable to paint while eliminating the risk of potential contamination from paint chipping. The nickel coating is designed to protect glass-lined process equipment and is particularly well-suited for pharmaceutical and fine-chemical applications that are sensitive to potential contamination by flaked paint chips, says the company. This impact-resistant coating is particularly well-suited for glass-lined accessories, such as protection rings, manhole covers, some reactor covers and piping. Nickel coatings also make it possible to apply a homogeneous coating to components with complex geometries, says the company. — *DeDietrich Process Systems, Mountainside, N.J.*
www.dedietrich.com

Repair pipelines, even at high pressure and under water

The Kalfix family of adhesives (photo; p. 28) helps to extend the life of pipelines. Kalfix 911 and Kalfix 913 are pressure-transfer fillers for repairing high-pressure pipelines and they provide extreme adhesion, even to under-

Covestro

DeDietrich Process Systems

Note: For more information, circle the 3-digit number on p. 98, or use the website designation.

Kalenborn Abresist

water surfaces. Kalfix 563, for pipeline coating or cold weather use, is an epoxy and curing agent that is able to displace water for a permanent bond to all substrates with minimal substrate preparation. Kalfix 206 is a combination liquid-epoxy resin and high-temperature curing agent. Although it has a relatively high heat distortion, it cures to a hard and dust-free condition at ambient temperatures, says the company. — *Kalenborn Abresist Corp., Urbana, Ind.*
www.abresist.com

Victrex

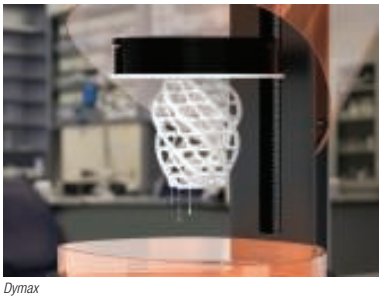
This solventless silicone resin broadens coatings capabilities

A new silicone resin, 2405 Resin, is designed to provide improved flexibility, impact resistance, film build and high-temperature resistance for room-temperature-curing coatings. This solventless methyl methoxy resin, when catalyzed by titanium compounds such as TnBT, cures within 60 minutes at ambient temperatures to form a medium-hard coating with good solvent resistance and high heat resistance, says the manufacturer. — *Dow Corning, Midland, Mich.*
www.dowcorning.com

RTP

High-performance polymers bring added functionality

This company's portfolio of high-performance polyaryletherketones (PAEK) polymer solutions includes several types of polymers, coatings, films and piping (photo). The new Victrex AE 250 composite provides a range of functionalities for many demanding chemical process and aerospace applications, while Victrex OGS 125 has been specifically designed to optimize the compression molding of large seals, says the company. The company's polyetheretherketone (PEEK) was recently used to develop the world's longest spoolable underwater pipe, which can be withstand extreme conditions at depths of up to 10,000 ft and pressures more than 1,000 bars. Other polymers in this family of products include a thermoplastic that is designed for sealing systems ranging from cryogenic temperatures (–313°F) to 392°F. — *Victrex, Thornton Clevelys, U.K.*
www.victrex.com



Dymax

Material helps to improve the fuel efficiency of engines

Stanyl HGR1 is a high-performance material based on Stanyl polyamide 46. This new material reduces frictional torque in automobile engine-timing systems and will provide OEMs with a cost-effective tool for reducing fuel consumption, says the company. Part of the frictional torque arises in engine-timing systems when the timing chain moves over an element that keeps it under tension. This chain tensioner is often injection-molded in polyamide 66, but increasingly this critical component is being replaced with Stanyl HGR1 to reduce frictional torque (by 10% in some applications) where it improves fuel efficiency.— *DSM Engineering Plastics, Singpore*
www.dsm.com

Structural thermoplastic addresses a performance gap

The new RTP 100 eExtra Performance (XP) Compounds (photo) are thermoplastic compounds that are formulated for higher strength, modulus and impact properties than any standard chopped-fiberglass polypropylene (PP) compounds available in the market today, says the manufacturer. With strength, stiffness and impact resistance performance that is close to the company's Very Long Fiber (VLF) compounds, the RTP 100 XP Compounds also enjoy the lighter weight and chemical resistance of standard PP compounds. This helps to expand the range of opportunities in industrial and commercial applications. For instance, compared to common glass-fiber-reinforced PP at similar loads, the inherently chemical resistant and non-hygroscopic RTP 100 XP Compounds exhibit up to 20% higher modulus values and twice the impact resistance, says the company, and their lighter density makes these compounds well-suited for applications where lower weight is desired. The RTP 100 XP Compounds are available as standard pellets in formulations containing from 10–50 wt.% glass fiber reinforcements, and can be easily injection molded into large or small complex geometries. Additives can be incorporated to meet other demanding requirements of the application.— *RTP Co., Winona, Minn.*
www.rtpcompany.com

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In focus for plant and infrastructure operators is the long-term security of investment. For this reason, Siemens has systematically further developed the SIMATIC S7-400 series. In this way, they ensure that the right controller will always be available for a vast range of automation solutions in all industries.

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- Scalable automation
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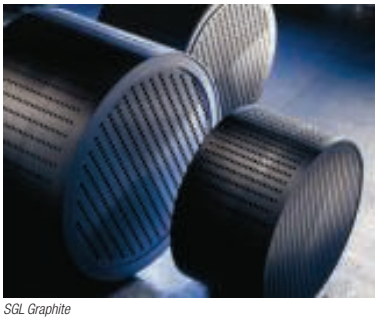
Lanxess

G. Otto Gehrckens



SGL Graphite

Oligomer resin proves worthy of 3-D inject printing systems

Bomar BR-970H is a stain-resistant oligomer with high modulus, making it ideal for 2-D and 3-D inkjet printing applications and graphic art applications (photo; p. 28). As a low-viscosity, di-functional, aliphatic urethane acrylate, BR-970H offers rapid cure and non-yellowing properties for higher optical clarity and color stability. Its relatively low shrinkage (0.7%) during curing makes it ideal for 3-D printing applications where good mechanical properties and aesthetics are expected, says the company. It also provides low water absorption (0.15), making it perfectly suitable for applications where 3-D printed parts are exposed to high-humidity environments or washed with water-based solutions. — *Dymax, Torrington, Conn.*

www.dynamax.com

Three glass-fiber-reinforced polymers are 'food-safe'

Ryton polyphenylene sulfide (PPS) compounds combine long-term heat resistance with excellent dimensional stability, very low moisture absorption, strong chemical resistance and inherent flame retardancy, says the manufacturer. Three new Ryton PPS products are now available for use in food-and-beverage applications. Two of them (Ryton R-4-242 and Ryton R-7-232 PPS) are entirely new products; the third (Ryton R-4-232 PPS) is a previously available product that is now approved for food-contact applications. These food-safe resins provide suitable alternatives to metal and thermosets in many applications, says the company. They comply with U.S. Food and Drug Administration NSF51 requirements, as well as the European Union's EU 10/2011 regulations for use as a component material intended for use in food-contact applications. — *Solvay Specialty Polymers, Alpharetta, Ga.*

www.solvayspecialtypolymers.com

This thermoplastic blend is ideal for complex geometries

Thermplastics with good melt-flow characteristics facilitate the design of large, thin-walled components of complex geometry (photo). Pocan C3230 XF (XtremeFlow) is a blend of polybutyleneterephthalate and polycarbonate (PBT/PC), reinforced with 30% glass fibers. This material can be used to produce precision components that can be subjected to high mechanical loads, and experience low warpage and good dimensional stability, says the company. The material displays roughly 40% better flow than a comparable standard PBT/PC blend reinforced with 30% glass fibers. This material has a tensile modulus of 7,500 MPa and a tensile strength nearly 100 MPa. These performance advantages result, in part, from the ability to uniformly distribute the compound's glass fibers, even in areas with a very low wall thickness, says the company. — *Lanxess AG, Cologne, Germany*

www.lanxess.com

Seal material remains flexible at extremely low temperatures

This company's temperature-flexible Vi 840 FKM fluoroelastomer compound allows precision O-rings (photo) and elastomer seals to be manufactured to provides sustained low-temperature flexibility. It maintains low-temperature flexibility to –40°C, and conforms to the DIN EN 14141 standard. And with a TR-10 value of –40.1°C, this performance compound is suitable for use at temperatures down to –46°C, fulfilling API 6A and 6D standards, says the company. — *G. Otto Gehrckens GmbH, Pinneberg, Germany*

www.cog.de

Resin-impregnated resin helps to produce rugged parts

The synthetic resin-impregnated Diabon NS2 graphite (photo) is available for pressure equipment that experiences temperatures up to 220°C, such as heat exchangers, columns, quenchers, syntheses, systems and related components. This product uses a special post-treatment process, which maintains the outstanding thermal conductivity and complete impregnability of the components, enabling the resin-impregnated proportion to be reduced from 20% to approximately 12%. The reduces corrosion and helps to maintain a stable structure. — *SGL Group, Wiesbaden, Germany*

www.sglgroup.com ■

Suzanne Shelley

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New Products

Schenck Process

New Pig

SPX Flow

A dust collector with an energy-saving cleaning system

Requiring no integrated plant air to function, the MCF PowerSaver dust collector (photo) generates energy cost-savings of up to 50% over conventional high-pressure pulse-jet or reverse air-cleaning systems, says the company. The MCF is built to handle heavy dust loads, including abrasive materials, and comes in configurations to fit most industrial air-quality applications. With a patented, controlled cleaning system, the MCF PowerSaver aligns the cleaning arm and bag segments, which positions the air nozzles to fire directly into the bags. No air is wasted, resulting in reduced energy consumption and extended filter-bag life. The MCF PowerSaver operates with medium-pressure cleaning air (7–9 psig) and provides cleaning capacities up to 250,000 ft^3/min. Additionally, the MCF PowerSaver handles extreme environments where temperatures can reach over 500°F. — *Schenck Process LLC, Kansas City, Mo.*

www.schenckprocess.com

Expansion joints now certified for handling potable water

This company's line of EPDM (ethylene propylene diene monomer) spool-type expansion joints has received NSF/ANSI 61 certification for equipment that comes in contact with either potable water or products that support the production of potable water. The certification applies to the following EPDM expansion joint products: Series 230; Series 233L/234L; Series 271; and Series RC/RE-23. These certified expansion joints are available in sizes ranging from 1 to 120 in. in diameter. For sizes less than 8 in. in diameter, the company recommends no more than one joint per 175 ft of pipe. All of the certified products are supplied with labels to identify them as NSF/ANSI 61. — *Proco Products, Inc., Stockton Calif.*

www.procoproducts.com

This solidification absorbent streamlines transport and storage

Absorb-&-Lock Liquid Solidification Absorbent (photo) is designed to stabilize and solidify excess liquids that separate out from industrial liquids in drums, bulk storage tanks, roll-offs and other containers before shipping and disposal. The loose absorbent contains large, highly compressed particles that work in a time-release action to reduce mix-off material separation during transportation. This absorbent is all-natural, biodegradable and more absorbent than traditional cob, sawdust or clay, according to the manufacturer. One 35-lb bag absorbs up to 21 gal of excess liquid. Furthermore, it is highly suitable for fuels blending, providing 7,500 Btu/lb with only 2.0% ash content. — *New Pig Corp., Tipton, Pa.*

www.newpig.com

Stainless-steel mixers designed for hygienic applications

The Lightnin SSi (stainless-steel inline; photo) and SSO (stainless-steel offset) mixers use high-efficiency gearing to match individual application needs and are specifically designed to meet the high standards required by the pharmaceutical, biotechnology and food-and-beverage industries. The mixers are suitable for a wide range of mixing applications in areas including buffer and media preparation, fermenters, bioreactors, product recovery and bulk pharmaceutical processing. Their hygienic design offers either USP Class VI or FDA GRAS elastomers and seal faces. The mixers have open-tank, lip-seal and mechanical-seal mounting options with a choice of ANSI, DIN or sanitary flanges. The units are further designed to accommodate longer shaft lengths to fit mix-tanks without the need for any in-tank bottom support. This makes the units easier to maintain and operate without the possibility of damage to the mixer or tank. Various motor options, plus a full spectrum of impeller types, are available to meet a wide range of tank sizes. — *SPX Flow, Inc., Charlotte, N.C.*

www.spxflow.com

Walk-in fume hoods for distillation processes

The UniMax series of floor-mount fume hoods (photo, p. 37) includes a wide selection of models that feature

fire-suppression systems. Standard models are available as follows: 6 to 24 ft wide; 4 to 8 ft deep; and 7 to 16 ft high. Tall-apparatus systems, distillation processes, roll-in reactors or long integrated instrumentation systems can be easily accommodated in these hoods. The hoods are constructed of chemical-resistant, non-conductive modular panels featuring composite-resin surface material. This modular design allows for onsite assembly and the ability to disassemble at a later date, move and reassemble. Custom sizes and designs can also be built to exact specifications. — *Hemco Corp., Independence, Mo.*
www.unimaxfumehoods.com

Eliminate waterhammer with this descaling poppet valve

This company's new proportional poppet valve (photo) for descaling applications is said to last three to five times longer than traditional poppet valves. By eliminating the effects of waterhammer and system shock, this poppet-valve technology promotes safety in the plant and cuts operating costs in half, says the manufacturer. The valve can be programmed to eliminate damaging waterhammer, which can lead to burst pipes and cracked welds. Typically, the speed is only reduced for the last 10 to 20% of the stroke, just before completely shutting off flow to the descale header. This slow rate of closure can be fine-turned via the integrated local control interface or programmable logic controller (PLC). To combat the high-velocity fluid flow created by the valve's slow rate of closure, the valve incorporates ceramic seating surfaces that prevent wear from the fluid flow. The full ceramic seat is more durable than conventional seat materials, such as heat-treated stainless steel. — *Hunt Valve, Salem, Ohio*
www.huntvalve.com

Valves fail closed with this mechanical interlock system

The Inflatable Seal Mechanical Interlock system for the Roto-Flate spheri-

Hemco

Hunt Valve

Roto-Disc

SignalFire Wireless Telemetry

Brass Knuckle Safety Products

Volkmann

cal valve (photo) enhances reliability and causes the valve to fail closed and inflated in the case of electric or pneumatic loss. The mechanical interlock prevents the inflatable seal from inflating before the valve dome is in the closed position. When utilized with a spring-return pneumatic actuator and normally open seal solenoid, the Roto-Flate valve now closes and inflates upon electrical power loss, regardless of the position of the valve at the time power is lost. The interlock also prevents unintended or premature inflation of the inflatable seal, thereby decreasing risk of damage during startup. For applications where the valve is required to also close on pneumatic loss, the Roto-Flate can be provided with a valve arrangement that will inflate the seal from a reserve air-source, and keep it inflated for extended periods. Applications that require a fail-open or fail-last disposition can also be easily accommodated. — *Roto-Disc, Inc., Erlanger, Ky.*
www.rotodisc.com

A level-monitoring probe with an integrated temperature sensor

The Sentinel Float Stick System (photo) serves as a wireless-communication link in the remote monitoring and control of tank levels and temperatures for offsite data processing. Consisting of a magnetostrictive level probe with integrated temperature sensors mated with a Sentinel wireless node, the Sentinel Float Stick System creates a wireless connection between a sensor and a gateway where sensor data, along with node-diagnostic information, is available via a Modbus RTU or TCP interface. Reported values include product level, interface level, temperature and status. Powered by internal lithium batteries or an optional solar package, the system has a ½-mile range and operating temperatures of –40 to 60ºC. The Sentinel Float Stick System is designed for Class 1 Division 1 intrinsically safe operation. In addition to monitoring tank levels, the Float Stick System integrates a temperature sensor to measure fluid temperature. — *SignalFire Wireless Telemetry, Hudson, Mass.*
www.signal-fire.com

These gloves provide protection in three complex layers

The SmartShell BKCR4599 heavy-duty protective glove (photo) provides ANSI Level 4 cut resistance, light-oil and moisture resistance, non-tacky slip resistance and shock-absorbing impact protection, all in a breathable and flexible package. On the palm and fingers, the BKCR4599 offers three layers of protection. The liner is an ultra-high-performance polyethylene (HPPE) and Spandex composite that delivers strong cut resistance without bulk. Bonded to the first layer is a gray polyurethane (PU) fabric topped with a gripping nitrile-rubber surface — a barrier to light oil or other light liquid penetration. In critical areas of the palm, padding provides impact resistance. Finally, the back of the hand is loaded with sonically welded thermoplastic-rubber (TPR) padding that counters workplace pounding and abrasion. — *Brass Knuckle Safety Products, Alpharetta, Ga.*
www.brassknuckleprotection.com

Suppress dust and spills with these cleanup units

The VHSC range (photo) of stand-alone or integrated dust collectors and vacuum cleanup conveyors are designed for high-volume air movement, providing dust control that meets ATEX-certified and explosion-proof standards for any powder having a minimum ignition energy (MIE) greater than 1 mJ. The units are available in three sizes with 10-, 14- and 18-in. diameters, and all contact parts are manufactured from 316L stainless steel. VHSC units provide multiple options for specific applications, including dust suppression, spillage cleanup or reclaiming excess product. With vacuum levels as deep as 26 in. Hg, the units cater to a wide range of materials, including slurries and dense metal powders, such as those used in 3-D metal printing. — *Volkmann, Inc., Bristol, Pa.*
www.volkmannusa.com

Higher blower efficiency for aeration tanks

More than 70% of operating costs of a wastewater treatment plant are related to energy costs, arising when the aeration tanks are provided with

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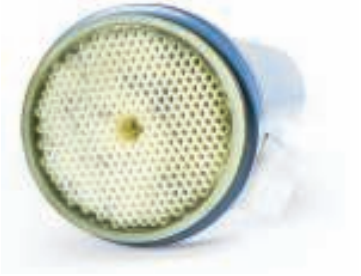

CUT Membrane Technology

Miko Marine

Schütz

Emerson Process Management

air. The combination of this company's blower, turbo and hybrid technology has previously offered efficient solutions in the industry. However, with the introduction of a new control combination, AERsmart (photo), performance can now be sustainably increased even further — additional savings of up to 15% can be achieved, says the company. AERsmart arranges volume flows amongst the machinery in a mode so that low, medium and high loads can be processed efficiently per an existing configuration, whereby the characteristic diagrams and the efficiency levels are integrated in the algorithm of the control system. As a consequence, the installed machinery is operated very close to the theoretical highest efficiency level. Even third-party products can be controlled via the overriding control system. AERsmart can arrange for optimized efficiency by interconnecting up to 12 machines. — *Aerzener Maschinenfabrik GmbH, Aerzen, Germany*
www.aerzen.com

These membrane modules are now available in PVDF or PES

The new T-CUT tubular modules (photo) with membranes made from polyvinylidene difluoride (PVDF) or polyethersulfone (PES) complement this company's CUT product range with a robust and efficient tubular module. The outstanding stability of the membranes and the possibility to apply chemical cleaning means that the T-CUT tubular modules can be used in challenging applications, such as for the treatment of chemical stripping baths used in the metal processing industry for separating oil and water, or for the separation of biomass from water. — *CUT Membrane Technology GmbH, Erkrath, Germany*
www.burkert.com/cut

Stop liquid leaks with this emergency pipe-repair kit

This company has developed a kit that can be used to seal leaks in high-pressure pipes (photo). The system uses specially formulated rubber patches that are slid over a leak and held in place by ratchet straps. The kits can be used to seal leaks in pipes ranging from 2 to 20 in. in diameter, and can cover holes up to 1-in. across. Users who employ the correct application technique can successfully seal a leak through which liquid is escaping at pressures up to 10 bars. The kits can be used in storage-tank farms, as well as many areas of the offshore oil-and-gas, marine, chemical and construction industries. — *Miko Marine AS, Oslo, Norway*
www.miko.com

A new name for new and refurbished IBCs

This company's Ecobulk intermediate bulk containers (IBCs) have been widely used in the industry. The modular design enables them to be configured to suit numerous requirements, including: providing special protection for highly permeable filling products; meeting the high hygiene standards for foods; or customizing for deployment in high-bay racking systems. The modular design of the Ecobulk is also a decisive factor in complete recyclability, providing economical and ecological efficiency. In order to make the close link between originality and quality instantly visible on its reconditioned IBCs, the company has launched a new brand name: Recobulk. Both packaging versions now have Ecobulk/Recobulk embossed on the label plate in order to document the recyclability of both products. — *Schütz GmbH & Co. KGaA, Selters, Germany*
www.schuetz.net

Continuously analyze up to 12 gases simultaneously

The Rosemount CT5400 continuous gas analyzer (photo) combines tunable diode laser (TDL) and quantum cascade laser (QCL) technologies within the same analyzer, and uses a patented "laser chirp" to provide near-instant high-resolution spectroscopy to detect and identify a range of molecules in both the near- and mid-infrared range with an enhanced dynamic range from sub parts per million (ppm) to percent levels. Unlike traditional process-gas analyzers requiring continuous calibration and verification, and other single laser-based systems that are limited to measurement of one or two components, the modular and scalable design of the CT5400 can incorporate up to six

high-resolution laser modules and can detect, measure, and monitor up to 12 critical components simultaneously. The CT5400 rack-mounted analyzer is designed for process applications, DeNOx/SCR, ammonium nitrate precursors, continuous emissions monitoring systems (CEMS), and continuous ambient monitoring systems (CAMS). — *Emerson Process Management, Shakopee, Minn.*
www.emersonprocess.com

Market introduction of a new CPVC welding rod

Key technologies for connecting semi-finished products in both pure thermoplastics and dual laminates are rod welding and extrusion welding. The post-chlorinated polyvinylchloride (CPVC) welding rod is therefore an important component for the entire system. Until now, many different CPVC rod qualities have been used, requiring precise specification and control of correct implementation. Together with fabricators GF DEKA and Simona, this company has developed a new welding-rod generation, which was commercialized last month. The new CPVC welding rod is available in diameters of 3 and 4 mm, and offers the following advantages: genuine system behavior with regard to corrosion resistance; compatibility with sheets and pipes; matching and exceeding the performance of state-of-the-art CPVC welding-rod products (for instance, in contact with wet chlorine or anolyte); and more. — *Lubrizol Advanced Materials Europe BVBA, Brussels, Belgium*
www.lubrizol.com

This bimetal thermometer is now qualified for –70°C

This company has extended the range of its model 55 bimetal thermometer (photo), which is now available in a version that can withstand ambient temperatures down to –70°C. Following the release of the PG23LT pressure gage, the company now also has a mechanical temperature-measuring instrument available for operation in extreme cold conditions. All components of the elastomer-free case are made of stainless steel, and its filling to prevent condensation is specified

Wika Alexander Wiegand

accordingly. Other environmental influences are prevented through IP65 and IP66 ingress protection (in accordance with EN 60529/IEC 60529). The device has a total measurement range of –70 to 250°C. — *Wika Alexander Wiegand SE & Co. KG, Klingenberg, Germany*
www.wika.de

A new generation of liquid-concentration analyzers

SensoTech

The new LiquiSonic V10 (photo) is an inline analytical solution for determining the concentration of process liquids. The sensors and controllers of the new V10 generation have advanced technological components, functional design and valuable features that increase user benefits, says the manufacturer. The sensor design includes a new electronics enclosure, which is characterized by increased compactness and maximum robustness. The use of the latest technology allows even more precise and faster measurement and improved repeatability. The V10 sensors use less energy and meet the increased requirements on energy efficiency and environmental protection. For use in hazardous areas, the V10 sensors are ATEX-, IECEx- and FM-certified, while other V10 sensor types are 3-A certified for use in the food and pharmaceutical industry. — *SensoTech GmbH, Magdeburg–Barleben, Germany*
www.sensotech.com ■
Mary Page Bailey and Gerald Ondrey

pH Measurement in Industrial Waters

Department Editor: Scott Jenkins

Determination of pH is a critical and ubiquitous operation whenever water is used in the chemical process industries (CPI). This one-page reference provides a review of pH chemistry and information on pH measurement equipment in CPI applications.

Chemistry of pH

The quantity pH is a measure of the acidity or basicity of an aqueous solution. It is expressed as the negative logarithm of the activity of hydrogen ions in solution (pH = – log aH^+; where aH^+ is the activity of hydrogen ions). Effectively, the activity represents the concentration of hydrogen ions. However, hydrogen ions (that is, free protons) do not exist by themselves in solution. H^+ ions quickly bond with surrounding water molecules, making H_3O^+ (hydronium ion).

Because the pH scale is logarithmic, a change of one unit of pH corresponds to a ten-fold change in hydrogen ion concentration. In a sample of pure water, it has been determined experimentally that the auto-ionization of water results in a H^+ concentration of 10^{-7} mol/L, which is equal to the concentration of OH^- ions. Because of this, neutral pH is said to be equal to 7.0. Values below 7 are acidic, while those above 7 are basic.

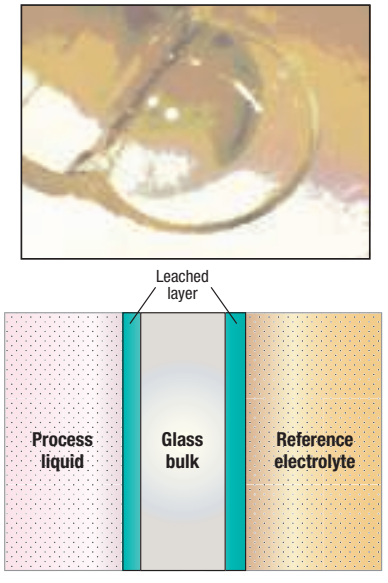

FIGURE 1. A typical bulb of pH-sensitive glass in a pH sensor is shown at the top and a schematic representation of the "leached" layer formation on the both sides of the pH-glass is shown below. If the pH of the reference electrolyte equals that of process solution, then no potential (E) is generated across the glass. Typically, the reference electrolyte is buffered to pH 7, so no voltage is generated if the process liquid has the same acidity as the buffer. If the process liquid is acidic, then $E < 0$, and negative potential is generated. If alkaline, $E > 0$, and positive potential is generated

pH electrodes

Measurement of pH is generally accomplished with a pH-sensitive electrode. In a glass pH sensor, the glass responds to the acidity level. pH electrodes consist of an inert glass tube with a pH-sensitive glass tip, usually with a bulb-shaped end. The tip contains a fill solution with a known pH. The electrochemical influence of the fill solution compared to the process solution generates a millivolt electrical potential. The glass electrode is coupled with a reference electrode and a temperature-sensing element (to account for the temperature dependence of pH).

pH electrodes use specially formulated glass capable of generating electrical potential (voltage) that is proportional to the pH of the solution it is measuring. In a standard pH-glass electrode, the sensing element is a gel layer with sub-micron thickness on the glass bulb. The potential change is measured in relation to a reference electrode that is in contact with the solution, such that a closed electrical loop is created.

Specific formulations of the pH glass are trade secrets for pH-sensor manufacturers. However, it is not a secret that alkali metals render silicate glass pH-sensitive. The "leached" layer is formed on the surface of the glass membrane once it's hydrated (Figure 1). The glass electrode must therefore be kept in an aqueous solution — once the glass is dehydrated (if the bulb is not immersed or is exposed to non-aqueous chemicals) the leached layer disappears and the sensor stops working or develops an erratic signal. The leached layer is only about 5–10 nm, but it contributes the most toward the conductivity of the pH glass.

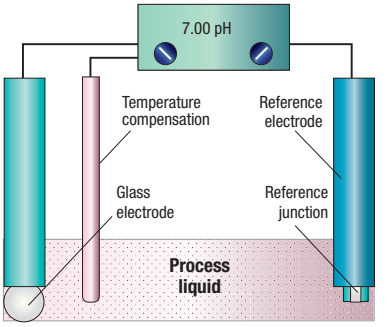

FIGURE 2. The glass electrode creates a potential proportional to the pH of the process liquid, while the reference electrode completes the electrical circuit and provides a small and stable potential as a reference for the pH signal. Electrode temperature compensation is highly desirable, especially at elevated temperatures

Reference electrodes

The purpose of the reference electrode is to create a stable reference potential against which the pH signal can be measured. Having a constant reference potential is essential for high-impedance measurement. The typical reference in commercial pH sensors uses a potassium chloride electrolyte. The consistency of the electrolyte can vary from liquid to gel to solid in order to slow down the migration of process ions inside the reference that come in through the reference junction (Figure 2). Depending on the application, the chemistry of the electrolyte can be changed to satisfy specific requirements of the chemical process. The competitive marketplace offers "rebuildable" sensors with a variety of fill solutions.

The reference junction is usually a part of a rebuild-kit and is pre-soaked in the corresponding electrolyte solution. The choice of the materials for the reference junction can vary from Teflon to ceramic, to wood. The purpose of the reference junction is to provide electrical continuity with the process liquid. It also serves as a guard to prevent the process liquid from penetrating and contaminating or poisoning the sensor. ■

Editor's note: The pH section was based on information from several sources, including the International Union on Pure and Applied Chemistry (IUPAC) Goldbook (goldbook.iupac.org). The section on electrodes was adapted from the following article: McMillan G. and Baril, R., pH Measurement and Control, *Chem. Eng.*, August 2010, pp. 32–39.

Terephthalic Acid Production from *p*-Xylene

By Intratec Solutions

Terephthalic acid is an aromatic dicarboxylic acid, mainly used to produce saturated polyesters, primarily PET (polyethylene terephthalate) followed by PBT (polybutylene terephthalate). A small portion of terephthalic acid is employed in other uses, such as polyamides, liquid crystal polymers and plasticizers.

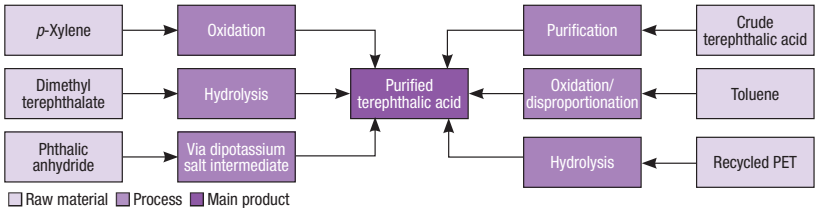

FIGURE 2. Several production pathways exist for purified terephthalic acid

The process

The process described here is a conventional technology for purified terephthalic acid (PTA) production from *p*-xylene, similar to one originally developed by Amoco Corp. (merged with BP in 1998) in the 1960s. Figure 1 presents a simplified flow diagram of the process.

Oxidation. *P*-xylene is mixed with acetic acid solvent and a catalyst solution and then fed to the oxidation reactor. In the reactor, *p*-xylene is oxidized to terephthalic acid, and most of the product generated is precipitated. The unreacted *p*-xylene, along with acetic acid and water formed are partially vaporized and sent to a scrubber column downstream for the recovery of the acetic acid and *p*-xylene. The residual gas from the scrubber is sent to a combustion unit, where volatile organic compounds are oxidized before disposal.

Crude terephthalic acid recovery. The crude terephthalic acid (CTA) slurry from the reactor passes through a crystallization step, and then it is centrifuged and dried. Solvent recovered from CTA crystallizers, CTA drying, scrubber and part of mother liquor from CTA solid-liquid separation are fed to a solvent-recovery step for water removal before it is recycled to the oxidation reactor.

The dry CTA obtained is subjected to further purification steps, since it still contains impurities that make it a product not acceptable in the polyester industry.

Purification. The CTA is dissolved with hot water and then sent to a hydrogenation step. During the hydrogenation, the undesired impurities are converted into soluble compounds, which remain dissolved in the mother liquor in a solid-liquid separation step downstream.

The effluent from hydrogenation passes through a second crystallization step and is subsequently centrifuged to separate PTA crystals from the mother liquor. Part of the mother liquor is then recycled back to the oxidation reaction in such a way that the dissolved hydrogenated compounds are converted to terephthalic acid. Finally, the PTA wet cake is dried and PTA product is obtained.

PTA pathways

PTA has been a commercial product since the 1960s. Since then, several production pathways have been developed, starting from different raw materials. However, most pathways have become unfeasible and, currently, virtually all commercial PTA is produced by oxidation of *p*-xylene. Figure 2 presents different pathways for PTA production.

Economic performance

The total capital investment estimated to construct a plant with capacity to produce 700,000 metric ton per year of PTA in the U.S. is about $790 million (data from the Q2 2014). The capital investment presented includes fixed capital, working capital and additional capital requirements. The production costs (raw materials, utilities, fixed costs, corporate overhead and depreciation costs) are about $1,100 per ton of PTA produced.

This column is based on "Terephthalic Acid Production from *p*-Xylene — Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/terephthalic-acid-production-cost. ■

Edited by Scott Jenkins

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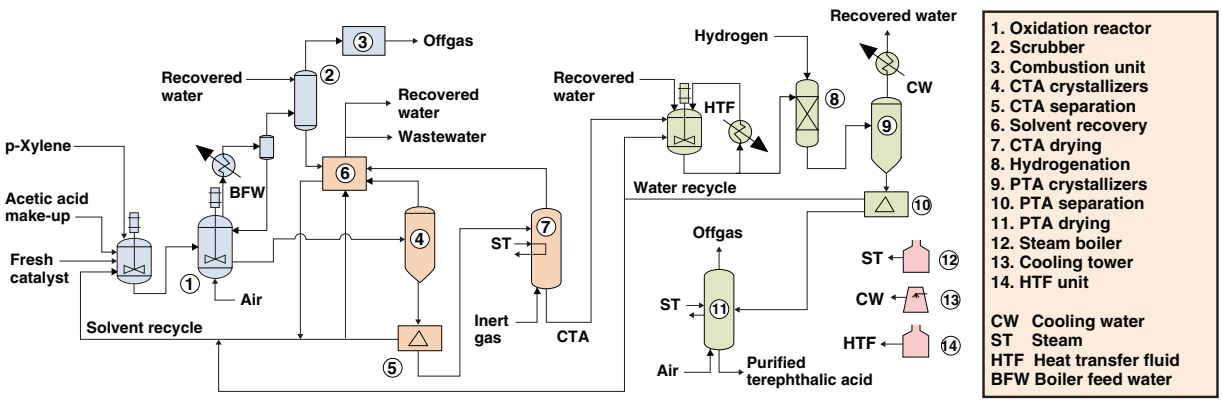

FIGURE 1. The flow diagram shows purified terephthalic acid production from *p*-xylene via a conventional catalytic oxidation process

Advantages Gained in Automating Industrial Wastewater Treatment Plants

Process monitoring and automation can improve efficiencies in wastewater treatment systems. A number of parameters well worth monitoring, as well as tips for implementation are described

JP Pasterczyk
GE Water & Process Technologies

IN BRIEF

IMPLEMENTING PROCESS CONTROL

PROCESS PARAMETERS

IMPLEMENTING PROCESS ANALYTICS

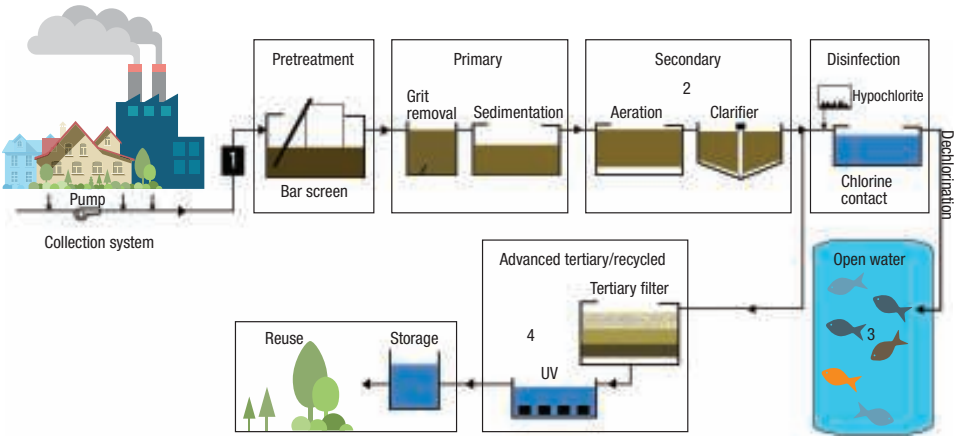

FIGURE 1. Most wastewater treatment systems use a common sequence of steps to treat influent wastewater and then discharge, store or reuse it in line with local regulations. Automating this approach helps an operator more effectively manage and treat wastewater, saving time and money in the process

There is growing interest in automating wastewater treatment processes across a broad range of industries. In particular, a paradigm shift is starting in automating industrial wastewater treatment in various sectors of the chemical process industries (CPI), such as foods (especially grain processing, sugars, sweeteners and edible oils), beverages (mainly soft drink bottlers and breweries), and hydrocarbon and chemical processing (particularly petroleum and petrochemical plants). The driving forces behind this evolution are economic. Wastewater process optimization most often leads to a more efficient use of chemicals, reduced energy consumption and less solid waste.

Most wastewater-treatment systems use a common sequence of steps (Figure 1), with the purpose of first removing solids materials in the influent wastewater, recovering lost product, removing solids, fats, oils and greases (FAG), treating the water biologically and chemically enhancing flocculation, coagulation and physical removal of the biological solids and sludge. The clarified and decanted wastewater is the effluent that may undergo tertiary treatments to be further oxidized or disinfected, or to undergo additional purification, including by granular activated carbon (GAC) or membrane separation, before reuse or discharge to a public sewer or open body of water.

A fully optimized, industrial wastewater-treatment plant will operate at a lower total cost of materials, labor and energy to do the following:

- Remove or reduce large solids and particulate matter (primary)
- Remove or reduce fats, free oil (and grease), dispersed oil and emulsions
- Remove organic materials efficiently (secondary) and withstand higher variable loading, with enhanced, biological activated sludge systems through:
  - Control of dissolved oxygen levels, minimizing energy required for aeration

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More advanced integration of technologies can be applied to meet requirements for reuse, whether within the facility (for example, wash water), for irrigation and agricultural purposes or higher purity applications, like clean water utilities. Depending upon the reuse application and corresponding water quality requirements, tertiary disinfection for pathogens and final polishing with GAC or reverse osmosis (or both) may be needed.

Implementing process control

In general industry, process automation is ubiquitous and integral to upstream control mechanisms and production yield. Statistical process control (SPC) can use process analytical technology to generate high-value data in real- and near-time, and is critical to closely control processes, quality and maximum production yield. There is a prevailing interest across industries to identify opportunities to gain process knowledge by understanding process effluent streams. These waste streams combine to become the wastewater treatment influent. Companies are investing in multiple tools, devices, analyzers and sensors, and integrating these measurements into process automation and control systems for the wastewater treatment plant (WWTP). They are looking at collecting useful data with the right parameters, and applying SPC tools, previously reserved for production purposes, to continually analyze and optimize their wastewater treatment processes. The proper design and execution of experiments can help show the pertinent relationships between multiple parameters that yield the best process performance. The application of this empirical process knowledge can translate into significant performance improvements and efficiencies.

Process parameters

Depending upon the physical and chemical characteristics of waste streams, a number of treatment modules are employed to remove, reduce and change sample stream constituents including, but not limited to, the following:

- Bar screens and strainers for grit and particles
- API (American Petroleum Institute) separators and corrugated plate separation for free oil and grease
- Chemicals and dissolved or induced gas (or air) flotation for oily

solids and emulsified oils
- Biological activated sludge and advanced membranes for organics, nitrogen and heavy metals
- Physical and chemical clarification and advanced membranes for microbial flocs
- Chlorine (gas, hypochlorite and chlorine dioxide solution) and ozone for trace organics and pathogens
- Granular activated carbon (GAC) for organics
- Chemical disinfection for pathogens (typically chlorination)
- UV (ultraviolet) for pathogens, trace organics and residual ozone destruction
- Chemical pH neutralization
- Reverse osmosis for inorganics and minerals

By employing a combination of discrete (grab) and online measurements before, after and at intermediate process points, each module's performance can be monitored and improved over time. Some of the parameters measured by the available probes, meters, sensors and analyzers include: flow, pH/ORP (oxidation-reduction potential), conductivity, dissolved oxygen (DO), suspended solids, specific ions [for example: nitrogen (ammonia, nitrates, nitrites), phosphorus (phosphates), chlorine], total organic carbon, sludge density index and turbidity.

Free oil and grease: Before introduction of the waste stream to the biological or activated sludge system, free oil and grease should be removed or reduced to below a maximum threshold of 50 mg/L, and ideally below 25 mg/L, to avoid interfering with the microbial activity. Some of the negative repercussions of allowing excess levels of free oil to come into contact with the biomass are rapid oxygen depletion, encapsulation of the bacteria, and foaming. Depending upon the levels of free oil, and geometry of the oil droplets, one can use API separators or corrugated-plate separation. Dispersed and emulsified oils are removed and reduced through a combination of chemicals, for lowering pH and enhancing the dissolved or induced gas flotation unit(s).

Organic carbon: The influent, organic carbon loading is a key process parameter for a WWTP, and has historically been quantified using chemical oxygen demand (2 hours) or biochemical oxygen demand (5 days; BOD_5). With the availability of online, process instrumentation for total organic carbon (TOC) analysis, a direct measurement of the organic concentration can be used to improve downstream performance. Specifically, by knowing the exact values of TOC, the plant can be operated to accommodate variation in the amount of organics, and remove them efficiently. For instance, there is often an introduction of chemicals (such as potassium permanganate, hydrogen peroxide or chlorine) after primary solids removal to reduce the total oxygen demand, often referred to as pre-oxidation. This step can be eliminated with lower influent organic concentrations, or minimized by using it only when the load is above a threshold limit based on the plant's treatment capacity.

Dissolved oxygen: In a biological or activated sludge system, there is an opportunity to adjust the amount of dissolved oxygen generated by the aeration system to a level commensurate with the organic load, while avoiding excessive aeration that can shear or tear the biological flocs, which in turn reduces the overall effectiveness of organics and biosolids removal. Continuous monitoring of influent organic loading and dissolved oxygen levels in select zones of the activated sludge basin provide an opportunity to optimize the aeration system, the largest energy expense in the operation of a WWTP.

Food-to-mass ratio: Industrial wastewater-treatment systems are looking at the ratio of organic load or "food," to the total biomass present in the biological system. The biomass of the mixed liquor can be estimated by measuring mixed liquor suspended solids and sludge density. This F:M or food-to-mass ratio, is a critical process control parameter that can indicate system overload or when there are insufficient organics to "feed" the microbial population. The plant operation can use near realtime information

FIGURE 2. Wastewater treatment often involves settling of solids in a tank such as this one

and take actions to address and improve process conditions before they become a stress to the biological system.

Nutrient addition: The organic or carbon loading can be used to assure the most appropriate levels of nutrients, specifically nitrogen and phosphorus, and improve the efficiency of the biological system. The proportion of carbon to nitrogen to phosphorus, commonly referred to as the CNP ratio, conventionally follows 100:10:1 (using BOD_5 instead of carbon). The amount of nitrogen or phosphorus present in a system depends upon the upstream processes and can be optimized using chemical addition, often through pH control. For example, if there is a deficient amount of phosphorus, and a basic pH, phosphoric acid can be used to reduce

FIGURE 3. The flocculation and coagulation steps, which allow small microbial flocs to form and join together for removal by clarification is achieved through a combination of chemical addition and physical separation

the pH while supplementing the phosphorus concentration. Supplemental nitrogen can be added using nitric acid, urea or anhydrous ammonia.

Clarification: The flocculation and coagulation steps, which allow small microbial flocs to form and join together for removal by clarification (Figure 3), is achieved through a combination of chemical addition and physical separation. The chemical feedrates are typically flow-paced, metered in direct proportion to the system flowrates. By utilizing online organic measurements, the chemical addition can be "trimmed" for better performance at a lower chemical cost.

Nitrogen removal: Systems with excess nitrogen can employ a biological or membrane-enhanced nitrification/denitrification process after the aerobic, activated sludge system. Nitrifying bacteria can convert ammonia nitrogen to nitrite, then nitrate, which can then be denitrified to nitrogen gas. These bacteria are more sensitive to process changes, particularly temperature, and may require an alternate food source, such as methanol and molasses, to supplement when nitrogen levels are low. Online nitrogen and organic measurements can be used to regulate the amount of organic food sources used in these applications.

Heavy metals: Some residual heavy metals, such as arsenic and selenium, can be removed through chemical, physical, biological and/or membrane-enhanced processes. These processes may require a combination of pretreatment, pH control and physical treatment steps.

Final polishing and purification: Tertiary treatment typically refers to final polishing, but can be interpreted differently by industry and is dependent upon the composition of the water and the next purpose, whether some form of reuse or discharge. Disinfec-

Continuous monitoring of influent organic loading and dissolved oxygen levels in select zones of the activated sludge basin provide an opportunity to optimize the aeration system, the largest energy expense in the operation of a WWTP

tion can be accomplished by several different chemical and physical methods, such as chlorine gas, sodium or calcium hypochlorite solution, chlorine dioxide, ozone, and UV light (254 nanometer wavelength). After disinfection, the end-of-pipe purpose will determine if additional treatment is necessary. Some industrial utilities have reused wastewater with a GAC step to absorb organics and excess chlorine, and reverse-osmosis membrane separation to remove inorganics and trace organics, achieving higher purity.

Managing process upsets: Upsets in the wastewater process can affect removal efficiencies at each treatment step. More severe upsets can overload a system, even leading to the loss of an entire, activated sludge biomass. The cost and time to reseed and restore lost biomass are significant, often upwards of tens of thousands of dollars and several months. Real- and near-time detection can also be used to prevent or mitigate the negative impact of process upsets. In the case of an unexpected event or excessive "shock" load to the system, the influent, online TOC measurement can be used to automatically divert to an equalization basin or temporary storage vessel, sometimes referred to as a calamity tank.

Effluent discharge monitoring: Meeting regulatory requirements for effluent discharge levels is critical to any business operation. There are continuous monitors for many of the common effluent-wastewater-quality characteristics, including pH, dissolved oxygen, total dissolved solids, total suspended solids, and total organic carbon (often used to trend chemical and biochemical oxygen demand). Finally, effluent pH for discharge should almost always be neutral, ideally pH 6.8 –7.2.

Solids disposal: The biosolids produced

from management of the activated sludge volume in the aeration basins and during clarification, are typically dewatered using a belt press or centrifuge, before being used as fertilizer or disposed of as waste. The cost of sludge handling and dewatering, in energy, chemical usage and disposal, is often the second highest expense in a wastewater treatment facility, after aeration. The ability to use the dewatered sludge as fertilizer is dependent upon the content of undesirable constituents, such as heavy metals or residual pathogens, including fecal coliforms such as *E. coli* (*Escherichia coli*). Instead of land application for agricultural purposes, the solid waste can be compacted or incinerated (or both) to reduce volume for disposal. A more sustainable approach is sending the sludge to anaerobic digesters to produce methane gas, which can be fed to gas-fired turbines to generate electricity.

Implementing process analytics

The data for each measured parameter can be tracked through a data collection and visualization system. A wide range of commercially available software, as well as discrete supervisory control and data acquisition (SCADA) systems, are employed by treatment facilities to monitor critical and complementary water-quality characteristics. With these tools, each treatment module indicates the measured parameters before, during and after treatment, while steady-state conditions can be established to better detect and anticipate upset and sub-optimal conditions. Many parameters integrate into a feedback or feed-forward loop for chemical feed, becoming statistical process control applications. New, multivariate relationships can be tested and inferred through sound experimental design and intrinsically valid, statistical analyses. Good process data leads to process understanding and SPC brings and maintains processes in control. Empirical evidence can support or modify preliminary assumptions and control schemes. This acquired learning can be impacted by changes in the upstream processes, as well as seasonal variations in environmental conditions such as ambient temperature and rainfall.

By employing continuous process monitoring tools and integration to automation and process control systems, more industries are finding better ways to effectively manage and treat their process and wastewater effluents. This automation provides more predictable and controllable processes, reducing the frequency of upsets and assuring a more consistent effluent that meets discharge requirements. The efficiency of the biological system to remove organics depends upon the quality of the upstream processes — oil and grease and solids removal, and the controllable, ambient conditions, such as dissolved oxygen, food-to-mass ratio and nutrient balance (CNP ratio). Utilization of process analytical instrumentation and automation controls enables these facilities to reduce total chemical and energy consumption, and solid waste disposal, by maintaining the dynamic treatment system in an optimal operational state. ■

Edited by Dorothy Lozowski

Author

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Challenges of Handling Filamentous and Viscous Wastewater Sludge

Excessive growth of filaments and biopolymers in activated sludge should be controlled in CPI wastewater-treatment plants, as both lead to sludge that is hard to handle. The sticky behavior of such sludge can be minimized by the addition of polyaluminum chloride

Bart Peeters and Luc Vernimmen
Monsanto Europe N.V.

IN BRIEF

FIGURE 1. Shown here are samples of the activated sludge used during wastewater treatment, to illustrate how its consistency changes during the course of dewatering and drying that is used to carry out volume reduction

For a classic activated-sludge wastewater-treatment plant (WWTP) to work effectively, the sludge flocs need to have good settling properties. Good floc formation allows for an efficient solid-liquid separation to be carried out, after the sludge has removed the organic contaminants from the wastewater in the biodegradation basin. Efficient solid-liquid separation between the sludge and the treated wastewater is typically carried out using simple gravity settling in the final clarifiers to yield a solids-poor effluent stream.

Filamentous bacteria are to blame

It is equally important, during downstream sludge processing, for the sludge to have good dewatering and drying properties, in order to minimize operational issues that can arise in these crucial solid-liquid separation steps. As was discussed in an earlier *Chem. Eng.* article by this lead author [*1*], the solid-liquid separations can be quite problematic due to the "sticky phase" of the sludge (Figure 1). This occurs when sludge is dewatered in part and its physical consistency becomes that of a pasty product that exhibits a high affinity to adhere to the dewatering or drying equipment. This stickiness is caused by the extracellular polymeric substances (EPS), which are produced by the microorganisms and have a glue-like or slimy consistency. This characteristic creates a formidable challenge in WWTPs used routinely throughout the chemical process industries (CPI) [*1*].

In addition to conventional microorganisms, filamentous microorganisms may be present in the activated sludge. These are microorganisms that grow in long strands and are, among other things, characterized by a much larger volume and surface area compared to the usual activated sludge flocs. In an "ideal sludge floc," conventional floc-forming bacteria and filaments — which

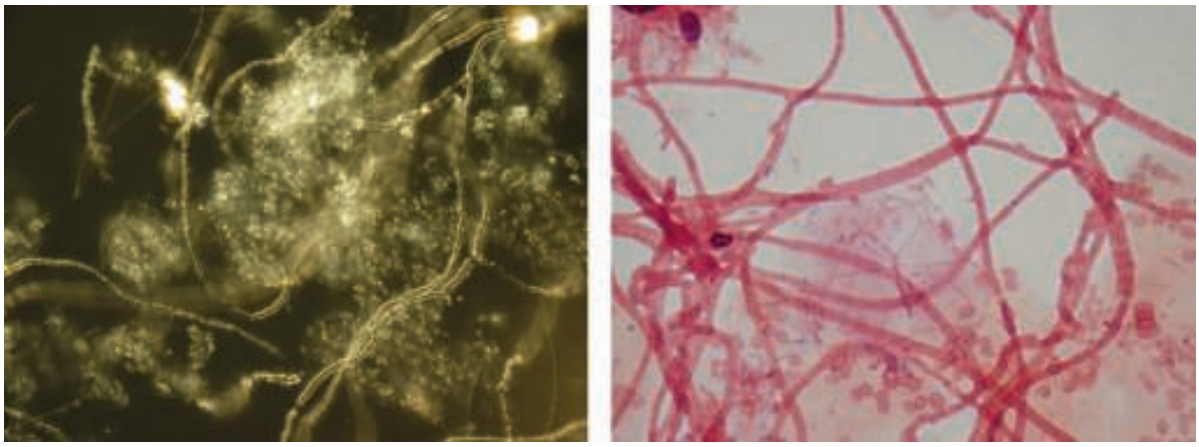


FIGURE 2. Microscopic filaments of *Nostocoida limicola* appeared in the activated sludge (both images have magnification of 400x). In the photograph right, the filaments show up clearly after a staining reaction. The hazy, fluffy-looking clouds are the slimy biopolymers (EPS) produced by the conventional micro-organisms

are retained mainly *inside* the flocs — are balanced, and the filaments provide a backbone to support floc growth and, in this way, the filaments strengthen the flocs [*2–3*].

In the ideal case, when filaments grow largely contained *within* the flocs, the filaments do not interfere with the sludge settleability and compaction. However, when the filaments protrude from the flocs into the surrounding bulk water, their presence will reduce sludge settling and compaction. When there is copious growth of filaments, the filaments themselves lead to bridging between the flocs, and a phenomenon known as "filamentous bulking" occurs. This translates into extremely poor sludge-settling and compacting characteristics [*2–3*]. Because the filaments occupy a large volume, the sludge as a whole cannot settle efficiently.

This article discusses why the excessive growth of filaments and excessive EPS production should be controlled in the WWTPs that are used in CPI operations. In particular, filamentous bacteria produce a variety of negative effects on 1) the sludge settleability; 2) the sludge's centrifugal compaction; and 3) the sludge's sticky phase.

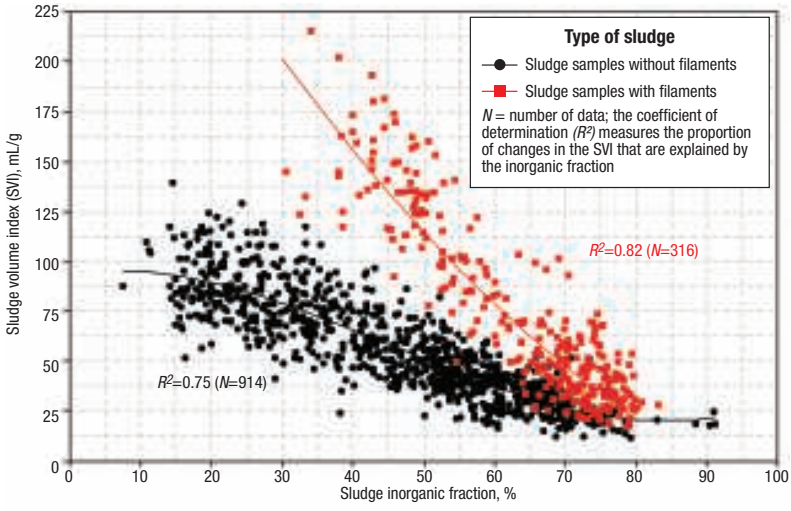
The article also discusses how the stickiness of the hard-to-handle waste sludge that is produced when filamentous bacteria are present can be reduced by adding polyaluminum chloride (PACl) to it — one of the three strategies cited in Ref. 1. The addition of PACl can help to address the operational issues that WTTP operators often encounter during sludge dewatering and drying when sticky sludges are present.

Understanding the challenges

There are more than 30 filamentous bacteria known that can be present in activated sludge. One of them is the filament *Nostocoida limicola,* which showed up in the activated sludge in a Monsanto WWTP (Figure 2). This bacterial population thrived as a result of insufficient phosphorus nutrient in the feed stream to our biodegradation basins, and an insufficient feed-to-biomass (so-called F/M) ratio. Under substrate- and P-nutrient-limiting conditions, these filaments benefit from their inherently high surface area and are able to gain access to scarce essential materials, and this allows them to maximize their growth at the expense of the development of conventional floc-forming bacteria [*2–3*].

Concomitantly with filaments appearing in the sludge in the WWTP discussed here, the resulting shortage of P nutrients also led to increased growth

FIGURE 3. Shown here is the sludge volume index (SVI) as a function of the inorganic fraction of the sludge, using a data set gathered at the Monsanto (Antwerp, Belgium) wastewater-treatment plant over a 12-year period. The data for sludge samples without filaments (shown in black) are taken from Ref. 6, and further extended with extra data points. The data in red are for sludge with filaments.



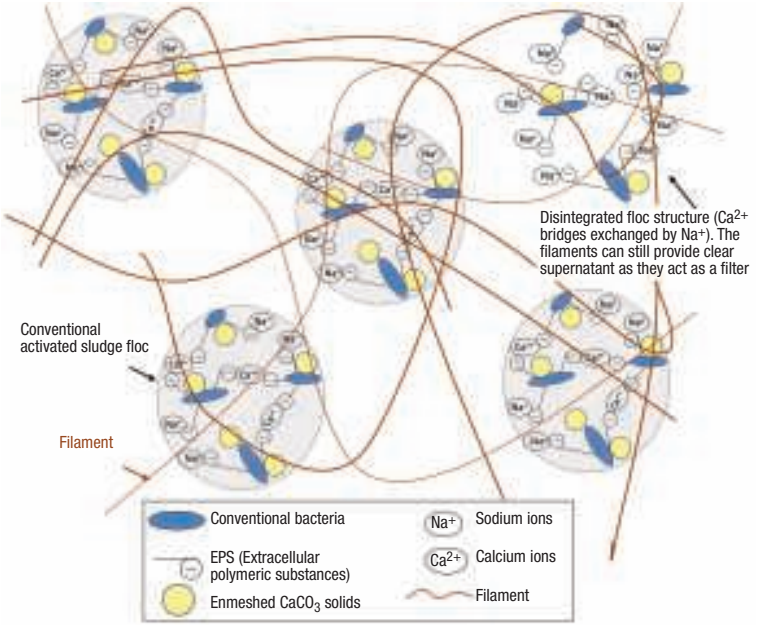


FIGURE 4. This schematic represents sludge that has filaments protruding from the conventional flocs. For illustrative purpose, a disintegrated floc is shown in the upper right corner; it has disintegrated due to a loss of the bridging calcium ions; the filaments, however, do play an important role as a filter, preventing the "wash out" of the small solids that are produced when flocs disintegrate

of jelly-like EPS. These biopolymers are well recognized in the microscopic photographs shown in Figure 2, appearing as hazy, fluffy-looking "clouds." The microorganisms produce larger amounts of these EPS when there is insufficient P and N available. Specifically, when the organisms are not able to produce sufficient P- and N-containing cell material from the breakdown of the organic components in the wastewater, they will, instead, start producing more extracellular polysaccharides.

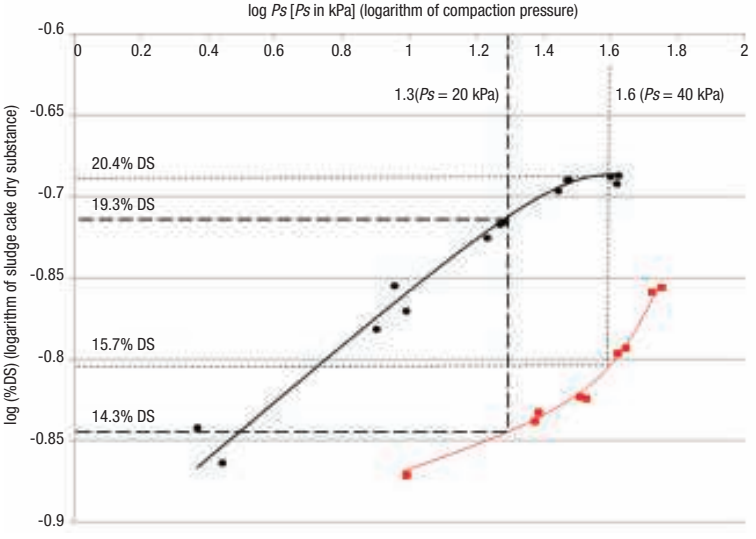


FIGURE 5. As a result of differences in their structure, conventional activated sludge flocs (data in black) and sludge with filaments and excessive biopolymers (data in red) show variable compaction curves (In this case, both sludge samples have a 45% inorganic fraction; DS refers to dry substance)

Impacting settleability

The settling ability of a sludge is measured by means of the sludge-volume index (SVI), which expresses the volume (in mL) that 1 g of activated sludge (referring to dry solid matter) occupies after 30 min of settling. The SVI is determined using an easily performed sedimentation test in the laboratory, in accordance with the Dutch norm NEN 6624 [*4*].

Using this test method, the mixed-liquor sample taken from the biodegradation basin is initially diluted with final clarified water, to obtain a settled volume in the range from 200 to 300 mL/L. The SVI of 1,230 sludge samples (covering a 12-year period, from 2003 until 2015) is shown in Figure 3, as a function of the sludge's inorganic fraction. This inorganic fraction is another important sludge-quality parameter, determined as the complement of the sludge's volatile (organic) fraction, which is determined according to APHA Standard Meth ods [*5*]. The data in Figure 3 are further stratified according to the type of sludge — that is, conventional sludge flocs (data points are shown in black color; N = 914) and sludge with filaments (data points are shown in red; N = 316).

From Figure 3 it can be discerned that the inorganic fraction has a major influence on the SVI. For instance, a higher inorganic fraction produced a heavier floc, and this led to better sludge-settling capabilities, which is represented by a lower SVI value (Note: The WWTP discussed here handles a stream that is characterized by varying and sometimes high levels of calcium [*6*]).

So-called "ideal sludge flocs" (the data points that are shown in black in Figure 3) are characterized by a maximum SVI of about 120 mL/g [*2*], which was attained at a low inorganics fraction of 15%. On the other side of the inorganics spectrum (at an inorganics rate of 90%), the SVI is as low as 20 mL/g.

As discussed earlier, the presence of filaments has a clear detrimental impact on sludge settling. At a high inorganic fraction (for instance, 70%), the negative impact of the filaments remains limited. In the WWTP discussed here, the average SVI increases from 25 to 50 mL/g. This still yields a sludge with very good settling qualities.

However, when the heavy inorganic fraction decreases as a result of less well-precipitated solids enmesh-

ing within the floc structure, the filaments have a more pronounced negative effect on the SVI. For instance, at a 40% inorganics level, the SVI reaches 150 mL/g on average, due to the presence of filaments, instead of 60 mL/g (Figure 3). When very severe filamentous bulking problems are experienced, the SVI can be as high as 700 mL/g [2].

The elevated SVI induced by the filaments does not necessarily imply that the final clarifier effluent will have a poor quality. However, if the SVI becomes so high that the increased sludge blanket in the clarifier causes the sludge to overflow in bulk, the resulting clarifier overflow would be of very poor quality. To avoid this scenario one needs to keep the amount of filaments under control, for instance, by adding the needed P nutrient in this specific case.

On the other hand, readers should note that when filaments are present, they can also help to provide clear supernatant on top of the sludge blanket in the clarifier [2]. For instance, when the conventional flocs disintegrate as a result of the loss of bridging divalent cations (such as Ca^{+2}) [6], the disintegrated sludge flocs — which will not settle well — are retained by the matrix the filaments create. In this case, the filaments themselves act as a filter for the smaller particles that would otherwise result in turbid effluent. Figure 4 shows a disintegrated floc (depicted schematically at the upper right corner), with all divalent Ca^{+2} ions exchanged by monovalent Na^{+} ions.

Centrifugal dewaterability

The centrifugal dewaterability of the sludge is measured using the laboratory protocol discussed in Ref. 7. Figure 5 shows the compaction curve obtained in the past for a sludge without filaments and a 45% inorganic fraction (data for these types of samples are presented in black). With the same 45% inorganic fraction, the sludge with filaments and excessive biopolymers exhibits significantly poorer compaction characteristics, as can be seen from the data shown in red in Figure 5.

As shown in Figure 5, for the filamentous sludge, compaction seems only to begin at higher compaction pressures beyond 40 kPa, whereas at 40 kPa the compaction of the conventional sludge flocs has already attained its plateau of maximum achievable dryness [7]. At this compaction pressure, the cake dryness is reduced from 20.4% for conventional flocs, to only 15.7% for the filamentous sludge. This resulted from the stretched floc structure that is shown in the microscopic photos in Figure 2, and shown in Figure 4.

The poor settling by gravity experienced by filamentous sludge (with a high SVI) discussed above translates, likewise, into poor compaction in decanter centrifuges and other mechanical dewatering devices, such as filter presses [8]. Such sludge results in lower cake dryness after mechanical dewatering (as illustrated by means of the compaction

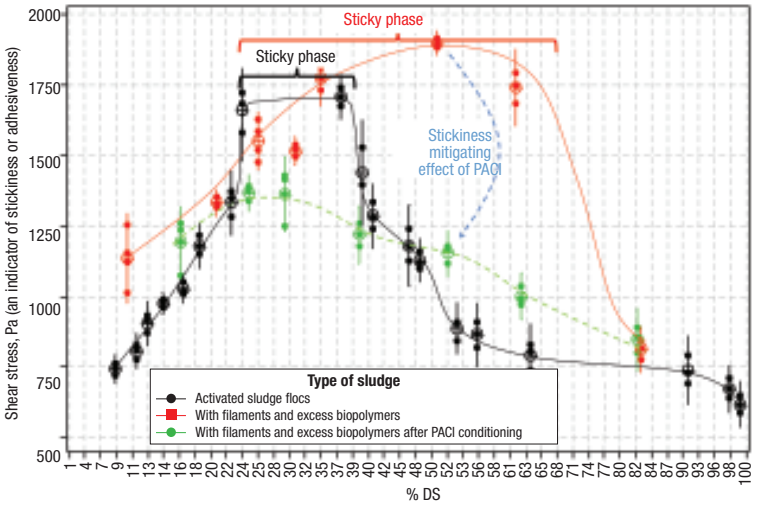


FIGURE 6. The data shown here for conventional activated sludge flocs (in black; data adapted from Ref. 9) and for sludge with filaments and excessive biopolymers (in red) show variable sticky phases (both sludges have roughly a 50% inorganic fraction). The applied PACl dosing of 200 g PACl/kg MLSS (data in green) reduces the stickiness of the filamentous sludge to a great extent. (Note: Data shown are three repeats of the shear stress at every %DS, and the bars are the 95% confidence interval; lines connecting the data are provided to guide the eye)

curves in Figure 5). The next drying stage following the mechanical dewatering will also be hampered by the presence of the filaments as delineated below.

Sticky phase

The detailed laboratory procedure used to map the sludge's sticky phase can be found in Ref. 9, and for a short discussion, readers can refer to Ref. 1. The mapping of the sticky phase for activated sludge with a 50% inorganic fraction is presented in Figure 6. In this figure, the data for conventional sludge flocs are represented in black, while the data for the filamentous and viscous bulking sludge (with an SVI of 160 mL/g) are shown in red. The most striking observation that can be made regarding the range of DS values that will yield a sticky phase is that the sludge with filaments has a markedly widened sticky phase — from roughly 25–70% DS. This is a significantly wider range compared to the sticky phase of the conventional sludge flocs (which is typically 25–40% DS) for sludge with approximately 50% organic fraction [*1*].

For both types of sludge discussed here (and in general, for all sludges), the drastic decrease in stickiness — once the sludge has passed through the sticky phase by dewatering, beyond 70% DS and 40% DS, respectively for the two sludges studied in this article — is attributed to the development of gaps at the interface between the contact surface of the equipment and the sludge, which lowers the sludge adhesiveness [*10*]. The surface defects are the result of the increasing concentration of the EPS — which increases as an overall proportion of the sludge as the sludge is being dewatered — to such a degree that these sticky biopolymers cannot unfold anymore on the entire contact surface. This results in the suddenly reduced stickiness that is observed.

For the filamentous sludge, the extended sticky phase is thought to be the result of the network that is produced by the filaments. This network allows for the EPS (which are intertwined with this framework of filaments) to expand the dryness region whereby the EPS can still spread out on the interface, prolonging the sticky phase of filamentous sludge. Hence, filaments may further compromise the sludge dewatering and drying units used in many CPI operations, by reinforcing (extending) the sticky phase caused by the EPS.

Coping with sticky sludge

Three tactics are available to cope with the sticky phase of sludge that occurs during sludge dewatering and drying operations; they are discussed in Ref. 1. One of them — sludge conditioning by the addition of polyaluminum chloride (PACl) — is discussed further here. A key feature of these PACl solutions is that they contain highly charged polyca-

When the organisms in the activated sludge are not able to produce sufficient P- and N-containing cell materials from the breakdown of the organic components in the wastewater, they will, instead, start producing more unwanted extracellular polysaccharides.

tions, $[AlO_4Al_{12}(OH)_{24}(H_2O)_{12}]^{7+}$, mostly referred to as Al_{13}-polymers (see, for example Ref. 12).

A model of these intriguing superstructures is presented in Figure 7, with a so-called ball-and-stick model. As is clear from the structural formula and the model, 12 molecules of hydration water are present in one molecule of Al_{13}-polymer. At high PACl dosages, the

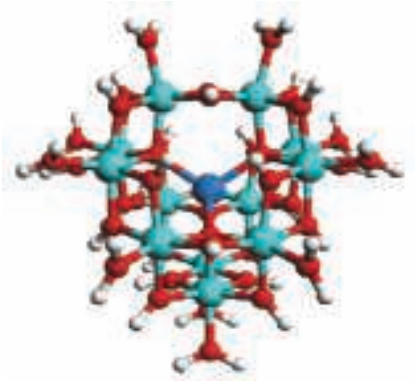
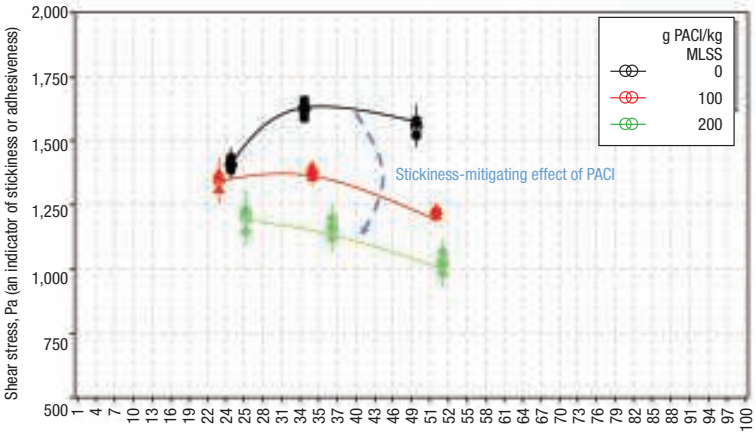


FIGURE 7: This model shows the $[AlO_4Al_{12}(OH)_{24}(H_2O)_{12}]^{7+}$ polycation, which is present in PACl solutions. The aluminum in the central $Al(O)_4$ unit is shown in dark blue, others in light blue. Oxygen is shown in red, hydrogen is shown in white (Source: Saukkoriipi, 2010 [*11*], with permission).



Analysis of variance: (ANOVA)	Source	*DF*	*SS*	*MS*	*F*	*P*
	% DS	2	60,052	30,026	30.3	0.000
	g PAX/kg MLSS	2	712,986	356,493	359.4	0.000
	Interaction	4	96,158	24,040	24.2	0.000
	Error	18	17,854	992		
	Total	26	887,049			

R^2= 97%

Notes: *DF* = degree of freedom; *SS* = sum of squares; *MS* = mean sum of squares; *F* = calculated F-value, *P* = *p*-value (when $p < 0.05$, there is a statistically significant effect), R^2 is coefficient of determination, or the fraction of the variation in the shear stress explained by the variation in the dry substance (DS) that remains after sludge dewatering and the applied PACl dosing

FIGURE 8. The effect of administering 100- and 200-g PACl/kg MLSS (mixed liquor suspended solids) on stickiness is shown. Every shear test was repeated three times, and bars shown are the 95% confidence interval.

Al_{13}-polymers tend to form voluminous clusters sizing a few micrometers [*12*].

The effect of PACl addition to the sludge, at a dosing rate of 200 g PACl per kg MLSS (MLSS = mixed liquor suspended solids), was evaluated, to determine its effect on the stickiness of the filamentous sludge (data shown in red in Figure 6). The PACl used is PAX-14.

The result of the PACl conditioning is shown in green in Figure 6, and clearly demonstrates the curing effect of the PACl on the adhesiveness of the filamentous sludge. This is in line with prior reported results by the authors for non-filamentous sludge [*10, 13*].

PACl-treated sludge barely experiences a sticky phase, thereby significantly simplifying sludge-dewatering operations. This salient and welcome feature of PACl is proposed to occur as a result of the bound hydration water of the Al_{13}-polymers which, once attached to the exterior of the sludge floc structure, enables aquaplaning for the sticky polymers [*10*].

Figure 8 shows the effect of two different PACl dosages on the stickiness of filamentous sludge (100 and 200 g per kg MLSS; this is the equivalent of administering roughly 10 and 20 L, respectively, of PACl solution to a sludge feed of 7 m^3 at industrial scale). The differences in the adhesiveness of the untreated filamentous sludges that are shown between Figure 6 and Figure 8 are likely due primarily to non-identical sampling times, as both sludges have the same SVI of approximately 160 mL/g.

This time, the stickiness was evaluated only at 25, 35 and 50 ± 2% DS (DS = the dry substance that remains after sludge dewatering). The Analysis of Variation (ANOVA) table depicted in Figure 8 (with the dryness of the dewatered sludge cakes rounded to 25, 35 and 50% DS) indicates that 97% of the variation in the observed shear stress is explained by the induced variation in cake dryness and sludge conditioning, with the PACl dosing solely accounting for 80% of the variation in the stickiness. For the sludge studied, increasing the PACl dosing from 100 to 200 g/kg MLSS is recommended, to facilitate sludge handling during the dewatering/drying treatment step. ■

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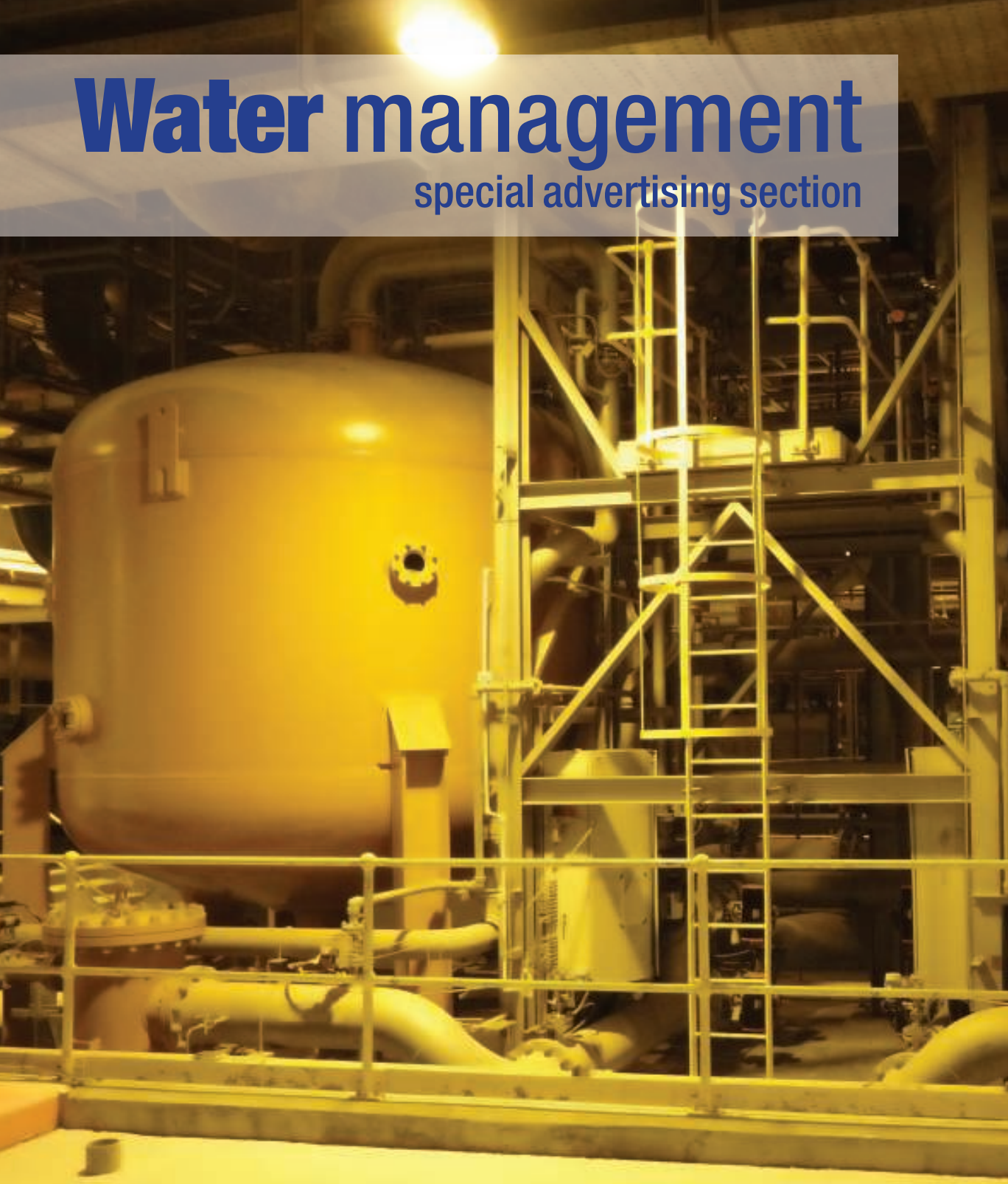
Water management

special advertising section



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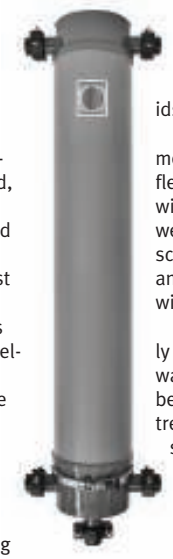
Hollow fiber modules for filtration

AQUADYN hollow fiber modules from MICRODYN-NADIR offer proven benefits



AQUADYN modules provide an effective alternative to conventional treatment

Conventional multi-step water treatment processes are complex, and often require variable amounts of expensive additives to cope with changes in raw water quality. Purely physical separation processes, on the other hand, can be simpler and more consistent. Ultrafiltration is an established water treatment technology that is environmentally friendly and almost waste-free.

AQUADYN hollow-fiber modules from **MICRODYN-NADIR** are an excellent solution for the efficient treatment of large volumes of water. The membrane of the new AQUADYN UA1060 module has a base of hydrophilic polyacrylonitrile (PAN), which has a low fouling tendency compared to membranes made of PVDF and PES. The lack of fouling and the double asymmetric hollow-fiber membranes ensure effective removal of solids and bacteria from the water. Problems such as pore clogging do not occur. Operation in "out/in" mode allows reliable operation even at high solids concentrations.

Effective cleaning and reliable sediment discharge are ensured thanks to flexible flushing modes (forward flush with raw water and air scouring, as well as a backflush with filtrate and air scouring). All this contributes to high and stable permeate performance, with high flowrates at low pressure.

AQUADYN hollow fibers are widely used to treat process water, river water and stormwater. They can also be used downstream of biological treatment plants, as a pre-treatment step for reverse osmosis, and for cooling water. Their compact design allows smaller plant sizes and a high level of plant automation.

www.microdyn-nadir.de

Focus on water

Water is an essential resource in the chemical process industries, from metals extraction to pharmaceuticals. *CE*'s annual Water Management Special Advertising Section focuses on equipment and services for supplying and managing water. Topics covered in the following pages include process water, drinking water, and the treatment of municipal and industrial wastewater. ■

Inside:

Condensate polishing with ammonium-form resin

Careful separation of mixed ion-exchange resins before regeneration allows the cation resin to operate in the ammonium form, greatly extending regeneration intervals

An Ovivo boiler-water treatment plant under construction

High-pressure boilers require high-purity water to prevent corrosion in the boiler circuit and precipitation of silica and other contaminants on the turbine. To ensure high water quality, a mixed-bed condensate polishing system is often used. However, this also removes ammonia that is dosed to prevent corrosion in the boiler circuit. Ammonia removal results in higher consumption not only of ammonia, but also of high-purity water and the chemicals required to regenerate the resin. The **Ovivo** solution to this is to allow the cation resin to exhaust into the ammonium form, continuing to operate the resin bed in service to remove the low levels of contamination found in the boiler circuit. Whereas a standard mixed bed may operate for a few weeks between regenerations, the same resin bed in ammonium form can operate for several months.

This sounds like a simple concept, but the efficiency of the regeneration system is critical to allow this conversion to ammonium form to take place. Before the mixed ion exchange resin bed is regenerated, the cation and anion resins have to be separated. This is necessary to prevent the chemicals used for regeneration contacting the wrong resin and contaminating it. In ammonium-form condensate polishing it is essential that cation resin is not contaminated with sodium from the caustic solution used to regenerate the anion resin. Any cation resin that does contact the caustic will be in the sodium form, and will release sodium into the boiler circuit as the ammonia saturates the cation resin during operation.

The Ovivo Conesep system is capable of separating the resins such that less than 0.07% of the cation resin remains in the anion resin after separation. As a result of this superior resin separation, the system can achieve sodium levels of <0.5 ppb in the treated condensate. Conesep is fully automatic, requiring no manual intervention to detect the resin interface even if the resin volumes are different between the mixed beds.

www.ovivowater.co.uk
www.ovivowater.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 is a pioneer in building valve solutions for OEM equipment and water treatment plant operations. The company has been providing innovative valve solutions to the treatment industry for over 23 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 casts, machines, 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.

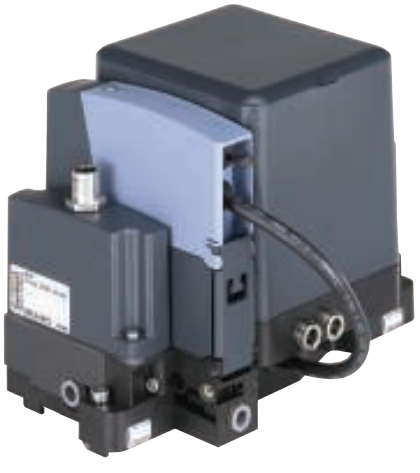
At the heart of Inline's success over the years has been its ability to deliver. Inline's headquarters, located in Rosemead, California, houses an extensive multimillion dollar inventory, machine shop, and automation center, enabling the company to ship 95% of all orders complete within 48 hours.

An Inline Industries 509F three-way valve with electric actuator

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

The self-cleaning analysis system

The Bürkert Type 8905 Online Analysis System is a valuable aid in drinking water treatment; the addition of a new automatic cleaning module further simplifies its operation



Bürkert's Type 8905 Online Analysis System supports waterworks in monitoring the most important water parameters and complying with the relevant legislation. The system gives drinking water treatment specialists an overview of the measured values. By aiding the optimization of individual treatment steps, this contributes to the efficient production of safe drinking water. Now, the Online Analysis System can also be cleaned automatically.

The composition of the water itself can contaminate the sensors of Bürkert's Type 8905 Online Analysis System. This is the case with calcium and iron deposits or algae, for example. The formation of coatings can then adversely affect measurements such as turbidity. To ensure consistently good measurements, the sensors should therefore be cleaned at regular intervals, at a frequency that depends on the quality of the water samples.

To automate this task, Bürkert has developed the Type MZ20 cleaning module for dosing of cleaning solutions. It can be connected as an add-on module upstream of the measurement system.

The cleaning module normally executes the cleaning process on a time-controlled basis. However, it can also be programmed individually to clean when certain measurement constellations of the connected sensor cubes exist. Based on the resulting changes in the measured values, the system checks that the cleaning was successful, and repeats the process if necessary.

Commercially available cleaning solutions are pumped from storage bottles into the measuring system. The cleaning system carries out its various functions, such as water sample shut-off, solution dosing and condition signaling, independently and fully automatically via the CANopen-based Bürkert system bus. **www.burkert.com**

The MZ20 cleaning system, which is connected upstream of Bürkert's Type 8905 Online Analysis System, regularly cleans the measuring cells independently and fully automatically

The right solution for every separation challenge

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

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

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

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

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

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

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

andritz.com/separation

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

Plastic diaphragm valves and actuators

Simple, robust, and corrosion-resistant, GEMÜ plastic diaphragm valves find use in a wide variety of industrial sectors

GEMÜ plastic diaphragm valves are available with a variety of high-quality plastic body materials and connections. The plastic diaphragm valves support a large range of industries and applications including chemical, environmental systems, power generation, water treatment, solar, semiconductor, microelectronics, food and beverage, and processing, just to name a few. Many of the plastic diaphragm valves are supported by an extensive line of pneumatic actuators that can be fully integrated into automated systems, allowing industries to save time and money on their operations, while increasing accuracy and efficiency in their performance.

GEMÜ's careful design of the diaphragm valve internals yields a low-friction fluid path with no dead spaces or obstacles where solids can collect

The structure and function of a diaphragm valve is that of a completely enclosed connection, with a weir and short intercepting shaft that accommodates the operation of a mobile seal identified as the diaphragm or membrane. This diaphragm is the essential part of the valve that controls the movement of media through the system the valve is integrated into. The diaphragm valve operates by pressing the diaphragm tightly against the weir, making a fluid-tight seal that prevents the flow of media. Alternatively, the diaphragm is lifted away from the weir to allow partial to full media flow. Operation of a diaphragm valve is therefore very simple, whether at full, partial, or zero flowrate.

GEMÜ leaves nothing to chance in the development and manufacture of its plastic diaphragm valves. Each valve is designed with the challenges of friction, turbulence, debris and trapped air in mind. GEMÜ plastic diaphragm valves are flow-optimized by incorporating a smooth media transition structure. This minimizes friction and turbulence, and reduces the potential for entrapment areas that could cause pockets to form or debris to collect in the system.

Additionally, GEMÜ plastic diaphragm valves utilize highly durable, low-maintenance pneumatic membrane actuators that give precise flow control in high-cycle operation.

GEMÜ plastic diaphragm valves are available with additional considerations of industry needs. These include having the same mounting height planes over multiple nominal sizes, compact plant design, reduced control air consumption for the pneumatically operated valves, and a variety of optional accessories for measurement and control. **www.gemu.com**

Pipe and vessels for starch

German company Südzucker is adding a wheat starch plant to its sugar factory in Zeitz, Saxony-Anhalt. **BUTTING Anlagenbau** (Plant Construction) in Schwedt was commissioned to fit the pipe systems and instal the equipment, as well as manufacturing and installing over 100 vessels.

The vessels and pipework cover all the production areas of the plant, including milling, saccharification, and gluten separation. The scope also includes a pipe bridge from the new starch production system to the existing sugar factory.

In total, BUTTING Anlagenbau laid 27 km of pipes with a total weight of 460 tons. The customer contributed over 120 tons of equipment, in the form of vessels, heat exchangers and pumps. Prefabrication of spools at BUTTING's plant in Schwedt yielded the familiar benefits of time saving and minimization of welding work at the construction site.

BUTTING supplied vessels and pipework for this starch plant

The container sizes range from 300 mm for a separator up to 11 m in diameter for a fresh water tank. Materials 1.4301, 1.4307 and 1.4404 were primarily used.

Although the deadline was very tight, BUTTING Anlagenbau was able to complete the entire scope of provision, including all follow-up orders, within the agreed time. **www.butting.com**

Valveless methanol pump

For small and mid-size wastewater treatment facilities, the QDX valveless metering pump is the answer for low-volume addition of methanol for denitrification, says **Fluid Metering, Inc.** (FMI).

The CeramPump QDX Hazardous Duty Metering Pump has proven to be an excellent choice for methanol metering due to its unique valveless design. This is especially applicable in small- to mid-size treatment facilities, where extremely low flowrates cause valved pumps to become air-bound and lose prime.

The CeramPump has only one moving part in contact with the process fluid: a rotating and reciprocating ceramic piston. The reciprocating motion pumps the fluid, while the rotation is synchronized to alternately open and close the inlet and outlet ports of the pump. At no point are the inlet and outlet ports interconnected, so there is no need for check valves. The pump drive is FMI's QDX Hazardous Duty Drive, typically required for pumping methanol.

The QDX pump doses methanol with no danger of losing prime

FMI has been supplying pumps for precision fluid control for over 50 years.

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fluidmetering.com

Water analysis made easy

Myron L Co. supplies a wide range of portable instruments for water professionals

Myron L Co.'s new ULTRAPEN PT5 dissolved oxygen (DO) and temperature test pen (photo) is accurate, fast, and simple to use. Advanced features include automatic correction for changes in membrane temperature; DO saturation adjustment for altitude and sample salinity; real-time readings; and three calibration methods (air, water, and 0 ppm DO). Its accuracy of ±0.01 ppm DO concentration and ±0.1% DO saturation, combined with waterproof, rugged construction, make it ideal for any DO application.

The ULTRAPEN PT5 is just one of a large number of instruments Myron L Co. has developed over the course of more than 50 years in business. Originally founded in 1957 as a research and development company, Myron L Co. is privately owned and based in Carlsbad, Calif. Today it is a leading manufacturer of high-quality and simple-to-operate conductivity and pH instrumentation.

Applications for Myron L Co. instruments include drinking water, wastewater treatment, environmental monitoring, pools and spas, deionized water, metal finishing, electronics manufacture, textiles, horticulture, and medical dialysis.

Companion products to the ULTRAPEN PT5 are the PT1 (conductivity/TDS/salinity), the PT2 (pH), PT3 (ORP), and PT4 (free chlorine equivalent); all pens also measure temperature. Their compact format belies their quality: housed in durable aluminum, they are tough, accurate and stable, with extensive calibration options not found in other instruments of this class.

Other portable instruments include the powerful ULTRAMETER III 9P with its accompanying titration kit for measuring conductivity, resistivity, TDS, pH, ORP, free chlorine, alkalinity, hardness, Langelier saturation index, and temperature.

The company also manufactures a range of controllers for the continuous control of conductivity/ORP, resistivity, and pH/ORP. Applications include reverse osmosis systems, desalination, power plants, wastewater treatment, metal plating, electronics, pharmaceutical manufacturing, and general laboratory use.

The DS series of portable meters are analog instruments that provide accurate readings of conductivity/TDS at the push of a button. The pDS version adds pH measurement. They cover ranges from 0–50 µM/µS to 0–10,000 µM/µS, or 0–25 ppm to 0–10,000 ppm TDS. Rugged, compact and accurate, they have evolved over 40 years.

To complement its instruments, Myron L Co. offers a wide selection of pH buffers and standard solutions for conductivity/TDS. All are traceable to NIST standards. **www.myronl.com**

The ULTRAPEN PT5 measures dissolved oxygen accurately, in a package that is both rugged and ultra-portable

How to stop water hammer

A new design from Plast-O-Matic Valves eliminates pulsations and safeguards piping

The PDS is a versatile unit that can smooth process flows, reduce pulsations, and absorb thermal expansion

New PDS pulsation dampeners/surge suppressors introduced by **Plast-O-Matic Valves** will steady pulsing flows caused by diaphragm pumps, piston pumps, peristaltic pumps and other equipment, preventing damage to filters, valves, and piping. Pulsation dampening provides the added benefit of smoothing the output supplied by many types of pumps, especially double-diaphragm pumps and metering pumps. This provides a steady, uninterrupted supply to points of use, which will greatly enhance system productivity, prolong pump life, and prevent splashing and foaming.

The unit may also be installed elsewhere in the pipeline to function as a water hammer arrestor. When used properly, water hammer will be reduced to just a few percentage points of the spike that the system would have without using the PDS. This helps prevent a number of flow control problems, including piping vibration and rupture, weakened and leaking connections, damaged instrumentation, valves and filters, loosened pipe supports, and ruptured tanks.

As a pump inlet or "suction" stabilizer – installed as close as possible to the pump inlet – the PDS will take in liquid when the system is pressurized. If the dome is properly charged with compressed air, the PDS will expel the liquid back into the pipeline when the pump draws liquid and the pressure drops. This repeated action ensures a continuous supply of liquid to the pump, reducing strain on the pump and greatly improving pump efficiency.

Like the inlet stabilizer function above, the PDS will take in liquid and function as an accumulator when the system is pressurized. If the dome is properly charged with compressed air, the PDS will expel the liquid back into the pipeline when pressure drops. This cycle is automatic, or the liquid and line pressure can be retained and released as needed simply by using a blocking valve between the PDS and the piping tee.

Finally, the PDS can serve as a thermal expansion tank to prevent rupture of closed systems. **www.plastomatic.com/pds.html**

Complete process control starts with the pump

SEEPEX ALPHA Systems are turnkey skid-mounted chemical dosing units whose use of progressive cavity pumps gives them unique advantages over traditional solutions

The environmental industry assumes that chemical metering pumps must always be subject to heavy monitoring, frequent parts replacement, and ultimate disposal on a regular basis. Pumps are expected to pulsate, allowing a greater opportunity for unstable flow as operators are forced to over- or under-feed chemicals. All this causes unplanned variances, water quality issues, and increased cost and downtime.

Yet it doesn't need to be this way. **SEEPEX**, the leading global manufacturer of progressive cavity pumps, has released SEEPEX ALPHA Systems, a market-driven solution for chemical metering. SEEPEX ALPHA Systems enable complete process control because they are equipped with self-priming NSF/ANSI 61-certified SEEPEX progressive cavity dosing pumps.

The unique design of a progressive cavity pump offers several advantages compared to conventional chemical metering pumps due to the simple pumping principle. A single helical metal rotor turns inside a double helical elastomer stator, forming compression-fit sealed, uniform cavities that progress from suction to discharge. The sealing aids process control because the flowrate is proportional to motor speed. This pumping characteristic provides constant, precise, repeatable metering with minimal pulsations and no vapor lock. Slip is minimized even when fluid temperature, viscosity, or discharge pressure fluctuates.

SEEPEX ALPHA Systems are easily integrated into a variety of water and wastewater chemical metering applications like disinfection, pH control, flocculation, and the removal of contaminants like iron, nitrogen and heavy metals. These plug-and-play skids minimize the time and cost associated with engineering, procuring, assembling, and installing flow control systems. SEEPEX ALPHA Systems can be adapted to any layout and are available in simplex, duplex, or triplex pump configurations for floor or wall mounting. They are delivered complete with user-customized color display touchscreen controls and all necessary components for chemical metering in a single unit. SEEPEX ALPHA Systems handle pressure ratings up to 175 PSI and flowrates of 0.1–350 GPH. Turndown can exceed 2,000:1. All wetted components are corrosion-resistant.

Progressive cavity pumps ensure reliable, pulsation-free dosing

www.seepex.com

Minimizing downtime, maximizing performance

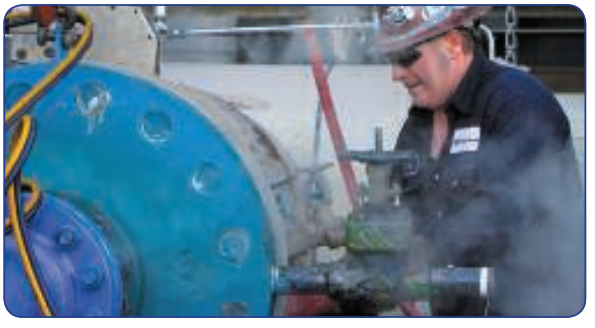
Team Industrial Services offers a wide range of specialized services that allow plant turnarounds to be conducted quickly, effectively, and above all safely

Turnarounds allow for necessary maintenance and upkeep of operating units and are needed to maintain safe and efficient operations. Founded in 1973, **Team Industrial Services** is the worldwide leader in minimizing equipment and asset downtime, providing a number of services to assist with turnarounds and outages including on-line maintenance, inspection and repair. The company provides critical services to its customers that enable them to maintain and operate their facilities and equipment in a safe and productive manner.

Team's line of specialized industrial services includes bolting/torquing, concrete repair, emissions control, exchanger services, field machining, fitness for service, heat treating, hot tap/line stop, isolation test plugs, leak repair, manufacturing/engineering, mechanical integrity, NDE/NDT inspection, project services, specialty welding, turnkey tank program, valve insertion, and valve repair.

Team employs only the best, most qualified technicians to ensure each and every job is completed to the highest standards every time. The company maintains management systems and documented work procedures designed to assure compliance with all applicable laws, regulations and internal requirements, as well as to facilitate the continuous improvement of its processes, products, and personnel. The highest priority at Team is the safety of employees, clients, and other contractors. The company is committed to safety excellence and strives daily for zero injuries and incidents.

Today, Team is rapidly growing its global footprint across a wide range of industries – with service locations in five continents. The company recognizes that its global success is ultimately measured by its customers' trust and confidence, which can only be earned through continuing outstanding service. Team's trained and certified technicians are available worldwide 24/7/365. From single part repair to turnarounds and shutdowns – planned or unplanned – Team has the training, experience, technology and know-how to deliver high-quality maintenance, inspection, and testing services anytime, anywhere.



Safe working methods are always a priority for Team personnel

www.TeamIndustrialServices.com

Webinars address challenges in fluid sealing

A.W. Chesterton Co. has launched a comprehensive series of water and wastewater webinars to help address industry sealing challenges

Clean water is an essential resource for people and their environments. Those who provide drinking water and wastewater treatment play a major role in returning clean, safe water to our homes, businesses and back to its source while being challenged with maintaining operational efficiency.

Chesterton has been providing cost-effective and reliable solutions to these industries for over 75 years and continues to help meet the demands of these critical infrastructures. The company's extensive experience and knowledge of the water and wastewater processes has allowed plants to dramatically improve process performance.

This five-part webinar series will tackle some of the most common but challenging problems facing the industry today. Some of the most experienced application engineers and subject matter experts host this informative series. With well over a combined 100 years of experience on offer, customers are sure to find valuable insight into the real root causes of their fluid sealing problems, and a variety of solutions to manage these challenges.

The next webinar in the series, Challenges of Wastewater Structural Degradation and Mitigation Strategies, takes place Friday, September 2, 2016 from 11:00 AM to 12:00 PM (EDT).

A recent NACE-sponsored report pegged the annual cost of corrosion in the water and wastewater sector in the U.S. at more than $36 billion, Chesterton points out. Much of this has to do with aging infrastructure and operating conditions which have become significantly more aggressive than what the original design construction methods and materials are capable of handling. This webinar will address the state of the marketplace, the mechanisms driving degradation, and the options and methods available to effect change, increase lifespan, cut costs, and increase system integrity. A specific area of focus will be protective coating technologies. Presenter Steve Bowditch will explain the primary coating systems in use, and how the right choice of coatings can slow or halt corrosion.

The correct choice of surface coatings can help to reduce losses from corrosion in the water industry

ChestertonRotating.com

Electric actuators mix performance with ease of use

HRS Series quarter-turn electric actuators from Hayward Flow Control cover a wide range of sizes, torque ranges, and options – in compact packages

The new HRS Series of electric actuators from **Hayward Flow Control** are the result of years of listening to customers' feedback and requirements, combined with the latest actuation technologies. The result is a complete line of quarter-turn electric actuators that bring high performance and ease of use to the market.

HRS Series actuators offer a small footprint for a given torque

The HRS Series provides highly efficient multiplication of motor power to produce uniquely compact torque ranges compared to other technologies. Larger models feature an epicyclic transmission system that negates the need for a brake, as the technology is self-locking. Larger units also offer a standard clutchless manual override capability and are equipped with two auxiliary switches and an internal heater as standard.

The HRS quarter-turn units drive dampers, ball valves, butterfly valves or inlet guide vanes that require torque ranges from 300 in-lb up through 177,000 in-lb. The HRS Series housings are designed to meet NEMA 4X/IP67 environmental demands, with ISO 5211-compliant mountings that readily adapt to most valves in the industries served. Other product features include powder-coated aluminum alloy housings, on/off or proportional control with 2–10 VDC / 4–20 mA inputs and outputs, multiple AC and DC voltages, integrated local control stations, and visual position indicators. HRS Series are CSA certified to CSA 22.2 No. 139–10 and UL 439 for ordinary location applications. The HRS Series is backward compatible with Hayward's EPM Series products to allow ease of replacement. The actuators are backed by Hayward's exclusive two-year warranty.

Additional options available for the HRS series include interchangeable ISO 5211 mounting and drive shafts, positioners, extended duty motors, three-position control, passive analog feedback, torque switches, a 3-phase motor control center, and IP68 submersible rating.

Typical applications include waste water and water treatment, chemical transfer and processing, aquatic and animal life support systems, mining and mineral processing, HVAC, pulp and paper, food and beverage, and marine.

haywardflowcontrol.com

Magnetically Coupled Pumps: Structure, Function and Best Practice

Understanding pump internals, especially the various sealing and coupling arrangements, is a critical step in selecting the optimal pump

Frank Bungartz
Paul Bungartz GmbH & Co. KG

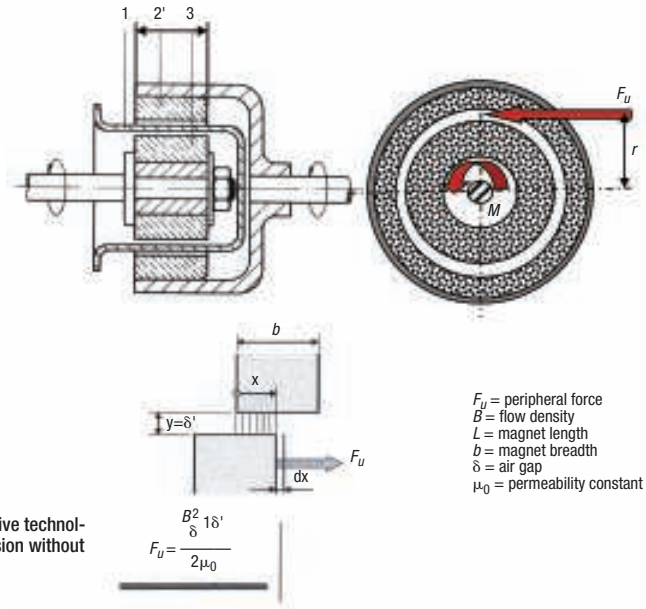


FIGURE 1. Modern magnetic-drive technology facilitates torque transmission without a shaft passing through

IN BRIEF

There is a significant risk for operators associated with the pump selection process. Economic issues, such as procurement and operating costs, as well as matters of safety, environmental protection and proper design must be considered. More recently, the issue of energy efficiency has become more prominent. In the chemical process industries (CPI), the complex interactions between the media to be pumped (for instance, very acidic or alkaline solutions, as well as toxic, corrosive, abrasive, gas-laden or extremely valuable substances) present particular challenges that can be difficult for some types of pumps to master. Painful experience from practice illustrates the problems that are caused by non-functioning pumps. Up to 90% of damage to pump systems is the result of deficiencies in design or operating errors. Often, the damage involves problems such as the occurrence of cavitation or the seal and bearing unit running dry. The associated production downtime quickly leads to high costs. On top of this, there are the time requirements for repairs, all of which impact the total cost of ownership (TCO).

In order to ensure fault-free pumping, it is necessary for new purchases or retrofits not only to include a precise description of the medium to be pumped — the exact data of the system and the circumstances of the installation location are also important.

Introduction to sealing schemes

Centrifugal pumps are considered quite robust, and account for up to 90% of the

pumps used in the CPI. In contrast to displacement pumps, they are suitable for media containing solids, which are frequently encountered in CPI facilities. Among centrifugal pumps' main benefits are their ability to function without closed pumping spaces and the fact that they can work without valves. Their functional principle is based on hydraulics, with an impeller, a casing and the seal and bearing unit. The task of the sealing system is to seal off the rotating shaft against the surrounding environment. The selection and combination of a suitable seal and bearing unit is highly important. The important factor here is the hazard potential that the pumped media represents for the surrounding environment.

For non-hazardous media, suitable seals include the following: stuffing-box packings made from various materials and lubricated with water, grease or graphite; hydrodynamic seals with downstream standstill seals; or labyrinth seals that are open to the environment and have pumping and blocking fittings.

When using shaft seal rings and simple mechanical seals, which are typically lubricated with the product to be sealed against, serious problems can result when there is contact with difficult media. Double mechanical seals can be used, but only if they are isolated and lubricated with a medium that is non-hazardous for the surrounding environment and compatible with the pumping medium. Canned motors and magnetic couplings are likewise in use, where the bearing of the shaft is designed as a plain bearing running in the medium, and where no shaft feedthrough is present.

For media with moderate to high hazard potential, the following sealing systems are suitable: double mechanical seal; magnetic coupling; and canned motor. In the case of mechanical seals, double mechanical seals are differentiated from liquid-sealed or gas-sealed versions. Despite major disadvantages, liquid-lubricated seals are used frequently. The disadvantages include the complex, but necessary, sealing systems, which incur higher maintenance costs. More difficult pumping tasks are performed by another variant, which has proven particularly effective with vertical pumps: the gas-lubricated mechanical seal. These seals are suitable because of the simple gas supply, and are characterized by low operating and maintenance costs. In terms of safety, and particularly where there is a risk of materials escaping into the atmosphere, magnetic couplings and canned motors are the preferred choice.

Hermetically sealed pumps

Pumps with canned motors and magnetic couplings are hermetically sealed pumps, with a comparatively reliable sealing. A rotating magnetic field is used to transfer the torque through the closed, thin, typically metallic wall to the pump shaft. This element is also de-

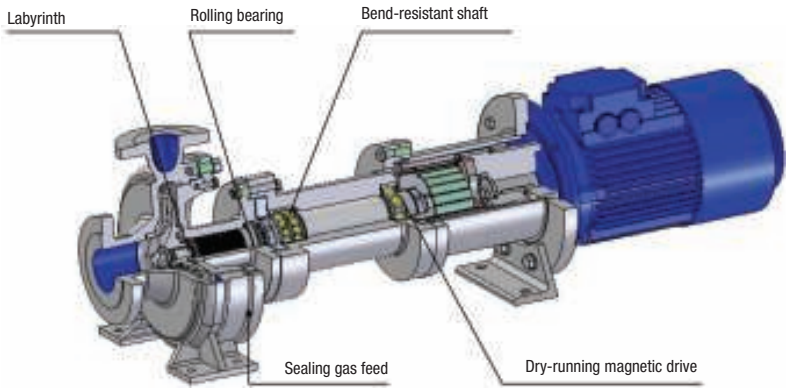


FIGURE 2. In situations with zero flowrate, it is imperative to ensure that the pump and its bearing can properly handle the ensuing conditions

scribed as the containment cup or can. In the canned motor pump, the pump and motor form a single unit. The rotor and impeller are mounted on a single shaft. In contrast to the double mechanical seal (which is sealed using a separate medium), the canned motor pump does not operate independently of the pumping medium. A further disadvantage of canned motor pumps is that in order to pump gas-laden or magnetizable media and solids, certain additional measures must be included, such as external flushing.

The aspects of energy efficiency and lifecycle costs highlight further severe disadvantages. From an energy-efficiency perspective, the canned motor pump is an obsolete model. Its overall efficiency is typically unsatisfactory by today's more rigorous standards. Over 30% of the drive energy is lost through heat generation, or heats the pumping medium. One reason for these poor values is the larger gap between the stator and the rotor. The eddy-current losses in the can and friction losses of the rotor in the pumping liquid are additional factors contributing to these pumps' inefficiency. Apart from the high energy losses from induced eddy currents (in the containment cup or can) and viscosity effects, the high maintenance and operating costs are an important factor when considering lifecycle costs. Compared to the procurement and installation costs (30% of the overall costs), the running costs are extremely high, at approximately 70%.

In contrast to canned motor pumps, a magnetically coupled pump's motor is not in the pumping medium. In the block design, the motor shaft carries the external magnet rotor, which transfers the magnet forces through the containment cup to the internal magnet rotor. Permanent magnets are located on the drive and pump shafts. The medium flows around the containment cup and plain bearing in the magnetically coupled pump (Figure 1).

Both pump types operate without leakage and satisfy even stricter requirements, because the containment cup or can guarantees a hermetic seal against the surrounding environment.

Magnetic coupling functions

The magnetic coupling is characterized by torque transmission without shaft feedthrough. Up to 15% of the drive energy is lost through eddy current losses in the metallic containment cup or through friction losses of the internal magnet rotor in the pumping liquid. Worth emphasizing, however, is the lower heat transmission into the pumping medium when compared to canned motor pumps. Particularly with media that have critical boiling points, the relatively high heat transmission from the motor to the pumping medium, which is typical of canned motor pumps, can lead to complications. If the efficiency of the drive motor of the magnetically coupled pump with a metallic containment cup is incorporated into the analysis, an efficiency advantage of approximately 5% is achieved for the magnetically

FIGURE 3. Simplified maintenance is a major advantage of dry-running, magnetically coupled centrifugal pumps; no complex modification work is required for pump replacement or commissioning

coupled pump when compared to the canned motor pump.

Media with critical boiling points and a proportion of solids represent a further area of consideration. Solids impair the plain bearing and containment cup, and can even disconnect the can. The greatest hazard potential for magnetic couplings relates to the fracture of the containment cup. If fracture occurs, liquid under pumping pressure can then escape into the atmosphere unimpeded.

When the liquid is directed through the bearing arrangement in a magnetic coupling configuration, the flushing flow is directed either from the outer diameter of the impeller through the casing wall, or from the pressure port to the bearing arrangement. The prerequisite here is that the difference between the flushing pressure (PD) and the suction pressure (PS) must be sufficiently high to generate an adequate flushing flow to transport away the heat. The flushing pressure of the bearing is higher than the boiling pressure of the pumping medium, and should be higher than the suction pressure of the bearing.

The heat balance also must be considered. Eddy-current losses and hydraulic losses increase the discharge temperature of the pumping liquid. This heating of the medium must be transported away with the pumping flow; the minimum flowrate is calculated from this.

In order to secure against the risk of a containment cup fracture, double-walled containment cups with leakage sensors or sealing systems

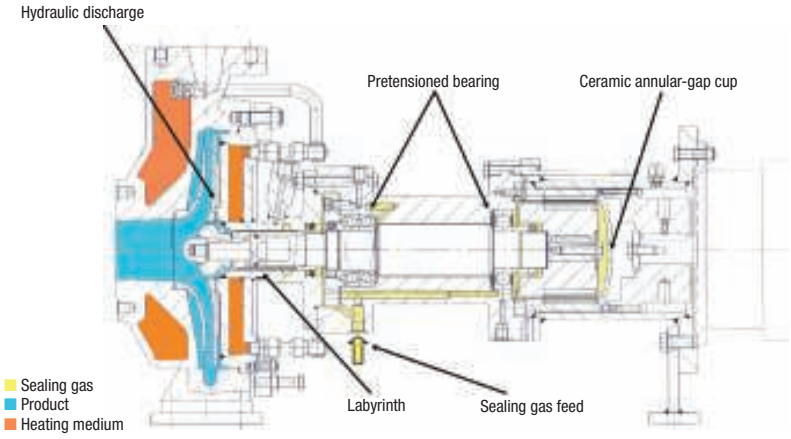


FIGURE 4. A heated variant of a dry-running magnetically coupled centrifugal pump is shown

downstream of the containment cup are used. By contrast, the canned motor is a secure hermetic seal, because after a can fracture, the liquid is first caught by the can, and does not escape into the atmosphere.

Through the use of appropriate sealing or flushing liquids, which are fed into the bearing area, and through complete monitoring of the operating parameters, every hermetically sealed pump can also be equipped for pumping difficult pumping media, such as media containing solids.

Hermetic sealing disadvantages

Hermetically sealed pumps of the kind described here bring about further disadvantages in practice. Firstly, as mentioned before, solids in the medium can block the cooling channels to the containment cup or destroy the bearing arrangement. This increases the wear of the containment cup. Gas components (from inadequate venting or cavitation), boiling or outgassing substances and low-viscosity liquids can interrupt the lubrication of the plain bearing and lead to stalling. Finally, the heating of a partial flow (by the coupling) can result in undesirable or even dangerous heating of the medium.

In order to achieve safe operations while dry running, further measures are required, which are complex and cost-intensive. For example, filters with a coupled differential-pressure monitoring system must be installed upstream of the pump or in a bypass flow. Fault-prone sensors are used for monitoring the containment cup, as well as the bearing and medium temperatures, and gas sensors or protection signals are used for monitoring dry running. Furthermore, to ensure a minimum volume flow, special control technology is additionally used, which again is subject to its own monitoring, and generates additional costs.

Overall, the impairment of the engineering processes is significant. The contamination of the pumping medium with flushing liquids, significant heating of the medium and the high effort dedicated to monitoring mean that a satisfactory result is difficult to achieve.

Dry-running safety

To approach some of the concerns described above, operators may ask how the efficiency of the magnetic torque transmission can be improved without impairing the safety or the bearing arrangement. Furthermore, how can a magnetic-field transmission be effected irrespective of the pumping medium?

First, an understanding of the concept of dry-running safety must be established. Dry-running safety is the ability of a pump to handle difficult operating situations without damage or causing a dangerous situation.

These difficult situations may include pumping processes in which there is only a little or even no pumping medium inside the pump casing, or where gas components occur in the pumping medium.

The solution: the "dry-running" of a magnetic coupling is only possible if the containment cup between

the internal and external magnet rotors permits eddy-current-free magnetic-field transmission. This is only possible through the use of electrical insulators, such as plastics like polyetheretherketone (PEEK) or a sandwich design of carbon-fiber-reinforced polymer or polytetrafluoroethylene (PTFE). Ceramics also work well for this purpose. Because of the eddy currents, a metallic containment cup would quickly heat up to high temperatures. Disastrous consequences can follow — first, comes demagnetization, and then after a few minutes, the total destruction of the coupling and bearing.

The logical conclusion is to use a dry-running bearing arrangement. This solution appears to be possible using ceramic roller bearings, which are manufactured in small unit numbers. They are suitable for a short period of dry running. They will not withstand continuous dry running under high mechanical loads from the hydraulic pump forces. Fundamentally, even plain bearings survive a brief period of dry running, but with extended dry running, there is quickly a risk of the plain bearing overheating. This is associated with the problem that the intake of the cooler pump liquid makes the rupture of the bearing shells unavoidable.

Subsequent development processes thus led to grease-lubricated roller bearings, which operate in a closed gaseous atmosphere. In this extremely clean environment, they achieve a long service life. The sections below describe some dry-running safety characteristics for various types of magnetically coupled pumps.

Conditionally dry-running magnetically coupled pumps. These pumps use special plain bearings that can survive extended dry running. Examples include diamond-coated bearings or ceramic roller bearings.

Zero-flowrate-safe magnetically coupled pumps. In the event of zero flowrate or stalling, the magnetic coupling is supplied by the static flushing pressure from the pressurized side. Pumps that use the liquid reservoir and the static pressure in the pressure line to lubricate the plain bearings in the event of zero flowrate against the open pressure line may include self-regulating centrifugal pumps. The following prerequisites are necessary here:

- The difference between PD and PS is approximately 1 bar, adequate heat removal is available (vapor return) and the flushing pressure of the bearing is higher than the suction pressure PS
- Internal throttling ensures that the bearing flushing pressure is higher than the vapor pressure

Continuously dry-running magnetically coupled pumps. Pumps equipped with a continuously dry-running magnetic coupling and a dry-running roller bearing arrangement include the special centrifugal pumps similar to the one illustrated in Figure 2.

Dry-running centrifugal pumps

Dry-running, hermetically sealed centrifugal pumps (Figures 3 and 4) have proven to be reliable, because the sealing and bearing technology used works independently of the pumping medium. They are far superior to conventional magnetically coupled pumps in terms of the flexibility to permit solid and gas components in the pumping medium. There are also benefits when handling toxic media with these pump types, due to the dry-running, depressurized magnetic coupling.

The bearing mount consists of a shaft with grease-lubricated roller bearings, which can increase the efficiency compared to conventional magnet pumps with plain bearings.

The shaft seal arrangement promotes safer operations as well. The hydraulic depressurization at the impeller and balancing holes reduces the shaft gap pressure to equal the feed pressure. The special labyrinth seal, which is filled with sealing gas between the impeller and the shaft bearing arrangement, separates solids so that they cannot enter into the bearing area. The lip seal ring upstream of the bearing arrangement comes into use if the nitrogen supply fails. The ceramic containment cup, the actual hermetic seal, is thus subject only to low pressures and operates without product contact. The eddy-current-free magnetic field transmission allows significant energy savings.

Low energy consumption is increasingly important, as environmental considerations and rising energy prices are encouraging companies to save energy — particularly in pumping operations. The use of roller bearings and a ceramic containment cup are responsible for these pumps' energy savings in a significant measure. With a realistic runtime of 8,000 operating hours and 10 KWh power consumption, compared to normal magnetic pumps with plain bearings and a metallic containment cup, this adds up to savings in the range of 80,000 KWh per year.

The volume of sealing gas required for the labyrinth seal is approximately equivalent to that of the gas-sealed double mechanical seal. Thanks to the hydrodynamic depressurization of the shaft gap, the required sealing-gas pressure at atmospheric feed conditions is generally no higher than 3 bars gage.

As a result of the minimal load on the containment cup, which works under low pressure in a gas atmosphere and without product contact, a high safety standard is achieved. A potential failure of the sealing-gas supply, which triggers an alarm, represents no immediate danger for the bearing, because a dry-running emergency seal between the labyrinth and the bearing arrangement can operate for a number of hours without sealing gas.

The design of the pump's roller bearing also facilitates pump operation without any liquid filling, eliminating hydraulic bearing forces, making this pump type unconditionally capable of dry running. In contrast to standard magnetically coupled pumps, these pumps can be used for virtually all pumpable liquids without any additional measures. The only monitoring requirements for the pumping system are for the sealing-gas flow. The prevention of operating errors is inherent in the system. As a result of the eddy-current-free magnetic-field transmission and the grease-lubricated roller bearings, this type of pump is among the most efficient standard pumps with single plain bearings.

Specific properties

The low-pressure loading of the containment cup (approximately 3.5 bars gage), which operates in a gas atmosphere with zero product contact prevents explosive mixture s from forming. Because the ceramic or plastic containment cup does not run in the liquid, there is also no electrostatic charging. Furthermore, the drive process and magnetic-field transmission do not cause any heating of the medium. Both of these features represent particular advantages during the pumping of media with critical boiling points.

Maintenance is also an important consideration, and dry-running magnetically coupled pumps have several characteristics that simplify maintenance demands. For instance, the feed pressure is applied only to the labyrinth seal, which operates with zero friction. The sealing-gas atmosphere contains no oxygen, moisture or solids. The grease-lubricated roller bearings have a long service life and may require no maintenance during this period. The bearing grease also has an extremely long service life, and is exposed to virtually no aging processes. In the internal sealing-gas atmosphere, the grease-lubricated roller bearings run free from contamination and moisture, and without oxygen. Because the sealing gas lifts up the lip seals, the pump operates without filters. The labyrinth is cleaned by sealing gas. There are very few sensors required for monitoring, removing some of the most frequent fault sources.

In practice, this type of special centrifugal pump has proven its effectiveness, even in extremely hot applications, such as those with liquid melts. The thermal compartmentalization permits extremely high product temperatures of up to 400°C.

Flexibility of media is another crucial benefit. Because neither the bearing nor the magnetic coupling has direct contact with the pumping medium, and because various impeller geometries can be used, the pump can be used almost completely irrespective of the liquid, even toxic media.

Dry-running, hermetically sealed centrifugal pumps have proven to be reliable problem-solvers, because the sealing and bearing technology used works independently of the pumping medium. Furthermore, they can handle solid and gas components in the pumping media. ■

Edited by Mary Page Bailey

Authors

Frank Bungartz is the director of centrifugal pump developer and manufacturer Paul Bungartz GmbH & Co. KG (Düsseldorf Straße 79, 40545 Düsseldorf, Germany; Email: bungartz@bungartz.de). Employed at Bungartz since 1999, he is the third generation to work at the family-owned company since its inception in 1947. After the university entrance exam and training as an industrial mechanic, Bungartz completed his studies in mechanical engineering with a specialization in international project management. He is an active member of associations and organizations, including the VDMA, the BVMW, the Society of Mechanical Engineers' Association of Pump Manufacturers and Dechema e.V.

AODD Pumps in Chemical Processes

Advancements in efficiency and the ability to handle a wide array of chemicals combine to make the air-operated double-diaphragm (AODD) pump a useful choice for chemical processors

Edison Brito and Rob Jack
PSG, A Dover Company

IN BRIEF

The circumstances surrounding the development of the air-operated double-diaphragm (AODD) pumping principle six decades ago involved a ruptured water pipe, a flooded workshop and an exclamation that the idea could "make a million dollars." In the ensuing 60-plus years, those words have proven to be prophetic, as the AODD pump technology that was said to be "conceived out of necessity, born in the arms of innovation, and inspired by sheer will and determination" has become a frequent choice for operators in heavy-duty industries that require the pumping of water, slurries or any finely divided substance, such as cement.

AODD pumps (Figure 1) can obtain dry self-prime, run dry, maintain suction lift up to 30 ft, withstand deadhead pumping conditions, operate while completely submerged and pass solids of up to 3 in. in diameter. However, in many ways since their invention, AODD pumps have become pigeonholed by many pump users, who see them as only usable in utilitarian, auxiliary or basic liquid-handling and transfer applications.

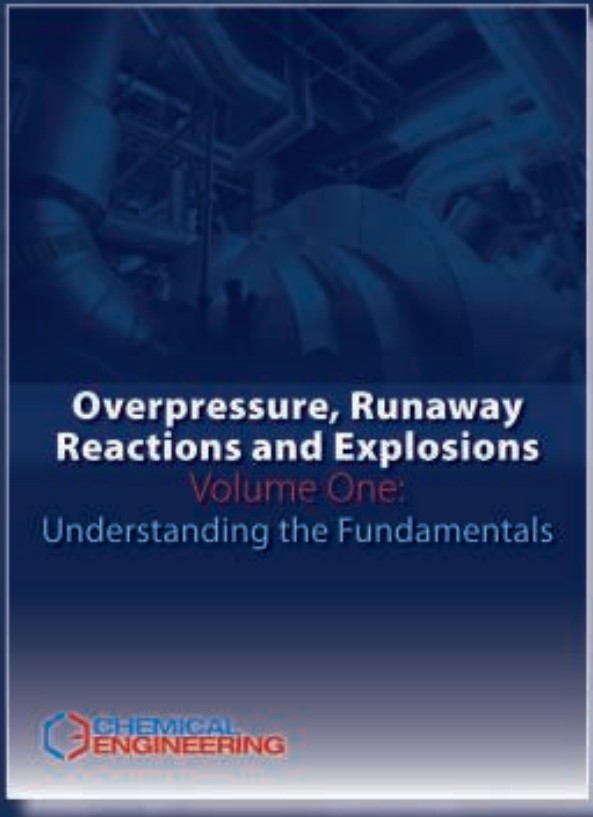
FIGURE 1. AODD pumps can handle a wide variety of materials, including very viscous media, and can also pass large solids

In reality, thanks to a series of noteworthy refinements that have economized the AODD pump's method of operation, the unit can now be considered a true "process" pump and has gained acceptance as such in the diverse sectors of the chemical process industries (CPI), including paints and coatings, ceramics, adhesives and sealants, foods, beverages, pharmaceuticals and cosmetics.

Overpressure, Runaway Reactions and Explosions

Volume One:
Understanding the Fundamentals

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



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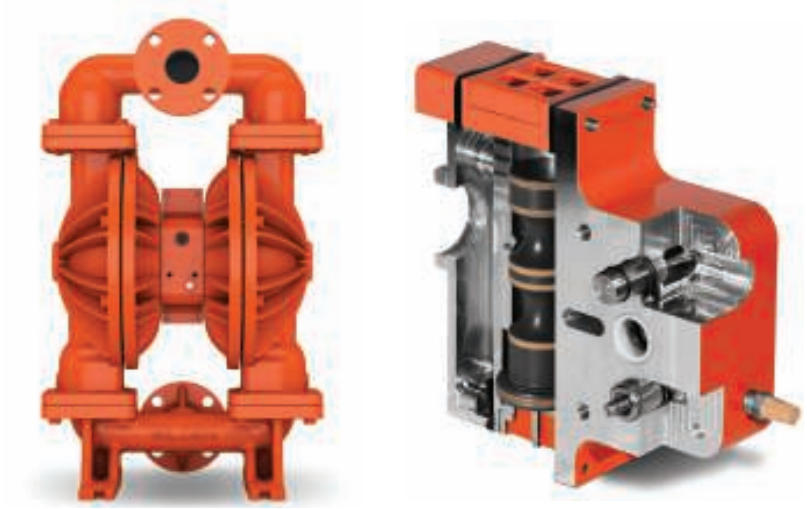

FIGURE 2. The hourglass-shaped air spool (right) within some air-distribution systems decreases overall air consumption and enables the handling of corrosive or hazardous materials

The air in there

Despite the fact that AODD pumps have proven their effectiveness in utilitarian liquid-transfer applications, there has always been one annoying glitch in their operation: at the end of every pump stroke, a small, but still significant, amount of air was wasted. This kept the pump from operating most efficiently and added to its bottom-line cost of operation.

Because of that, AODD pump manufacturers must find methods to decrease or eliminate the air loss at the end of the pump stroke. This led to a series of advancements in the technology behind air distribution systems that have enabled the AODD pump to optimize air usage while still maintaining its operational characteristics.

While air loss has been a constant concern within the operational window of AODD pumps, the earliest air distribution systems were designed first and foremost to battle another operational irregularity in the AODD pump's performance: stalling and icing. It was only once those performance inhibitors were conquered that designers turned their attention to developing ways to more efficiently govern the pump's air consumption.

One of the first air-distribution systems designed to promote energy efficiency featured a dial that could be used to tune the pump's operating speed by restricting the amount of air that was allowed to enter the pump. It's a fact of AODD pump life that a slower-running pump is more efficient. For example, a dial-in air distribution system running at full throttle may consume 50 std. ft^3/min of air in order to pump 100 gal/min of fluid. Using the dial, the incoming compressed air can be dialed back to a 35-std. ft^3/min rate, where the pump will transfer the liquid at a flowrate of 80 gal/min. This is a 20% reduction in flowrate, accompanied by a 30% reduction in air consumption, which makes the pump more efficient.

While the dial-in air-distribution system represented an undoubted advance in AODD pump operation, there was still more field that needed to be plowed if pump performance was to reach true levels of optimized air consumption. A more recent technology for air-distribution systems features an air-control spool (Figure 2), which is shaped, more or less, like an hourglass. This development was driven by an evaluation of the pressure dynamics that occur within the AODD pump during its operation.

This evaluation clearly revealed that air consumption was significantly impacted by an increase in air pressure at the end of each diaphragm stroke. Specifically, when the shaft would come to a full stop at the end of each stroke, a shift signal would be sent to indicate that the flow of air should cease. However, there was a small time lag between the stopping of the shaft and the sending of the signal, meaning that the full force of

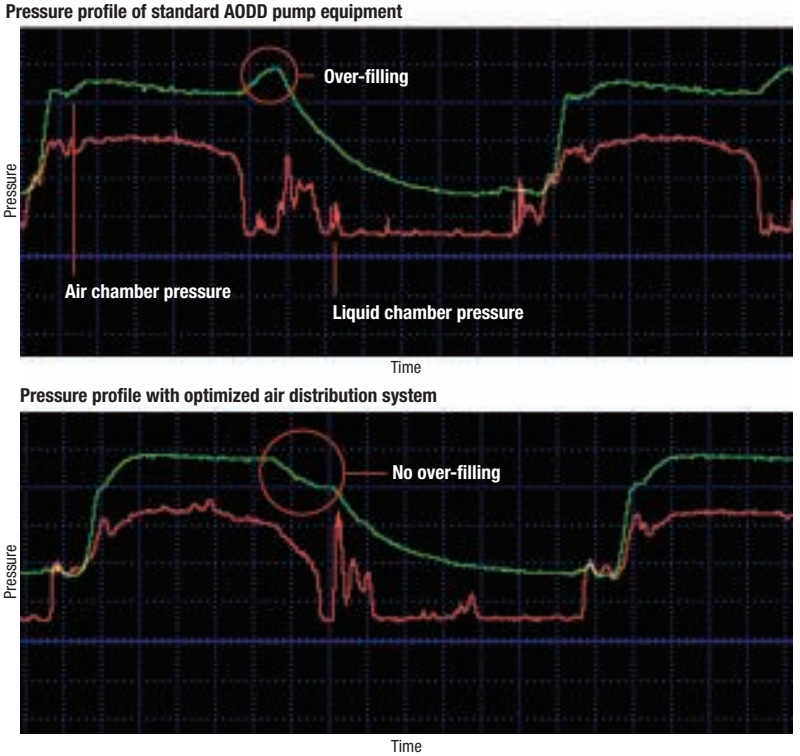

FIGURE 3. Some AODDs experience wasted air when overfilling occurs at the end of each pump stroke, but modernized air-distribution systems allow for more optimized air consumption by eliminating overfill

FIGURE 4. An air-control spool can reduce AODD air consumption by as much as 60%

the compressor continued to push compressed air into the air chamber, but that air was not doing any actual work and was lost to the atmosphere upon exhaust.

The function of the air-control spool is to decrease the amount of air that is allowed into the pump at the end of the stroke, which drastically reduces the amount of "wasted" energy that had traditionally been "force fed" into the pump, as shown in the charts in Figure 3. This allows the AODD pump that is equipped with this type of air-distribution system (Figure 4) to experience up to 60% savings in air consumption, while delivering more yield per std. ft^3/min than AODD pump models that feature legacy air-distribution systems.

Through thick and thin

The favorable reputation of AODD pumps is built on the technology's versatility, or ability to handle a wide range of liquids with varying characteristics. One of the most important fluid properties to consider is viscosity, or the thickness of the liquid that is being transferred. A pump's true best operational efficiency is only achieved if the lowest possible volume of air is consumed while delivering the highest possible flowrate, no matter the viscosity. Specifically, in the operation of AODD pumps, slip is almost eliminated, regardless of the viscosity of the fluid, as it is controlled by the ball check valves in the pump. Other technologies, such as gear, screw and lobe pumps, have fixed tolerances to control slip, which makes them unable to adequately adjust to viscosity changes.

When working with a centrifugal pump, the fluid viscosity is a design factor for the pump equipment and its selection for a specific application.

Impeller dimensions and styles are specifically tailored to be compatible with thick or thin fluids. The specificity with regard to fluid dynamics makes moving a pump from one application to another less feasible. When working with an AODD pump, however, the viscosity need not be a factor for operation. This is a major benefit of the AODD pump in this realm: its ability to handle multiple or different viscosities without regard for equipment setup.

For example, gear pumps may be a suitable choice for very thick oil or viscous liquids, but they are poor choices for thinner liquids like ethanol or water. The AODD pump, on the other hand, operates consistently whether the fluid is thick, thin, particulate-free or laden with particulate matter; its design allows it to pull in the liquid, no matter its composition, and drive it downstream. AODD pump manufacturers do publish viscosity correction tables, but these are simply helpful in predicting pump performance given specific system discharge and air inlet pressures and a known viscosity. In reality, the design of the AODD pump does not need to change for liquids that have highly viscous or very thin consistencies.

Pump flow paths are another area

where recent technological advances can make it easier to efficiently transfer highly viscous or particulate-laden liquids. In fact, some AODD pump models with optimized wetted paths deliver flowrates up to 50% higher than legacy models (Figure 5). This enhanced flow capability may also allow the operator to use, for example, a 2-in. pump where a 3-in. model may have been the choice in the past, with attendant initial cost of ownership and maintenance cost reductions — smaller pumps equal a smaller price.

A caveat must be noted, though, that AODD pumps do have a few performance limitations, most commonly on the suction side of the pump, since the only pressure that is available to bring the liquid to the pump is atmospheric. In cases of extreme suction conditions, the physical location of the pump relative to the pumped media is a crucial component of application success, meaning that the pump should be moved as close to the source of the fluid as possible. This will reduce the line friction leading to the pump. Whenever possible, locate the pump below the supply tank — this will enable gravity to assist the "feeding" of the pump. Also, eliminate as many fittings and elbows on the suction side of the pump as possible. Operators and system designers may additionally consider over-sizing the plumbing leading to the pump, all in an effort to reduce friction on the suction side. Note that these are general recommendations for any pumping system and are not exclusive for AODD pumps.

Discussing diaphragms

There's no question that the improvements in overall AODD pump operation and air-distribution system capabilities have been significant over the years, and the same can be said for diaphragm materials and design. As AODD pumps have begun to be used in more process-type applications, the advances in diaphragm performance have kept pace. Correct diaphragm material selection is critical to ensure safe AODD pump operation. The six primary factors to consider when choosing a diaphragm are as follows:

- Chemical compatibility
- Temperature range
- Abrasion resistance
- Flex life
- Performance
- Cost

To help meet these diverse operational criteria, the number of effective diaphragm materials has also grown and now consists of three basic subsets: synthetic rubbers, such as Neoprene, Buna-N, ethylene propylene diene monomer (EPDM) and Viton; thermoplastic elastomers (TPEs), such as polyurethane, Santoprene, Hytrel and Geolast; and polytetrafluoroethylene (PTFE or Teflon). Manufacturers have experts on hand to help pump users select the best diaphragm material and design for their applications.

FIGURE 5. AODD pumps' flow paths can be optimized to further reduce air consumption

Advances have also been made in diaphragm design that help make the AODD pump more hygienic in its operation, which allows its use in contamination-sensitive manufacturing applications like food and beverage, pharmaceutical and personal care. Integral-piston diaphragm designs place the shaft-connecting plates within the diaphragm itself, which means that all product-entrapment areas and leak points between the piston and diaphragm have been eliminated, resulting in a reduction in the chance that product contamination or leaks will occur.

Integral-piston diaphragms are also easily cleanable and there is no interaction between the diaphragm and the outer piston plate that can lead to abrasive diaphragm failure. For the chemical facility operator, downtime and pump maintenance are typically more expensive than the spare parts required to keep the AODD pump operating. This allows the pump to run twice as long before requiring maintenance and will translate directly to a healthier bottom line.

In general, standard AODD pump builds that feature PTFE diaphragms have a Neoprene backup for reduced-stroke configurations and a Santoprene backup in full-stroke configurations. Santoprene is actually an excellent backup choice for both reduced- and full-stroke diaphragm configurations since it has excellent chemical-resistance properties and long flex life. Another option is Hytrel backup diaphragms; this material has the lowest compression set of any elastomer in use and performs well in sealing the diaphragm at the inner/outer piston interface and the outside diameter bead.

Chemically speaking

So, what does all of this mean for the CPI? Chemical manufacture features some of the most intricate and complex industrial processes in the world. The complexity of chemical manufacture is highlighted by the vast number of unit operations that must be completed during the overall manufacturing process.

One of the most critical of these unit operations is the transfer of liquids along the production chain. Because of the importance of the myriad transferring operations within the entire chemical-manufacturing process — raw materials to storage tanks, raw materials to blending tanks, finished products into fixed-weight containers and so on — facility operators must identify the best pumping technology for the job, one that possesses the versatility to perform reliably and efficiently at any number of points in the production hierarchy.

It had almost become an automatic choice among chemical manufacturers that centrifugal pumps were the best technology for transfer op-

FIGURE 6. A major advantage of AODD pumps is the simplicity of their integration into existing plant footprints

erations within the chemical plant, for several reasons:

- Centrifugal pumps work best with thin, water-like fluids, which have long been a staple in chemical manufacturing
- A kind of "if it ain't broke don't fix it" attitude has made the centrifugal pump an easy fallback option for operators who have undoubtedly worked with the technology at some point in their careers
- There was an overriding perception that centrifugal pumps have a lower operating cost when compared to the operations of an AODD pump, but this has been shown to not necessarily always be the case

A closer look, though, shows that despite its reputation, the centrifugal pump doesn't appear to be the all-conquering technology that is required for efficient and optimized chemical-processing applications.

Specifically, centrifugal pumps work best when they are operated at their best efficiency point (BEP). Unfortunately, that BEP is rarely realized for an extended period of time during typical fluid-transfer operations, which can result in flowrates that may fluctuate constantly. Additionally, consistent operation away from the BEP can lead to potential problems, not only from the equipment's operational point of view, but also with regard to the production process and the way the chemical is formulated.

Additionally, when a centrifugal pump operates below its BEP, radial loads increase due to the way the pump generates pressure along its volute by reducing the fluid velocity. This method of operation increases shaft deflection at the seal faces, which results in increased seal wear and a decrease in the pump's life expectancy. Working to the left of the curve will also increase axial loads that can overload the thrust bearings, especially in open-impeller and diffuser-type multi-stage centrifugal pumps. Finally, as a centrifugal pump operates close to the zero-flow point (zero efficiency), heat will be generated at levels that can be highly harmful to heat-sensitive chemicals or products themselves, which can also adversely affect safety and the quality of the resulting product.

At the other end of the spectrum, when a centrifugal pump works above its BEP, other problems may occur. Specifically, the level of net positive suction head (NPSH) required increases, which may cause efficiency-harming cavitation to occur. Since liquid-transfer processes in the CPI, particularly when handling specialty chemicals, are managed in batches, an insufficient NPSH condition may be more complicated to detect, but it will nonetheless deteriorate the pump's operational capabilities continuously, meaning that the pump's ability to handle any resultant cavitation will be compromised.

By comparison, the fluid-delivery curve for an AODD pump is very similar to that of the centrifugal unit, but without the negative behavior that occurs when operating away from BEP. The AODD pump will perform based on the inlet air pressure supplied to the pump and the system pressure it encounters. If adequate suction pressure is available, fluid will flow into the pump and be discharged based on the relationship between the air pressure operating the pump and the system pressure.

The larger this pressure differential is, the faster the pump will operate, and when the differential is reduced, the pump's operation will slow. This is referred to as "infinitely variable speed operation." If the system pressure should increase unexpectedly, the pump will operate until the inlet air and system pressure are equal, at which time the AODD pump will stop — in what is termed a "deadhead" condition — with no equipment damage. The system remains pressurized, but no differential pressure exists to continue driving fluid. The pump will restart when the system pressure falls below the operating air pressure, which is particularly important in batch processes.

In contrast, a closed valve can cause damage to or destroy a centrifugal pump, and with different positive-displacement pump technologies operating against a closed valve, can create havoc for a system by reaching the burst pressure of the piping in very short order.

If a valve is restricted on the inlet side of a centrifugal pump, the pump can cavitate, leading to impeller and volute damage. If the inlet were closed completely, the operator should expect bearing and wear-ring failure due to heat buildup. If this condition occurs when operating an AODD pump, the pump will slow, and if the inlet were closed completely, the pump would stop, waiting for the inlet line to be open once more, when it would resume its pumping operations.

In summation, AODD pumps can match the assumed advantages that centrifugal pumps may have while also highlighting some of the centrifugal pump's operational disadvantages:

- AODD pumps are eminently appropriate for use with liquids with high viscosity and can easily move fluids that range from water-like liquids to medium and very viscous liquids
- AODD pumps can run dry and strip discharge lines without getting damaged; if the pressures are too high, the pump will just stop running, but will not break. On the other hand, centrifugal pumps cannot run dry, and when extra pressure is created, their seals, bearings and piping can break, which leads to added downtime and repair costs, as well as increased safety risks for plant personnel
- AODD pumps are very simple devices (Figure 6), and controlling accessories consist typically of solenoid operators, pump-cycle counters and surge-dampener assemblies
- Operating costs can be similar when all the maintenance, accessories and controllers are evaluated, and in many cases, the total cost of ownership is lower over the operational lifespan of an AODD pump when compared to a centrifugal model

From its inception, the industrial pump has faced the same demand from its operators: perform its duties reliably and with a limited amount of downtime and ancillary repair or replacement costs. The AODD pump's operational characteristics — dry-run capability, high suction lift, particulate-handling, to name a few — can make it suitable for chemical manufacturers who are searching for a pump technology that meshes cost-conscious energy consumption with streamlined flow. ■

Edited by Mary Page Bailey

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Design of Experiments (DoE): How to Handle Hard-to-Change Factors Using a Split Plot

This methodology facilitates multifactor testing. However, it comes at a price: a loss in power for detecting effects

Mark J. Anderson
Stat-Ease, Inc.

The traditional approach to experimentation — often referred to as the "scientific method" — requires changing only one factor at a time (OFAT). Unfortunately, the relatively simplistic OFAT approach falls flat when users are faced with factor interactions, for example, when evaluating the combined impact of time and temperature on exothermic reactions. Because interactions abound in chemical process industries (CPI) operations, the multifactor test matrices that are provided by the design of experiments (DoE) approach appeal greatly to chemical engineers. However, carrying out DoE correctly requires that runs be randomized "whenever possible" [*1*] to counteract the bias that may be introduced by time-related trends, such as aging of feedstocks, decay of catalysts and the like.

But what if complete randomization proves to be so inconvenient that it becomes impossible to run an experiment that is designed in an ideal manner with regard to statistics? In this case, a specialized form of design — called "split plot" — becomes attractive, because of its ability to effectively group hard-to-change (HTC) factors [*2–3*]. A split plot accommodates both HTC factors (for instance, cavities that are being evaluated for their effects on a molding process), and those factors that are considered to be easy to change (ETC; such as the pressure applied to the part being formed).

Split-plot designs originated in the field of agriculture, where experimenters applied one treatment to a large area of land, called a whole plot, and other treatments to smaller areas of land (subplots) within the whole plot. For example, Figure 1 shows two alternative experiments [*4*] that were carried out to evaluate their impact on six varieties of sugar beets (Numbers 1 through 6) that were sown either early (E) versus late (L) in the growing season:

- The top row shows a completely randomized design that was carried out in one field, versus
- The bottom row, which shows the whole plot (a single field) split into two subplots (in this case, parcels with beet crops that were sown early versus sown late)

E5	L1	L4	E2	E6	E3	L3	E1	L6	L5	E4	L2
E4	E1	E6	E5	E3	E2	L2	L3	L6	L5	L1	L4

FIGURE 1. This figure illustrates a completely randomized experiment (top row) versus one that is split into two subplots (bottom row) [*4*]

The split-plot layout made it far sweeter (pun intended) for the sugar beet farmer to sow the seeds according to the proposed grouping, since it is far easier to plant subplots early versus late, rather than doing it in random locations.

Industrial use of the split plot

DoE pioneer George Box developed a clever experiment that led to the discovery of a highly corrosion-resistant coating for steel bars [*5*]. Four different coatings (C1–C4) were tested (which is easy to do) at three different furnace temperatures (which is hard to change), and each experiment was run twice to provide statistical power. The design that Box developed (a split plot) for this experiment is shown in Table 1. Results for relative corrosion resistance — the higher the better — are shown in parentheses. Note the bars being placed at random by position.

Observe in the layout for this experiment how Box simplified the execution of his experiment: in addition to grouping by temperature (which Box called "heats" in [*5*]), he increased the furnace temperature run-by-run and then decreased it gradually. This was done out of necessity due to the difficulties of heating and cooling a large mass of metal. The saving grace, however, is that, although shortcuts like this may undermine the resulting statistics when they do not

TABLE 1. USING A SPLIT-PLOT DESIGN TO INCREASE THE CORROSION-RESISTANCE OF STEEL BARS

Group	Heat (°C) (Whole plots)	Positions (Subplots)			
1	360	C2 (73)	C3 (83)	C1 (67)	C4 (89)
2	370	C1 (65)	C3 (87)	C4 (86)	C2 (91)
3	380	C3 (147)	C1 (155)	C2 (127)	C4 (212)
4	380	C4 (153)	C3 (90)	C2 (100)	C1 (108)
5	370	C4 (150)	C1 (140)	C3 (121)	C2 (142)
6	360	C1 (33)	C4 (54)	C2 (8)	C3 (46)

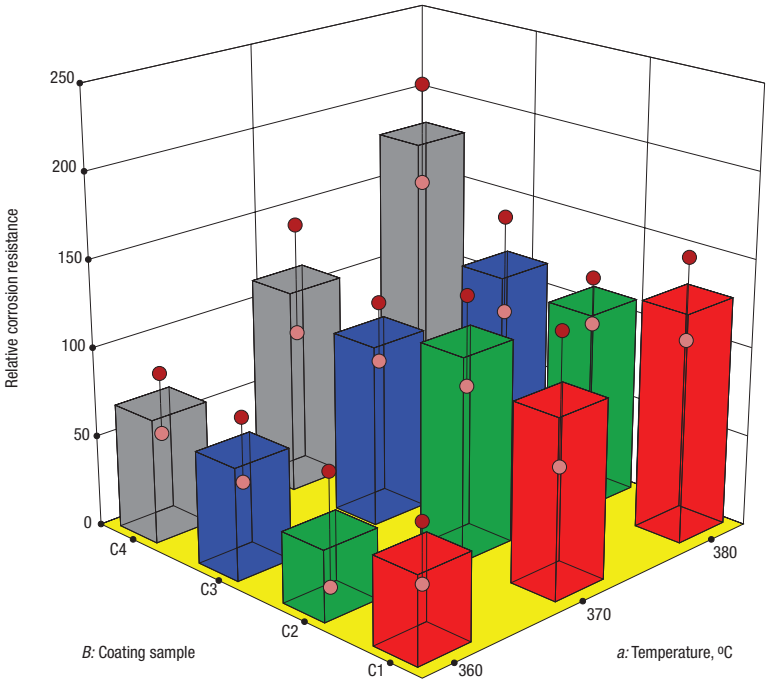

FIGURE 2. In this effects graph, 3-D bars show the impact of temperature (*a*) versus coating (*B*) on corrosion resistance — the higher the better

account for the restrictions in randomization, the estimates for the effects remain true. Thus, the final results can still be assessed on the basis of subject matter knowledge (in terms of whether they indicate important findings). Nevertheless, if at all possible, it will always be better to randomize levels in the whole plots and, furthermore, reset them (for instance, turn the dial away and then back to the same value) when they have the same value (for example, between Groups 3 and 4 in this design).

In this case, as often happens, the resetting of an HTC factor (temperature) created so much noise in this process that, in a randomized design, it would have overwhelmed the ability to detect the effect of temperature on coating performance. The application of a split plot overcomes this variability by grouping the heats (that is, oven batches), in essence, filtering out the temperature differences.

As shown in Figure 2, the best corrosion resistance occurred for coating C4 at the highest temperature (see the tallest grey tower, located at the back corner). This finding — the result of the two-factor interaction *aB* between temperature (*a*) and coating (*B*), achieved significance at $p<0.05$ (that is, a level of statistical relevance exceeding 95% confidence). The main effect of coating (*B*) also emerged as statistically significant.

If this experiment had been run in a completely randomized way, the *p*-values for the coating effect and the coating-temperature interaction would have been roughly 0.4 and 0.85, respectively — that is, not sufficient to be considered statistically significant.

In his work, Box concludes by suggesting that metallurgists try even higher temperatures with the C4 coating while simultaneously working at better controlling the furnace temperature. Furthermore, Box urges the experimenters to work to gain a better understanding of the physiochemical mechanisms causing the corrosion of the steel. This really was the genius of George Box — his matchmaking of empirical modeling tools with his subject-matter expertise.

Some caveats

Split plots essentially combine two experiment designs into one. As a result, they produce both split-plot and whole-plot random errors. For example, the corrosion-resistance design discussed above introduces whole-plot error with each furnace re-set. Such errors arise from potential variation that results from, for instance, operator error in dialing in the temperature, inaccurate calibration, changes in ambient conditions and so forth [6]. Meanwhile, subplot errors stem from bad measurements, variation in the distribution of heat within the furnace, differences in the thickness of the steel-bar coatings and more.

This split-error structure creates complications in computing proper *p*-values for the effects, particularly when departing from a full-factorial, balanced and replicated experiment, such as the corrosion-resistance

TABLE 2. SPLIT-PLOT EXPERIMENTS HELP TO IMPROVE CHEMICAL YIELD

Group	Run	*a* (Temperature, °C)	*B* (Catalyst, %)	*C* (Agitation rate, rpm)	*D* (Feed rate, L/min)	*E* (Atmosphere, nitrogen versus air)	Yield, %
1	1	10	1	120	140	Nitrogen	
1	2	10	2	120	140	Air	
1	3	10	2	100	180	Air	
1	4	10	1	100	180	Nitrogen	
2	5	10	1	120	180	Air	
2	6	10	2	120	180	Nitrogen	
2	7	10	1	100	140	Air	
2	8	10	2	100	140	Nitrogen	
3	9	15	2	120	140	Nitrogen	
3	10	15	1	100	180	Air	
3	11	15	2	120	180	Air	
3	12	15	1	100	140	Nitrogen	
4	13	15	2	100	180	Nitrogen	
4	14	15	1	120	180	Nitrogen	
4	15	15	1	120	140	Air	
4	16	15	2	100	140	Air	

TABLE 3. COMPARISON OF POWER IN SPLIT-PLOT VERSUS RANDOMIZED EXPERIMENTS					
	a	*B*	*C*	*D*	*E*
Split-plot	19%	94%	94%	94%	94%
Random	72%	72%	72%	72%	72%

case. If you really must use this route, be prepared for your DoE software to apply specialized statistical tools that differ from standard analysis.

Furthermore, you cannot expect that doing an experiment more conveniently will not come at a cost — nothing good comes free. The price you pay for taking advantage of split plots is the loss of power to pin down some effects on those factors that are grouped, that is, not completely randomized [*7*].

Consider the experiment in Table 2, which tests five factors at two levels, an example taken from a workshop on DoE [*8*]. The factors are:

1. *a* =Temperature, °C
2. *B* = Catalyst, wt.%
3. *C* = Agitation, rpm
4. *D* = Feedrate, L/min
5. *E* = Atmosphere (blanketed by nitrogen or left open to the air)

Note that the first factor is designated by the lower case letter a to distinguish it as being hard to change (HTC), versus the others (*B* through *E*), which are characterized as being easy to change (ETC).

The objective in this experiment is to determine molecular yield, for which normal variation is 2.5% (this is considered "noise"), and a difference of 5% or more is desired to be detected (this is the "signal"). The actual results are not provided here, as that is not relevant to the issues being discussed here. They are matters of experiment design.

Observe in Table 2 how the experiment design groups the runs by temperature (*a*) — an HTC factor. This is characteristic of a split-plot design, as opposed to a standard DoE that is completely randomized. The other four factors — those that are ETC — are randomized within each of the four groups.

Based on the user-specified signal-to-noise ratio of 2-to-1, and an HTC/ETC variance ratio of 1 (a standard assumption), the DoE-dedicated software [*9*] that was used to build this design computed the power results that are shown in Table 3.

Not surprisingly, the power for the main effect of *a* (the HTC factor of temperature) drops to a fraction of

In some cases, a split-plot design is a viable alternative to a fully randomized design, and accommodates both "hard-to-change" factors and those factors that are considered to be easy-to-change

what it would have been in a completely randomized design — far below the generally accepted level of 80%. On the other hand, the power for the ETC factor effects goes up a bit due to being "protected" from the impact of changing temperature by the grouping.

Furthermore, it turns out that the power for interactions of the HTC with ETCs (that is, the interactions between temperature and catalyst, *aB*), also comes in higher, for the same reason. Thanks to this bonus, a split-plot design such as this one is a viable alternative to a fully randomized design when a factor such as temperature cannot be easily or quickly changed without creating a big upset in the reaction.

Closing thoughts

Keep the power on HTC factor(s) in mind before settling for a split-plot design. Perhaps grouping HTCs for convenience may not be worth this cost — you would be better off taking the trouble to randomize the whole design. However, for many processes, running any experiment may become impossible if it requires certain factors, such as temperature, to be re-set and equilibrated for each test run; the time and expense to do this becomes prohibitive. These are situations for which a split plot can come to the rescue. ■

Edited by Suzanne Shelley

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Author

Mark J. Anderson is a principal and general manager of Stat-Ease, Inc. (2021 East Hennepin Ave., Suite 480, Minneapolis, MN 55082; Email: mark@statease.com; Phone: 612-746-2032). Prior to joining the firm, he spearheaded an award-winning quality-improvement program for an international manufacturer, generating millions of dollars in profit. Anderson has a diverse array of experience in process development, quality assurance, marketing, purchasing and general management. He is the co-author of two books (Ref. 2 and 3) and has published numerous articles on design of experiments (DOE). He is also a guest lecturer at the University of Minnesota's Chemical Engineering & Materials Science Department, and Ohio State University's Fisher College of Business. Anderson is a certified Professional Engineer (PE) in Minnesota, and a Certified Quality Engineer (CQE) in accordance with the American Society of Quality. He holds a B.S.Ch.E. (high distinction) from the University of Minnesota, and an MBA from the University of Minnesota, where he was inducted into Beta Gamma Sigma (the honorary academic society).

Show Preview

Presented by The Water Environment Federation (Alexandria, Va.; www.wef.org), the Weftec 2016 conference and exhibition will take place Sept. 24–28 at the Morial Convention Center in New Orleans, La. In addition to an exhibit hall featuring nearly 1,000 exhibitors, this year's event will include 130 technical sessions and 29 educational workshops. This Show Preview highlights a small selection of the water-related products and services that will be on display inside the Weftec 2016 exhibit hall.

A self-cleaning filter with automatic solids recovery

This company has expanded the application of its Automatic Self-Cleaning Filter and Solids-Recovery System (photo) beyond filtration into the realm of solids management. The patented water filter provides filtration in the 10–100 µm range, and can achieve continuous, fine filtration even in water with ultra-high and variable total suspended solids up to 25,000 ppm. The integrated solids-recovery system utilizes proprietary sensor technology that measures solids buildup electronically and activates an automatic purge valve to remove it. This enables simplified recovery of solids and product in industrial process streams, and a major reduction in diluted wastewater that can significantly lower cleanup expenses. Booth 3129 — *Spiral Water Technologies, Inc., San Rafael, Calif.*
www.spiralwater.com

Gas-tight foam basins for sewage applications

The Evolution E-Series Basin (photo) is a maximum-durability structural foam basin that is resistant to cracks and dents. The E-Series features self-tapping lags for cover attachments and 180-deg dual, raised flat pockets for a tight inlet seal. All basins are gas-tight for sewage and radon-mitigation applications. E-Series basins are available in diameters up to 30 in., with foam covers up to 24 in. Additionally, epoxy-coated steel and non-skid fiberglass covers are available. The basins can accommodate 4-in. composite inlet hubs and require no external stacking ribs that may interfere with the use of external filtration configurations. Booth 2207 — *TOPP Industries, Inc., Rochester, Ind.*
www.toppindustries.com

An interface between sensors, controls and automation

The new Signet 3-0486-D Profibus Concentrator communication protocol (photo) allows users to connect multiple Signet sensors, actuated valves and other products to their automation system, thereby reducing wires, cables, setup time and maintenance. The device meets UL, CSA and IEC61010 safety approvals and is certified by Profibus International. The Profibus Concentrator can interface six sensors, plus an additional 4–20-mA current loop input and output channel with proportionally controlled actuated valves or other 4–20-mA devices. Booth 4401 — *GF Piping Systems, Irvine, Calif.*
www.gfsignet.com

Drain large tanks without mechanically installed nozzles

The Full Drain Outlet (FDO) assembly (photo) drains tanks of 2,500 gal and larger without mechanically installed nozzles. The FDO assembly is suitable in applications where heavy solids or salts can accumulate in the bottom of tanks. The assembly virtually eliminates the need for confined-space entry and difficult maintenance work. The assembly is equipped with a metallic molded insert that is available in 316 stainless steel, titanium and Hastelloy C-276, allowing for storage of a wide range of chemical types. The FDO also features a polyethylene flange adaptor that can be removed so that tanks can be installed on flat surfaces without a concrete pad. Booth 2657 — *Assmann Corp. of America, Garrett, Ind.*
www.assmann-usa.com

Single-stage turbocompressors with a large turndown range

This company's STC-DO single-stage, direct-drive turbocompressor utilizes a high-speed motor with the impeller mounted directly on the shaft. The compressor features turndown to 35%, which is said to be the widest turndown range in the industry. Tai-

Spiral Water Technologies

TOPP Industries

GF Piping Systems

Assmann

GE Power, Water & Process Technologies

lored for use in wastewater treatment in both industrial and municipal settings, the compressor features a flow capacity range of 1,000 to 13,000 m^3/h, and differential pressures up to 1.1 bars. The machine is 100% oil-free and comes with electrical filters as standard. The turbocompressor also boasts low noise production with no pressure pulsations. The company's DualPoint control process allows for independent regulation of the flow and head of the compressor, providing efficiency even at off-design conditions. Booth 7039 — *Siemens USA, Spring House, Pa.*
www.usa.siemens.com

Newark Wire Cloth

Flexible and resilient MABR modules

The ZeeLung membrane aerated biofilm reactor (MABR) utilizes a gas-transfer membrane that is specifically designed for MABR applications. Hollow-fiber oxygen-permeable gas-transfer membranes are distributed longitudinally around the circumference of a yarn-based reinforcing core, resulting in a flexible, yet resilient module (photo). The top header delivers and distributes air to the inside of the fiber lumens, and exhaust gas is collected in the bottom header. Modules are installed in cassettes for deployment in bioreactors. ZeeLung cassettes can be installed directly into a bioreactor, and have little effect on existing equipment and operations. In the low-energy process, oxygen is delivered at an efficiency that is said to be four times greater than fine-bubble aeration processes. Booth 6239 — *GE Power, Water & Process Technologies, Trevose, Pa.*
www.gewater.com

Krohne

Sanitary strainers that can handle a wide viscosity range

This company's product line of SaniClean strainers (photo) is engineered to suit specific requirements in a wide variety of both batch and continuous processes. The strainers are manufactured in single and duplex configurations and can be easily integrated into existing or new piping layouts. The standard material of construction for the SaniClean line is 316L stainless steel, but other corrosion-resistant alloys are also available for handling highly corrosive materials. Rugged construction allows the strainers to withstand rigorous production cycles. Capable of coarse straining and fine-particle filtration, the strainers are available in varying capacities to handle a broad range of viscosities. Booth 7944 — *Newark Wire Cloth Co., Clifton, N.J.*
www.sanicleanstrainers.com

Analytical sensors with integrated transmitter technology

Smartpat is a family of two-wire loop-powered analytical sensors (photo) with integrated transmitter technology for direct connection of the sensors to process-control systems. All sensors are digital and can be calibrated or re-calibrated offline in a laboratory under controlled conditions. For offline calibration, the sensor can be connected directly to a PC running the same FDT/DTM frame applications (for example, PACTware) as applied in common asset-management systems, using a USB interface cable for bi-directional HART 7 communication and power supply. According to the manufacturer, this is a significant improvement over other analog analytical sensors that must be calibrated onsite together with the transmitter, even if installed at remote or difficult-to-reach measuring points, which can also cause sensor calibration to trigger false values in the process-control system. Booth 3807 — *Krohne, Inc., Peabody, Mass.*
www.us.krohne.com

Control dissolved gases without the use of chemicals

Liqui-Cel Membrane Contactors are compact and modular devices that control dissolved gases in liquids without chemicals. They are capable of achieving purity levels of less than 1 ppb O_2 and less than 1 ppm CO_2. Reducing chemical usage can decrease the blowdown frequency due to scaling from chemical deposits. CO_2 removal can improve efficiency and reduces chemical consumption in mixed-bed or electrodeionization (EDI) technologies. Booth 7113 — *3M Membranes, Charlotte N.C.*
www.3m.com/water ■

Mary Page Bailey

Europe

special advertising section

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European equipment and services vendors represent some of the finest technologies and business practices available to the chemical process industries (CPI). This Europe Special Advertising Section shows off just a tiny fraction of the best that Europe has to offer. Topics covered on the following pages include furnace optimization, pumps, valves and actuators, drying, vacuum, solids solidification, packaging, smart management of field instruments, and zero-liquid-discharge (ZLD) plants for water treatment. ■

Inside:

Electric actuators with PROFINET

A new interface for AC .2 actuator controls now allows AUMA actuators to be integrated into PROFINET networks

The increasingly popular PROFINET standard gives actuator manufacturer **AUMA** a second Industrial Ethernet-based networking option alongside Modbus TCP/IP.

"We see an increasing trend towards robust and versatile Industrial Ethernet standards, which combine the advantages of common fieldbus protocols with the speed and proven design of Ethernet-based technologies", says Werner Laengin, Senior Product Manager at AUMA.

The new interface meets PROFINET specification 2.3 and supports Conformance Class B (CC-B). Rates of up to 100 Mbit/s are possible. Implementation into line and loop topologies is facilitated by the integrated switch function. Loop topologies additionally provide redundancy via the Media Redundancy Protocol (MRP). Physical connection is via field-assembled RJ45 connectors. Commissioning, operation, and diagnostics are easy, thanks to features including automatic address assignment.

PROFINET-enabled actuators integrate smoothly into network infrastructures. An integrated web server facilitates connection tests, status requests and fault diagnostics. The standardized device description (GSDML) allows the use of all the commands and feedback signals offered by the Profibus DP protocol.

The new PROFINET interface allows AUMA actuators to be integrated into Industrial Ethernet environments

The PROFINET interface is available now for SA multi-turn actuators and SQ part-turn actuators with AC integral actuator controls.

www.auma.com

Bluetooth simplifies flow and level sensor adjustment

VEGA has added a Bluetooth option to its plics level and pressure transmitters, reducing the need for permits to work in hazardous areas

Level and pressure instrumentation specialist **VEGA** has brought a Bluetooth solution to the market – the first sensor manufacturer to do so, according to the company. A new generation of the Plicscom universal display and adjustment module allows any transmitter in VEGA's plics instrument platform to be remotely operated via a smartphone or tablet app.

In introducing the new Plicscom, VEGA is further enhancing the scope of its plics modular instrument platform. Bluetooth wireless communication is suitable for all industries, and especially applications in difficult-to-access locations, harsh industrial environments and Ex hazardous areas. The new module is backward compatible, which means it can be used on the entire installed base of more than 1.5 million plics sensors, many of which have been in operation since 2002. They are found in plants all around the globe – across all measuring principles, with a proven adjustment system, and without the need for software updates.

Users wishing to take advantage of the Bluetooth functionality simply need to download the VEGA Tools app and insert Plicscom into the instrument. They can then immediately set up and adjust any plics sensor from a safe distance, using a smartphone or tablet. All communications are encrypted for security, and remote display and diagnostic functions are also available.

For those who still want to adjust their plics sensors close-up, a magnetic pen allows contactless operation right through the viewing window of the closed lid. The instruments are thus always well protected from bad weather and dirt. This is a major advantage over optical communication methods, VEGA says. The magnetic pen and Bluetooth option offer another advantage: complex authorizations for working in hazardous areas (hot work permits) are no longer needed for instrument adjustments.

VEGA's Plicscom display and adjustment module with Bluetooth enables encrypted, wireless setup and adjustment, measured value display and sensor diagnostics, all via smartphone or tablet

www.vega.com/plicscom

Securely bagged and wrapped

BEUMER supplies complete packaging lines for the chemical industry, from weighing and bagging, through palletizing, to stretch hood application

The **BEUMER Group** supplies complete packaging lines which fulfill the complex requirements of manufacturers in the chemical industry. These include highly efficient filling, palletizing and packaging systems. Customers also get comprehensive support.

When the BEUMER Group implements a packaging line in the chemical industry, the bulk material typically first passes from a silo along a conveyor section to the BEUMER fillpac FFS (form fill seal) system. This bagging machine is fitted with an integral, high-precision weigher that ensures the accuracy of the bag weights.

High-performance palletizers from the BEUMER paletpac range then stack the bags quickly and accurately on pallets. Depending on the product requirements, the palletizers are fitted with a rotary clamp or double-belt turning device to move the filled bags into the required position. Even bags filled with granulate can be gently palletized, remaining dimensionally stable when stacked.

Finally, customers use equipment from the BEUMER stretch hood series to secure the load. For businesses in the chemical industry, efficient packaging of palletized goods is a crucial competitive factor. The film fits snugly over each product on the pallet, ensuring safe transport and good load stability. The film is highly stretchable and secures the material as it contracts. It is also very transparent and permits a clear view of the packaged goods, so barcodes on the products can be read without difficulty. When the cover film extends to the top of the pallet, the goods are protected on all six sides.

Stretch hood packaging equipment gives extra protection for palleted goods during storage and transport

Customers get a complete solution from a single source and have a reliable point of contact for the whole job. Together with Crisplant a/s and Enexco Teknologies India Limited, the BEUMER Group employs 4,000 people worldwide, and has an annual turnover of about EUR 700 million. **www.beumergroup.com**

Zero liquid discharge: An environmental necessity

Wastewater treatment systems that generate no liquid effluent are efficient in business terms as well as benefiting the environment, argues GEA

Zero liquid discharge (ZLD) technologies provide efficient and environmentally friendly wastewater processing systems that improve in-plant water reuse, enhance product recovery, and convert a fluid discharge to non-liquid waste.

GEA can supply complete ZLD lines comprising the key elements of centrifugal separation, membrane filtration, evaporation, crystallization and drying technologies, offering the following benefits:

- meet stringent discharge regulations;
- treat and recover valuable product from waste streams;
- better management of internal process water streams;
- reduce the need to draw fresh water; and
- minimize energy consumption, transportation and disposal costs.

An example of a fully integrated and customized system is a hybrid ZLD process that GEA developed for a molybdenum production facility. The wastewater contains various sulfates and sodium chloride. With a wastewater capacity of up to 110 m^3/h, the process consists of a brine purification pretreatment section followed by a reverse osmosis pre-concentration unit and subsequent concentration in a falling-film evaporator driven by mechanical vapor recompression. Crystallization and solid separation completes the process, which produces pure water for reuse. The process has shown excellent results, with concentrations of critical compounds (such as colloidal SiO_2, Mn and Fe, which cause fouling and encrustation) below critical limits.

Water conservation is a key consideration for the global processing industries, particularly those affected by the scarcity of available water sources or suitable wastewater recipients. GEA is a single-source supplier of cost-effective, energy-efficient, reliable solutions for wastewater treatment and emission control. The benefits of GEA systems include:

- energy-efficient operation;
- corrosion-resistant materials;
- ability to handle variable waste flows;
- limited cleaning requirements; and
- advanced automation systems.

A high level of expertise in materials and corrosion, and industrial pilot facilities, enable GEA to supply custom-designed systems that are efficient, reliable and technologically advanced. **www.gea.com**

An advanced ZLD system with chemical pretreatment at a molybdenum mine

Measure reformer tube temperatures continuously

A new NIR borescope from AMETEK Land enables the continuous measurement of reformer tube wall temperatures for higher productivity and longer furnace life

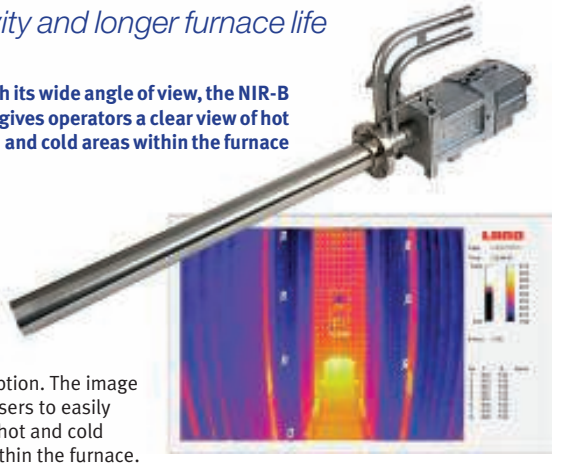
AMETEK Land, the leading industrial infrared non-contact temperature measurement specialist, announces the Near Infrared Borescope (NIR-B) 3XR for continuous reformer tube wall temperature (TWT) measurement and furnace optimization and monitoring.

ATEX- and IECEX-approved for use in Zone 2 gas atmospheres, the NIR-B 3XR provides a high-resolution thermal image offering real-time temperature measurement of both the tube skin and the refractory surface. Using the shortest wavelength possible to minimize errors associated with varying emissivity, it allows highly accurate temperature point data to be measured, stored and trended over the lifetime of the furnace.

The high-resolution image combined with the wide-angle field of view (90°) allows multiple reformer tubes to be imaged and measured simultaneously. This is critical to extending asset life and maximizing efficiency, as a –10°C measurement error can reduce productivity by 1%, while a +10°C error can cut tube life by 25%.

AMETEK Land developed the NIR-B 3XR in partnership with leading syngas catalyst manufacturers, global operators and reformer designers. In addition to improving accuracy, the NIR-B 3XR also reduces risk to personnel by removing the need for an operator or technician to be in the hazardous area on a regular basis. With advanced digital communications, the image and data can be viewed in real time from the safety of the control room.

The NIR-B 3XR is an invaluable tool for prolonging reformer tube life time, optimizing production throughput and reducing energy consumption. The image allows users to easily identify hot and cold areas within the furnace. Uneven heating due to unbalanced burners or gas mix can clearly be seen, with corrections viewed in real time. During start-up, any burners that are not operating correctly can be quickly identified and the effect of any impinging flames can be seen.



With its wide angle of view, the NIR-B 3XR gives operators a clear view of hot and cold areas within the furnace

With over 20 years' experience in high-accuracy process thermal imaging, AMETEK Land's image and data processing software platform supports long-term data trending, aiding process optimization while reducing the risk of tube failure. **www.landinst.com**

A single tool to set up and maintain process instruments

Siemens' Simatic Process Device Manager can configure, parametrize, commission and service instruments from 200 manufacturers, and now works on mobile terminals

Version 9 of the Simatic PDM works on local terminals

With Industry 4.0 and digital operations gradually entering the process industries, process instruments are taking on a new role, says **Siemens**. Increasingly, they are playing a vital part in generating process information and evolving into "smart sensors". With increasing intelligence, however, comes complexity: being smarter means having more functionalities and hence more parameters to adjust.

Siemens' Sitrans devices, for instance, come with on-board maintenance and diagnostic functions such as self-test, drag indication, partial stroke tests and multiple adjustable limit values. A whole range of further sophisticated functions are available for process monitoring and control.

In the process industries, the Simatic Process Device Manager (PDM) is one of the most widely used tools for gaining access to all the parameters, diagnostic and maintenance information available from process devices. More than 4,500 devices from over 200 different manufacturers can be commissioned, parametrized, or serviced using this single program with a consistent and familiar user interface.

The latest release of PDM, version 9, supports both stationary and mobile clients, freeing operators from having to use a single engineering station for different plant units. Up to 30 clients can be connected to one SIMATIC PDM server without needing to install SIMATIC software.

Access to intelligent field devices can now be made through a local client, while the data is still centrally stored. With this functionality in place, maintenance personnel no longer need access to the central engineering workstation. This simplifies coordination, and allows more efficient processes and higher plant availability. It also considerably reduces the time service engineers need to spend in the control room or moving from one location to another.

From calibration and change logs, to trend curves, manuals and lifecycle data – all device-related information is accessible in one place. In support of predictive maintenance, the device data and diagnostic functions help operators to identify when a device needs to be re-calibrated, for instance, and allows the hassle-free transfer of settings and parameters from an old device to its replacement. All data logs of parameters, maintenance and diagnostic information are archived in a consistent database. This helps to translate data and alerts into timely and effective action for plant asset management. **www.siemens.com/processinstrumentation**

The solution for post-drying APIs

EKATO's SOLIDMIX VPT dryer is ideal for the task

Sensitive active pharmaceutical ingredients (APIs) are often dried in spray dryers. However, small amounts of residual moisture remain in the product, due to the amorphous structure of the particles and the bond between solvents and particles.

A post-drying step is therefore required to remove the last trace of solvent. To overcome the physical bonding of the solvents and work against the capillary action of the particle structure, moderate heat under gentle mixing has to be applied over a long period of time.

The EKATO SOLIDMIX VPT removes solvent that is beyond the reach of spray dryers

The **EKATO** SOLIDMIX VPT has proven best results in post-drying of APIs. This dryer consist of a vertical jacketed vessel with a conical bottom and a low-shear hydrofoil-type impeller: the EKATO ISOPAS. Designed for maximum efficiency in shear-sensitive products, the EKATO ISOPAS creates a three-dimensional mixing pattern that ensures even heat transfer from the jacket, and surface motion that allows solvent vapor to escape. Optionally, the system can operate under partial vacuum to aid solvent removal.

For pharmaceutical use, the EKATO SOLIDMIX VPT is designed for maximum yield on emptying. **www.ekato.com**

Solidification for every kind of product

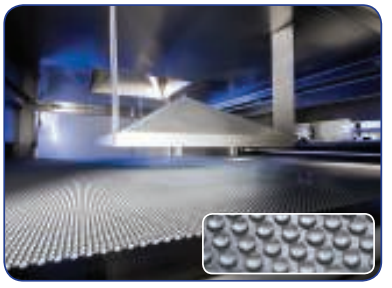
R&D over more than 30 years has yielded an entire family of models for Sandvik's Rotoform solidification system

The development of a comprehensive Rotoform product range has not only led to faster and more efficient pastillation, but has also enabled the processing of chemical products with melt temperatures as high as 300°C, and those with abrasive, sedimenting or corrosive properties, says **Sandvik Process Systems**.

Systems are available to handle products with viscosities up to 40,000 mPas, and pastilles can be produced in sizes of 0.8–36 mm in diameter. Throughputs can be as high as 15 t/hr.

The Rotoform itself consists of a heated cylindrical stator – which is supplied with liquid product – and a perforated rotating shell that turns concentrically around the stator, depositing drops of the product across the whole operating width of the steel belt. For high capacity, the steel cooling belts can be up to 2 m wide.

Heat released during solidification and cooling is transferred by the steel belt to cooling water sprayed underneath. This water is collected in tanks and returned to the water-chilling system; at no stage does it come into contact with the product.



The Rotoform system yields uniform, free-flowing pastilles from melts with viscosities up to 40,000 mPas

The Rotoform system produces free-flowing, uniform pastilles that are easy to handle, bag and transport. Because little dust is created in the production process, or subsequently by the pastilles, the entire production is environmentally friendly.

www.processsystems.sandvik.com

A world first in safety for Roots pumps

OktaLine ATEX from Pfeiffer Vacuum are the world's first magnetically coupled and ATEX-certified Roots pumps

Pfeiffer Vacuum has introduced the world's first ATEX-certified Roots pumps with magnetic couplings to the vacuum market. The new OktaLine ATEX series builds on the tried-and-tested Roots pump principle. These vacuum pumps are ideal for use in explosive areas or for evacuating explosive gases as required by the European Union's ATEX directive. Applications include chemicals, coatings, semiconductor manufacture, R&D, and general industrial use.

The complete OktaLine ATEX line covers pumping speeds of 280–5,190 m^3/h. Depending on the application, clients can choose between ATEX equipment categories 2 and 3. All pumps are suitable for temperature class T3.

Thanks in large measure to their magnetic couplings, these hermetically sealed pumps have very low leakage rates: less than 1×10^{-6} Pa m^3/s. The magnetic coupling makes it possible to omit the shaft sealing rings, which are inherent weak points when pressure surges occur and also have high maintenance needs. OktaLine ATEX pumps resist pressure surges of up to 1,600 kPa. In addition, the absence of a seal prevents any gas exchange between the process side and the atmosphere.

The OktaLine ATEX from Pfeiffer Vacuum

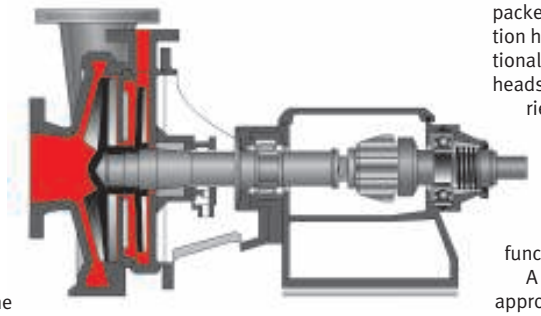
The gearbox and bearing areas in these Roots pumps are separate from the gas pumping chamber. The contactless operating principle of the Roots rotors ensures technically dry operation. Another advantage is the use of air cooling, so operating costs are significantly lower than with water cooling. **www.pfeiffer-vacuum.com**

Slurry pumps for tough process conditions

Special pumping systems tailor-made by Paul Bungartz GmbH & Co. KG are in continuous use around the world, handling the most difficult media

BUNGARTZ centrifugal pumps of types MOS/UMOS and MOR/UMOR reliably pump even extreme media, which can be simultaneously hot, abrasive and corrosive. Nor are these pumps troubled by media that are sticky, gas-containing, crystallizing or even gelling.

The pumps take advantage of a frictionless hydrodynamic shaft sealing system. This basically consists of a set of additional vanes to the rear of the impeller. These carry the pumping medium away from the shaft seal, which is thus protected. Depending on the suction head, another seal "expeller" may be added to create an equal pressure opposing the system pressure or discharge pressure. The back vanes and optional seal expeller allow the pump speed to be varied without compromising the hydrodynamic sealing effect.



UMOR pump showing the main impeller and the expeller that protects the shaft seal

The capabilities of special centrifugal pumps in this series are many and varied. Bungartz custom-builds the pumps for specific requirements, using different designs of casing, impeller, and shaft seal. The basic MOS variant is fitted with a cylindrical packed gland and is suitable for low suction heads. UMOS, equipped with an additional seal expeller, is used for high suction heads. As with all other pumps in the series, these have exceedingly low maintenance needs and operate without leakage. Their suitability for solids is legendary: one pump of type MOR, recently dismantled, had been running since 1948. It was fully functional to the last.

A choice of materials allows a flexible approach to the challenges presented by different process conditions. A new wear-resistant material based on silicon carbide (SiC), for instance, significantly extends the service life of components.

A typical application is in the fertilizer industry for handling phosphoric acid, ammonium nitrate, iron oxide, saline solutions, sulfuric acid, and urea melt.

www.bungartz.de

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46 Piping, Tubing, Fittings
47 Pollution Control Equipment & Systems
48 Pumps
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50 Size Reduction & Agglomeration Equipment
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58 Materials of Construction
59 Compressors

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6	21	36	51	66	81	96	111	126	141	156	171	186	201	216	231	246	261	276	291	306	321	336	351	366	381	396	411	426	441	456	471	486	501	516	531	546	561	576	591
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15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390	405	420	435	450	465	480	495	510	525	540	555	570	585	600

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Economic Indicators

2014 2015 2016

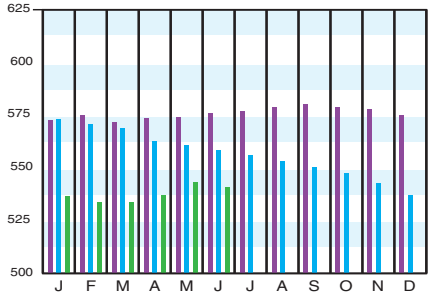
Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	June '16 Prelim.	May '16 Final	June '15 Final
CE Index	541.1	543.5	558.3
Equipment	645.3	649.3	673.0
Heat exchangers & tanks	559.0	560.5	601.7
Process machinery	650.3	650.5	659.5
Pipe, valves & fittings	801.0	813.0	836.3
Process instruments	385.5	385.1	398.7
Pumps & compressors	970.5	970.4	957.8
Electrical equipment	506.8	508.7	512.9
Structural supports & misc	708.4	719.1	737.7
Construction labor	326.6	325.9	321.0
Buildings	544.1	543.5	541.4
Engineering & supervision	316.1	315.6	318.7

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

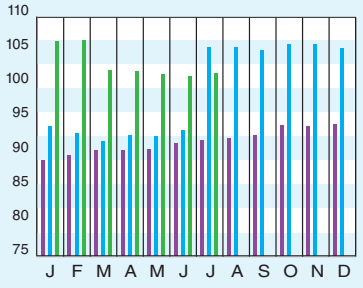
Annual Index:
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8



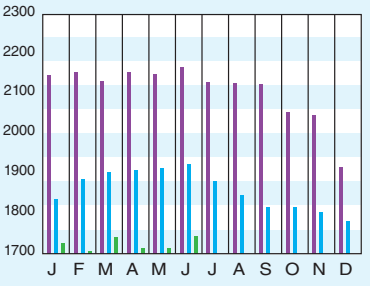
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS		YEAR AGO
CPI output index (2012 = 100)	Jul '16 = 101.7	Jun. '16 = 101.1	May '16 = 101.6	Jul '15 = 101.6
CPI value of output, $ billions	Jun '16 = 1,743.1	May '16 = 1,718.4	Apr. '16 = 1,711.2	Jun '15 = 1,887.3
CPI operating rate, %	Jul '16 = 74.8	Jun. '16 = 74.4	May '16 = 74.7	Jul '15 = 75.0
Producer prices, industrial chemicals (1982 = 100)	Jul '16 = 223.2	Jun. '16 = 227.9	May '16 = 225.0	Jul '15 = 251.5
Industrial Production in Manufacturing (2012=100)*	Jul '16 = 103.6	Jun. '16 = 103.1	May '16 = 102.8	Jul '15 = 103.5
Hourly earnings index, chemical & allied products (1992 = 100)	Jul '16 = 169.2	Jun. '16 = 166.2	May '16 = 163.7	Jul '15 = 159.1
Productivity index, chemicals & allied products (1992 = 100)	Jul '16 = 101.1	Jun. '16 = 100.7	May '16 = 101.4	Jul '15 = 102.2

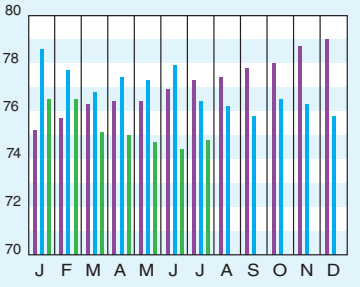
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



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

CURRENT TRENDS

The June 2016 preliminary value for the *CE* Plant Cost Index (CEPCI; top; the most recent available) ticked lower than the previous month, reversing the direction from the May value, but continuing a general lowering trend over the past several months. The Equipment subindex fell, while the other subindices rose slightly. The preliminary June 2016 CEPCI value is 3.1% lower than the corresponding value from June last year. Meanwhile, the latest Current Business Indicators (CBI; middle) for July 2016 showed a small increase in the CPI output index compared to the previous month. Producer prices for industrial chemicals fell in July, while the June value for the CPI value of output index increased slightly from the previous month.

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