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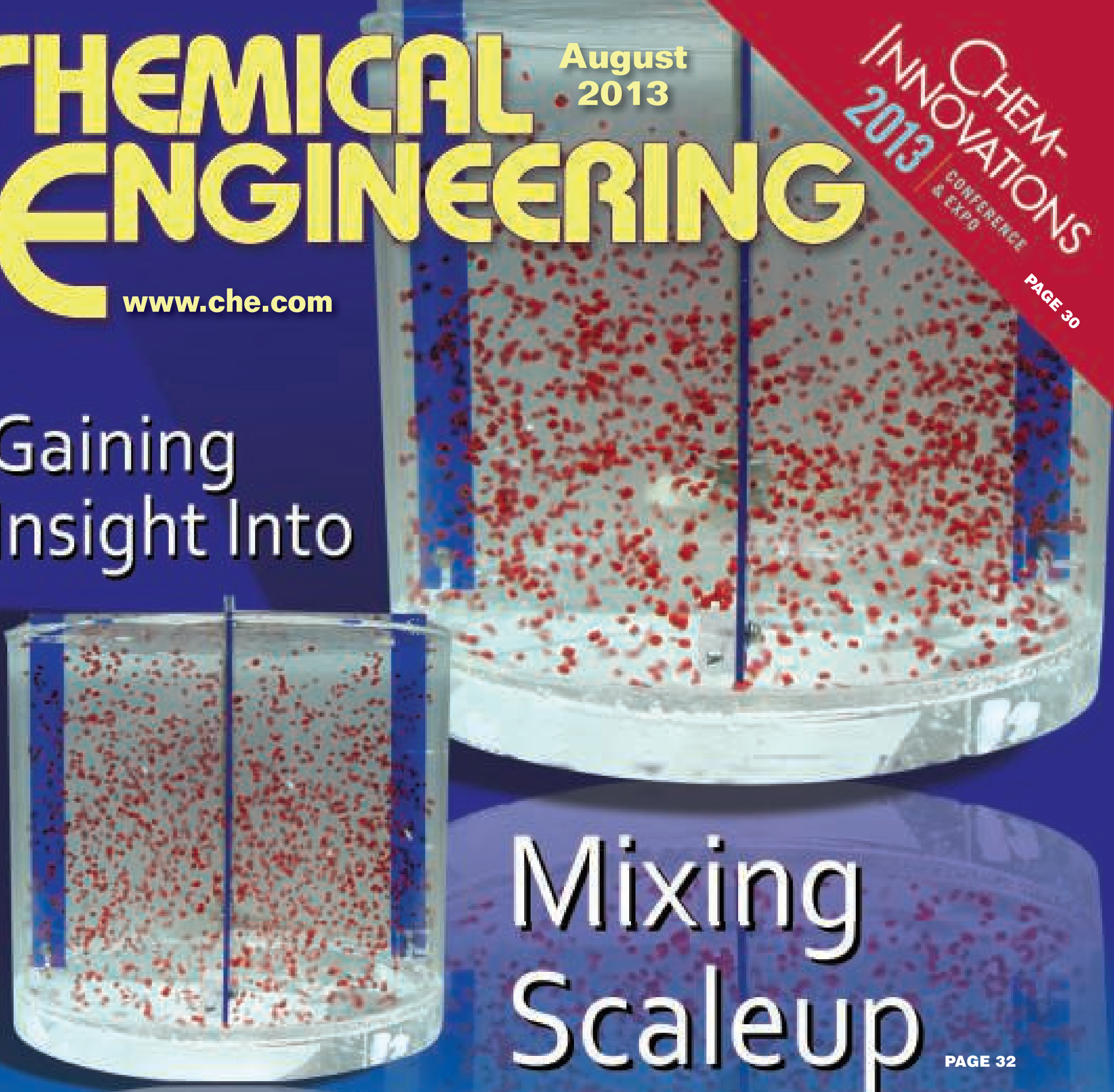

Chem-Innovations 2013 Conference & Expo

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Gaining Insight Into Mixing Scaleup

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Pinch Analysis for Production Planning

Modeling Optimized Processes

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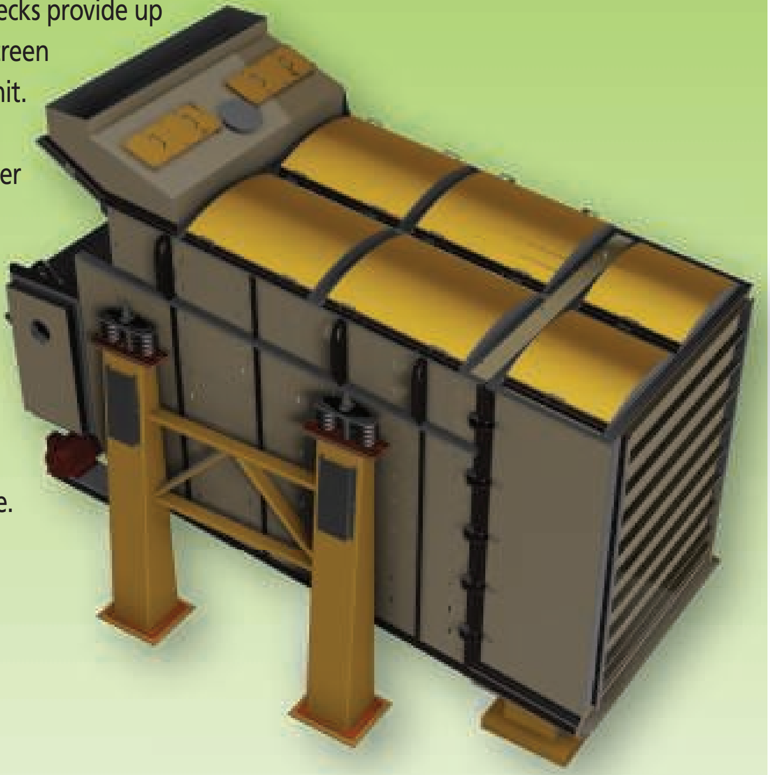

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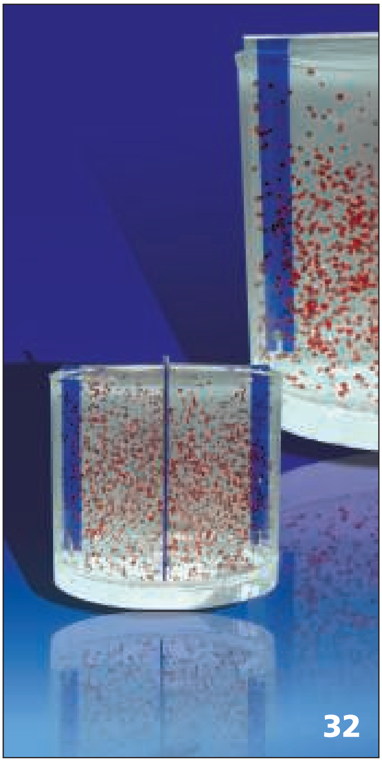

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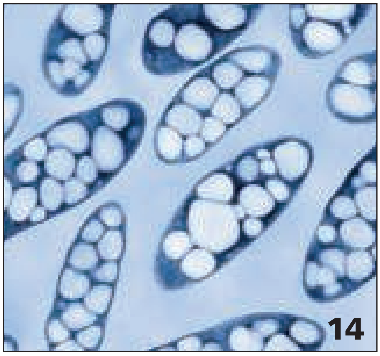

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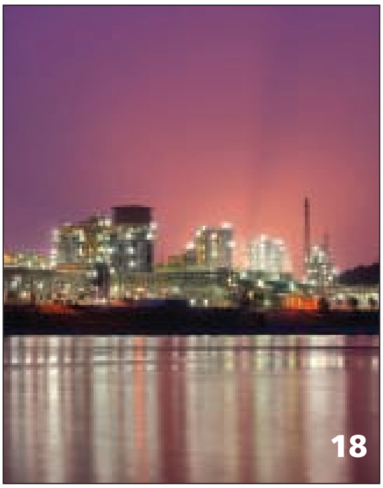

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Editor's Page

The greening of China

The AchemAsia exhibition and conferences (www.achemasia.de) are a pretty good guide to trends in the chemical process industries (CPI) in China. Held every three years, you can measure changes simply by studying what is on show, and what delegates have come to hear. When the 15,000 or so attendees came to Beijing this past May, one of the biggest things on their collective mind was environmental protection and water treatment. Organizer, Dechema e.V. (Frankfurt am Main, Germany; www.dechema.de), says that of 418 exhibitors, 116 were showing environmental solutions, while 135 were displaying water treatment technologies. The AchemAsia conference program was no less focused on the environmental future. We have come to think of environmental concerns as being at the bottom of the list for China in its dash for growth. But that may be changing. Here's why:

First, China's business model is shifting fast. The last 30 years have seen the country become the world's factory, based on low-cost production. Those days are over. China's costs are rising rapidly, for labor, for raw materials, and for energy. It no longer makes sense to import oil valued at $90–100/barrel to convert it into cheap plastic goods for Americans and Europeans to buy. There may be a transition period as commodity industries move inland to the West of the country to take advantage of lower wage costs there, but China's will have to become a high-tech economy. Nothing else will be sustainable in the long-term. The shift to high-tech will be accompanied by more efficient use of energy and resources, and a shift out of commodity businesses. Expect to see the rise of materials science companies, focused on and enabling the growth of sectors such as energy efficiency, renewables technology, biotechnology, batteries, electric cars and semiconductors.

The second reason is that China is investing in alternative energy with the same all-out ferocity that it once reserved for coal investments. Its current five-year plan calls for a rise in the proportion of power generated from non-fossil fuels of 3.4% to 11.4% of total energy use by 2015, to be accompanied by a reduction in carbon dioxide emissions of 17% compared with 2010. Solar, wind, renewable fuels and nuclear all have growing shares of the energy mix.

China also has big reserves of shale gas. The deposits are not in wide flat beds like in the U.S., but are often affected by fault lines and other geological features that make drilling difficult. The country lacks the technology to recover shale gas over long distances from the well head and many basins are in water-poor areas. But when these problems are overcome, as they will be, we can expect China to shift its energy generation platform quickly to include a significant proportion of gas, resulting in cleaner-burning fuel, with much lower greenhouse gas emissions than coal, if it is managed properly.

Finally, you cannot forget that China is a centrally planned economy, at least for now, and that the full weight of the state can get behind renewable fuels, for example, without waiting for legal and incentive structures to come into place, as would happen in the U.S. or Europe. And while five-year plans are not reliable guides to what happens in practice, they do indicate intent – in this case to go "greener."

China's green shift will have implications for the CPI around the world. We can expect more basic R&D and process design to originate in China as it searches out a high-tech future. We can expect a redrawing of the world map of where high- and low-tech products are made. Finally, as the wealth and power of China's 1.2 billion people starts to rise, we will see that China's decisions today will affect the manufacturing standards we adopt tomorrow. ■

John Pearson, CEO, Chemical Industry Roundtables

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Letters

The pending water shortage

I thank you for the exciting editorial titled The pending water shortage in *CE*, June 2013 [p. 5].

I fully agree with you that voluntary efforts are needed immediately to do everything possible to drastically bring down the water intensity of present industrial operations.

Taking note of your points, we are [working] on serious efforts in engaging with India's chemical industry to manage water use effectively.

Dr. M.P. Sukumaran Nair FIE
Director, Centre for Green Technology & Management
(formerly special secretary to Chief Minister,
Government of Kerala, India).

Accepting Fellowship applications

The Institution of Chemical Engineers (IChemE; Rugby, U.K.; www.icheme.org) is inviting applications for The Ashok Kumar Fellowship, which gives a chemical engineering graduate the opportunity to spend three months working at the U.K. Parliamentary Office for Science and Technology (POST).

The successful candidate will be the fourth graduate to hold The Ashok Kumar Fellowship since it was established in 2010.

Kumar, an IChemE Fellow was the only serving chemical engineer in U.K. parliament at the time of his sudden death in 2010. The Fellowship provides a unique opportunity for one successful graduate, from anywhere in the world, to spend three months working at the U.K. Parliamentary Office for Science and Technology (POST). The project is jointly funded by IChemE and the North-East of England Process Industry Cluster (NEPIC).

Previous graduates to receive the Fellowship include Iwan Roberts, James Lawrence and Katie Atkinson.

The closing date for applications is October 31, 2013. Full details, including eligibility and an application form, are available from IChemE's website.

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Calendar

NORTH AMERICA

Energy Storage North America. Messe Düsseldorf North America (Chicago, Ill.). Phone: 312-781-5185; Web: mdna.com
San Jose, Calif. **Sept. 10–12**

Winding: Machines, Mechanics and Measurements. Assn. of International Metallizers, Coaters and Laminators (Fort Mill, S.C.). Phone: 803-948-9470; Web: aimcal.org
Chicago, Ill. **Sept. 19–20**

The 2013 Polyurethanes Technical Conference. American Chemistry Council, Center for the Polyurethanes (Washington, D.C.). Phone: 202-249-7000; Web: americanchemistry.com
Phoenix, Ariz. **Sept. 23–25**

4th Annual ChemInnovations Conference & Expo. TradeFair Group, an Access Intelligence Company (Houston). Phone: 713-343-1891; Web: cpievent.com
Galveston **Sept. 25–26**

42nd Turbomachinery and 29th International Pump Users' Symposia. Texas A&M University (College Station, Tex.). Phone: 979-845-7417; Web: turbolab.tamu.edu
Houston, Tex. **Sept. 30–Oct. 3**

Coating Process Development. Assn. of International Metallizers, Coaters and Laminators (Fort Mill, S.C.). Phone: 803-948-9470; Web: aimcal.org
Chicago, Ill. **Oct. 1–2**

Solution Preparation and Mixing. Assn. of International Metallizers, Coaters and Laminators (Fort Mill, S.C.). Phone: 803-948-9470; Web: aimcal.org
Chicago, Ill. **Oct. 3–4**

Valve Manufacturers Assn. Annual Meeting. VMA (Washington, D.C.). Phone: 703-554-3609; Web: vma.org
Palm Beach, Fla. **Oct. 3–5**

WEFTEC 2013. Water Environment Federation (WEF; Alexandria, Va.). Phone: 751-830-1545. Web: weftec.org
Chicago, Ill. **Oct. 5–9**

Elastomer Technology & Seal Design for the Oil & Gas Industry. Precision Polymer Engineering Ltd. (Blackburn, U.K.). Phone: +44-1254-295400 Web: idexcorp.com
Houston **Oct. 8**

2013 AFPM Q&A and Technology Forum. American Fuel and Petrochemical Manufacturers (AFPM; formerly NPRA; Washington, D.C.). Phone: 202-457-0480. Web: afpm.org
Dallas, Tex. **Oct. 7–9**

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Houston **Oct. 8**

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Santa Clara, Calif. **Oct. 10**

Gasification Technologies 2013 Conference. The Gasification Technologies Council (Arlington, Va.). Phone: 703-276-0110. Web: gasification.org
Colorado Springs, Colo. **Oct. 13–16**

Process Expo: Food and Beverage Processing. Messe Düsseldorf (Chicago, Ill.) Phone: 312-781-5185; Web: mdna.com
Chicago, Ill. **Nov. 3–6**

EUROPE

5th Symposium on Continuous Flow Reactor Technology. AIC ASTI Incentives & Congressi S.r.l. (Pisa, Italy). Phone: +39-50-598808; Web: aicgroup.it
Pisa, Italy **Sept. 11–12**

K 2013 Annual Trade Fair for Plastics and Rubber. Messe Düsseldorf North America (Chicago, Ill.). Phone: 312-781-5185; Web: mdna.com
Düsseldorf, Germany **Oct. 16–23**

Elastomer Technology & Seal Design for Oil & Gas. Precision Polymer Engineering Ltd. (Blackburn, U.K.). Phone: +44-1254-295400; Web: idexcorp.com
Duisberg, Germany **Oct. 22**

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Dresden, Germany **Oct. 24**

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Elastomer Technology & Seal Design for Critical Sealing Applications. Precision Polymer Engineering Ltd. (Blackburn, U.K.). Phone: +44-1254-295400; Web: idexcorp.com
Suzhou, China **Sept. 13**

2013 International Symposium on Pharmaceutical Solid-State Research. Crystal Pharmatech Co. Ltd. China (Princeton, N.J.) and American Chemical Soc. (Washington, D.C.). Phone: 609-529-4135; Web: crystalpharmatech.com/conference/
Suzhou, China **Oct. 17–19** ■

Suzanne Shelley

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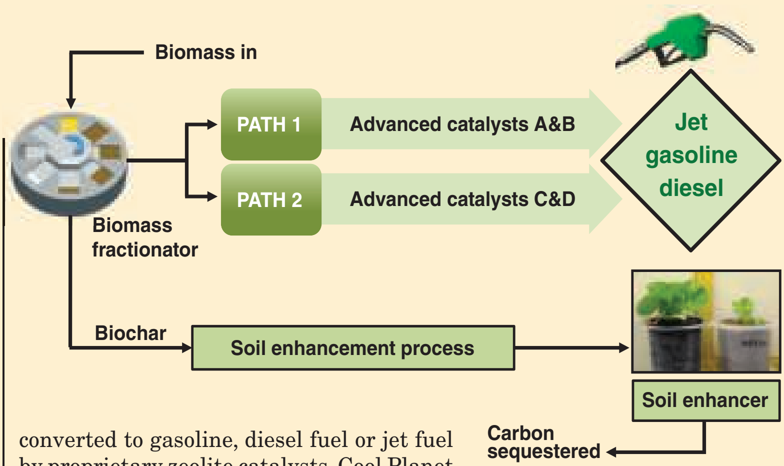
Commercialization is set for a biomass-to-gasoline process

A process that is expected to produce high-octane gasoline from non-food biomass for an average cost of $1.50/gal, depending on feed costs, will be commercialized by Cool Planet Energy Systems (Denver, Colo.; www.coolplanet.com). The company has tested the process in a 200,000-gal/yr pilot plant in Camarillo, Calif., and now plans to install 400 10-million-gal/yr microrefineries across the U.S. by 2020.

The plants will be built from modules. Construction is scheduled to start early next year on a manufacturing plant to produce the modules, which will be shipped to the field for assembly. "We will take the modular plants to where the biomass is and we don't intend to ship biomass from farther than a 30-mile radius," says Michael Rocke, vice-president.

In Cool Planet's process (flowsheet), biomass is fractionated thermo-mechanically by a patented "Biomass Fractionator" at 300–500°C and 2 bars in a controlled flash-pyrolysis step. The carbonized biomass residue (biochar) is recovered from the bottom of the fractionator for use as a soil enhancer, while the gases (a mix of carbon, hydrogen and oxygen) exit the top of the unit. The gases pass to a reactor and are converted to gasoline, diesel fuel or jet fuel by proprietary zeolite catalysts. Cool Planet has programmable catalysts and uses up to two per reactor, says Rocke. The structure of the modified ZSM-5 catalysts, as well as the process conditions, are tailored to obtain the desired product.

Rocke emphasizes that the fuels are identical to those obtained from petroleum and contain no oxygen, normally an undesired component of biofuels. In Cool Planet's process, he says, O_2 combines with H_2 to form byproduct water. He adds that the char soil enhancer not only increases crop yields, but when it is sequestered in the ground, it removes CO_2 from the atmosphere, resulting in a carbon footprint reduction of up to 150%.



Anti-hydrolysis agent

Teijin Ltd. (Tokyo, Japan; www.teijin.co.jp) has developed a new carbodiimide anti-hydrolysis agent that is said to exhibit "superior" anti-hydrolysis properties to improve the durability of plastics. The agent has the additional advantage of not emitting isocyanate gas, which is usually generated during the use of carbodiimide agents. Thus, the new agent is expected to help improve working environments for manufacturers. Samples are being provided to potential users, and the company plans commercialization by 2015, with an annual production target of 100 tons by 2018.

Based on an agent already used in Teijin's Biofront heat-resistant bioplastic, the new agent has now been confirmed for application in other types of plastic, including polyesters, polyamides and polyurethanes. The cyclic carbodiimide can be used in relatively smaller quantities to increase plastic's durability, and because it is heat resistant to at least 300°C, it can be mixed with plastics at higher temperatures. It can also be used as a cross-linking agent to harden or adjust the viscosity of paint and coating agents.

Inorganic membranes show promise to halve energy consumption in distillation

Japanese researchers from the New Energy and Industrial Technology Development Organization (NEDO; Kawasaki City; www.nedo.go.jp), Waseda University, JX Nippon Oil & Energy Corp. (JX_NOE) and five other companies along with five more universities have developed an inorganic membrane that enables energy savings of up to 50% compared to conventional dewatering distillation processes. Developed under a five-year NEDO research project that began in 2009, the membrane has already achieved 200 h of continuous operation since February in a 60 kg/h bench plant at JX_NOE's Kawasaki factory.

The membrane is said to be more hydrophobic than existing inorganic membranes made of A-type zeolite, and thus more widely applicable. It is made by a crystal-fabrication technology that optimizes the crystal composition at the nanoscale. The research group has also developed a manufacturing process to produce separation modules with membranes on a porous ceramic support.

The membranes are used in a hybrid process within the reflux section of a distillation column. Initially, the test application is the dewatering of an isopropanol/water mixture. The group plans to demonstrate 1,000 h of continuous operation under real industrial conditions, and scale up the process in 2016. Another membrane with acid-resistant characteristics is also being co-developed in the project for the dewatering of acetic acid.

Note: For more information, circle the 3-digit number on p. 52, or use the website designation.

Linde to help commercialize an oil-from-algae process

Sapphire Energy, Inc. (San Diego, Calif.; www.sapphireenergy.com) and The Linde Group (Munich; www.linde.com) have signed an agreement, with a minimum span of five years, to commercialize Sapphire's process for producing crude oil from algae. The agreement expands an existing partnership in which the two companies have developed a low-cost method for delivering CO_2 to algae ponds. Linde will now help refine and scale up Sapphire's hydrothermal process for crude production. The two companies also plan to adapt the process for other feed materials, including municipal solid waste and farm waste, and to license the technology jointly.

Sapphire's process differs from conventional algae-to-crude methods in that the feed is not concentrated to an algae content of greater than 90% solids for oil extraction. Instead, the feed is subjected to a simple dewatering, using technology adapted from the wastewater industry, to obtain an algae concentration of about 20%. The solution is then pumped to a hydrothermal reactor, where the algae is converted to crude at 250–350°C and 700–3,000 psig in a continuous process. When the mixture leaves the reactor the oil is separated from the water by conventional liquid-liquid solvent extraction, says Ben Saydah, Sapphire's director of conversion and upgrading. The solvent is then boiled off and recycled and the water phase is recycled as nutrients.

The main advantage of the process is that it avoids the costly dewatering step prior to oil extraction, says Saydah. "With our process, once you produce oil the dewatering is much easier. Also, we don't boil the water, which saves energy, and we will be able to recover a lot of the heat."

A 2-barrels-per-day (bbl/d) pilot plant has been operating for nine months in Las Cruces, N.M., processing algae produced at Sapphire's algae farm in Columbus, N.M. A 100-bbl/d demonstration plant is in the design stage. Sapphire has an agreement with Tesoro Corp. (San Antonio, Tex.) under which Tesoro will purchase crude from Sapphire. In test runs, about 85% of the carbon in the algae oil has been converted to diesel fuel after hydrotreating, says Saydah.

This FCC process shown to enhance olefins production

JX Nippon Oil & Energy Corp. (JX_NOE; Tokyo, Japan; www.noe.jx-group.co.jp) has demonstrated enhanced propylene and butenes yields by its high-severity, fluid-catalytic cracking (HS-FCC) technology. In a 3,000-bbl/d semi-commercial plant, which has been operating at the company's Mizushima Refinery since May 2011, propylene yields have been found to be enhanced by 25 wt.% — 5% higher than previously anticipated, and much higher than the 4 wt.% yield achieved in the existing FCC unit. The butenes yield was also enhanced by 6% to 20 wt.%, and the yield of high-octane gasoline was 29 wt.%.

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

JX_NOE has been developing the HS-FCC process for several years. In cooperation with Japan Cooperation Center, Petroleum (JCCP; Tokyo) and King Fahad University of Petroleum and Minerals (Dharan, Saudi Arabia), the company built a 30-bbl/d demonstration plant at Saudi Aramaco's Ras Tanura Refinery that operated in 2003–2004.

Syngas from CO_2 + H_2

Last month, a three-year, €9.2-million research project was started to develop a process to make synthesis gas (syngas) from CO_2 and H_2. The project is funded by the German Federal Ministry of Education and Research (BMBF; Bonn, Germany; www.bmbf.de) within its Technologies for Sustainability and Climate Protection — Chemical Processes and Use of CO_2 scheme (for more projects, see *CE*, July 2013, pp. 16–19). The partners — BASF SE (Ludwigshafen), the Linde Group (Munich), ThyssenKrupp Uhde GmbH (Dortmund) ThyssenKrupp Steel Europe (Duisburg), hte AG (Heidelberg), VDEh Betriebsforschungsinstitute (Düsseldorf) and the Technical University of Dortmund — are developing a two-stage process. First, methane is decomposed thermally at high temperatures into H_2 and carbon, without the addition of O_2 or water. This H_2 is then catalytically reacted with CO_2 to form syngas (CO and H_2).

The H_2-production step alone is expected to reduce CO_2 emissions by about 50% compared to conventional steam methane reforming, and the solid carbon byproduct may potentially be used to replace hard coal in the coke and steel industries, says BASF. The partners hope to develop a pilot plant design and a concept for integrating the technology into existing chemical and steel-producing sites.

Utilizing offgases

Siemens Metals Technologies (Linz, Austria; www.siemens.com/metals) and LanzaTech (Roselle, Ill.; www.lanzatech.com) have signed a ten-year cooperation agreement to develop and market integrated environmental solutions for the global

(*Continues on p. 12*)

Ethylene in FCC off-gas is upgraded to motor fuels

A typical fluid catalytic cracking unit (FCC) generates about 200 tons/d of dry gas — a mixture of off-gases that is burned as refinery fuel. However, about 40 tons of that gas is ethylene, which would have much greater value as gasoline or diesel fuel. A process that converts better than 40% of the ethylene to motor fuels in a single pass is being developed by UOP LLC, a Honeywell company (Des Plaines, Ill.; www.uop.com).

A conventional way to recover the ethylene is by oligomerization to fuels, says Christopher Nicholas, lead scientist in exploratory catalyst research with UOP, but the recovery is usually below 25%. This is because dry gas contains impurities (NH_3, H_2S, CO and CO_2) that can poison the catalyst, which is often a zeolite. UOP's catalyst, consisting of nickel on an amorphous silica-alumina (ASA) base, is stable in the presence of the impurities, he says.

(*Continues on p. 13*)

Modified PU foam shows promise as sponge for soaking up oil spills

Scientists from the Chinese Academy of Sciences (Beijing; www.cas.ac.cn) have found a way to transform polyurethane (PU) foam into a sponge that is strongly water-repellent and oil-absorbing, making it suitable for soaking up chemicals and petroleum from spills. One of the Chinese scientists, Zhaozhu Zhang, says that sponges previously developed to absorb oil from spills also soak up water as well, so their absorption capacity is not fully utilized to remove the oil. And although several superhydrophobic and superoliophilic materials have been prepared in the past, they require complex and time-consuming methods to make them, and they exhibit low stability and flexibility, as well as poor absorption capacity and poor recyclability, says Zhang.

The new oil-absorbing sponges are made by a simple vapor-phase polymerization of pyrrole onto PU foam (purchased from a local furniture store). To prepare the sponge for its coating, the foam is first dipped into ferric chloride and 1H, 1H, 2H, 2H-perfluorooctyltriethoxysilane (PTES). The PTES-coated sponge is placed into a sealed chamber over a pool of volatile pyrrole. The PTES helps the pyrrole adhere to the sponge surface while the iron from the ferric chloride catalyzes the polymerization of the pyrrole into a thin coating of polypyrrole over the sponge's pores.

The new sponge was shown to absorb more than 20 times its dry weight for each of the oils tested (including motor oil and soybean oil). After a simple mechanical squeezing and washing process, the oil contaminated sponges can be recovered and recycled many times in the oil-water separation. After many such cycles, the sponges could still absorb at least 17 times their own weight in oil, says Zhang.

Electromagnetic separation technology applied to aquaculture

Technology originally developed for harvesting oil from algae has now been applied to sanitize water and remove ammonia from commercial aquaculture ponds. Electro Water Separation (EWS) technology, developed by OriginOil Technologies (Los Angeles, Calif.; www.originoil.com), applies pulses of tuned electromagnetic waves in specific patterns to a series of long tubes containing the fluid needing separation.

In the case of algae dewatering and harvesting, the electric pulses cause algae cells to cluster together (flocculate) for efficient harvesting, while for water-oil mixtures in treating produced water from hydraulic fracturing

(*Continues on p. 12*)

Model relief devices in flow-balanced simulations.

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(Continued from p. 10)

steel industry. The collaboration will use fermentation technology developed by Lanzatech, to reuse the offgases from the converter, coking plant or blast furnace processes as nutrients and a source of energy. The patented fermentation process allows steel-plant operators to make use of the chemical energy contained in the offgases (CO, CO_2 and H_2) for the production of bioethanol or other base chemicals, such as acetic acid, acetone, isopropanol, *n*-butanol or 2,3-butadiene.

LanzaTech has been operating a pilot plant in Auckland, New Zealand since 2008 utilizing raw steel-mill gases. In 2012, LanzaTech became the first company to scale up gas-fermentation technology to a pre-commercial level. It developed and operated two facilities, each with a capacity of 300 ton/yr, that convert fluegas from Baosteel and Shougang steel plants into ethanol. The company is now planning to begin construction on two commercial facilities in China in 2013, with production expected in 2014 (for more process details, see *CE*, December 2010; p. 12). ❑

Reduce air consumption from AODD pumps with this technology

New technology developed for air-operated, double-diaphragm (AODD) pumps can reduce consumption of compressed air by up to 60% without electronic components, while maintaining the same flowrates. The reduced air consumption translates directly to lower energy usage.

Developed by Wilden Pump Inc. (Grand Terrace, Calif.; www.wilden.com), and tradenamed the Pro-Flo Shift Air Distribution System, the technology consists of a cylindrical-shaped air-control spool that shifts back-and-forth between the two diaphragms of the AODD pump. The spool automatically meters air toward the end of the pump stroke, optimizing the pump's performance, explains Wilden innovation specialist and technology inventor Carl Glauber.

The mechanically actuated spool works by controlling the timing of the air intake during the pump cycle, restricting the airflow from the compressor toward the end of each pump stroke. The pump cavity is thereby filled with only enough air to maintain the fluid flowrate, but no excess air. Although improvements have been made to the air-distribution system of traditional AODD pumps, a significant amount of air is still being lost during the time period from the end of the pump stroke to when the air valve shift is completed, explains Glauber. By restricting the air supply to the air chamber toward the end of each pump stroke, Pro-Flo Shift prevents overfilling and saves air and power, while the pump still performs the same amount of work.

Wilden has built a laboratory test skid to mimic plant conditions to compare the Pro-Flo Shift's fluid-flow and air-consumption performance to other AODD pumps. According to Wilden, pumps equipped with the Pro-Flo Shift consume up to 60% less air compared to a host of popular AODD pumps. The Pro-Flo Shift technology is commercially available and can be retrofitted onto existing pumps, says the company.

A solid way to eliminate contaminants from wastewater

CSIRO Minerals Down Under Flagship (Perth, Western Australia; www.csiro.au/MDU) has developed a method that uses hydrotalcite formation to simultaneously remove contaminants from mining and industrial wastewaters in a single step. Current wastewater-treatment processes typically produce lime-based slurries, often with large amounts of water, which requires additional treatment. In contrast, hydrotalcites settle rapidly out of solution and can be easily removed using centrifugation, leaving behind a much cleaner solution.

Hydrotalcites, [general formula, $Mg_6Al_2(CO_3)(OH)_{16}\cdot 4(H_2O)$], consist of layers rich in Al and Mg that are separated by interlayers of negatively charged ions, such as sulfates. They form when Al and Mg are present in an ideal ratio and in a medium with a pH of 6 or higher. As hydrotalcites form, the Al and Mg can be partially replaced by other metals, such as Cu, Pb and Cd, and anions such as chromate and arsenate can also be incorporated into the interlayers. This property makes it possible to trap contaminants into hydrotalcites, which can then be easily removed as a solid.

Because mining wastewater often already contains substantial amounts of Al and Mg, it is possible to create hydrotalcites utilizing common contaminants also present in the wastewater by simply adjusting their concentration and adding alkaline compounds to rapidly increase the pH level, explains CSIRO scientist Grant Douglas.

Initial applications of the CSIRO process have focused on treating wastewater generated from mining and extraction of uranium at the Ranger mine in the Northern Territory. The process effectively removes a range of contaminants, including uranium, rare-earth elements, transition metals and anions. Commercialization of the process is under way with Virtual Curtain Ltd. (Perth, Australia).

ELECTROMAGNETIC SEPARATION TECHNOLOGY (*Continued from p. 11*)

wells, the pulses break oil-water emulsions (see *CE*, July 2012, p. 12). The same technology can effectively rupture bacteria cells and denature viruses, allowing its use in increasing algae shelf-life, eliminating bacteria from produced water, and sanitizing water from aquaculture ponds.

The company recently announced results of a demonstration carried out at aquaculture facilities in Coachella Valley, Calif. Operated in a continuously circulated loop, the EWS technology eliminates microorganisms from pond water without the need for chemicals or antibiotics, helping protect fish and shellfish from disease. The EWS can also remove ammonia from the water, by converting it to nitrates or nitrogen gas. The nitrate-rich water can be used to nourish algae, which is then harvested using EWS to be pelletized into nutritious feed.

The ability to remove ammonia can greatly increase productivity in aquaculture ponds without adding capital costs, comments Jose Sanchez, OriginOil vice president of quality assurance and service. Continuously removing ammonia allows densities of shrimp or fish that are twice or three times as high as with conventional ammonia handling, without changing pond infrastructure, Sanchez says.

Thin-film deposition

Last month, Southwest Research Institute (SWRI; San Antonio, Tex.; www.swri.org) was awarded $1.5 million by the Defense Advanced Research Projects Agency (DARPA; Arlington, Va.; www.darpa.mil) for a three-year project to develop alternative technologies for depositing thin films. The project is part of DARPA's Local Control of Materials (LoCo) program, which aims to overcome the reliance on high-thermal-energy inputs by examining the process of thin-film deposition at the molecular level in areas including reactant flux, surface mobility and reaction energy. The LoCo program will try to develop low-temperature deposition processes and a new range of coating-substrate pairings to improve the surface properties of rotor blades, infrared missile domes, photovoltaics and others.

The first year of the project will focus on a proof-of-concept demonstration of SWRI's HiPIPS (high-power impulse plasma source), which provides a high flux of reactive species to a surface, while maintaining an overall low deposition temperature. In subsequent years, the project will integrate the plasma source with other technologies, and more.

ETHYLENE IN FCC OFF-GAS

(*Continued from p. 10*)

The process obtains motor fuels from ethylene in a two-step oligomerization. First, the Ni converts ethylene to butanes and hexenes, then the ASA finishes the oligomerization to fuels. Process conditions range from 200 to 400°C and 700 to 1,100 psia, says Nicholas, "with gasoline yield coming at lower temperature and pressure than maximum distillate yield." The product is readily separated from unconverted components in the dry gas feed via a single boiling-point column fractionation, due to the large difference in molecular weight between the product and the feed.

Desalination

Researchers from the University of Texas at Austin (www.utexas.edu) and the University of Marburg (Germany; www.uni-marburg.de) are developing a process, called electrochemically mediated seawater desalination, that promises to be an inexpensive way to desalinate small volumes of water. The patent-pending method — described in the June issue of *Angewante Chemie* — uses a plastic chip with a branched microchannel. At the junction of the branch, an embedded electrode neutralizes some of the Cl^- ions, creating an ion-depletion zone, which increases the local electric field compared to the rest of the channel. The resulting electric-field gradient redirects the salts into one branch, allowing desalinated water to pass through the other branch.

Startup company Okeanostech (Union, Ky.; www.okeanostech.com) is working to commercialize the technology with its so-called WaterChip — a solid-state, massively parallel desalination (MPD) platform. ■

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Renmatix

BIO-BASED CHEMICALS GAIN MARKET ACCEPTANCE

An acceleration of commercialization for a number of bio-based building-block chemicals signals further confidence in the industry as a whole

Genomatica

FIGURE 1. Lanxess produced polybutylene terephthalate from Genomatica's bio-based 1,4-butanediol at this plant in Leverkusen, Germany

As an industry sector, bio-based chemicals have seen significant expansion over the past year, with several commercial developments occurring in a group of four-carbon commodity chemicals, including succinic acid, butanols, butadiene and butanediol. While a host of technology-based companies have built new facilities and scaled up production capabilities, others have formed alliances with established players in the chemical industry in the form of strategic partnerships and development agreements.

Meanwhile, larger chemical companies are seeking to incorporate bio-derived chemicals into their product portfolios, either through their own development or through partnerships. Cumulatively, the activity may have placed the bio-based chemicals industry on the cusp of a rapid acceleration, in terms of volume increases and market uptake for bio-based products.

However, the successes in commercialization have not come without difficulties. Some companies have shifted their focus toward lower-volume, higher-margin products, and away from the larger market for fuels. Also, they have had to navigate a set of changes to the chemical industry that have been wrought by increased natural gas production from shale. "The industry has been somewhat soured by over-promising and under-delivering in the past, but there is now the potential for explosive growth," says Fred Moesler, chief technology officer at Renmatix Inc. (King of Prussia, Pa.; www.renmatix.com), a maker of cellulosic sugar for the bio-based chemicals industry.

Taking stock of the recent activity in setting up demonstration- and commercial-scale plants, Alif Saleh, vice president of sales and marketing for the succinic acid and derivatives business unit of Myriant (Quincy, Mass.; www.myriant.com), says "The chemical markets are starting to take the advent of commercial supply of bio-based chemicals more seriously." Combined with the new facilities, this factor helps create an environment for bio-based chemicals where commercialization will start occurring even more rapidly going forward, he adds.

"While there hasn't been across-the-board success in this sector, there is a growing sense of credibility for the bio-based chemicals industry," says Ronald Cascone, a principal with Nexant (White Plains, N.Y.; www.nexant.com). Bio-based chemicals may be at a "tipping point" preceding even more rapid growth, he explains, where a critical mass of companies has adopted a stance favorable to using bio-based materials, and enough technologies have advanced to the point where they are at or approaching cost parity with corresponding petroleum-based products.

Along with Nexant colleague Bruce Orr and others, Cascone has developed and applied a capacity analysis coupled with a risk analysis methodology for assessing developments in the bio-based chemicals market. Nexant projects that the bio-based industry will have added 4 million tons of novel bio-based capacity between 2012 and 2015, out of a total of 6 million tons of announced capacity, including cellulosic sugars, Cascone says. Other Nexant work suggests there may be as much as 15 million tons of cumulative capacity by 2020.

C4 chemicals opportunity

The flood of inexpensive natural gas from shale in the U.S. has had a transformative effect on the chemical industry in the region, and the effect has been felt by the bio-based chemicals industry in a number of ways. Shale gas has made it more difficult for bio-based chemical producers to compete economically in the C2 and C3 olefins space. But the shift on the part of flexible-feedstock crackers toward using ethane and away from naptha in making ethylene (see *Chem. Eng.*, October 2012, pp. 17–19) has created a shortage of C4 chemicals, and this has opened up an opportunity for bio-based chemical makers.

"When you run a cracker with lighter feeds, you end up with dramatically lower output of C4 chemicals," says Christophe Schilling, CEO of Genomatica (San Diego, Calif.; www.genomatica.com). "That plays havoc

Gevo

FIGURE 2. Bio-based isobutanol produced by Gevo will be made into *para*-xylene and oligomerized for jet fuel at this facility in Silsbee, Tex.

with regional availability, overall supplies, contracts and pricing — both for the C4 chemicals themselves, and for the value chains and products that depend on them. So if you're in the business of supplying C4s — or you are dependent on them — you are really, really hungry for a strategic alternative that lessens your business' dependence on the ups and downs of how crackers are fed," he says. The result, Schilling points out, helps drive the companies' desire for renewable chemicals as strategic alternatives — "not just for all the benefits of a reduced environmental footprint, but as a business necessity."

Nexant's Cascone says cheap shale gas is a boon for makers of C2 and C3 olefins, and there have been announcements of additional ethane cracking (for ethylene) and propane dehydrogenation (propylene) capacity. In the U.S., "bio-based chemicals are not competitive in this space, but there are many opportunities for biobased chemicals in the C4, C5 and C6 compounds, such as isoprene, butadiene, bio-benzene (and other aromatics) and others," Cascone says. Nexant is currently developing a PERP (process economic/research planning) report on bio-butadiene that illustrates the opportunity.

In April of this year, Genomatica announced the establishment of a technology joint-venture development with Versalis S.p.A. (a subsidiary of Eni; Milan, Italy; www.versalis.eni.com) for developing a complete "end-to-end" process for the on-purpose production of butadiene from non-food biomass. Genomatica has not shared details of the technological route that this project will take, other than confirming that non-food biomass will be the feedstock.

The recent activity in C4 intermediates has coincided with a shift in philosophy on the part of several bio-based companies to focus on higher-margin, lower volume chemicals. There's a growing realization that bio-based chemicals have higher margins and require somewhat lower volumes, explains Nexant's Cascone, so there's been a shift away from biofuels to fungible intermediate chemicals, such as *para*-xylene and butadiene. However, the shift may not be permanent. As technology improves and economics change, some companies may move back toward the huge market for fuels — particularly because of government support and mandates.

Succinic acid and BDO

Two related four-carbon compounds — succinic acid and 1,4-butanediol (BDO) — have advanced significantly this year in terms of commercial production. BDO is used in the manufacture of over 2 million tons of plastics, polyesters and fibers annually. Succinic acid is used in markets such as pigments, coatings, pharmaceuticals, solvents and polymers.

BioAmber Inc. (Plymouth, Minn.; www.bio-amber.com) currently supplies its brand of bio-based succinic acid from a production facility in Pomacle, France and the company plans to expand capacity in 2014 with a 30,000 metric ton (m.t./yr) plant in Sarnia, Canada. In resins and coatings applications, BioAmber says its succinic acid product enables formulation flexibility for customers, and the opportunity to develop tailored properties that offer performance in more sustainable solutions. The company has a licensing agreement with DuPont (Wilmington, Del.; www.dupont.com), which has set specific goals for sourcing a large portion of its plastics products from renewable chemicals.

In December 2012, Reverdia (www.reverdia.com; a joint venture between Royal DSM N.V. (Heerlen, The Netherlands; www.dsm.com) and starch-derivatives maker Roquette (Lestrem, France; www.roquette.com) began producing bio-based succinic acid at what is said to be the world's first large-scale plant for producing bio-based succinic acid. The facility, in Cassano Spinola, Italy at a Roquette property, uses a low-pH yeast-based fermentation technology and has a capacity of 10,000 ton/yr of bio-succinic acid.

In June 2013, Myriant began customer shipments of its high-purity bio-based succinic acid from a new plant in Lake Providence, La., the first full-scale commercial facility for bio-succinic acid in North America and the largest in the world. "We are ramping up production volumes now," says Myriant's Saleh. The plant has a capacity of 15,000 ton/yr succinic acid and the production costs for bio-succinic acid are lower than its conventional petroleum-derived counterpart, Saleh says.

Myriant also teamed with Johnson Matthey-Davy Technologies (JM Davy; London, U.K.; www.davyprotech.com), a leading chemical technology licensing company, in the successful production of bio-butanediol and tetrahydrofuran (THF) from Myriant's bio-succinic acid. Qualification work for the project was conducted at JM Davy's facility at Teesside, England using bio-succinic acid supplied by Myriant and the JM Davy BDO/THF process. Combining the efficiencies of Myriant's bio-succinic acid process and the JM Davy BDO/THF process, the bio-butanediol and bio tetrahydrofuran has an overall carbon efficiency of 87%, a percentage that Myriant believes to be substantially better than that achieved in the direct-fermentation route to bio-butanediol.

Myriant's Saleh thinks the multiple players in the bio-succinic acid market will help each other by increasing purchasers' confidence in the supply of the chemical. For customers to switch from petroleum-based to bio-based succinic acid, they need to see more than one commercial supplier in the market to assure supply security, he says.

In the BDO space, Genomatica announced in May 2013 that it has licensed its technology for producing bio-based BDO to BASF SE (Ludwigshafen, Germany; www.basf.com). The licensing deal represents "a huge landmark for both the industrial biotechnology industry and for the overall mainstream chemical industry," says Genomatica's Schilling. Genomatica's BDO has also been used by the Far Eastern New Century Corp. to make high-performance fibers with high bio-based content.

Genomatica also partnered with Lanxess AG (Cologne, Germany; www.lanxess.com) in a project where Genomatica's bio-based BDO was used to make polybutylene terephthalate (PBT) in Lanxess' regular commercial process (Figure 1). In June, the two companies announced that Lanxess had fed 20 m.t. of 100% bio-based BDO into its continuous PBT production process. Lanxess said the properties and quality of the resulting bio-derived PBT are fully equivalent to conventional PBT in all tested parameters.

Bio-butanol

Another C4 chemical that has seen significant commercial activity recently is bio-based butanol. Gevo (Englewood, Colo.; www.gevo.com) manufactures isobutanol through a fermentation process for both chemical and fuel applications. The bio-isobutanol can be manufactured into various chemicals and can be used as an alternative to ethanol as gasoline blendstock.

The company is anticipating its next commercial facility, in Silsbee, Tex., to come online at the end of 2013 (Figure 2), following the successful production of isobutanol at its Luverne, Minn. facility since a year ago. At the Texas site, Gevo will use isobutanol from the Luverne plant to make para-xylene for renewable polyethylene terephthalate (PET) for beverage bottles, says Brett Lund, Gevo's executive vice president. The company also has an operational isobutanol-based jet fuel plant in Silsbee that started production last year. Gevo has a supply agreement with the U.S. Air Force surrounding renewable jet fuel.

Gevo's commercialization model has been to retrofit former corn ethanol plants with its proprietary technology to produce bio-isobutanol. Its second such endeavor will occur at a former ethanol plant in South Dakota.

Other companies are pursuing bio-butanol as well. In April development tests, Cobalt Technologies (Cobalt; Mountain View, Calif; www.cobalt-tech.com) produced *n* -butanol at the fermentation scale of 100 m^3 per run, demonstrating lower production cost than butanol produced from petroleum (see *Chem. Eng*., July 2013, p. 15).

Three enablers

Three factors that will have a large impact on the future of bio-based building-block chemicals are: the availability of economically priced sugars from outside the foodchain; establishing new supply chains to connect feedstock and manufacturing; and market pull from end-use companies of bio-based materials.

"One of the key enablers [for the future bio-based chemicals industry] is the ability to economically convert cellulosic feedstock to sugars that can then be processed into chemicals," explains Nexant's Cascone, avoiding the need for corn-based sugars. Murray McLaughlin, of the Sustainable Chemistry Alliance (SCA; Sarnia, Ont., Canada; www.suschemalliance.ca) agrees, calling the economic extraction of sugars from non-food sources "a key to the future" of the industry (Figure 3).

Renmatix is one company trying to serve the need for a bridge between upstream biomass and downstream processing of bio-based chemicals. "Cellulosic feedstock is significantly more stable than the price of crude oil, and is not subject to the same perils that annual crops are subjected," says Renmatix CTO Fred Moesler.

Renmatix converts three dry tons per day of cellulosic biomass to sugar in its facility in Kennesaw, Ga. (Figure 4). The privately held company recently entered an exclusive joint-development agreement with pulp-and-paper manufacturer UPM (Helsinki, Finland; www.upm.com) to further develop Renmatix's Plantrose process, which breaks down woody biomass through supercritical hydrolysis to make low-cost sugar intermediates (C5 and C6 sugars) for subsequent downstream processing into bio-based chemicals.

"Trying to develop a process to breakdown cellulosic biomass into sugar feedstock and simultaneously work on a process for making building block chemicals from the sugar is difficult. It compounds risk; so many companies focus on one or the other," says Gevo's Brett Lund.

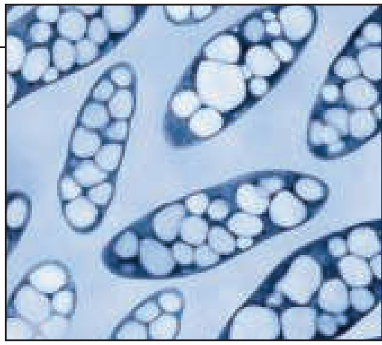
Metabolix

FIGURE 3. Fermentation-based chemical processes require economically produced sugars from cellulosic biomass

A second driver for increased traction of bio-based intermediates is the pull from large companies that have consumer-facing brands. Many large product manufacturers are increasingly seeking bio-based products. "If you can get pull (demand) from end-market companies, like what happened with [Coca Cola's PlantBottle], that is very good for everyone in the supply chain," says Lund. The PlantBottle is a PET beverage bottle containing a portion of bio-based PET.

"Being a 'green' product means more as you get closer to consumer products," says Nexant's Cascone, citing Coca Cola's PlantBottle as an example where there is market value derived from the bio-based product. "There is high interest right now for bio-based chemicals in disposable products, in biologically derived *para*-xylene and in recycling bio-based components," Cascone says.

Because the demand for renewable content in products has grown so much in the last year, the challenge becomes establishing effective supply chains. "The challenge for the bio-based chemicals industry is piecing together a new value chain and bridging feedstock suppliers with chemical producers," says Max Senechal, vice president for bio-based chemicals at Metabolix Inc. (Cambridge, Mass.; www.metabolix.com).

Economics are king

Although it appears that the three enabling elements are moving into place, challenges remain for the bio-based commodity chemical makers. These include achieving process economics with their core technology, securing financing for expansion and scaleup.

With shale gas available in the U.S., "all players in the bio-based chemicals space realize that it's all about eco-

FIGURE 4. The Renmatix Plantrose process uses supercritical water to produce fermentable sugars from woody biomass

nomics now," comments Cascone. "Economics has taken the front seat."

"Bio-based chemicals need to be equal to or better on price than petroleum-derived alternatives, or else no one will buy them," says SCA's McLaughlin.

That philosophy has been central at Myriant and elsewhere. "Myriant does not believe the market will accept a price premium [for bio-based products], nor do we count on it," explains Saleh.

If bio-based chemicals are to become a viable alternative to petroleum-derived chemicals for customers in various applications, manufacturers must be able to secure financing to expand to the volumes necessary to take advantage of economies of scale. And the funding challenge continues even after commercialization, says David Berry, partner at Flagship Ventures (Cambridge, Mass.; www.flagshipventures.com).

"The two biggest challenges are funding and scaleup," says Gevo's Lund. Financing growth has become more difficult, he says, but a company with a strategically important product that is within striking distance of the market will have a much easier time.

"Ten years ago, the funding environment was more favorable, and a number of bio-based chemical and fuel companies started in that timeframe," remarks Berry, so there has been a lot of commercialization activity with those companies. But a potential problem for the industry is that there are not as many companies in the "second wave," he says. "Part of that drop-off is that there is a massive funding gap, and getting the large amount of capital needed to bring ideas to commercial products is not easy.

Into the mainstream

Having a sufficient number of bio-based companies in enough product areas producing bio-based chemical building blocks commercially in high-enough volumes will take time, and the industry should not have any illusions of displacing the petrochemicals industry, explains SCA's McLaughlin. "We think the bio-based chemicals industry should not try to compete with the petrochemicals industry — we want them to work together to complement the petrochem industry. We want to reduce the dependency on petroleum feedstocks, but we're not going to displace the petrochem industry." ■

Scott Jenkins

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MODELING OPTIMIZED PROCESSES

Advanced features in easier-to-use formats allow chemical engineers to take advantage of process modeling solutions for organization-wide optimization

FIGURE 1. Advanced features in easier-to-use formats allow process engineers to take advantage of process modeling solutions for organization-wide optimization

Modeling and simulation are at the heart of chemical engineering design and operations today, whether it is using traditional process flowsheeting tools, computational fluid dynamics, advanced process-modeling environments, or specific equipment design packages (Figure 1). However, much of this modeling is currently performed in isolated "silos" within organizations.

"In oil production, for example, the reservoir is typically modeled using one simulation environment, the subsea production network using another, and the topside facilities, a third," says Mark Matzopoulos, marketing director with Process Systems Enterprise (PSE) Ltd. (London, England; www.psenterprise.com). "Operations like this could benefit significantly from an integrated modeling approach that would open up the possibility for large-scale optimization" (Figure 2).

Matzopoulos adds that since much of today's modeling is in the form of traditional process steady-state flowsheet simulation, which calculates heat-and-material-balance information and stream properties, and "optimization" tends to be by trial-and-error analysis, chemical process organizations could benefit significantly by taking advantage of more sophisticated advanced process-modeling techniques.

"The [other] chemical process industries [CPI] would do well to learn from the food and pharmaceutical industries where having an accurate predictive model of a plant or process allows chemical engineers and scientists to rapidly explore the decision space from laboratory to operating plant," he says.

Why? Because this expanded view enables chemical engineers to quickly rank and screen design alternatives, come up with optimized process designs, confidently scale up to industrial size, and perform plant-wide process optimization, to list just some of the benefits.

For new chemical processes, it is now possible to deploy modeling systematically across the process lifecycle, from R&D and conceptual design, through detailed design, and on to online operation. This can be done in a way that not only leverages knowledge contributed from different parts of the organization, but also provides a vehicle for knowledge transfer between groups or "silos."

Matzopoulos shares an example: "Early-stage experimental data can be used with a model of the experimental setup to estimate kinetic parameters and build a definitive reaction set. This forms the heart of a reactor model used by reaction engineers for ranking different reactor configurations. The model of the chosen reactor configuration is then used by process engineers in simultaneous whole-plant process optimization to trade off reactor and separation costs, based on high-fidelity predictive models."

Some companies, according to Matzopoulos, have reported improvements in process economics of tens of millions of dollars using such techniques. And then, once the process is built, the same models can be run online for monitoring, yield accounting, look-ahead analysis, as part of advanced process-control systems, or to troubleshoot poor operation.

And, much of the application of advanced process modeling software is about optimizing process economics by maximizing or minimizing "headline" key performance indicators, such as annualized operating profit or cost, or secondary KPIs (key performance indicators), such as quality, throughput, or energy use, using process flowsheet models that incorporate detailed predictive unit operation models.

Typical applications may range from detailed design of individual units, such as multi-tubular reactors or crystallizers to whole-plant process optimization. According to Matzopoulos, some examples are: reliable scale-up of units such as reactors and crystallizers; maximizing batch reactor or crystallizer throughput by minimizing recipe time; maximizing the yield of high-value grades of polymer from a batch polymer process by determining the optimal temperature profile; optimizing the mechanical design of a reactor to give the maximum catalyst life by avoiding hot spots; optimizing the de-coking interval for a cracking furnace in an olefins plant, to avoid the extremes of excessive downtime or poor conversion; optimizing the feed-tray locations and number of stages (or even the number of columns) in a distillation train to give the best (capi-

THE BENEFITS OF USING MODELING FOR OPTIMIZATION

According to PSE's Matzopoulos, the major benefits of modeling, especially advanced process modeling, can be summarized as follows:

The ability to innovate quickly and reduce time to market. Innovation is not just about new processes, it can refer to applying a new catalyst within an existing reactor, or devising a new process control strategy for an old plant. Acceleration comes from the ability to explore the process decision space rapidly to screen and rank alternatives, the potential to avoid building costly pilot plants, the integration of experimentation and process design and engineering phases to shorten project cycles, and the ability to make decisions confidently and rapidly based on accurate numbers.

The ability to manage technology risk during innovation. Model-based engineering approaches are now being used to scale up new processes with confidence. Also, the integration of experimental data and models can be used to provide information about key model parameters. This has two benefits: first, it is possible to identify where the greatest data risk lies and devote resources to eliminating this or bringing it to an acceptable level; and, second, it is possible to analyze the propagation of parameter uncertainty on process/plant KPIs to understand the real operational risk.

Better designs and better operations. A model-based approach allows designs to be optimized for whatever objective function is important, such as maximized profit, maximized flexibility for different feedstock options, minimized energy use or pollutant generation.

R&D efficiency. For many companies, particularly in R&D-intensive sectors, such as pharmaceuticals, this is a key target. Modeling can be used to guide experimentation to minimize time and cost. Model-targeted experimentation can be used to generate information to maximize the accuracy of models, which are then used to scale up or optimize the process rapidly (as opposed to trying to optimize the process through experimentation, which many companies still do). ❑

PLANT MODELING SOFTWARE GOES BEYOND DESIGN

"Many chemical processors use process modeling software throughout the plant, but most owner operators do not use the modeling software that models their physical assets, the software that was used to design the facility, the physical assets or the pipelines joining equipment," says Anne-Marie Walters, global director for industrial process and operations with Bentley Systems, Inc. (Exton, Pa.; www.bentley.com). "But they should take advantage of these very advanced 3D-plant-modeling tools, beyond having them serve as a record."

In the past, a few adventurous processors might have used the plant models from the design firm for training or maintenance purposes, but in today's optimization environment, so much more can and should be done with these models, according to Walters.

"We are trying to encourage operations to use the 3D models and link them into a mobile environment to provide a sophisticated walk-through product," says Walters. "We also encourage owner operators to use laser scanning techniques and match the results against the models they have to see what has been added and what may be different from the as-built models."

Need another reason to not just leave plant models on a shelf? Aside from making training, plant inspections and maintenance easier, plant models can be used to determine the cost efficiency of building a new facility or line or adding on to the existing one, says Walters. "Virtually every plant will be faced with adding another line or finding another place for required environmental protection equipment," she says. "Having a good 3D plant model not only helps determine if there is a place to put the things they need now or in the future, but it helps them determine whether it is financially more sound to add on or build new."

But, these benefits will be best realized, if like process modeling and simulation software, the 3D models can be integrated to work with other tools. For this reason, Bentley opted to provide true interoperability for 2D and 3D plant design engineering through integration of the ISO 15926 standard as an intrinsic data model. The open scheme provides interoperability with any other design system using ISO 15926. This allows the software to share design information for small projects and can help manage multi-billion dollar engineering design projects with global design teams. ❑

PSE

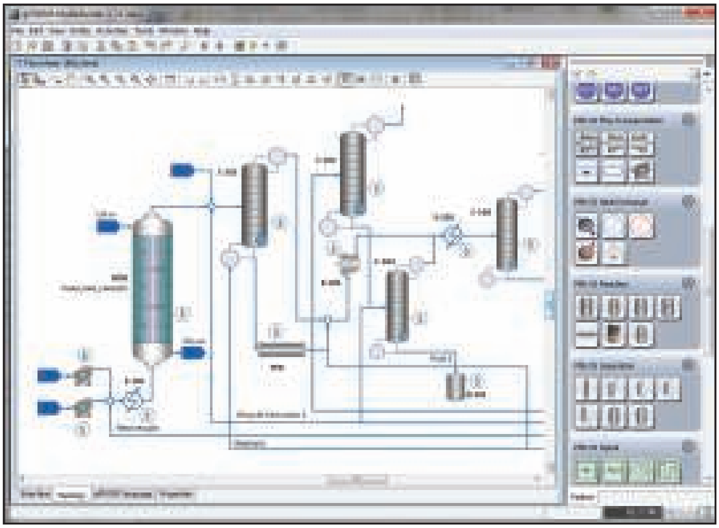


FIGURE 2. PSE's gPROMS ModelBuilder advanced process modeling package allows simultaneous optimization of reaction and separation sections using high-fidelity predictive models to determine optimal process economics

tal plus operating) economics; or optimizing startup of plants to minimize startup time; and more.

Once seen as a management dream, this type of workflow is possible today, if companies are willing to adopt a systematic "model-based engineering" approach that focuses on plant-wide optimization, says Matzopoulos. So, the question is, why aren't more chemical processors doing this?

"Optimization of a single variable or the entire plant is something most users simply don't take advantage of," says Steve Brown, COO with Chemstations, Inc. (Houston; www.chemstations.com). "But built into most simulation software tools are very powerful optimization algorithms that allow users to set constraints, set boundary conditions, and define objective functions. They can look and seem very complex and we find that our users are daunted by that technology, even though the benefits of having a more optimized process are very significant."

For this reason, Chemstations and other modeling-and-simulation software providers, are looking into making their tools easier to use and more intuitive. "One of the biggest challenges facing the simulation industry is what we call the 'chemical engineering computing environment,' which includes all the tools, applications, and operating systems chemical engineers use to attack their job. This environment is constantly changing, so we are likely to find anything from Windows XP to Windows 8 in use. There are different versions of Microsoft Office in use, which means there are different versions of Excel.

"Because the chemical engineering computing environment is not static and is not homogeneous, we have to make sure that any tool or update we release will fit into any of these environments so that our tools not only successfully communicate the data to Excel and run in a given interface, but also look intuitive to users. If it appears to be difficult or daunting, users won't even embrace the program basics, much less advanced features," continues Brown.

So, Chemstations has been working on a new graphical user interface that will be released this year. "This will solve not only the first problem of fitting into multiple computing environments as they are changing, but it also involves a tool set that is easier to use."

Aspen Technology, Inc. (Burlington, Mass.; www.aspentech.com) has redesigned the user experience so that workflow is upfront and provided capabilities to get users started with online training. "We provide access to pre-built models, tricks and tips on a support website, so that our users are able to start quickly," notes Vikas Dhole, vice president of engineering product management with AspenTech. "We also streamlined the workflow so that the tools all users — occasional and experienced alike — will use are upfront and then grouped more complex features in a systematic way behind the front workflow."

The company also offers a Web interface that provides a single user interface that is common across its product lines, allowing plant engineers and operators to have a common reference point for easier exchange of information and data (Figure 3).

In addition, AspenTech has instituted what it refers to as "activation" to certain activities. "To perform activities such as energy, equipment, or cost analyses, users have to bring data from the simulation product into different analysis products. Through activation we have brought those capabilities inside the simulation environment," he says. "At the click of a button, the software analyzes the model and gives results to the user so they don't need expertise in equipment modeling or analysis, but can still get information in a simple-to-execute and simple-to-understand way. This makes it easier to change from modeling alone to modeling for process optimization."

AspenTech

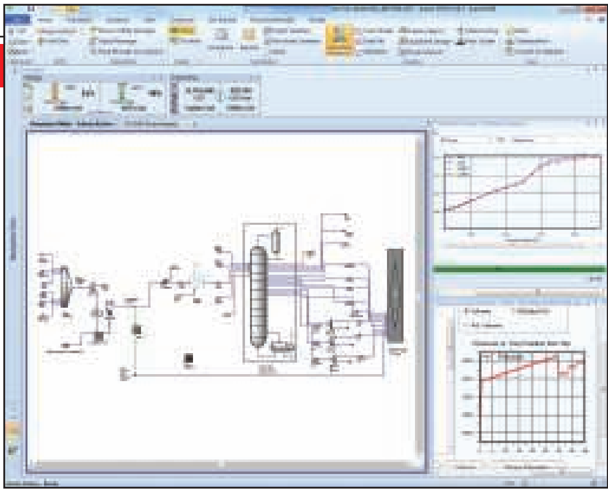


FIGURE 3. The new aspenONE adds a Web-based interface to Aspen Plus and Aspen HYSYS. Now it is possible to access AspenTech's process simulators to view models and plant data through Web-enabled devices — without special software installation

Invensys

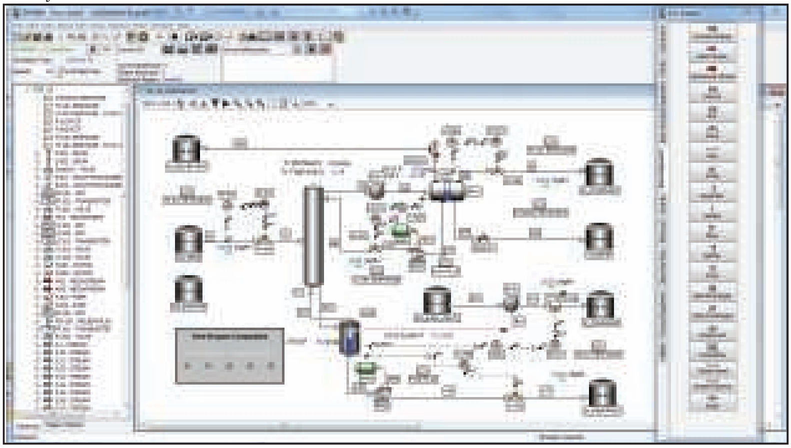
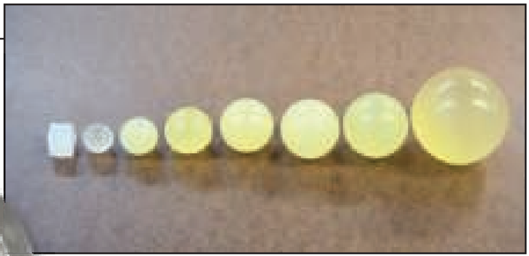


FIGURE 4. A well designed DYNSIM model accurately depicts the same hydraulic, heat transfer and other equipment constraints as the actual plant and provides a single scalable application that can help companies reduce capital costs, improve plant design, trim commissioning time, increase asset availability and train and certify control room and field operators in a safe environment

Integration between tools also makes modeling for process optimization easier, according to Tobias Scheele, vice president, advanced applications, with Invensys PLC (Houston; www.invensys.com; Figure 4). For example, in the petroleum refinery industry, the company offers an off-site solution that integrates planning, scheduling, and off-site systems to its optimization software. This new solution allows refineries that already have blend operations and optimization practices in place to leverage these two sources of information, ultimately improving efficiency and profitability. The integration provides an easier way to update linear programming models when refinery feedstock profiles or physical configurations are significantly changed. This also works with knowledge-management software that provides accurate and timely crude oil information across an enterprise, from ranking crude oils in trading to optimizing petroleum refinery processes and maximizing reliability. The planning and scheduling solution provides a collaborative, multi-user environment for sharing common data and models across all supply chain work processes. ■

Joy LePree


Sifter Parts & Services

FOCUS ON

Screening


Haver & Boecker


Great Western Manufacturing


Triple/S Dynamics

All screening needs are contained in this mobile trailer

The Mobile Quality Assurance Sifter (photo) is said to be ideal for inline sifting on product delivery or receipt; sifting at a trans-loading location; silo evacuation or load-out; and emergency situations. The self-contained trailer includes this company's inline sifter, which features stainless-steel trays containing all of the interior serviceable components (gaskets, screens and cleaners). The screens are mechanically stretched and bonded to the screen trays, which can be rescreened indefinitely. Because the tray is a structural component, the intermediate stainless-steel sieve rings are of simple design, thereby eliminating much internal structure making the trays lightweight and easy to clean. Hinged guards provide full access to the sifter and drives for inspection and maintenance. The trailer also includes a touchscreen PLC workstation; smooth Al interior panels, Al diamond-plate decking; hydraulic leveling legs and controls; generator and compressor. — *Great Western Manufacturing Co., Inc., Leavenworth, Kan.*
www.gwmfg.com

Magnetic, metal-detectable screen cleaners

This company recommends the use of U.S. Food and Drug Admin. (FDA; Washington, D.C.) approved polyurethane (PU) screen-cleaning balls (photo) and cubes to prevent sifter screens from clogging with product. PU balls are said to be more abrasion-resistant than screen cleaners manufactured from other materials, and provide a much longer life. Unlike rubber, PU balls are non-porous and extremely oil-, moisture- and chemical-resistant, says the company. The addition of a stainless-steel core to the ball and cube make them both magnetic and metal-detectable. PU balls range in size from 5/8- to 2-in. dia. — *Sifter Parts & Services, Inc. Wesley Chapel, Fla.*
www.sifterparts.com

Reduce power, noise and more with this fine-mesh screener

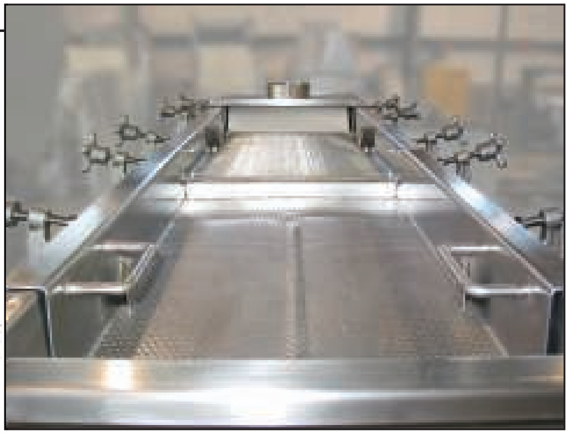
Unlike typical vibrating screens that shake the entire screen box, the new Longhorn Fine Mesh Screener moves only the screen cloth through a vibrating rail. Among the advantages of the Longhorn are the following: minimal structural vibration; low power consumption; very low noise levels; very low maintenance requirements; and no screen blinding, even at very fine mesh sizes, says the company. The Longhorn can screen down to 325 mesh. Standard size decks (in feet) include 4 × 8, 5 × 10, 6 × 10 and 6 × 12. Up to five decks can be configured in series. A 5 × 10, three-deck unit (photo) is available for free testing of products at the company's laboratory. — *Triple / S Dynamics, Dallas, Tex.*
www.sssdynamics.com

Screens with variable-frequency ultrasound cleaners

This company offers ultrasonic screening systems (photo) with innovative frequency variation, developed in cooperation with Artech Ultrasonic Systems. This type of equipped screening system provides efficient screening that improves screen throughput, promotes the disintegration of agglomerates, reduces the share of oversized material and delivers a permanent cleaning effect for the screen, says the company. Ultrasonic solutions can be used for cut sizes from approximately 25 to 1,000 µm. With ultrasonic screening, a special sound conductor is put

Note: For more information, circle the 3-digit number on p. 48, or use the website designation.


Vibra Screw


Rotex Global

into high frequency vibration, which spreads over the screen deck. Through this action, the frictional resistance between the particles and screen mesh is less, the tendency to clog is reduced, clog cleaning is minimized, and throughput is increased. What's special about the Artech process is that the varying frequency — as opposed to the usual resonance processes — avoids patterns of continuous large resonance amplitudes. As a result, not only the mechanical loads on the screen decks are reduced, but so is the formation of so-called hot spots. — *Haver & Boecker, Oelde, Germany*
www.haverboecker.com

Meter, screen and convey just about any dry material
This company's line of vibrating pan feeders and conveyers (photo) offers a simple and efficient way to meter, screen and convey virtually any dry bulk material. Feeders are available with variable speed drives and can be paired with the company's vibrated pins to provide a compact, low-cost hopper/feeder package. With the addition of one or two screen decks, these machines offer an alternative to conventional gyratory screens. As conveyers, they can handle up to 15,000 ft^3/h and are available in lengths up to 25 ft. All feeders, screeners and conveyors are in carbon steel and stainless steel with a variety of surface finishes and liners. — *Vibra Screw, Totowa, N.J.*
www.vibrascrew.com

An alternative to bar rakes and screens in headworks
The Max-Flow Annihilator Grinder System (photo, p. 23) is a custom-engineered headworks debris-handling system that protects pumps, valves and process equipment in water treatment plants. The low-maintenance

Circle 7 on p. 52 or go to adlinks.che.com/45775-07

Moyno

Witte

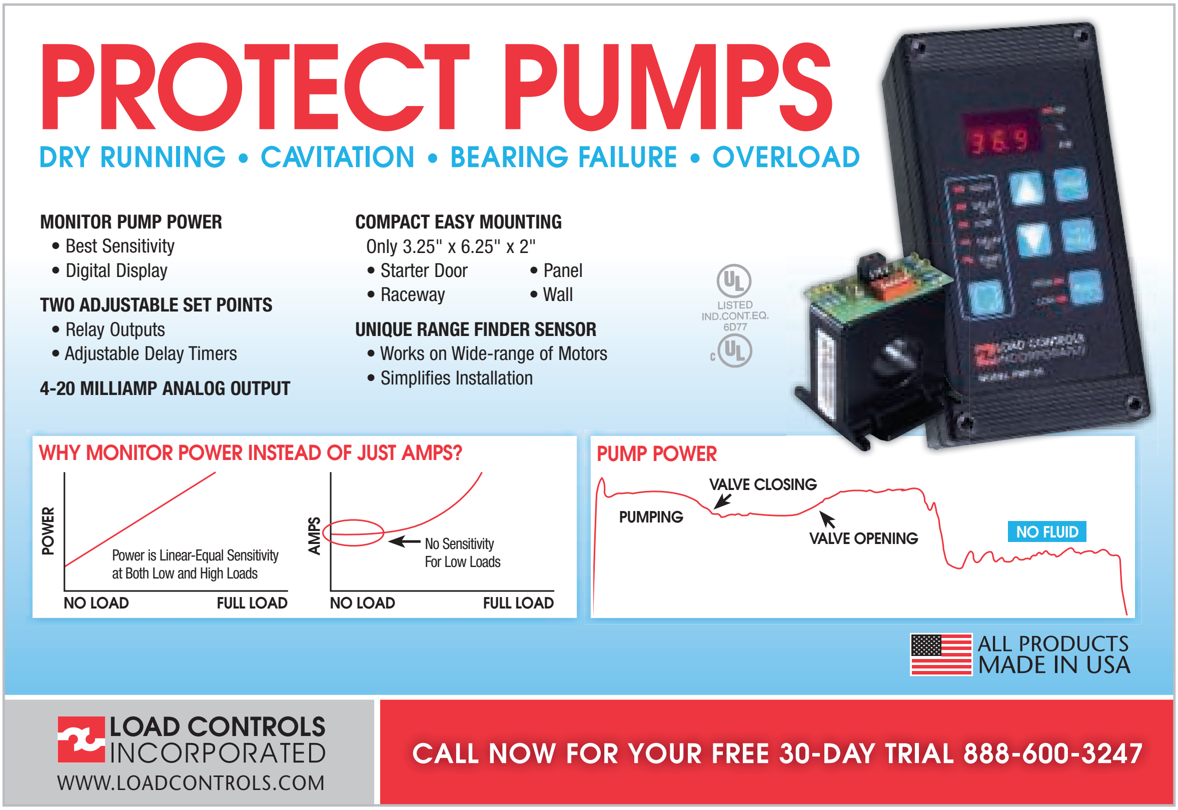
system can be used in place of bar rakes and screens, as well as drum screen grinders for enhanced performance, says the company. The Max-Flow system contains two or more Annihilator grinders mounted side-by-side in a stainless-steel retrieval frame. They can be installed in an in-line, staggered or offset configuration to accommodate a variety of channel widths. The frame includes guide rails to permit the independent retrieval of each grinder. Steel panels can also be inserted in place of a grinder to divert the flow to the remaining grinders during maintenance. — *Moyno, Inc., Springfield, Ohio*
www.moyno.com

This minerals screener also accepts hot materials

The Megatex XD/Mineral Separator (photo, p. 22) is designed for superior screening performance and increased uptime. The machine's design also allows for material with temperatures up to 400°F (205°C) to be effectively screened at constant feedrates. The elliptical-linear motion of the separator and equal feed distribution to all screening decks ensures material quickly stratifies and quickly spreads across the width of the screen surface. The long-stroke, low-frequency of the unit gently separates material without violent action that can reduce yield of on-specification product. — *Rotex Global, LLC, Cincinnati, Ohio*
www.rotex.com

Screeners with full access, fast disassembly for easy cleaning

Vibrating screeners (photo) from this company are designed to permit fast, easy and full access to the loading tray, screening area and pan to allow frequent, thorough cleaning and speed product changeover while minimizing downtime. Easily disassembled in minutes by a single person with no tools, these low-maintenance vibratory screeners are accessed by opening the company's one-handed C-clamps



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mounted around the perimeter. This releases the optional dust-control covers and screens for removal and reveals the entire pan for inspection. The screeners are available with a choice of wire mesh or perforated screens in standard widths of 10, 23, 35 and 47 in. The screen is also available in 100% stainless steel with continuously welded and polished seams to meet FDA requirements. — *Witte Company, Inc., South Washington, N.J.*
www.witte.com

Backflush screen changers can reduce material losses
This company recently equipped a food-packaging-film producer's recycling lines with backflush screen changers. The filtration process enables PET flakes to be processed at a throughput of 500 kg/h. The backflush screen changer has a self-cleaning function, which is activated when the specified pressure limit is reached. In this process, a filter screen is automatically moved out of the production position, and then backflushed by the redirected melt stream. The contamination is removed from the screen cavity and ejected via the drain channels. Compared to the use of a screen-wheel filter, the backflush screen changer reduced product losses by 50%, says the manufacturer. It was also possible to increase the fineness of the filter mesh, the company adds. — *Kreyenborg GmbH, Muenster, Germany*
www.kreyenborg.com

Clean-in-place sanitary screener scalps and dedusts
A new sanitary, clean-in-place (CIP) Vibroscreen Double-Deck Screener removes oversize and undersize particles from on-size chemicals, minerals, plastics, foods, dairy products, pharmaceuticals and other bulk materials. The 40-in.-dia. unit contains two horizontally mounted screens in a cylindrical housing supported on a circular base by rugged springs. The screener is equipped with quick-disconnect clamps between each screen frame, providing rapid interior access for inspection and screen changes. An integral CIP wash system employs spray nozzles strategically placed to emit cleaning solutions, rinsing solutions or steam for sanitizing the interior of the screening chambers without the need to open or otherwise disassemble the unit. Constructed of stainless steel with ground and polished welds, it meets 3-A, FDA and BISSC sanitary standards, as well as UL, ATEX, CSA and CE electrical standards. The unit is also offered in diameters from 18 to 100 in., and can operate on a batch or continuous basis, screening several pounds to 70 ton/h. — *Kason Corp., Millburn, N.J.*
www.kason.com ■

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Detection and Prevention of DP:DPO Fluid Leaks

The management of process plants requires understanding and applying the fundamental tenets of safe design, construction and operation of facilities. This overview summarizes best practices that have been developed to ensure the safest possible use of DP:DPO (diphenyl–diphenyl oxide) eutectic heat-transfer fluids. A review of the concepts necessary for effectively maintaining a leak-tight heat-transfer-fluid (HTF) system is provided.

HTF system requirements

A "typical" HTF system is composed of an energy source, such as fired heaters or waste-heat recovery systems, as well as pumps to force the fluid flow, an expansion tank to accomodate the volume expansion of the fluid and one or more heat consumers.

High-temperature heat-transfer systems are usually closed systems, so a release of fluid can only occur in the case of accidents or malfunctions. As with all HTF systems, the design must accommodate the volume expansion of the heating fluid. The extensive network of piping, instruments, and vessels, combined with elevated vapor pressures, can increase the potential for leaks from systems if adequate design and maintenance measures are not incorporated.

Leak sources

Primary sources of leaks are flanged connections, flexible connectors or rotary joints, and pump seals. When insufficient flexibility is provided in piping networks, the resulting force applied to the flange pair can reduce gasket compression and lead to leakage. Stainless-steel flexible hoses were extensively installed on the early concentrating solar power (CSP) systems. Experience in the mode of failure in such hoses has found that the hoses develop small cracks. A properly installed flex hose will avoid torsion and misalignment, and maximize its usable life. When flexible hose is used in place of rigid pipe, consult manufacturers' recommendations of inspection and replacement frequency.

Rotary joints have the advantage of greater wall thickness, which give rise to a more robust joint, yet maintaining the flexibility to support the demands of mobile piping. For high-temperature service, the joints will typically require periodic injection of graphite-based packing to maintain leak-free performance in a fire-resistant design.

Standard centrifugal pumps will typically use mechanical seals. While some seepage is not uncommon, problems can arise that can reduce seal life and lead to more significant leakage (see "Pump and pump seals" section).

When DP:DPO eutectic fluids freeze, the material contracts in volume by over 6%. If the product then melts between frozen plugs of product or other mechanical boundaries, tremendous pressure can result. The pressure can lead to release of the product through the weakest constraint. When thawing a frozen section of piping or equipment, it is very important to accommodate the expansion in volume into unobstructed piping or equipment.

Component selection

Because the HTF is significantly above its normal boiling point at process temperatures, adequate overpressure protection in the form of pressure relief valves (PRVs) and rupture disks must be provided with adequate capacity for relief between selected points of isolation.

Piping, flanges and gaskets. Seamless carbon steel has been shown to be an appropriate selection for piping with organic HTFs in plants up to their maximum bulk-operating temperatures. Fully welded construction in piping is preferable to threaded fittings, which should be avoided. Graphite-based, paste thread sealants have demonstrated marginal success with threaded connections, in cases where they cannot be avoided, such as in instrument connections, pump-casing drain plugs and others.

With any metallurgy employed, the linear expansion and contraction of the piping must be accounted for through the use of expansion loops and flexible connection members. Pipe supports should be generously spaced to prevent sagging. Where flanges are necessary, Class 300 and Class 600 ring-joint flanges or raised-face flanges are commonly used. When using raised-face flanges, gaskets should have a metal ring for blowout resistance, and graphite-filler with 316 stainless-steel spiral windings for fire-resistance. A key necessity for flanged connections is to ensure that adequate and uniform sealing compression (seating stress) is provided on the gasket faces.

Pumps and pump seals. Pumps in high-temperature service can have double mechanical seals, or can be of a sealless design. Excessive temperatures at mechanical seal faces can vaporize the HTF, resulting in an absence of lubrication and mechanical damage to seal-face materials. In order to avoid excessive temperatures (which can create particles that can erode the seal face and result in leakage), cooling of the stuffing box and seal gland is important to maintain lower temperatures and also improve lubricity of the HTF.

Valves. Valves in DP:DPO service may include forged or cast steel, or stainless steel bodies, balls, plugs and disks. Bellows seal designs can provide physical barriers for reduced emissions and leaks. Soft-seat materials should be avoided, since they can burn out in case of fire, potentially adding to the complexity of the HTF release. Small valves with welded end-connections should be considered to reduce potential leak points, and larger valves should be considered with flanged end connections. Relief valves can use engineered installations of rupture disks beneath.

Leak detection

Human senses. When there is leakage, even above its normal boiling point, the vapor emitted can quickly condense to form a visible, near-white mist cloud. For small leaks it may be possible to observe liquid droplets present at the source of the leak, such as valve stems, pump seals, flanges, and so on, as well as on the ground.

Also, the odor threshold is 9 parts per billion (ppb) for DP:DPO in air, making detection by odor possible without exceeding established airborne exposure limits for either component. In indoor areas, the airborne HTF may not dissipate readily, preventing easy tracing back to the leak point. In outdoor environments, the odor is more closely localized around the leak point due to the more rapid dissipation in air.

Process level indications. Today's installations will have installed instrumentation for the routine measurement of liquid HTF levels. Changes in liquid level in vessels can be a somewhat crude, but important component of detecting material loss.

Specialized instrumentation. Instruments using the principal of photoionization are well suited for use in all kinds of process plants. These instruments can readily detect concentrations as low as the ppb range. For realtime personnel exposure monitoring, the ppb sensitivity is appropriate to quantify exposure. For maintenance needs, parts-per-million (ppm) sensitivity is sufficient to determine orders of magnitude of identified leak sources so that repairs can be scheduled on a prioritized basis. The instruments are available as hand-held units or as fixed-mount, continuous area monitoring stations.

While not comprehensive, the above guidance can help develop practices enabling a safer system design, reduce leaks and lower make-up fluid costs.

MAINTENANCE PRACTICES

Simply put, three keys for adequate maintenance practice are:

- Respond to identified leaks promptly with repairs
- Repairs should address the cause of the failure, and not just the consequence
- Learn, document, and practice recommended preventive maintenance of the equipment

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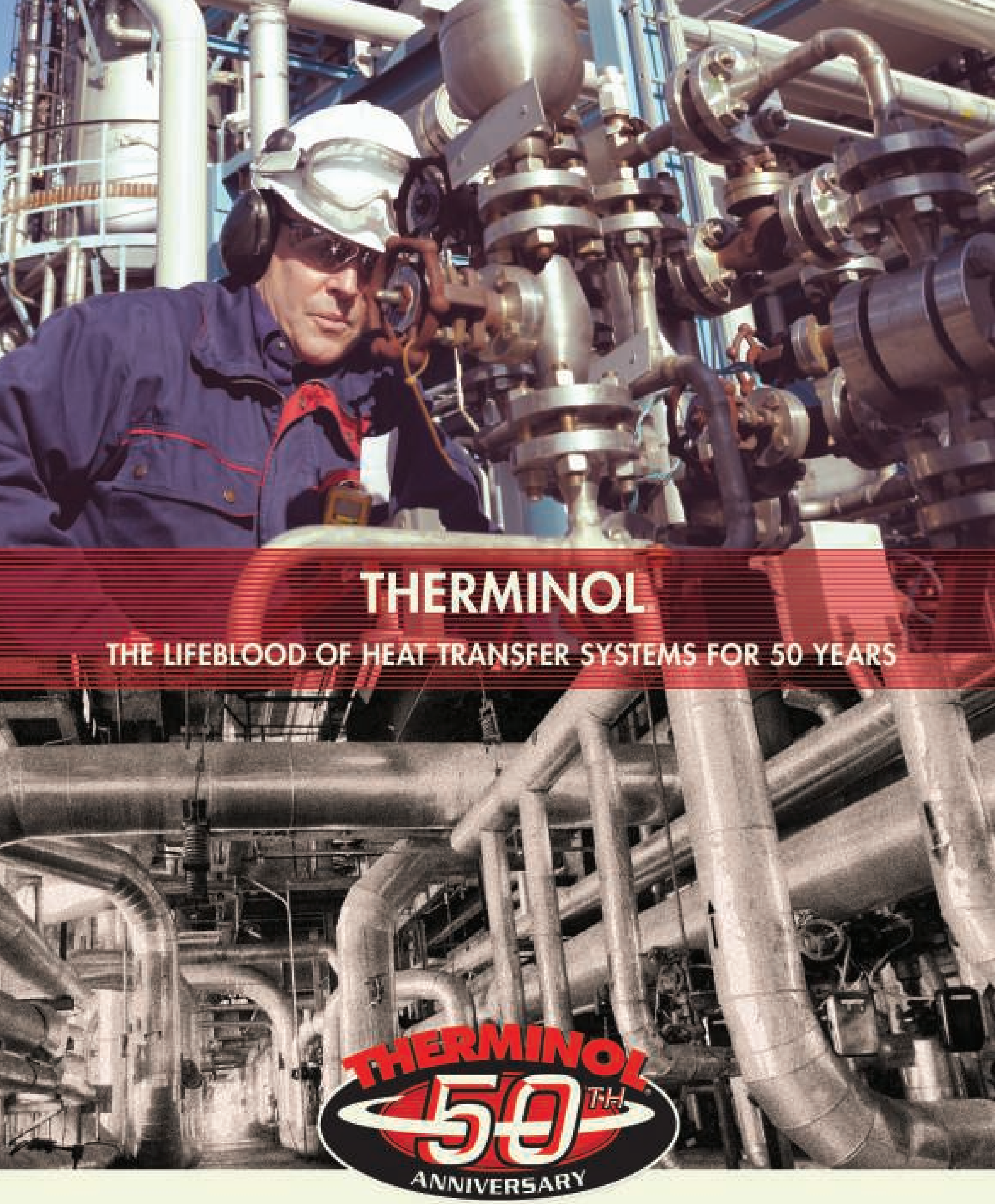

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Technology Profile

Methanol-to-Propylene Technology

By Intratec Solutions

Propylene has been established as an important part of the global olefins business, trailing only ethylene in terms of volume of product. Because inexpensive natural gas from shale in the U.S. is increasingly used as a feedstock for producing ethylene, lower quantities of three- and four-carbon olefins are available. For this reason, new chemical processes for on-purpose propylene using low-cost raw materials are gaining importance. An example of such a process is methanol-to-propylene (MTP) technology.

The main raw material used in the MTP process is methanol that is produced from synthesis gas which, in turn, can be obtained in large-scale from natural gas or coal.

The process

The MTP process consists basically of two reaction steps: an initial one to dehydrate methanol to dimethyl ether (DME) on an aluminum oxide catalyst, and a second one to transform DME and methanol into a variety of olefins, ranging from ethylene to octenes. However, using a zeolite-based catalyst (ZSM-5), the process yields mainly propylene. A set of purification columns is necessary to obtain the polymer-grade (PG) propylene.

Figure 1 illustrates a process similar to the ones licensed by Lurgi GmbH (the MTP process; Frankfurt am Main, Germany; www.lurgi.com) and JGC Corp. (Yokohama, Japan; www.jgc.co.jp) and Mitsubishi Chemical Corp.'s (Tokyo; www.mitsubishichemical.com) DTP process, which can be divided into three main areas: reaction and regeneration; quench and compression; and product fractionation.

Reaction and regeneration. In this stage, the methanol feed is vaporized, mixed with recovered methanol and dimethyl ether (DME), superheated and sent to the DME reactor, where dehydration occurs.

The product is mixed with recycled hydrocarbons and steam before being fed into the MTP reactors. The reactors were designed with several stages to better approach isothermal conditions. Propylene synthesis is conducted in multiple reactors: while one set of reactors conducts the reaction, the remaining ones are in regeneration or on stand-by mode. The recycling of olefins increases propylene yield and absorbs the heat generated in the reaction.

After leaving the reactors, the mixture is cooled and sent to the quench and compression steps.

Quench and compression. The output from the reactors is quenched, where most of the water is removed. A portion of this water is sent to the methanol-recovery column, while the remaining water is vaporized and used as dilution steam in the MTP reactors. The vapor stream from the quench stage is compressed, partially condensed and then separated into liquid and vapor streams.

Product fractionation. The liquid stream from the quench and compression stages is sent to the debutanizer, to separate four-carbon C4 hydrocarbons (and those with less than four carbons) and DME from those with greater than five carbons (C5+ components). The C5+ stream from the column bottom is then separated (in the dehexanizer) into a C5/C6 stream that is to be recycled to the MTP reactors and into a heavier-hydrocarbons stream (gasoline).

The debutanizer overhead stream is mixed with the vapor stream from the compression stage and sent to the DME removal system. The system overhead product, mainly propylene, is sent to the de-ethanizer, while the bottom is mostly recycled. The bottoms from the de-ethanizer is routed to the C3 splitter, to obtain polymer-grade propylene, while the overhead is recycled to the MTP reactors. The bottoms material from the C3 splitter is purged as liquid petroleum gas (LPG).

Economic performance

An economic evaluation of the process was conducted based on data from the fourth quarter of 2012. The following assumptions were taken into consideration:

- A 560,000 ton/yr unit erected on the U.S. Gulf Coast (the process equipment is represented in the simplified flowsheet)
- There is no storage for feedstock and product
- Outside battery limits (OSBL) units considered: propylene refrigeration system

The estimated capital investment (including total fixed investment, working capital and other capital expenses) to build the MTP plant is about $370 million. The capital investment for a similar plant built in China is about $295 million. Figure 2 illustrates the operating costs for both regions.

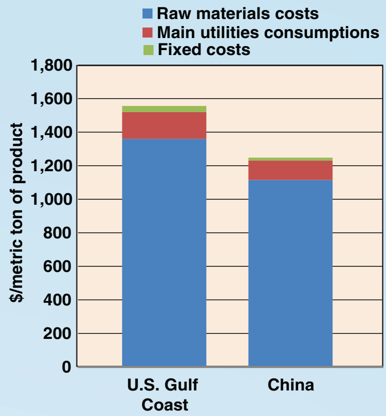

FIGURE 2. Both China and the U.S. are favorable regions for MTP plants because of coal in China and shale gas in the U.S.

Currently, the existing MTP commercial units were constructed in China, inside huge complexes, where coal is extracted and transformed to synthesis gas, which is used to synthesize methanol in high-capacity facilities (over 1 million ton/yr of methanol).

China possesses large reserves of coal, making it a favorable region for MTP plants. In the U.S., the growing availability of natural gas extracted from shale guarantees the availability of synthesis gas to produce the methanol required for the MTP process. Therefore, the country is also a promising region for future MTP units. ■

Edited by Scott Jenkins

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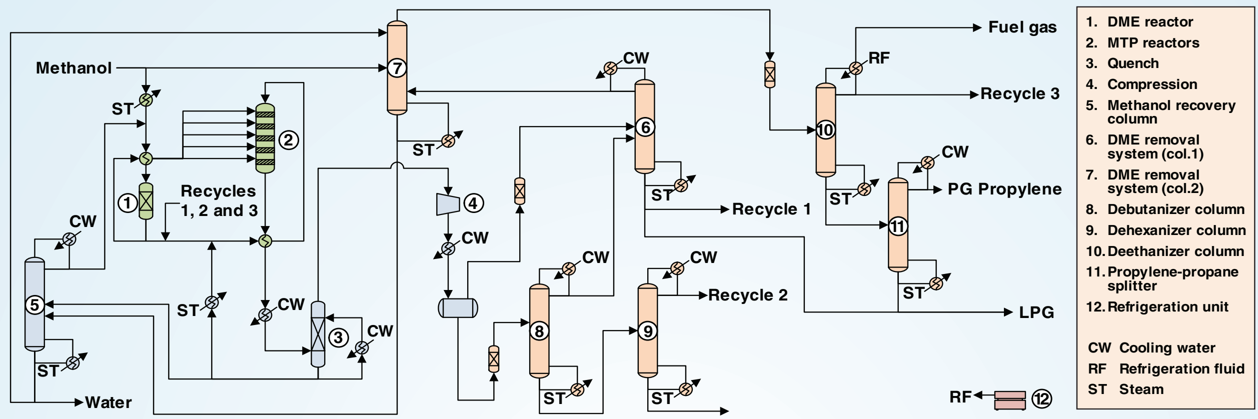
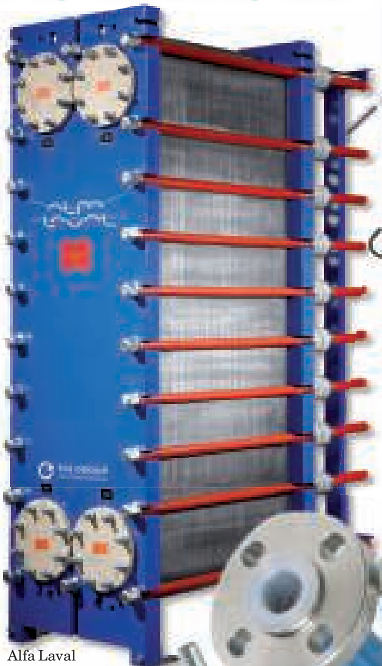


FIGURE 1. **Propylene production from methanol, according to a process similar to the Lurgi MTP and JGC Mitsubishi DTP processes**

Emerson Process Management

AUGUST New Products



Alfa Laval

Larson Electronics

Parker Hannifin

Kin-Tek Laboratories

Wireless capability simplifies level and interface monitoring

The Rosemount 3308 Wireless Guided-Wave-Radar (GWR) transmitter (photo) is designed for continuous level and interface monitoring in remote locations where installing cable is costly or impractical. GWR transmitters are used for process level measurement in vessels and storage tanks in refineries, oil fields, offshore petroleum platforms, chemical and industrial plants. Top-mounted for direct level and interface measurement, the Rosemount 3308 is virtually unaffected by changing process conditions, such as density, conductivity, temperature and pressure. The transmitter has no moving parts, thus minimizing calibration and maintenance needs. Costs are further reduced when compared to wired transmitters since there is no need for cabling, trenching, conduit runs or cable trays. — *Emerson Process Management, St. Louis, Mo.*
www.emerson.com

Use this explosion-proof LED lamp in hazardous locations

The EHL-LED-230X24LV-300 Explosion-Proof Hand Lamp (photo) is designed for rugged use with an aluminum lamp body and globe guard, impact-resistant bulb cover, and rubber housing bumpers for added protection. The high-output LED lamp runs on low-voltage 12– or 24–Volt current supplied by an inline transformer and offers international 230–V d.c. operating capability. The risk of accidental burns is greatly reduced due to the lamp's cooler operation when compared to typical incandescent bulbs. This lamp is also impervious to shattering and blowout when dropped. The lamp includes a long-reaching 300-ft cord, which comes without an attached plug, allowing operators to match plugs to the design of local outlets. — *Larson Electronics, LLC., Dallas, Tex.*
www.larsonelectronics.com

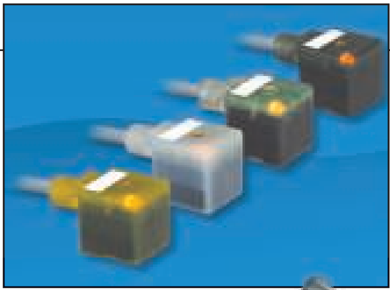
Use this exchanger for heat recovery with corrosive media

The Diabon S15 plate heat exchanger (photo) provides efficient heat transfer in a corrosion-resistant environment, suitable for use with corrosive media up to 200°C. It is constructed from Diabon graphite material, which is a dense, synthetic resin-impregnated graphite with a fine pore structure. Combining high turbulence and countercurrent flow, the Diabon S15 maximizes heat recovery, yielding energy savings. Designed to reduce maintenance, the exchanger features accessible plates and a special plate pattern that reduces fouling. The S15 is larger than other heat exchanger types, with the potential to replace several shell-and-tube or block exchangers. — *Alfa Laval, Lund, Sweden*
www.alfalaval.com

These hose assemblies offer greater vacuum resistance

This company's heavy-wall convoluted hose assemblies (photo) can handle vacuum applications in temperatures up to 500°F. These hoses' thicker PTFE walls provide improved vacuum resistance at high temperatures as well as greater kink resistance and reduced permeation. The PTFE core also serves to reduce friction, effectively minimizing pressure drops and deposits. Manufactured in sizes from ½- to 4-in. I.D., stainless-steel or polypropylene braids are available. Additional accessories include fire sleeves, spring guards, heat-shrink for color-coding and static dissipative assemblies. — *Parker Hannifin Corp., Cleveland, Ohio*
www.parker.com

Note: For more information, circle the 3-digit number on p. 52, or use the website designation.



Turck

Yokogawa

Bionomic Industries

Exair

Overmolded cordset is alternative to field-wireable connectors

New overmolded valve plug cordsets (photo) from this company provide connectivity in harsh environments, as the overmolded face eliminates the need for an additional sealing gasket. Featuring a translucent molding material with embedded LEDs, these cordsets provide visibility for power indication from any angle with black, grey, yellow and clear coloring options to accommodate diverse applications. These fully assembled cordsets require no wiring prior to use. Fully factory tested, the cordsets conform to both NEMA #1,#3,#4, #6P and IEC IP67 standards, as well as meeting the EN 17 5301-803 standard for electrical connectors that service pressure sensors and hydraulic and pneumatic solenoid valves. — *Turck, Inc., Minneapolis, Minn.*
www.turck.us

A portable pressure calibrator with diverse measuring ranges

The new CA700 Portable Pressure Calibrator (photo) features many functions including a variety of measuring ranges, as-found/as-left data storage and memory capacity to store calibration procedures. Equipped with a silicon resonant sensor, the CA700 provides a calibration and verification tool for pressure or differential pressure transmitters and other types of field devices for commissioning or regular inspection. This calibrator can also generate and measure both current and voltage. Maintenance is streamlined through the calibrator's ability to store and record data and error rates, allowing for analysis of device performance and service requirements. The CA700 is available in three different models. — *Yokogawa Corp. of America, Sugar Land, Tex.*
www.yokogawa.com/us

These permeation tubes blend high-pressure gases

The Trace Source 57 Series refillable, gas-fed permeation tubes are used for preparing trace mixtures containing atmospheric gases, light hydrocarbons, hydrides, acid gases and dilute multi-component mixtures. These permeation tubes can employ analyte compounds, such as high-pressure gases (O_2, CO, CO_2 and CH_4) as the permeate source. Usage of controlled-pressure analyte vapor as the permeate source allows for permeation of low-boiling compounds. Mixtures at the parts-per-million and parts-per-billion levels can be directly blended from pure gases with these tubes. — *Kin-Tek Laboratories, Inc., La Marque, Tex.*
www.kin-tek.com

These external spray nozzles provide precise flow control

This company's new external spray mix nozzles (photo) atomize fluids in various spray patterns for a wide range of uses, especially in applications requiring high liquid volumes or viscous liquids (up to 800 cP). Available in a round or flat pattern, these external mix nozzles combine liquid and compressed air to create a coating of liquid. Liquid and airflow are controlled independently, providing precise liquid flow. Constructed of stainless steel for corrosion resistance, these nozzles are useful in painting, coating, cooling and treating a variety of products. — *Exair Corp., Cincinnati, Ohio*
www.exair.com

This unit simultaneously scrubs gas and particulate matter

The Series 6500 Jet Venturi Scrubber (photo) utilizes a high-velocity spray and scrubbing liquid flow to achieve simultaneous removal of gaseous contaminants and particulate matter as small as 0.75 µm. Standard gas capacity is 5–60,000 ft^3/min. Featuring a high liquid-to-gas ratio, this scrubber is appropriate for applications such as temperature reduction of highly exothermic reactive gases, steam condensation and operations involving large variations in gas volume. Offered as a standalone device, additional accessories are available, including proprietary multi-spray zone staging and polishing packed tower, complimented by a full range of mist eliminator and sump tank capacities. Pre-engineered skid-mounted system arrangements are also available. — *Bionomic Industries, Inc., Mahwah, N.J.*
www.bionomicind.com

New Products

Honeywell International


Omega Engineering


Rotork Fairchild


Mouvex


Reliable Fire Sprinkler

Use this pressure sensor with very viscous media

The new Model 427 Wing Union/Hammer Union pressure sensor (photo) provides a wide and shallow sensing port that facilitates the flow of viscous fluids. The sensor's one-piece design and stainless-steel construction allow for quick installation and durability, even with abrasive or corrosive media. Featuring ±0.2% accuracy, the sensor detects small changes in pressure for applications such as drilling, mud pumping, fracturing, cementing and acidizing. Giving personnel the ability to quickly adjust flow pressure, potentially dangerous conditions such as the emergence of gas bubbles are decreased. Multiple electrical connections are available. — *Honeywell International,Inc., Morristown, N.J.*
www.honeywell.com

This pump series gets an upgrade

The A Series eccentric-disc pump (photo) incorporates a variety of upgrades, including the implementation of ISO PN 16/ANSI 150 flanges. The A Series has also doubled its maximum differential pressure from 5 bars (72 psi) to 10 bars (145 psi), enabling it to be used for the safe transfer of viscous, non-lubricating, volatile or delicate fluids in a variety of new applications. These pumps enable product transfer at temperatures up to 250°C. They have a maximum speeds of up to 7,450 rpm, maximum flowrates to 55 m^3/h, as well as suction and discharge ports from 1- to 4-in. size. These positive-displacement pumps utilize eccentric disc technology, which enables self-priming and dry-running capabilities. — *Mouvex, Auxerre, France*
www.mouvex.com

Use these plastic flow switches in very tight spaces

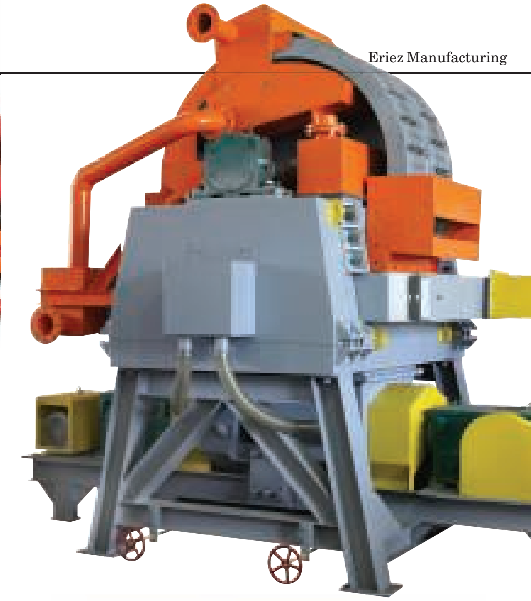
The FS-120 Series of mini plastic flow switches (photo) are designed for use with water and water-based solutions and can handle high-volume applications. Weighing only five ounces, the compact switches are suitable for space-constrained applications, such as coolant or chemical monitoring in portable equipment. As the switch points are calibrated based on water flow, other liquids may require field-testing. Constructed of plastic and stainless steel, the switches feature an operating temperature range of –17 to 107°C. Setpoint differential is 20% maximum and setpoint accuracy is ±15% maximum. — *Omega Engineering Inc., Stamford, Conn.*
www.omega.com

Precise pressure regulation in a small-footprint design

The Model 55 polymer pressure regulator (photo) provides high-precision pressure control within a lightweight, compact package. Manufactured entirely from polymer and stainless steel, the small-footprint Model 55 offers compatibility with gases such as nitrogen, helium and oxygen. The regulator features a non-rising stem and a patent-pending Venturi design. Applications for this regulator include precision pressure-decay and leak-testing, medical ventilators, respiratory diagnostic systems, balloon pumps and sterilization equipment. Featuring a supply capacity up to 10 bars and and flow capacity up to 280 L/min, the Model 55 precisely controls output pressure up to 0.7 bars, even with fluctuating or rapidly decreasing supply pressure. The regulator also operates accurately at low control pressures of 0.5 bars or less. — *Rotork Fairchild, Winston-Salem, N.C.*
www.fairchildproducts.com

This wet alarm valve has a new stainless-steel trim

The new Euro Trim Model E2 in stainless steel is designed for use with the company's Model E and E3 Wet Alarm Valves (photo). This new trim has a rated working pressure of 175 psi and 300 psi, respectively, and is available in 4-, 6-, and 8-in. sizes. The trim conforms to EN12259-2 and meets the requirements of BS EN 12845. All trim pipework is prefabricated in stainless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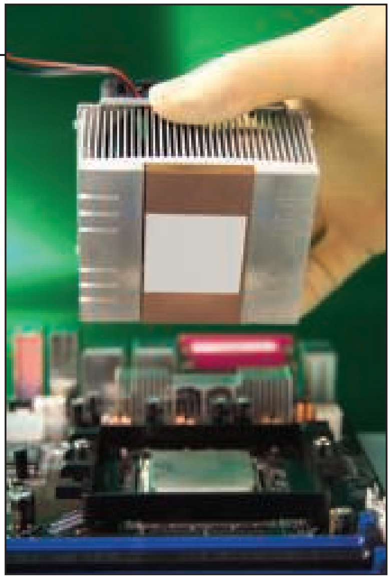
Schubert & Salzer Control Systems


Dow Corning


Quantachrome Instruments

steel, which reduces the potential for internal or external corrosion. Reduced connections minimize the risks for leakage onsite. — *Reliable Fire Sprinkler Ltd., East Grinstead, U.K.*
www.reliablesprinkler.com

Purify non-metallic ores with these magnetic separators

New Wet High-Intensity Magnetic Separators (Whims; photo) provide maximum recovery on even weakly magnetic materials. Whims separate weakly and moderately magnetic minerals and can remove impurities from non-metallic minerals. Typical applications include hematitic iron ore, metallic ores, rare earth ores and more. These separators simplify operation and maintenance with features such as direct water-cooling, no-step motion, air-assisted discharge for less water usage and drier concentrate, as well as vertical upside-down washing to clean the entrainment matrix, reducing clogging. Whims are available in a number of models and sizes. — *Eriez Manufacturing Co., Erie, Pa.*
www.eriez.com

Motorized valve actuation with precision and speed

The new motorized actuation of the 2030 series valve actuator (photo) is composed of an electric stepping motor (400 steps per revolution), a flexible coupling, a gear box and stroke detector. Every part of the gear box is made of stainless steel to ensure long service life. The actuator can achieve positioning speeds of up to 1.3 mm/s, and each step of the motor results in a displacement of just 1.5 µm. The use of a 12-bit a.c./d.c. converter and a special interpolation process makes it possible to detect the position the stroke with a resolution of about 1.3 µm. — *Schubert & Salzer Control Systems GmbH, Ingolstadt, Germany*
www.schubert-salzer.com

Address thermal challenges in electronics with these materials

The TC-5622 and TC-5351 Thermally Conductive Compounds (photo) are designed for electronics applications in many markets, including transportation, semiconductors, power electronics, solid-state lighting, data centers, telecommunications and consumer electronics. Using these compounds can aid in maintaining the long-term performance and reliability of equipment. Boasting low specific gravity and high bulk-thermal conductivity, TC-5622 offers high-quality thermal performance and improved stability against hardening or dry-out in end-use applications. TC-5622 also exhibits low thermal resistance in both thin and thicker bond line thickness (BLT) applications that demand high heat dissipation. Formulated with high viscosity, TC-5351 is well suited for applications demanding resistance to high temperatures and large gap thicknesses, as well as vertical applications requiring a thermal material able to remove heat without flowing out of the gap or changing viscosity as temperatures rise. — *Dow Corning, Midland, Mich.*
www.dowcorning.com

This water sorption analyzer features large temperature range

The Aquadyne DVS-2HT precision water sorption analyzer (photo) is capable of analysis temperatures from 10 to 85°C. This analyzer measures the amount of water vapor a sample can adsorb, and the rate at which it is adsorbed and desorbed. The instruments' precision microbalances are located inside the temperature-controlled housing, providing a high level of sensitivity and reproducibility. The DVS-2HT's high temperature range makes this model appropriate for simulating real-world conditions of a product's exposure to moisture over time, especially in fuel cell and building material applications. — *Quantachrome Instruments, Boynton Beach, Fla.*
www.quantachrome.com ■

Mary Page Bailey and Gerald Ondrey

Show Preview

CHEMINNOVATIONS 2013 CONFERENCE & EXPO

The fourth ChemInnovations Conference and Expo will be held September 25 and 26 in Galveston, Tex. at the Moody Gardens Convention Center. Programmed by chemical industry leaders and designed for professionals in the chemical process industries (CPI), the event aims to supply information that will help companies and individuals prepare for the future of the industry. The conference portion of ChemInnovations is organized into eight tracks and also includes two general sessions, networking opportunities and a set of pre-conference workshops that will be held on September 24.

Keynote speaker David Bem, Dow Chemical Co. global R&D director

General sessions

The keynote address on the morning of September 25 at the conference will focus on the impact of the shifting feedstock slate that the shale gas "boom" has enabled. To be delivered by David Bem, global R&D director for the Dow Chemical Co. (Midland, Mich.; www.dow.com), the presentation will begin with how shale gas has revitalized the CPI in the U.S. While the economic benefits of inexpensive shale gas have been widely described, discussion about the impact of the great increase in ethane cracking has been much more limited. Bem will explain how the shifting feedstock slate creates both challenges to the industry and opportunities for new technologies.

Bem joined Dow in 2007 and has held various leadership positions at the company. Prior to working at Dow, Bem held positions at Celanese Corp. and UOP LLC. He was recently named part of the National Academy of Sciences' Board on Chemical Sciences and Technology (BCST) and to the scientific advisory board at Oak Ridge National Laboratory's Energy and Environmental Sciences Directorates. He holds a Ph.D. from West Virginia University (Morgantown, W.Va.; www.wvu.edu) and nine U.S. patents.

On the event's second day, the general session will mark the return of the Plant Manager's Roundtable, an opportunity to hear insights and perspectives on the CPI's current trends from a panel of plant managers from the Gulf Coast Region. The makeup of the roundtable is currently being finalized.

Conference tracks

The ChemInnovations conference track topics were developed with the help of a distinguished advisory panel, who helped identify and frame key issues for the CPI. The group focused on assembling sessions to include as much practical information and insightful context for conference attendees as possible in each track. The conference topics are indicated by the track titles listed in the box.

Acknowledging the central role of safety in the CPI, the Process and Occupational Safety track is designed to identify a variety of safety risks and present solutions to address them. The track is divided into three sessions, the first two of which concentrate on process safety, while the third focuses on occupational safety. The track features a talk from Beth Rosenberg, a member of the U.S. Chemical Safety and Hazard Investigation Board (CSB; Washington, D.C.; www.csb.gov). In her presentation, Rosenberg will discuss how incidents drive the Board's recommendations. She will also give updates on recent incidents at the Chevron Refinery in Richmond, Calif. and the fertilizer plant in West, Tex.

Prior to being confirmed to the CSB at the beginning of 2013, Rosenberg was a researcher in environmental and occupational health at Tufts University School of Medicine.

Lessons learned from industrial incidents, along with team situational awareness, will be the topic of another presentation in the process safety track. The talk will come from two partners at Human Centered Solutions LLC (Lone Tree, Colo.; www.aplyhcs.com). Additional presentations in the track will focus on controlling static electricity in hazardous areas and managing plant-worker fatigue.

Another issue that is increasing in importance globally is maintaining a longterm water supply. The conference's Water Management track consists of three sessions, all surrounding the theme of implications of water management for the chemical and petroleum refining industries. This track at ChemInnovations includes a session on water reuse and conservation in the CPI, where conference attendees will hear from speakers at Dow Water & Process Solutions,, Veolia Water Solutions (Paris; www.veoliawater.com) and Seimens En-

CONFERENCE TRACKS

TRACK 1: Process and Occupational Safety

TRACK 2: Industrial Water Management

TRACK 3: Maintenance and Reliability

TRACK 4: Regulatory Issues Affecting the CPI

TRACK 5: Critical Workforce Issues

TRACK 6: Automation and Control Solutions and Strategies

TRACK 7: Energy Optimization and Efficiency

TRACK 8: Practical Tools for CPI Professionals ergy Inc. (Orlando, Fla.; www.usa.siemens.com). In addition to conservation, attendees will also hear talks on wastewater treatment and discharge from representatives of Nalco Co. (Naperville, Ill.; www.nalco.com) and Yates Environmental Services (Spokane, Wash.; www.yatesenvironmentalservices.com). Also, the track will feature a session on the water-management issues that may be specific to the U.S. Gulf Coast region.

Beth Rosenberg, U.S. Chemical Safety and Hazard Investigation Board (CSB)

Properly maintained process machinery maximizes equipment lifetimes and reduces process downtime. In the Maintenance and Reliability track, conference participants will hear from experienced speakers about risk-based inspections for instrumentation, fitness-for-service techniques and the future of managing asset-intensive businesses. Other presentations in the track will cover practical solutions for maintenance and reliability.

Along with water management, another topic of growing importance for the CPI is hiring and retaining the workforce needed to accomplish business goals. To address this critical current issue, the Workforce Issues track features presentations on developing technical leaders, accelerating operator development and recruiting, and hiring key employees.

The Automation and Control track focuses on introducing new technologies and on applying existing technologies in new ways. One focus of the track will be the use of wireless devices in the CPI.

As a key input for chemical facilities, energy is an ever-present concern. Its efficient and sustainable use helps companies compete more effectively. The Energy Efficiency conference track includes a presentation on how energy will be used out to 2040, given by Larry Gros, the polyolefins production technology manager at ExxonMobil Corp. (Houston; www.exxonmobil.com). Another talk, to be delivered by the director of operations and sustainability for the Fluor Corp. (Irving, Tex.; www.fluor.com), Jeffrey Goetz, is titled "From Integrated Automated Plant Design to Excellence in Operational Optimization through Energy Efficiency." The track also contains a presentation on combined heat and power (CHP).

The Practical Tools track offers engineers a chance to learn both about vital technical and non-technical skills. In the non-technical session, attendees will hear talks on effective communication, executing investigations and asset performance. The technical skills session of this track includes presentations on troubleshooting of process pumps and statistical process control in the chemical industry.

Currently being finalized, the Regulatory Issues track will examine the most recent changes on the regulatory front, and how they are likely to impact the CPI.

Awards, exhibits and workshops

In addition to the conference sessions, the ChemInnovations staff will host an awards banquet on the evening of September 25 at the conference location. At the banquet, the winners of the 2013 Kirkpatrick Award for Chemical Engineering Achievement will be announced. Also, a group of other awards, both company and individual, will be presented in areas such as innovative energy strategies, community involvement, safety investment and others.

ChemInnovations attendees will also be invited to explore the exhibit floor, where over 100 companies will display their equipment and services. The September issue of *Chemical Engineering* will contain more information on the specific technologies being showcased on the exhibit floor.

The pre-conference workshops on September 24 cover topics including the basics of corrosion, root-cause analysis and integrating a TWIC (transportation worker identification credential) reader. ■

Scott Jenkins

Ten Things You May Not Know About Liquid Mixing Scaleup

Close attention to these aspects of scaleup can ensure greater success

David S. Dickey
MixTech, Inc.

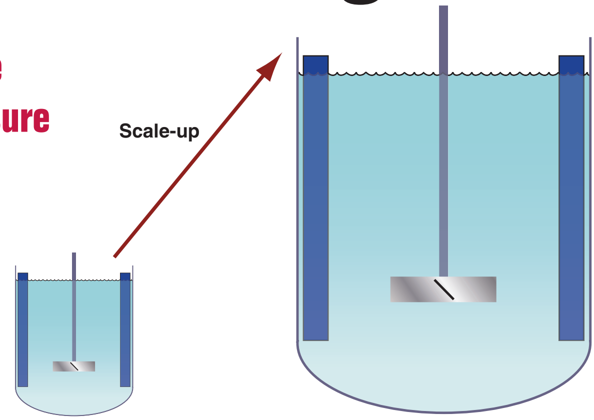


FIGURE 1. Scaleup applies to any kind of development or testing conducted in smaller equipment, and using those results to design and operate successfully in larger equipment. While absolute size does not matter, the small-scale results must be relevant to the large-scale equipment

The scaleup of liquid mixing systems does not have to be a mystery. The principles are quite well understood, although knowing which principles apply is not always obvious. Follow this guidance to improve operation.

1. Liquid mixing scaleup. Liquid mixing is the most common use of scaleup methods in chemical engineering. The concept of scaleup is to take small-scale results and predict results in larger-scale equipment (Figure 1). The term "liquid mixing," more broadly called agitation, can be extended to include most types of mechanically induced fluid motion that is carried out for the purpose of increasing the uniformity of concentration, composition or temperature.

In this article, the term mixing applies to all types of mechanically induced fluid motion, including blending, suspension and dispersion. Fluid mixing also includes the blending of viscous fluids, the suspension of solids in liquids, the dispersion of gases in liquids, the dispersion of immiscible liquids and other efforts to combine materials that behave as fluids.

The reason that scaleup efforts are so prevalent for mixing processes is that the possible combinations of tank geometry, impeller types and process applications related to combining fluids are almost limitless. To understand how fluids behave when they are mixed or agitated, you must understand the fluid properties, the tank size and shape, the impeller type and the rotational speed of the impeller. In basic terms, three factors determine the size of any mixer required: 1) *How much fluid must be agitated;* 2) *How difficult the fluid is to move;* 3) *How intense the agitation needs to be for the application.*

The answer to the question of "how much" can be quantified by either volume or mass. However, because fluid density is an important factor in turbulent power, all combinations of volume, mass, and density should be known. The "how difficult" question is measured by the properties of the fluid. Viscosity describes the difficulty for the motion of liquids, and may be applied to high concentrations of solids in slurries or pastes.

The settling rate of solids for a solids suspension or the volumetric flowrate of a gas for gas dispersion are also difficult factors for multi-phase systems. Small-scale testing is often the best — and sometimes the only — way to decide "how intense" mixing needs to be. Properly designed and evaluated testing will include all three factors.

Deciding "how much" fluid needs to be mixed may also involve knowledge about the shape of the tank. Tall, slender tanks and short, fat tanks may present different mixing problems for the same quantity of fluid. Tank features, such as the existence of baffles and feed locations, may also influence mixing intensity. Testing is usually done with a fluid that has the same properties as expected in the full-scale application, although a test fluid with a different viscosity may be chosen if the flow pattern will change with scale. For instance, the flow pattern in larger tanks, with a higher impeller Reynolds number, is less influenced by viscosity than in smaller tanks.

Scaleup efforts will never be successful unless the real objective and critical variables have been identified correctly. For instance, scaleup for product quality may be different from scaleup for yield quantity. In some cases, a high-quality product may result in less quantity, or the opposite.

For example, the investigator should ask if a minimum requirement exists for either quality or quantity, and how much can be achieved for the other objective within the limiting constraint? The process of testing should explore the alternatives so that engineers can choose a successful direction for scaleup and truly understand how certain adjustments might be made on the large-scale system to compensate for potential uncertainties. Testing to identify a range of possible conditions that will be successful provides valuable information about how production-scale adjustments can be

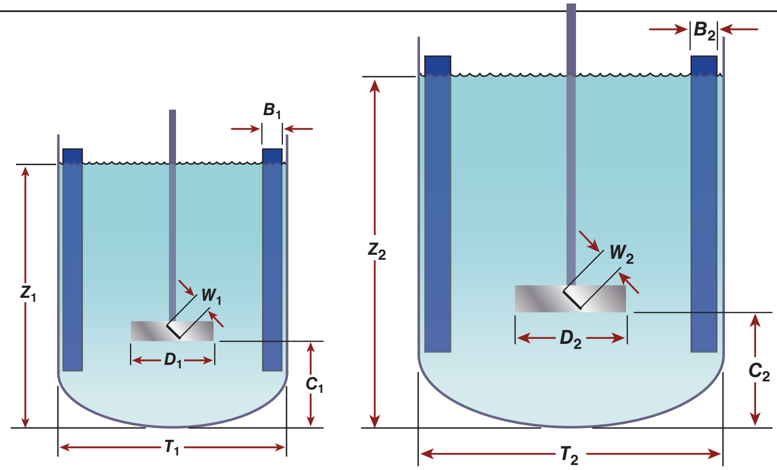


FIGURE 2. With geometric similarity, linear dimensions are in the same proportion in both scales. For instance, the ratio of impeller dia. to tank dia. will be the same in both scales.The relative size of all of the large-scale dimensions will be in the same proportion to the small-scale dimensions

made to ensure the desired outcome.

Other examples of problem definition arise when considering solids suspension. What aspect is the most important for the specific application: Keeping solids from settling on the bottom? Or distributing solids uniformly? Or dissolving solids in the liquid? Or reacting the solids with something in the liquid? Each may be governed by a different scaleup requirement. The box on p. 35 shows sn off-bottom solids suspension, which is one type of suspension that can be observed visually.

Similarly, gas dispersion may be limited by several factors, including:

- Mass transfer between the bubbles and the liquid
- Concentration uniformity in liquid
- A reaction taking place in the liquid
- Stoichiometric depletion of a component in the sparged gas

Correct identification of the primary or a key process element is essential.

2. Small failures. One major advantage of conducting small-scale tests before designing full-scale applications is that mistakes or problems can be observed using a smaller quantity of material. For instance, a reaction or formulation failure on the small scale is less likely to create significant hazard or excessive quantities of waste.

For investigators, one essential aspect of those small-scale failures is noting the conditions that lead to the failure, and establishing the reason for failure — whether the problem is formulation or mixing related — to avoid repeating those conditions.

Insufficient mixing is more likely to cause a problem than excessive mixing, but both extremes need to be understood. Often knowing the lowest intensity of mixing that is necessary for success will result in the most economical mixer scaleup.

3. Geometric similarity. Geometric similarity means that all of the length dimensions in the different scale tanks are in the same relative proportions to one another (Figure 2). Geometric similarity is not essential for all small-scale mixing tests, but it usually helps. Geometric similarity alone may be a sufficient reason for conducting some small-scale tests. Unusual tank geometry, impeller type or fluid properties may be the primary reason for small-scale testing. Geometry will dictate what flow patterns are created and whether they will effectively control the entire tank.

Scaleup with geometric similarity means that the only remaining variable to be chosen is the rotational speed of the large-scale mixer. Because geometric scaleup from one size to another means that every length dimension of the small scale is in the same proportion to the corresponding length dimension in the large-scale unit, any convenient length ratio can be used to calculate a large-scale mixer speed. The most common length ratios to use for this approach are the impeller dia. or the tank dia.

$$N_{large} = N_{small}\left(\frac{D_{small}}{D_{large}}\right)^n = N_{small}\left(\frac{T_{small}}{T_{large}}\right)^n \quad \textbf{(1)}$$

where:
N = the rotational speed of the mixer, rpm or rps
D = the impeller dia., in. or m or mm
T = the tank dia., in. or m or mm
n = the exponent on the scale ratio, unitless

Because all calculations are ratios, the units for each variable should be the same for the different sizes.

During scaleup with geometric similarity, the ratio of impeller diameter (from small scale to large scale) is the same as the ratio of the tank diameter (from small scale to large scale) so the calculation can be carried out either way.

The exponent, n, on the scale ratio determines how much the impeller speed changes from small to large scale. For any positive value of n and any practical scaleup criterion, the large-scale rotational speed will be less than that of the small-scale mixer.

Some values for the exponent n have a physically significant meaning for turbulent mixing. For instance, an exponent value of $n = 1$ means that the rotational speed is reduced in proportion to the linear dimension increase. This speed change means that the impeller tip speed, πND, will be held constant for scaleup. The constant π cancels out of the ratio of tip speeds, so ND is held constant on scaleup.

If $n = 2/3$, the power per volume or power per mass is held constant with scaleup. The exponent n can be developed by simple algebra, using Equation 2:

$$P \propto \rho N^3 D^5 \quad \textbf{(2)}$$

where:
P = impeller power, hp, W or kW
ρ = fluid density, lb/gal or kg/m^3 or g/cm^3
N = rotational speed, rpm or rps
D = impeller dia., in. or m or mm

Equation 2 is only a proportionality not an equality, so appropriate constants and conversion factors are needed to calculate actual values.

The constant of proportionality for power involves the impeller power number, which is a characteristic of the impeller geometry. Conversion factors are necessary to ensure consistent units for power, speed, and diameter. If the same fluid is used in both scales, the fluid density will be a constant for scaleup, and will cancel out of the ratio for small to large scale. For scaleup using the same fluid, the power-per-volume and power-per-mass scaleup are equivalent.

As shown in Equation 3, the tank volume, V, is proportional to the tank diameter cubed, which is also proportional to the impeller diameter cubed with geometric similarity.

$$V \propto T^3 \propto D^3 \quad (3)$$

The constant of proportionality is determined by the tank geometry for T, and by the impeller-to-tank diameter ratio for D. Combining the expression for power with the expression for volume results in the Equation 4:

$$\frac{P}{V} \propto \frac{N^3 D^5}{D^3} \propto N^3 D^2 \quad (4)$$

Keeping N^3 times D^2 constant or equal at both scales maintains power per volume as a constant, as shown in Equation 5:

$$\frac{P}{V} \propto \frac{N^3 D^5}{T^3} \propto \frac{N^3 D^5}{D^3} \propto N^3 D^2 \quad (5)$$

This equality can be rearranged to obtain the large-scale speed as a function of the small-scale speed times the scale ratio raised to the 2/3 exponent.

$$N_{large} = N_{small} \left(\frac{D_{small}}{D_{large}} \right)^{2/3} \quad (6)$$

In practice, nearly all of the practical scaleup exponents for mixing fall between the exponents for equal tip speed (1) and equal power per volume (2/3). Other less practical scaleup exponents for geometric similarity can be derived by similar rearrangements of expressions. An expression for equal Reynolds number can be obtained by keeping D^2N constant, resulting in an exponent of 2 on the scale ratio. Equal Reynolds number scaleup results in too little mixing in the large scale.

An expression for equal blend time can be obtained by keeping rotational speed constant, resulting in an exponent of zero. Equal blend time requires an impractical increase in power for any significant tank size increase. Reasonable expectations would be that blend times in a large tank would be longer than those for a small tank.

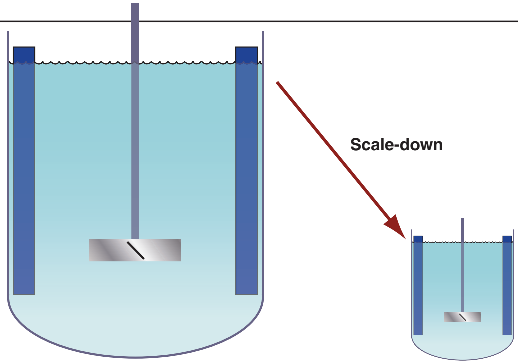


FIGURE 3. Scale-down is most often used as a means of investigating possible improvements to an existing process. The smaller scale provides a means of conducting tests more quickly and efficiently, while avoiding large errors or waste if a failure occurs

With some justification, equal fluid motion can be achieved with equal torque per volume. Torque is proportional to power divided by speed, or is proportional to the rotational speed squared times the impeller diameter to the fifth power for turbulent conditions. Equal torque per volume results in an exponent of one, like equal tip speed, but only with geometric similarity.

Testing is strongly recommended if the effects of impeller type are involved. For instance, test results obtained in a small-scale tank with a pitched-blade turbine may be difficult to interpret in a large-scale tank with a hydrofoil impeller. The flow patterns created by different impeller types are likely to be different — sometimes in a critical way. Some small-scale testing may be devoted exclusively to understanding flow patterns within a tank.

Computational fluid dynamics (CFD) provides another means of modeling flow patterns. However, CFD usually lacks the ability to establish the effects of mixing intensity and flow pattern fluctuations that can be observed or tested in a physical model. In these instances, small-scale testing can provide more practical information compared with computer modeling.

Geometric similarity is also strongly recommended for solids-suspension testing. The way the discharge flow pattern from the impeller strikes the bottom of the tank affects both the intensity and the direction of the fluid flow, which will lift particles off the bottom and carry them upward. Off-bottom clearance of the impeller can be an important factor affecting the bottom flow pattern. Liquid level and other tank geometry will further influence the fluid flow and thus the suspension uniformity.

4. Determining scaleup rules. The "rules" for scaleup usually mean keeping one variable —such as tip speed, power per volume, off-bottom suspension, or torque per volume — constant. The variable held constant depends on the application, although general "rules" are not absolutes. Ideally, the scaleup method chosen will maintain a controlling aspect of mixing intensity. If testing shows that power per volume must be held constant for the desired results, then power per volume should be maintained for scaleup.

Deciding which aspect of mixing intensity gives the desired process results needs to be determined as part of the small-scale testing effort. Merely changing the mixer speed in a series of tests will only determine the mixing intensity that is required in the small scale. Knowing the small-scale intensity will not adequately identify the intensity characteristic that must be held constant for successful scaleup.

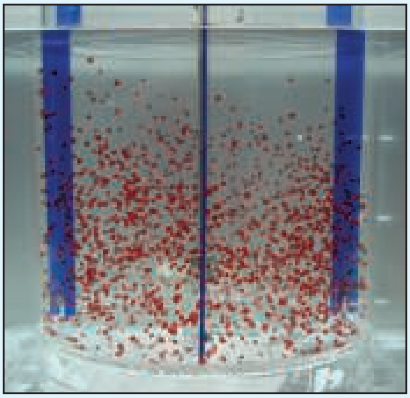
Increasing the rotational speed of a mixer will increase the power, tip speed and torque, simultaneously. However, changing both the impeller diameter and the rotational speed can test equal power, equal tip speed and equal torque independently. Matching equivalent conditions in the small scale will help to identify the most appropriate aspect of intensity that must be held constant.

5. Different scaleup for different applications. Although doing scaleup by fixed "rules" can lead to problems, some processes are controlled by fluid dynamic mechanisms, and those mechanisms behave in predictable ways during scaleup. For instance, rapid chemical reactions will occur when micro-scale turbulence brings the reactants together.

For complicated chemical processes that follow series-parallel reaction paths, the mixing intensity and local turbulence may result in different products, because of different reactant com-

OFF-BOTTOM SUSPENSION — IMPELLER DESIGN MATTERS

One process result that can be observed and defined is off-bottom solids suspension. Off-bottom suspension occurs when the mixer speed is just sufficient to keep all of the particles from resting on the bottom for more than a second. The transition from solids just moving on the bottom, to solids being lifted off the bottom, can be observed visually in a transparent tank. Off-bottom suspension is defined well enough that it is usually described in terms of a just-suspended mixer speed, N_{js}. The speed depends on the impeller type, impeller location, tank geometry, solids properties and concentration. ❑



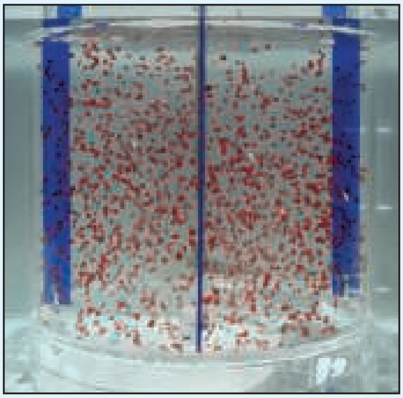


FIGURE 5 (RIGHT). This photo shows solids suspension with a hydrofoil impeller operating at the same power, speed, and torque as the pitched-blade turbine in Figure 4. Using an impeller operating at the same power, speed, and torque is equivalent to replacing a different type of impeller on the same mixer drive. Because the hydrofoil impeller has a lower power number than the pitched-blade turbine, the observed hydrofoil impeller has a slightly larger dia. than the corresponding pitched-blade turbine.The hydrofoil impeller creates strong downward axial flow, which lifts the solids off the bottom and carries them further into the upper portion of the tank compared with the pitched-blade turbine

FIGURE 4 (LEFT). Off-bottom suspension with a pitched-blade turbine is shown with red plastic beads in a transparent tank.The mixing intensity provided by the this type of turbine is sufficient to achieve off-bottom suspension. None of the particles remain on the bottom of the tank for more than a second and the particles are lifted into the upper portion of the tank

binations. The length of the turbulent micro-scale eddies is related to the local dissipation of power per mass, which is also power per volume for the same density fluid. For scaleup efforts with geometric similarity, the local power per volume is some proportion to the total or average power per volume For instance, the local power per volume in the impeller region might be ten times the average power per volume. With geometric similarity, that ratio between local power per volume and average power per volume should remain the same. So while the power per volume in the impeller region may be greater than the average power per volume, the average will scale proportionately for similar locations in the tank.

Scaleup by power-per-volume with reactant injection near the impeller is often the best approach for controlling rapid chemical reactions. Using power-per-volume scaleup also results in a conservative scaleup, providing intense mixing in the large scale.

Simpler rapid chemical reactions, such as acid-base neutralization reactions, which have only one path and produce consistent final products, may be more influenced by liquid blending. Mixing intensity may affect the rate of reaction, but not the final product constituents. In those cases, assuring that all parts of the tank are in motion may be enough for successful scaleup. Applications with simple reactions may hardly need small-scale testing for proper design — experience with similarly sized tanks may suffice.

Note that small-scale mixer testing does not always involve chemical reactions. Many mixing processes involve just formulation — blending different materials to uniformity. What makes formulation difficult is the variety of types of mixing (such as blending different liquids, suspending solids, dissolving solids, heat transfer, dispersion of immiscible liquids, dispersion of gas, viscous mixing and more) that may be needed for a single batch.

The challenge is that no single mixer design may be best for all of these process steps, yet the batch operation still needs to be completed in a single tank. Additionally, the liquid level and fluid properties may change as the batch is being processed. Pilot-scale testing may focus on basic aspects of the operation, such as order of ingredient addition, time required for dissolution or blending, proper location of impellers, and other practical matters related to variables in the batch process.

6. Scale-down is difficult. Sometimes scale-down (Figure 3) is used to investigate an existing process for problem solving or process improvement. If geometric similarity were the only critical aspect for pilot-scale testing, scale-down would be easy.

The more common problem is that scale-down of a large-scale process does not happen uniformly. For instance, one aspect of the process may scale down at constant tip speed, while another may scale down at equal power per volume. The result will be a small-scale process that behaves differently than some aspects of the large-scale process.

The most critical aspect of the process must be studied separately. Just as with scaleup, only one or two process behaviors can be duplicated at different scales. For instance, if solids suspension can be duplicated on the small scale, then powder addition may be different, and vice versa. When scale-down is expected to duplicate all aspects of the large process equally well, the results will always be disappointing; some aspects of the process will always change.

Just as knowing the objective for scaleup is important, knowing the objective for scale-down is critical, too. For example, if the process problem involves solids settling on the bottom of the tank with some of the important ingredient being left behind, then solids suspension may be the focus of small-scale testing. If powder addition is the problem, then the testing effort should focus on proper scale-down of surface motion and rate of addition.

Investigation of solids suspension should focus both on turbulence intensity and fluid velocity near the bottom, since these factors account for lifting

OPTICAL DISTORTION WHEN VIEWING MIXING IN A TRANSPARENT CYLINDRICAL TANK

Scaleup is often used to take experimentally observed results from a small-scale transparent tank and use them to create similar results in a large-scale tank. Visual observation of what happens with an unusual tank geometry or impeller type can be extremely useful in predicting results in a large-scale tank.

Making good observations sometimes involves an extra effort, even for a tank filled with water. Simply seeing what happens in a clear tank filled with water will be limited by the optical distortion that occurs when looking into the tank. The optical distortion is caused by the curved surface of the cylindrical tank and the difference between the index of refraction for air and water.

To reduce optical distortion, a cylindrical tank can be placed inside a square box. When both the cylindrical, stirred tank and the surrounding box are filled with water, the distortion is almost eliminated because the air-water transition occurs across a flat surface. This double-tank arrangement is shown in the oblique top view of the tank and box with the mixer in the center (Figure 6). The side view (Figure 7) shows the different optical effects. Starting at the top of the picture, when neither the cylindrical tank nor the square box are filled with water, the blue baffles are easily seen along the side of the tank. In the middle of the picture, only the cylindrical tank is filled with water. The optical distortion makes the blue baffles disappear almost completely.

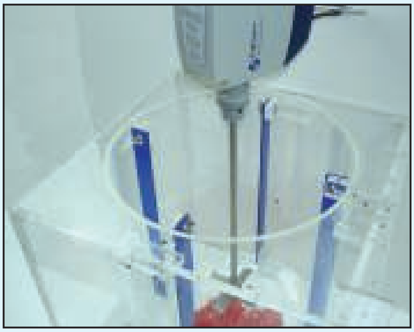


FIGURE 6. **The double-tank arrangement shown here can be used to visually observe or photograph flow patterns in a cylindrical tank. All mixing action occurs in the cylindrical tank, just as in a process tank. Optical distortion occurs when looking into the side of a cylindrical tank filled with water, much as a curved lens distorts or magnifies visual observations. The external tank with a square cross section eliminated most of this optical distortion. The flat side of the outer square tank causes minimal distortion**

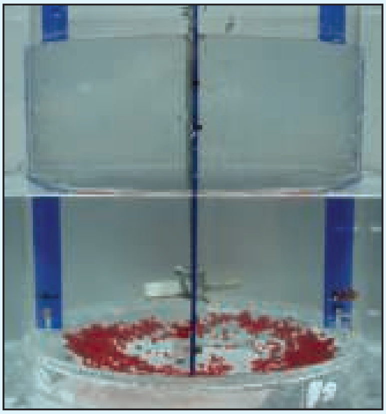


FIGURE 7. **At the top of this photo, one can see how the baffled tank looks when neither tank is filled with water. When looking at the empty tanks, the blue baffles are easily observed along the sides of the cylindrical tank. When only the inner cylindrical tank is filled (as seen in the center of the photo), the optical distortion causes the blue baffles to disappear visually. When both tanks are filled with water (at the bottom of the photo), the baffles can be seen, almost as they appeared in air at the top of the picture**

The bottom portion of the picture shows what happens when both the cylindrical tank and the square box are filled with water. The blue baffles reappear, as they were seen in the top portion without water. Almost half the volume of the tank, around the perimeter of the cylinder, disappears from view when the distortion is not corrected. ❑

particles and sweeping them away. If surface addition of solids is being investigated, then surface velocities must be duplicated and the addition rates must be scaled to account for volumetric flow of solids per surface area. In many cases, choosing not only the scale factor for adjusting the mixer speed, but also adjusting other rates, may be essential for success.

An objective, such as the rate of dissolution of a solid, may not be affected by mixing intensity once all the particles are suspended off the bottom of the tank. The critical factor in the dissolving of solids is often solubility, which tends to be strongly affected by temperature and particle size. Rate of dissolution is affected by the surface-to-volume ratio. For a given application, the mixing intensity must be sufficient to ensure off-bottom suspension of solids (Box, p. 35) and rapid enough to maintain a nearly uniform concentration of solids in the liquid. The dissolving rate for the same material and particle size may be nearly identical in the small scale and larger scale, although the blend time will increase with tank size.

7. Limitations of scaleup information. Two questions are often asked with respect to mixing:

- What is the smallest tank in which I can get good mixing results?
- What is the largest scale change I can make successfully?

Neither has a simple answer for all types of scaleup, just as the reasons for testing are different.

The smallest tank for mixing tests depends on at least three variables:

- The accuracy of the impeller shape
- The ability to observe flow patterns,
- The scale of mixing to be observed

Small impellers always have proportionately thicker blades when compared with large impellers, to ensure that the small ones are not too fragile to handle. Also, small impellers — for instance, those less than 6 in. (300 mm) in dia. — typically come in size increments of about 1 in. (25 mm), which is more than 15% of the dia.

Increments for impeller size for diameters that are larger than 20 in. (0.5 m) may be about 2 in. (50 mm), or less than 10%. While percentages seem small, the power increments are to the fifth power of the impeller diameter in turbulent conditions. That effect of those impeller diameter increments represents double the power between small impeller sizes, and about a 50% increase between larger sizes.

The common recommendation for testing to observe mixing flow patterns in small tanks is for tank diameter between 1 ft (1/3 m) and 2 ft (2/3 m). In that size range, model impellers should create flow patterns similar to those expected in larger tanks. And with low-viscosity liquids, the flow patterns will be fully turbulent. Such tests may improve the certainty of scaleup for large tanks.

In today's world of high-value products and process minimization, a tank with a 1/4-m-dia. may be larger than the standard production scale. In which case, more must be known about the controlling processes that are observed in the laboratory. Scale testing and efforts must be carried out to observe the effects of mixing, especially if changing the stirrer speed in a flask or beaker will affect the results.

Another scaleup consideration is how much of a change can be done successfully. For instance, doubling a length dimension increases the volume by a factor of eight. Thus, an increase of ten times the length scale results in 1,000 times the volume.

For complicated scaleup applications or those with limited small-scale data, a two-, three- or four-fold increase in a linear dimension may create significant uncertainties. In other cases, laboratory data — even for a chemical reaction — may allow for scale changes involving a 10- or even 20-fold increase in the length dimensions and the corresponding increase in volume. Many large processes undergo limited experimental testing, in very small scales, yet mixing requirements can be met with large increases in size.

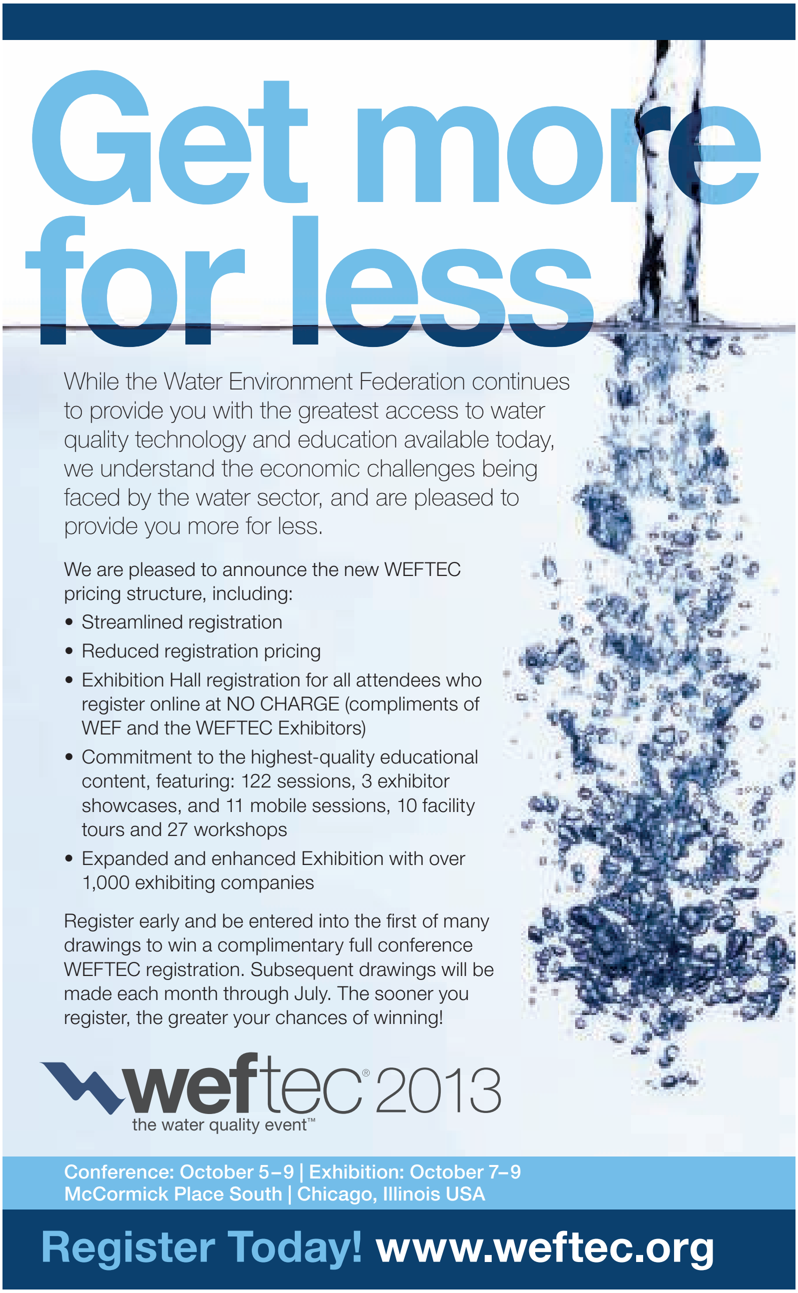
Geometric similarity is not an essential for scaleup, provided the process requirements are well understood and the critical mixing variables are held constant. A large-scale mixed tank, especially a pressure vessel, may be much taller in relation to its diameter compared with the small-scale tank that was used for development testing and geometry modifications. For storage tanks, small-scale testing is rarely done, but large storage tanks may be shorter in relationship to diameter.

8. Viscous mixing. Applications involving viscous mixing often experience many problems during scaleup, so small-scale testing is especially important. Rarely does a single viscosity value adequately describe the properties of a viscous fluid. High-viscosity fluids are usually non-Newtonian, which means that the apparent viscosity includes effects of not only temperature but also shear rate, time dependence, and possibly yield stress. Making things more complicated, the properties that complicate viscosity are often those properties that are sought to enhance the quality of the end products.

Mixing viscous materials often involves changing from turbine-style impellers to large-diameter, close-clearance impellers. Even with turbine-style impellers for moderately high viscosities, more impellers and larger-diameter impellers are needed just to move all of the fluid in a tank. As a result, testing at a small scale can be useful in determining which type, size, or number of impellers works best for moving the fluid.

Because flow is often laminar, stretching and folding mechanisms must replace turbulence and random motion for mixing. These slower processes increase blend time and make complete motion more difficult. For all of the experience in mixer design with low-viscosity liquids, limited experience and design guidance is available for mixing high-viscosity fluids using close-clearance impellers.

However, a bright side to scaleup exists with viscous blending. Most viscous



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mixing scaleup can be handled by equal tip speed. The power requirements for nearly all of the blending processes depend on Reynolds number, which is affected more strongly by a primary length dimension, such as tank or impeller diameter, than velocity. So, if tip speed, which translates to fluid velocity, is held constant during scaleup, the Reynolds number increases in direct proportion to the increase in the length dimensions of the tank.

As the Reynolds number increases with tank size, the effect of viscosity in the laminar and transitional ranges is reduced. This change means easier fluid movement and potentially greater mixing intensity. For the same Reynolds number, the large-scale mixer could even be considered to be operating as if the fluid had a lower viscosity. The reduced effects of viscosity should make mixing easier with scaleup.

9. Chemical reactions. Most new chemical reactions are developed at the laboratory scale. Commonly available laboratory mixers may be as simple as magnetic stir bars in glass beakers, or flasks on a shaker table. These mixer types are not effective in large-scale processes because the rotational flow patterns do not create sufficient vertical and horizontal motion for good mixing. The only reason that the swirling motion in laboratory glassware is adequate is that in such small containers the ingredients mix quickly regardless of the flow pattern.

Scaleup of chemical reactions often follows two different paths — an easy one and a more difficult one. The easy path occurs when the new reaction is similar to one previously put into production, where the reaction steps and any exothermic heat generation have already been successfully scaled. Other reactions with different kinetics, stoichiometry and heat release may require extensive pilot testing before going into production.

While work in a pilot plant may provide additional information about the reaction, a pilot reactor should be designed to test and observe the effects that mixing has on the chemical reaction. Pilot testing needs to investigate the positive and negative effects that mixing has on the reaction, in terms of yield, quality and even the overall success of the process. Mixing is necessary to bring reactants together and to distribute the reactants and product uniformly in the tank. Heat addition or removal may also be part of the chemical process.

Information about the process must also establish critical mixing variables that are required to ensure the success of the reaction. Insufficient mixing may not provide adequate uniformity or blending that is rapid enough for the reaction to produce the desired products. Excessive mixing may introduce air, or may negatively impact

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product properties. In any case, understanding the limits of successful reaction, and understanding the problems that may arise outside the acceptable range, will help engineers determine both the methods and the range of scaleup options.

For complicated chemical reactions, power per volume is often the most effective scaleup method, especially where mixing affects the product distribution. With slower reactions, uniform blending commonly associated with flow patterns and liquid velocity may be more important for maintaining batch uniformity. Reaction rate and blending uniformity are both essential for scaleup.

10. Scaleup uncertainties. A variety of uncertainties arise during scaleup. In simple cases, deciding which mixing mechanism is critical to the process and keeping the critical variable constant is easy. Geometric similarity and constant velocity (equal tip speed) scaleup may be sufficient for batch and continuous processes involving basic blending. However, if multiple reactions are involved, one reaction may be limiting in the small scale while another may be limiting in the larger scale.

Some of these interacting hydrodynamic effects also may appear in solids-suspension applications, where local turbulence may lift particles off the bottom of the tank and local velocity will move particles away from the bottom and into the upper portion of the tank. The result is the determination of a scaleup exponent that falls between equal power per volume, associated with turbulence, and equal tip speed, associated with velocity. The effects may depend on the particle size, settling rate and concentration.

Scale changes always involve changes in the relative amount of surface and volume effects. A scale- ratio change in a length dimension, such as tank diameter, results in a scale-ratio-squared change in area, tank diameter squared, and a scale-ratio-change cubed in volume, tank diameter cubed. Thus, any increase in scale will result in volume effects becoming more significant when compared with area effects.

A significant downside to this effect involves any chemical reaction resulting in a significant heat of reaction (exothermic or endothermic). In the small scale, heat transfer may not be a problem, but with scaleup, the heat-transfer surface area decreases compared with the heat of reaction, which is a volume effect. Temperature control becomes more difficult as the tank size increases. For an exothermic reaction, reduced heat removal will cause a bulk temperature rise, which could lead to a runaway reaction.

In most scaleup efforts, the certainty of making the correct scaleup decisions may never be resolved until the large-scale process has been built and is operating. Even at the large scale, the operating limits of the process may not be well defined. Several aspects of scaleup may improve with size, such as reduced impact of viscosity as represented by increasing Reynolds number, while other aspects may become more difficult with increased size, such as the reduction of the surface-to-volume ratio.

The key to effective mixing scaleup is always to carry out a thorough investigation of the effects of mixing on the small scale. That investigation involves not just deciding what works, but learning the limits and avoiding situations that do not work. Simple liquid blending may not need any experimental testing because of a basic understanding of mixing. However, innovative applications involving complicated chemical reactions or non-Newtonian fluids may be much more difficult to understand and scale up successfully. The process of investigating mixing effects on the small scale will often be a critical tool in creating a successful large-scale process. ■

Edited by Suzanne Shelley

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Feature Report

Pinch Analysis for Production Planning in Manufacturing Industries

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The two new graphical techniques presented here can help optimize factory capacity and financial resources

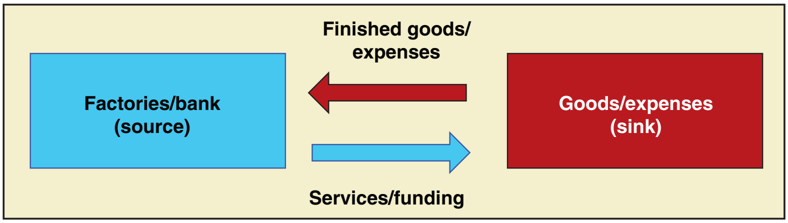

FIGURE 1. Production sinks demand resources, whereas production sources supply the resources

Manufacturers face seasonal supply-and-demand variations in their production cycle due to fluctuations in both market demand and supply of raw materials. Therefore, manufacturers need solutions that can help them to cope with this challenge in effective production planning. Pinch analysis, which has been used for resource conservation in the past few decades, has recently been extended to production planning problems. In this article, two novel graphical tools are proposed to address two common production planning problems, namely, factory capacity planning and financial resource planning. Industrial case studies on the small-scale production of high-value products are shown to illustrate the approach.

Pinch basics

Pinch-analysis techniques have been widely used as systematic design tools in the chemical process industries (CPI) over the past three decades. The techniques were initially developed for the synthesis of heat-recovery networks [*1*]. Through heat-and-mass transfer analogy, the proposed techniques were later extended for mass-integration problems [*2*]. More recently, pinch-analysis techniques were developed for resource conservation networks, focusing on industrial water conservation [*3–7*] and utility gas recovery [*7–9*]. In addition, pinch analysis techniques have also been extended to a variety of non-conventional areas, such as financial management [*10*], supply chain management [*11, 12*], "emergy analysis" [*13*], carbon-constrained energy planning [*14*] , short-term scheduling of batch processes [*15*], carbon capture and storage [*16, 17*] as well as human resource planning [*18*]. However, there has been very limited work on the use of pinch analysis in the area of production planning.

In most manufacturing companies, the producers are typically faced with seasonal supply-and-demand problems, which leads to the emergence of lean and peak periods. Such variation in supply and demand are beyond the manufacturer's control. In order to overcome such problems, manufacturing companies can only plan the production based on constraints, such as production capacity or available financial resources, in order to accommodate the varying demand.

Some earlier attempts to use a pinch-analysis approach for aggregate planning in the supply chain have been developed by Shenoy and co-workers based on a graphical approach [*11, 19*]. An equivalent algebraic-targeting technique was later developed by Foo and colleagues [*12*]. The later work also caters to cases with the limitations of minimum and maximum inventories, as well as the scheduling of process shutdowns that were not considered in the earlier works [*11, 19*]. Subsequently, Ludwig and others [*20*] extended the techniques for production with seasonal variations in demand. Note that those previous works demonstrated the usefulness of pinch analysis as a decision-support tool for production-planning problems. Also, the main objective of those works was to determine the production rate based on the seasonal forecast for a given planning horizon. Besides, Foo and others [*15*] extended pinch-analysis approach for short-term scheduling of batch reactors in multi-purpose plants. However, none of the above techniques address the minimization of outsourcing; nor do they explore opportunities for operational changes.

The underlying principle of pinch analysis is the use of information about stream quantities, such as production, manpower, heat, water and carbon, in conjunction with data about the quality of those systems to optimize the overall system. Depending on the application, stream quality may be defined by key process variables, such as temperature for heat recovery or concentration for mass integration [*3–9,*

TABLE 1. INVENTORY DATA AND FACTORY CAPACITY FOR CASE STUDY 1													
Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Inventory (containers)	5	5	10	10	15	5	5	10	15	20	10	5	115
Factory capacity	20				20					20			60

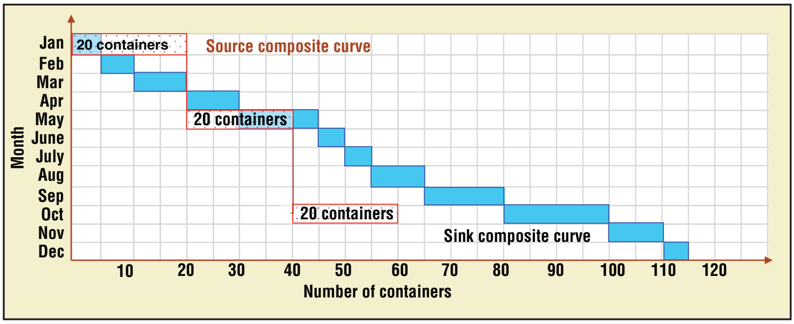

FIGURE 2. This PPPD for case 1 (noni factory) is not feasible because the part of the source composite curve is below the sink composite curve

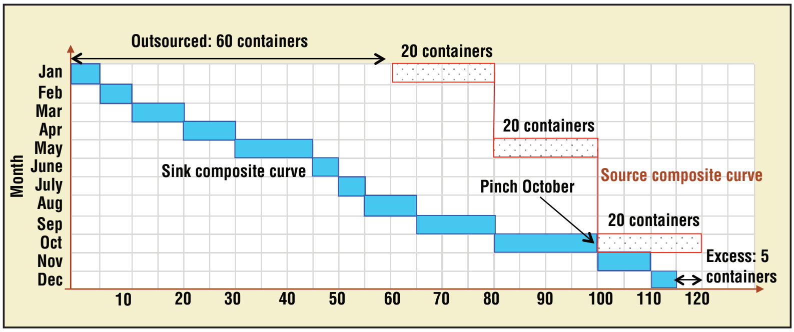

FIGURE 3. This feasible PPPD is obtained by horizontally shifting the source composite curve of Figure 2 to the right

21]. In many management extensions of pinch analysis, time is used as the quality index [*11, 18–20*].

In this article, two novel graphical techniques for production planning are proposed, namely *production planning pinch diagram* (PPPD) and *production planning grand composite curve* (PPGCC). These new production planning tools can be used to optimize factory capacity and financial resources, which are common challenges in most companies. Such problems are particularly critical for small and medium enterprises (SMEs), which typically are heavily constrained by limited capital resources. The problem arises when a company or facility is maximizing the use of its company resources, such as inventory or the factory capacity, while minimizing outsourcing by reducing idle space or excess factory capacity. This goal implies the minimization of additional costs.

Large or multi-national companies (MNC) usually acquire adequate space for future expansion of plants and warehouses, and purchase machines that are custom-made to meet their production capacities (the machines sometimes cater for expansion, too). On the other hand, SMEs have relatively limited financial resources, and thus tend to rent readily available industrial spaces as production units that are readily available in the market. Therefore, proper production planning in SMEs presents unique challenges. With these newly developed tools, SMEs will be able to handle the production planning problems more effectively.

Underlying principles

The basic principle of the newly developed graphical techniques is based on the work of Ooi and colleagues [*17*], which was originally developed for CO_2 capture-and-storage planning problems. In order to address the problem of production planning, we shall first identify the *production sinks* and the sources of the planning problem.

Production sinks are defined as the units or sections that demand resources. Production sources are units or sections that contain the resources. For instance, production of "noni" powder (a nutritional product extracted from the tropical fruit, *Morinda citrifolia*) is treated as a sink that requires production space. On the other hand, factories are treated as sources, as they can be used to satisfy the production requirement of the goods. In this context, sources may be viewed as providing services (for example, production space) to the sinks. The overall concept is illustrated in Figure 1.

Although supply and demand of goods are typically beyond the manufacturer's control to a certain extent, control of time and capacity adaptation is still possible. Note that production capacity or factory space can either be fixed or variable. For instance, if a factory is located in a standard industrial lot with fixed dimensions, it is classified as a fixed capacity/variable time problem. On the other hand, cases where the factory, or production units are flexible (that is, if the manufacturer could acquire them according to their exact requirements) can be classified as a variable capacity/variable time problem. For example, such cases usually occur in pharmaceutical and allied industries. Both cases are illustrated in the following industrial case studies. The objective of the proposed approach is to determine the minimum outsource requirement. To fulfill the objective, the PPPD and PPGCC are used, and are illustrated using the following case studies.

Case Study 1

We first consider an example involving production planning for a powder-production factory. This case study describes a food processing factory that produces noni powder that is dried at very low temperature using infrared drying technology. Table 1 shows the forecasted inventory data based on the previous year's record. In this case study, a production campaign across a one-year planning horizon is considered.

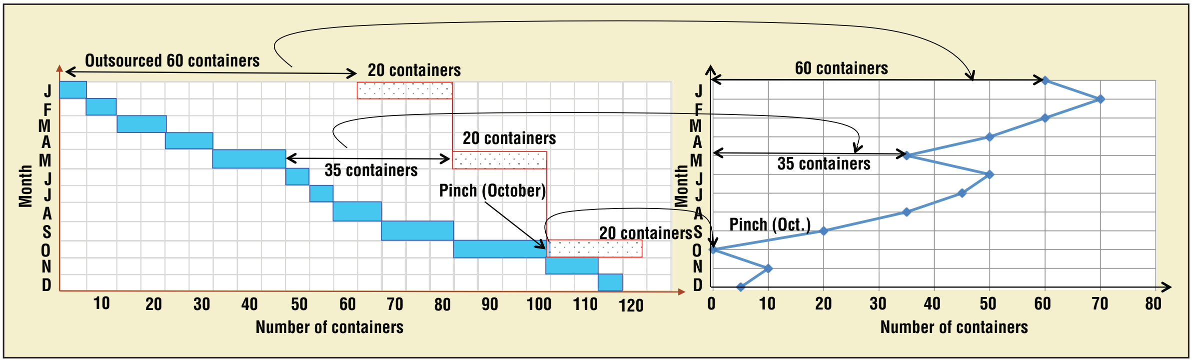

FIGURE 4. The PPGCC is plotted to reflect the horizontal gaps between the source and sink composite curves

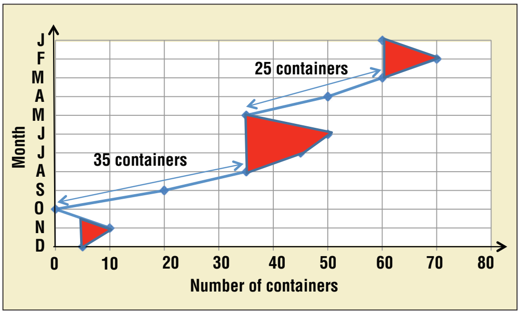

FIGURE 5. The shaded area of the PPGCC is the time pocket for Case Study 1, where the production requirement is satisfied by internal capacity (existing factories)

Scenario 1. Three noni factories, each with a capacity of 20 containers, are available. However, the availability of these noni factories is different. Factory 1 is available from the start of the planning horizon. However, Factories 2 and 3 are only made available in the months of May and October, respectively. The company may outsource the production at added cost if the capacity of these factories is insufficient. To minimize the outsourcing requirement, the usage of all factories should be maximized.

As mentioned above, the factories are treated as sources, as they provide production space and services for the inventory (sinks). To make use of the PPPD, we first translate the production forecast data into the *sink composite curve*. Each horizontal segment of the composite curve is plotted, based on its inventory amount on the *x*-axis, against a corresponding time period on the *y*-axis. On the other hand, the sources (corresponding to factory capacities in this case) are identified and plotted to form the *source composite curve*, similar to that of the sink composite curve. Figure 2 shows the PPPD of this case study. Note that both composite curves take the shape of a staircase due to the consideration of the time factor. The *y*-axis of the composite curve represents the time of availability of the production sinks (inventory) and sources (factory) throughout the entire planning horizon while their horizontal distances represent the total amount of product.

As shown in Figure 2, part of the source composite curve stays below the sink composite curve. This is an infeasible situation, as sources (that is, factories) cannot be used to produce goods before they are ready for production. Hence, the source composite curve is shifted horizontally to the right until the source composite curve is entirely above the sink composite curve and touches the latter at the pinch point, to form the feasible PPPD (see Figure 3). As shown, all storage sources are now prepared much earlier than the sinks that they will need to serve. Note that only a horizontal shift is permitted for the composite curves, as the *x*-axis represents the amount of inventory for both sink and source composite curves, while the *y*-axis is the true timeframe for the planning horizon.

Based on Figure 3, it is noted that there is a gap at the top section of the composite curves. This indicates that 60 containers of product need to be outsourced through production at off-site facilities. This is due to the time pinch that is formed in October; the latter may be viewed as the overall time bottleneck for the factory allocation problem. Note also that excess capacity is found at the end of the planning horizon (five containers). This means that

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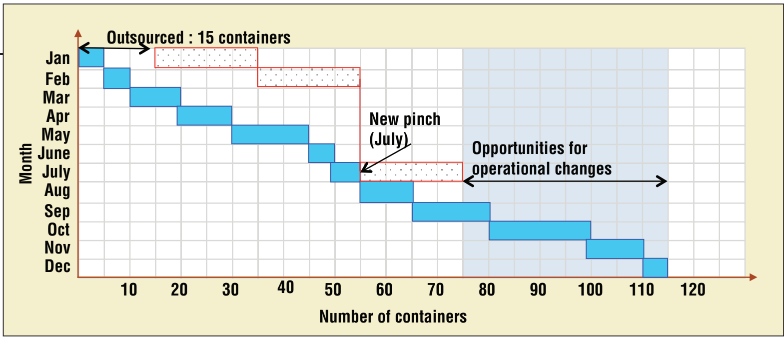

FIGURE 6. The PPPD for the second scenario of Case Study 1 shows rescheduling of the noni factories

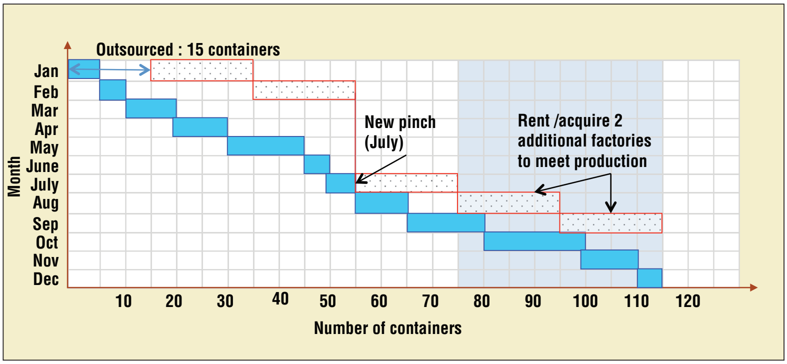

FIGURE 7. Here, the PPPD for the second scenario of Case Study 1 shows rescheduling of the noni factories with renting additional production capacity

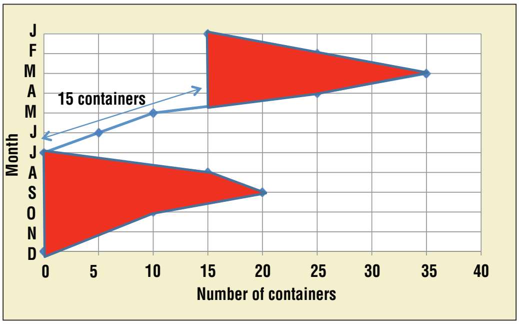

FIGURE 8. The new PPGCC for the rescheduled scenario of Case Study 1 is depicted here

the factory is under-utilized after the time pinch has passed. In other words, the company may be able to make use of this excess capacity for producing other products or provide the storage service to other manufacturers.

From Figure 3, it is noted that 60 containers are needed to fulfill the given planning horizon. However, the outsourced containers are not needed at the beginning of the project. In other words, the outsourced containers may be delayed until it is indeed necessary. However, the exact day when the outsourced container is needed cannot be seen directly in the PPPD. This calls for the use of the PPGCC, which has been used extensively for appropriate utility selection in heat integration [*1*].

The construction of the PPGCC for Case Study 1 is shown in Figure 4, where the horizontal distance between the source and sink composite curves of the PPPD are plotted against time throughout the entire planning horizon. Once the PPGCC is constructed, time pockets — the shaded areas in Figure 5 — can be determined. The *time pocket* is analogous to the heat pocket for heat recovery [*1*], where the required production requirement (sink) may be supplied by internal capacity. The opening at the top of the PPGCC indicates when the outsourcing (60 containers of product) are needed. As shown, storage outsourcing is needed between March and May (25 containers of products), as well as for August to September (35 containers of products).

Scenario 2. The opportunities of rescheduling can also be considered with the aid of the PPPD. In a different scenario, we shall reschedule the *noni* factories in order to make use of its excess capacity identified earlier. In this case, it is assumed that the factory can be rescheduled by producing some goods earlier than originally planned. Assuming that Factories 2 and 3 can now be rescheduled three months ahead of the original schedule, the pinch point moves forward to the month of July instead of October (see Figure 6). Note that any factory rescheduling or operational adjustment can only be made after the pinch, where there is excess resource availability. On the other hand, adjustments before the time pinch do not bring any benefit. Shifting the pinch point earlier, thus gives the company room for operational adjustment. In this particular case, the outsourced requirement is reduced from 60 to 15 containers. Apart from outsourcing, the company may decide to rent another two production facilities each with capacities of 20 containers during the months of August and Sep-

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tember. Based on this strategy, the production requirement of the factory can be fulfilled (see Figure 7).

Following the same approach as before, the PPGCC for the case with two rented production facilities is shown in Figure 8. Note that the opening of the PPGCC indicates that outsourcing 15 containers is only required between April and July (see Figure 8).

Case Study 2

The second case study involves a cellular food factory that produces a nutritional beverage. The monthly expenses include purchases of raw materials, rental of factory premises, salaries, utilities, administrative and marketing costs. Table 2 shows the monthly expenses for Case Study 2, where a production campaign across a year planning horizon is considered.

Scenario 1. For this problem, the headquarters allocates funds amounting to $30,000, $50,000 and $70,000. However, the availability of these funds is at different times. Fund 1 is available from the start of the planning horizon. Funds 2 and 3 are only made available in May and September, respectively. The goal is to minimize any external requirement for added financing (for instance, through short-term loans). Alternatively, if economically justified, the production planner may also decide on the amount of external borrowings/overdraft needed in order to ensure the operations run smoothly. In this context, funding is readily available, via internal funding or overdrafts, and could be drawn down as required.

Figure 9 shows the feasible PPPD for the fund allocation problem. As shown, the monthly expenses are represented by the sink composite curve, while the amount of available funds is plotted as the source composite curve. The feasible PPPD shows a gap at the top section of the composite curves, which represents the minimum capital injection into the project; in other words, external funding is required. In this case study, $80,000 needs to be injected into the project. This is mainly due to the time pinch that is formed in the month of September; and is the bottleneck for the monthly expenses requirement problem. On the other hand, excess funds of $30,000 are found at the end of the planning horizon. This result shows that the excess funds, which are under-utilized after September (when the time pinch occurs) can be used elsewhere for other investments. Figure 10 shows the PPGCC for this scenario, where external funds are needed in the periods of January–February and July–August.

Scenario 2. The opportunities for rescheduling can also be considered with

TABLE 2. MONTHLY EXPENSES AND AVAILABLE FUNDS FOR CASE STUDY 2

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Expenses													
$1,000	20	20	10	0	0	10	20	50	30	20	10	10	200
Funds													
$1,000	30				50				70				150

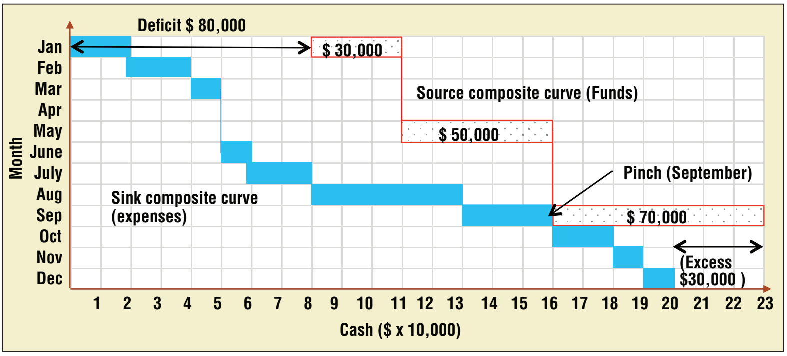
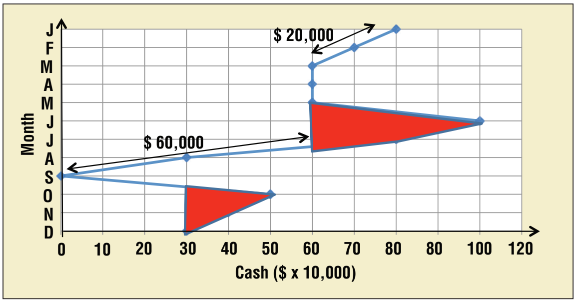


FIGURE 9. A feasible PPPD for targeting minimum outsourcing is given for Case Study 1

FIGURE 10. The PPGCC is plotted to graphically illustrate that external funds are needed in the period of January–February and July–August



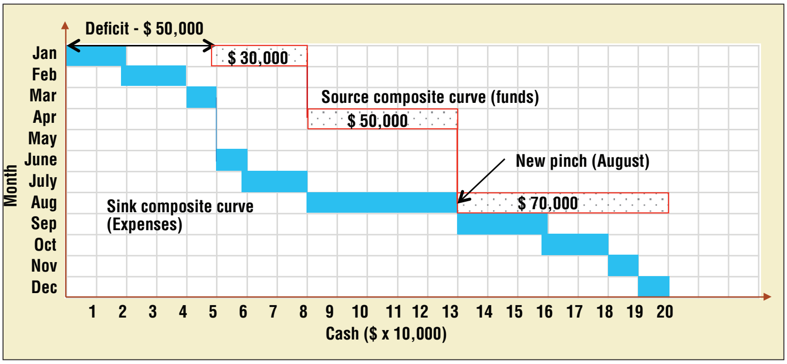


FIGURE 11. The PPPD for scenario 2 (rescheduling) of the project funding example (case study 2)

the aid of PPPD. In a different scenario, we shall reschedule the funding allocation in order to make use of the excess fund identified earlier. In this case, it is assumed that the headquarters has allocated the funds for the factory and may reschedule the funds as required. Assuming that these funds can now be rescheduled one month ahead of the original schedule, the time pinch moves forward to the month of August instead of September (see Figure 11). Note that any process rescheduling or operational adjustment can only be made after the pinch, as there now appears to be excess resource availability. Shifting the pinch earlier gives the company room for operational adjustment. In this particular case, the outsourced fund requirement is reduced from $80,000 to $50,000. This results in zero excess funds at the end of the planning horizon similar to that in Case Study 1. The PPGCC for Case Study 2 in Figure 12 shows that capital injections are needed in the same period as Scenario 1, but the amount is smaller.

Final remarks

Novel graphical-pinch-targeting techniques have been developed for production planning problems. Two industrial case studies on capacity and financial planning illustrate how these graphical tools for decision support may be used for real-life problems. They can be used to optimize the utilization of company resources, such as factory capacity and financial allocation, while minimizing idle company resources.

These techniques reduce the need for outsourcing of production or acquiring additional funds through loans. Significantly, the graphical nature of these tools is also useful for easy communication and visualization in management meetings, technical presentations and reports by non-engineers, decision makers or stakeholders. They provide intuitive visual insights that may be readily grasped with minimal training, unlike alternative tools such as mathematical programming. The proposed techniques also are user-friendly and may be implemented using simple spreadsheet software. ■

Edited by Gerald Ondrey

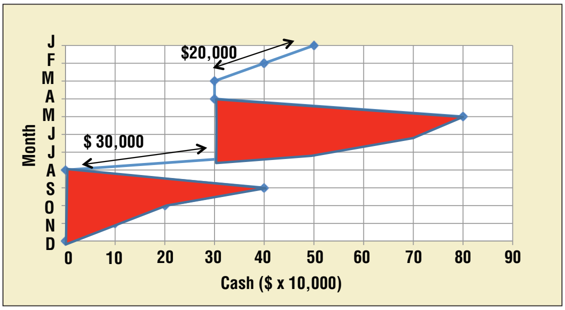


FIGURE 12. The PPGCC for Case Study 2 is shown here

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Engineering Practice

Absorber Optimization: Employing Process Simulation Software

Applying simulation-model case studies in the field yields significant savings with no capital investment

FIGURE 1. This photo shows the EOEG plant at Reliance, Dahej Manufacturing Division

Jignesh P. Patel, **Viral Desai**, and **Dipak Mehta**
Reliance Industries Ltd.

Sunil Patil
Aspen Technology, Inc.

Raw materials and energy represent two of the largest expenses in the chemical process industries (CPI). Energy reduction is necessary to sustain cost-effective production and manage capacity in the ever-changing CPI marketplace. Process simulation software can prove extremely valuable in evaluating energy reduction potential. This article discusses the successful application of process simulation software to optimize the ethylene oxide (EO) absorber operations at Reliance Industries' ethylene oxide and ethylene glycol (EOEG) plant (Figure 1). By applying optimization techniques determined in the software simulation studies, raw material (absorbent) flow was decreased, thus reducing steam load and pumping energy requirements. These reductions translate into significant energy savings, resulting in annual savings of 9.5 million Indian Rupees (INR; approximately $160,000) without any capital investment.

Background

Gas absorbers are extensively used in the CPI to separate components through absorption by contact with a liquid in which one of the components is soluble. The solute is transferred between the gas and liquid phases. In the EOEG plant, ethylene undergoes vapor-phase oxidation over a silver-base catalyst in the presence of oxygen to form EO. The reactor effluent cycle gas is then passed to the EO absorber and stripper process (Figure 2) where EO is separated from the cycle gas. The cooled cycle gas enters the EO absorber from the bottom and is contacted counter-currently with lean absorbent, which absorbs the ethylene oxide, and produces a dilute EO stream, the rich absorbent. The rich absorbent then flows to the EO stripper for recovery of EO. The concentration of EO in the absorber top recycle-gas product is maintained by adjusting the lean absorbent flow. It is important to minimize the EO present in the overhead recycle stream to avoid downstream process issues.

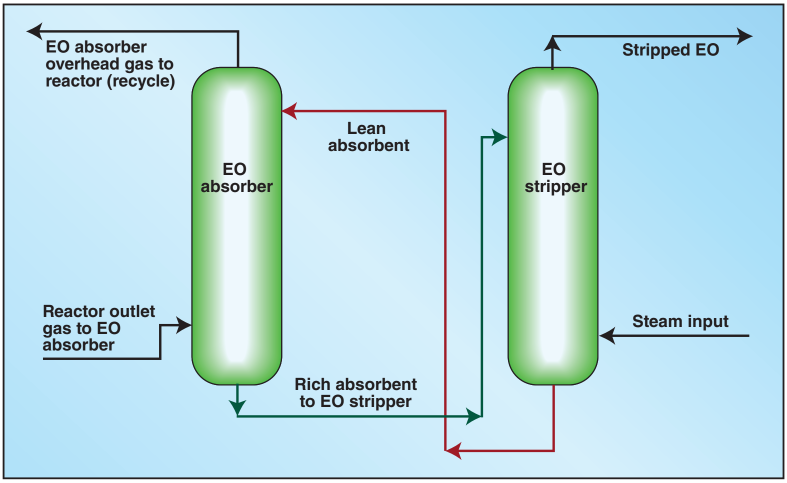

FIGURE 2. Reactor cycle gas flows through the absorbing and stripping process for recovery of EO

Simulation study

The main objective of the simulation modeling study was to evaluate the energy reduction potential in the EO absorber without any capital investment, and to check the effect of higher throughput on EO absorber column performance. The energy reduction studies primarily focused on adjusting lean absorbent flow and temperature at constant inlet cycle-gas flow.

Determining an appropriate property method is vital to developing an accurate simulation model. Selection of the software's commercial rigorous column model for steady-state operation, along with the SR-Polar Equation of State (EOS) resulted in a good

TABLE 1. EFFECT ON EO ABSORPTION BY VARYING THE LEAN ABSORBENT FLOW (AT CONSTANT INLET CYCLE-GAS FLOW)	
Reduction in lean absorbent flow versus normal operation, %	EO mole concentration in EO absorber overhead gas, simulated values, ppm
-5	3
-10	3
-15	4
-18	4
-20	5

TABLE 2. EFFECT ON EO ABSORPTION BY VARYING THE LEAN ABSORBENT TEMPERATURE (AT CONSTANT INLET CYCLE-GAS FLOW)	
Lean-absorbent temperature increase versus normal operation, °C	EO mole concentration in EO absorber overhead gas, simulated values, ppm
1°C	3
2°C	3
3°C	3
4°C	4
5°C	4

TABLE 3. PLANT TRIAL PLAN TO REDUCE LEAN ABSORBENT FLOW		
Lean-absorbent flow reduction step	Days	Total reduction in lead absorbent flow to EO absorber, %
Step 1	Day 1	1.0%
Step 2	Day 2	1.0% (Total 2.0%)
Step 3	Day 3	1.5% (Total 3.5%)
Step 4	Day 4	1.5% (Total 5.0%)
Step 5	Day 5	1.5% (Total 6.5%)
Step 6	Day 6	1.5% (Total 8.0%)
Total reduction in lean absorbent flow = 8%		

approximation of the EO absorber operation. Simulation data comparisons with licensor process-flow-diagram (PFD) data and actual operating data validated the SR-Polar EOS.

Ensuring correct inputs to the process simulation software is also a key step in creating an accurate model. Initially, the PFD data were used for feed composition, and the model predictions were compared to the stream compositions for the top and bottom products from the design-case material balance. Later, the actual feed compositions were taken from the online analyzer and the model predictions were again evaluated. The model was then fine-tuned by adjusting the absorber's Murphree tray efficiencies to match the following parameters with actual plant data:

- Temperature profile along the column
- Top and bottom product composition

Once the model was tuned, it was used for sensitivity analyses with respect to changes in the following properties:

- Lean absorbent flow
- Lean absorbent temperature

The objective of the sensitivity analyses was to optimize operations without compromising the EO absorber performance. The evaluation with respect to lean absorbent flow led to the conclusion that an 8% decrease in flow had no detrimental effect on

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TABLE 4: PLANT PERFORMANCE AFTER IMPLEMENTING STUDY RECOMMENDATIONS				
EO absorber performance after implementing study recommendations				
	Lean absorbent flow, %	Cycle gas flow	EO content in EO absorber overhead gas, ppm	Lean absorbent pumping energy, kW
Reduction	8	None	Reduced from 95 to 73	39
Effect of EO absorber optimization on EO stripper operation				
	Rich absorbent feed flow, %		Steam flow to EO stripper reboiler, kg/h	
Reduction	8		1,000	

product quality. Table 1 illustrates the resulting overhead EO composition with incremental lean absorbent flow reductions, as predicted by the process modeling software. This study also examined the absorber's potential for column flooding by rating the trays based on existing tray geometry and current operating conditions. This hydraulics study revealed that during normal operation, the column was near its flooding limits, but that the recommended reduction of lean absorbent would decrease potential tray flooding and increase the unit's efficiency.

Changes in lean absorbent temperature can also impact the absorption of EO from the cycle gas. The sensitivity analysis with respect to temperature looked at typical summer conditions to evaluate the absorber's performance as lean absorbent temperature increases. The study's results, presented in Table 2, show that a variation of up to 2°C in lean absorbent temperature does not significantly affect EO absorption.

Plant trials and results

To apply the optimized models in the plant, lean absorbent flow was incrementally decreased over a six-day period (Table 3). With each reduction of flow, key operating parameters and compositions were measured once the unit achieved stable performance. On the sixth day, the absorber reached the simulated optimized conditions with 8% lean-absorbent flow reduction. Simulation data also predicted that operations would experience the following benefits upon optimizing lean absorbent flow:

- Decreased steam consumption in the EO stripper
- Higher efficiency in the lean absorbent water cooler
- Lower lean-absorbent supply temperature
- Decreased pressure drop across the absorber
- Less energy consumption required for pumping

The results of the plant trials validated the findings of the simulation study, as all predicted benefits were observed in field operations. A summary of unit performance after the plant trials is shown in Table 4. Most importantly, the absorber unit reached the desired 8% reduction in lean absorbent flow without compromising throughput or EO recovery. Other notable operational improvements included a 39-kW reduction in pumping energy and a 1,000-kg/h reduction in low-pressure steam in the EO stripper reboiler. These improvements will save the company an estimated 9.5 million INR annually, with no additional capital investment required. This study underscores the value of using process simulation technology for optimization, driving operations to new levels of efficiency. ■

Edited by Mary Page Bailey

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Fractionation Column

'Evil' chemicals

I was at the local Panera Bread. I almost screamed. I would have, except there was a sign on the front door that said "Positively No Screaming."

I was sitting within earshot of a junior-high-school science teacher whom I did not know. She was describing to a friend the details of a unit that she just taught on "chemicals." She implied to her students that there were no good ones. Yes, I am serious.

She first explained to her students how the gasoline companies formerly put lead into gasoline and how the lead poisoned the environment. She seemed to have no idea why the lead was put there in the first place, nor how the gasoline companies maintained octane numbers after removing the lead.

Her next target, of course, was carbon dioxide and global warming. She proudly brought some students to tears by showing them a photograph of a lonely polar bear clinging to life on a tiny iceberg. There was no second side to her story, no contradictory evidence, no mention of the fact that Earth is coming out a relatively recent ice age. The glaciers have been melting for tens of thousands of years; the melting did not begin with Henry Ford. She did not seem to know the source of the carbon dioxide. It just came from — somewhere. (At this point I was concerned for her students but I was nowhere near the "scream point.")

Then, she started talking about DDT (dichlorodiphenyltrichloroethane). She played a song for her students on her CD player: "Big Yellow Taxi" by Joni Mitchell — "Hey farmer, farmer put away that DDT now; give me spots on my apples, but leave me the birds and the bees — please." She quoted Rachel Carson's "The Silent Spring" and how an early generation of environmentalists saved the eagles, hawks and falcons, and probably all of the birds. The science teacher proudly told her friend that half of her students were now in tears. The teacher did not know, or did not want to know, any of the following: 1) The bird shell research work is regarded by some as highly flawed; 2) The World Health Organization supports the indoor use of DDT for malaria control, and; 3) Some have estimated that in the last 50 years, 50 million African children might have died needlessly from malaria. "Positively No Screaming."

Based on what I heard, it is entirely possible that an entire class at Stillwater Junior High School believes that all chemicals are injurious — not just Pb, CO_2 and DDT. They might also believe that all environmentalists are always right. The environmentalists of our world have truly done an excellent job of alerting us all to the dangers of pollution and over-consumption, but they're not always right. And I'm not always right. Maybe I was wrong — not to scream. ■

Mike Resetarits

Mike Resetarits is the technical director at Fractionation Research, Inc. (FRI; Stillwater, Okla.; www.fri.org), a distillation research consortium. Each month, Mike shares his first-hand experience with *CE* readers

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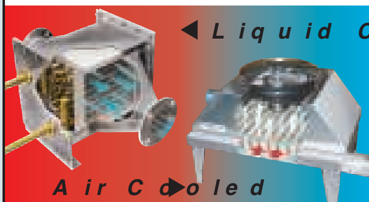

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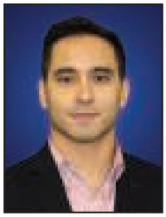

Usuki

Amato Spagnoletti becomes president of **Taylor Wharton Cryogenics** (Theodore, Ala.), a maker of cryogenic equipment for the industrial gases, life sciences, and liquefied natural gas markets.

Ulrich Spiesshofer becomes CEO of **ABB** (Zurich, Switzerland). He was formerly the head of ABB's discrete automation and motion division.

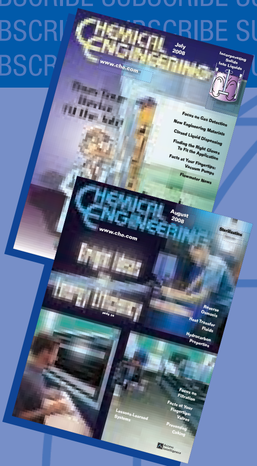
Foth Infrastructure & Environment, LLC (Green Bay, Wisc.), an engineering, science and construction company, welcomes *Todd Fryzek* as lead environmental engineer, and *Bruce Rehwaldt* as LEED AP.

Devin International (Lafayette, La.), a subsidiary of Greene's Energy Group and equipment supplier for onshore and offshore oil-and-gas operations, names *Buck Evans* special operations coordinator.

BASF (Ludwigshafen, Germany) announces two promotions: *Ralph Schweens*, currently managing director of BASF Mexicana S.A., becomes president of the South America regional division based in Sao Paulo, Brazil. *Michael Stumpp*, currently senior vice president in BASF's global home and personal care business, will succeed Schweens as managing director of BASF Mexicana S.A.

Pump Solutions Group (Oakbrook Terrace, Ill.) names *John Pepper* vice president of integration, and *Andrew Usuki* vice president of sales and business development in the Americas. ■

Suzanne Shelley



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BUSINESS NEWS

PLANT WATCH

Sasol awards integrated complex contract to WorleyParsons

July 11, 2013 — WorleyParsons Ltd. (North Sydney, Australia; www.worleyparsons.com) has been awarded a contract by Sasol North America, Inc. (Sasol) for an integrated gas-to-liquids (GTL) and ethane-cracker complex, which includes an ethane cracker producing 1.5 million metric tons per year (m.t./yr) of ethylene with downstream derivative plants and a 96,000-bbl/d GTL facility. It will be located near Sasol's existing chemical complex in southwest Louisiana. Project costs are estimated to be $16 to 21 billion.

CNOOC selects Ineos Technologies' process for a new project in China

July 11, 2013 — Ineos Technologies (Rolle, Switzerland; www.ineos.com) has licensed its Innovene S Process for the manufacture of 400,000 m.t./yr of medium-density and high-density polyethylene to CNOOC Oil and Petrochemical Co. for its cracker complex located in Huizhou City, Guangdong Province of China.

Teijin to build new meta-aramid fiber plant in Thailand

July 11, 2013 — Teijin Ltd. (Tokyo, Japan; www.teijin.co.jp) has developed a new heat-resistant, dyeable meta-aramid fiber, which the company will produce in a facility in Ayutthaya Province, Thailand. Construction begins Dec. 2013 and production is scheduled for July 2015. Teijin will invest around ¥4.5 billion ($45 million) to build the plant on the premises of Teijin (Thailand) Ltd.

EuroChem announces fertilizer project in Louisiana

July 10, 2013 — Fertilizer company EuroChem (Moscow, Russia; www.eurochem.ru) announced intention to build an ammonia and urea production plant in Louisiana. The project requires an estimated investment of approximately $1.5 billion and four years of construction work. EuroChem expects to finalize its decision on the parameters and location of the facility within the next year.

Clariant and Wilmar receive clearance to establish JV

July 8, 2013 — Clariant International Ltd. (Muttenz, Switzerland; www.clariant.com), a specialty chemicals producer, and Wilmar International Ltd., an Asian agribusiness group, have received merger clearances for the establishment of a 50-50 joint venture (JV), which is now in operation. The JV is headquartered in Singapore.

Praxair enters into industrial gas JV with Kuibyshevazot

July 2, 2013 — Praxair, Inc. (Danbury, Conn.; www.praxair.com) has entered into an agreement to form a JV with OJSC KuibyshevAzot (Moscow, Russia; www.kuazot.ru), in Russia's Samara region, to produce and sell industrial gases. The JV will produce on-site O_2, N_2 and compressed dry air for KuibyshevAzot's caprolactam, fertilizer and ammonia production, as well as liquid gases. Praxair and KuibyshevAzot will construct a new air-separation unit that will produce 1,400 m.t./d of O_2, N_2 and argon, and is scheduled to start up mid-2016.

Technip awarded contract for two hydrogen reformers in Venezuela

July 1, 2013 — Technip (Paris, France; www.technip.com) was awarded a contract by the Hyundai-Wison consortium for two hydrogen reformers in Venezuela. The contract covers the complete engineering, fabrication, modularization, procurement as well as pre-commissioning and start-up assistance. These 151,000-Nm^3/h reformers are part of the Deep Conversion project for Petroleos de Venezuela SA to upgrade the Puerto La Cruz refinery. The project is scheduled for completion in mid-2014.

SGL Group and Samsung establish JV for carbon composites

June 20, 2013 — SGL Group (Wiesbaden, Germany; www.sglgroup.com) and Samsung Petrochemical have established a marketing and sales JV for carbon-fiber-composite materials. The partners will each hold a 50% share. The JV will operate under the name Samsung SGL Carbon Composite Materials. The JV will be headquartered in Ulsan, South Korea, at a Samsung Petrochemical facility.

Unipol technology selected for Qatar's first polypropylene plant

June 19, 2013 — Union Carbide Chemicals & Plastics Technology LLC, a wholly owned subsidiary of The Dow Chemical Company (Midland, Mich., www.dow.com), has signed a license agreement with Qatar Petroleum/Qatar Petrochemical Company (QP/QAPCO), for Unipol Polypropylene (PP) Process Technology. Unipol PP will be licensed at QP/QAPCO's facility to be located in Ras Laffan, Qatar. Slated to produce 540,000 m.t/yr of PP, the QP/QAPCO facility will be Qatar's first polypropylene plant.

MERGERS AND ACQUISITIONS

Michelman acquires Ecronova Polymer, adds water-based polymer capabilities

July 9, 2013 — Michelman, Inc. (Cincinnati, Ohio; www.michelman.com) has acquired Ecronova Polymer GmbH (Recklinghausen, Germany), a manufacturer of water-based polymers. The purchase includes all assets, technology and manufacturing facilities. The name Ecronova Polymer will continue to be used for business operations.

Huntsman signs agreement to acquire Oxid

July 8, 2013 — Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com) has signed an agreement to acquire Oxid L.P., a privately held manufacturer of specialty urethane polyols based in Houston. The financial terms of the agreement were not disclosed. The transaction is expected to close during the 3rd quarter of 2013. Oxid generated $86 million of revenue in 2012.

Borealis acquires GPN and majority of Rosier European market

July 1, 2013 — Borealis AG (Vienna, Austria; www.borealisgroup.com) says it has fully acquired GPN SA from the Total Group. GPN S.A. is France's largest nitrogen fertilizer manufacturer. GPN employs around 760 employees in France, all of whom will be transferred to Borealis. On the same date, Borealis closed an agreement with Total S.A. to acquire its majority interest in Rosier S.A., a mineral fertilizer manufacturer. Rosier generated sales of €278 million in 2012.

Siemens acquires rolling mill specialist Service Guide

July 1, 2013 — Siemens Industry AG (Erlangen, Germany; www.siemens.com/industry) announced it has completed the acquisition of Service Guide, Inc. (Cortland, Ohio), which provides repair and refurbishing services for steel and aluminum mills. Financial details of the transaction will not be disclosed.

Novozymes acquires agricultural company TJ Technologies

June 26, 2013 — Novozymes (Copenhagen, Denmark; www.novozymes.com), has signed a definitive agreement to acquire South Dakota-based TJ Technologies Inc., whose annual revenue is approximately $15 million. The financial terms of the agreement were not disclosed. ■

Mary Page Bailey

FOR ADDITIONAL NEWS AS IT DEVELOPS, PLEASE VISIT WWW.CHE.COM

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2011 — 2012 — 2013

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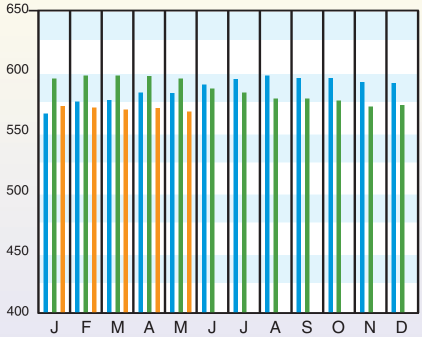
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	May.'13 Prelim.	Apr.'13 Final	May.'12 Final
***CE* Index**	566.4	569.4	593.8
Equipment	685.4	689.5	726.2
Heat exchangers & tanks	624.3	626.2	683.6
Process machinery	655.0	656.5	680.1
Pipe, valves & fittings	863.4	875.6	926.7
Process instruments	410.8	413.2	428.9
Pumps & compressors	919.3	924.5	928.1
Electrical equipment	513.1	512.6	515.2
Structural supports & misc	741.7	746.8	763.8
Construction labor	319.1	319.8	322.9
Buildings	534.0	536.5	527.7
Engineering & supervision	326.0	327.6	328.3

Annual Index:

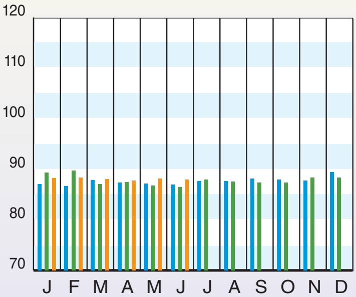
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6



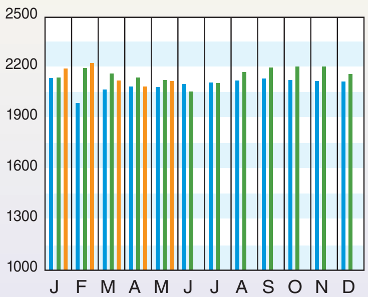
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS		YEAR AGO
CPI output index (2007 = 100)	Jun.'13 = 87.9	May.'13 = 88.1	Apr.'13 = 87.7	Jun'12 = 86.5
CPI value of output, $ billions	May.'13 = 2,122.3	Apr.'13 = 2,098.1	Mar.'13 = 2,126.0	May'12 = 2,127.1
CPI operating rate, %	Jun.'13 = 74.5	May.'13 = 74.7	Apr.'13 = 74.3	Jun'12 = 74.0
Producer prices, industrial chemicals (1982 = 100)	Jun.'13 = 304.0	May.'13 = 301.7	Apr.'13 = 308.7	Jun'12 = 299.4
Industrial Production in Manufacturing (2007 = 100)	Jun.'13 = 95.7	May.'13 = 95.5	Apr.'13 = 95.2	Jun'12 = 94.0
Hourly earnings index, chemical & allied products (1992 = 100)	Jun.'13 = 156.2	May.'13 = 156.6	Apr.'13 = 155.3	Jun'12 = 156.3
Productivity index, chemicals & allied products (1992 = 100)	Jun.'13 = 104.0	May.'13 = 104.7	Apr.'13 = 104.4	Jun'12 = 105.9

CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)

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

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CURRENT TRENDS

Preliminary data for the May 2013 *CE* Plant Cost Index (CEPCI; top; the most recent available) indicate that the composite index decreased by 0.5% from the the final April value. The data for each of the subindices decreased in the May preliminary numbers, except for the index value for electrical equipment, which rose. The May 2013 preliminary PCI index value stands at 4.6% lower than the corresponding final PCI value from May 2012. Meanwhile, the latest Current Business Indicators from IHS Global Insight (middle) moved in both directions, with the CPI output index edging slightly downward, while the CPI value of output increased slightly in the latest numbers. ■

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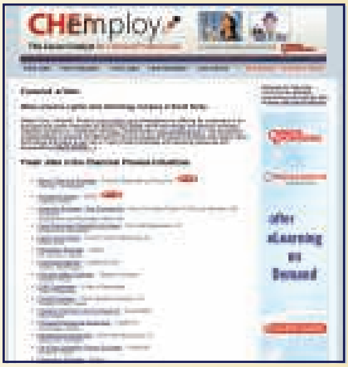

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