CHEMICAL ENGINEERING

September 2013

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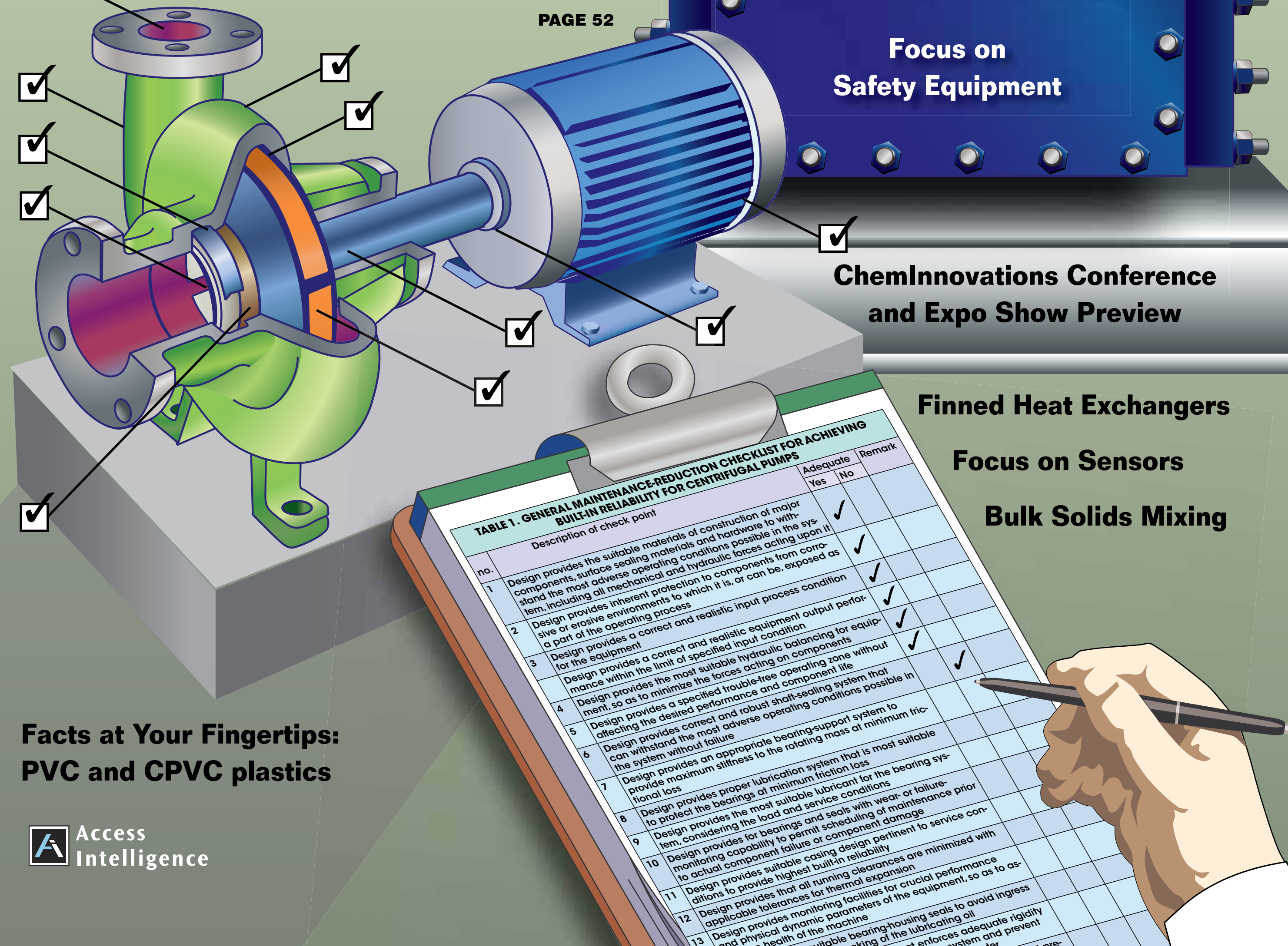

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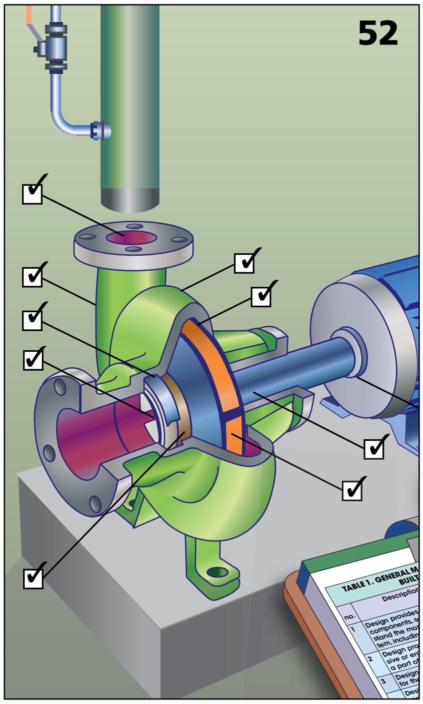

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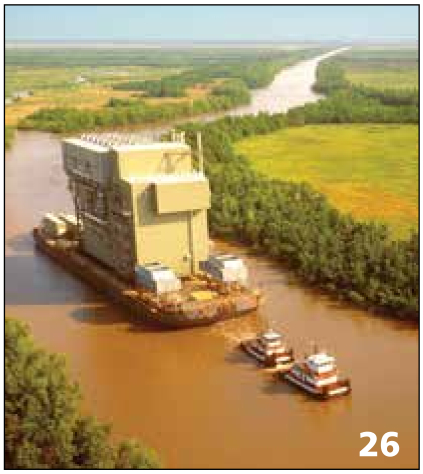

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Cover: David Whitcher


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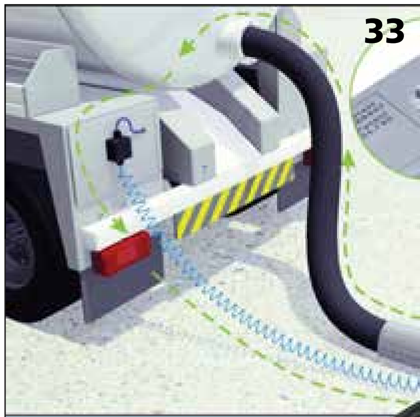
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Editor's Page

Connecting at ChemInnovations

Where will you be on September 25 and 26? The *Chemical Engineering* staff will be in Galveston, Texas at the ChemInnovations Conference and Expo. We hope you will be too.

Four years ago, we had the idea to start a conference and tradeshow dedicated to the chemical process industries (CPI). That idea materialized, rather quickly that first year, into the annual event that has been held in Houston, New Orleans and now, this month, it will be in Galveston. I've been part of a number of CPI plant startups in my career, but this is the first time I have been involved with the startup of a new conference and expo event. It has been both exciting and eye-opening.

This year I have had the privilege of chairing the ChemInnovations Advisory Board. The Advisory Board is an enthusiastic group of about fifteen industry representatives, our *CE* editors and members of the event staff. The list of board members is a who's who of the CPI, with participation from Solvay S.A., Axiall Corp., Eastman Chemical Co., Celanese Ltd., Shell Oil Products, BASF AG, Chevron Phillips Chemical Company LP, Braskem America, Honeywell Process Solutions, Emerson Process Management, WorleyParsons, KBR, Lloyd's Register Energy Americas, Inc., Cornerstone Chemical Co. and Apex Measurement and Controls. It has been truly uplifting to work with a group whose every member is fully engaged and an active contributor. The enthusiasm at those meetings remains contagious.

In addition to the input from the Advisory Board, outreach meetings were held at a number of CPI plant locations to ask the managers and operators about the issues and challenges they are facing, and would like addressed in our program. I and other *CE* editors accompanied the event organizers to several of those meetings. Many of the topics discussed through this outreach program were incorporated in the programming of the ChemInnovations conference.

The resulting conference program addresses timely topics in a practical way. The eight tracks, consisting of presentations and panel discussions, include topics related to water management, maintenance and reliability, safety, automation and controls, workforce issues, energy and practical tools. The keynote address, to be given by Dr. David Bem, global R&D director for The Dow Chemical Company, will discuss perhaps lesser-known impacts of the shale-gas boom. A Plant Manager Roundtable will explore the challenges affecting the CPI from the perspective of the plant managers.

In addition to the conference program, the exhibit hall will feature an array of products and services available to the CPI. A sampling of what will be on display can be found in this issue on p. 42. The exhibit floor will also be host to "TechTalk", an informal discussion among industry experts that is new to ChemInnovations this year.

ChemInnovations is also the venue where an Awards Banquet will honor leaders in the CPI. Among the awards to be announced and presented is the Kirkpatrick Award for Chemical Engineering Achievement. The five finalists for that biennial award, which this magazine has bestowed since the 1930s, were announced in this column in July.

Details about the ChemInnovations Conference and Expo can be found at www.cpievent.com and in this issue. We hope to see you at the Moody Gardens Convention Center in Galveston on the 25th. If you are there, stop by *Chemical Engineering*'s booth to say hello. If you absolutely cannot make it, we will miss you, but you can follow us on Twitter @ChemEngMag for updates, photos and more. ■

Dorothy Lozowski, Editor in Chief

Call for abstracts: AIChE Meeting

Professionals working in all areas of chemical engineering and related disciplines are invited to submit abstracts for the AIChE Spring Meeting (New Orleans, La., March 30–April 3, 2014), in a number of subject and topical areas including the following:

Subject areas: Chemical Engineering & the Law; Education; Energy; Environmental Issues; Flow Assurance; Fuels & Petrochemicals; Management; Manufacturing; Process and Product Development; Process Safety; Separations; Sustainability; Training for Young Engineers

Topical Conferences: Upstream Engineering; Shale Gas and Light/Tight Oil; 2nd International Conference on Upstream Engineering and Flow Assurance; 14th Topical Conference on Gas Utilization; 17th Topical Conference on Refinery Processing; 26th Ethylene Producers' Conference; Distillation Symposium; Manufacturing in the 21st Century; Emerging Technologies in Clean Energy for the 21st Century; The 10th Global Congress on Process Safety, featuring the 29th CCPS International Conference, 48th Loss Prevention Symposium, and the 16th Process Plant Symposium

Deadlines for submissions are October 1 for the Global Congress on Process Safety, and October 28 for other submissions. To submit a proposal, visit www.aiche.org/spring.

Postscripts, corrections

June, The second and third paragraphs of the Chementator, "A new butadiene process is set for commercialization," on p. 15, each had a mistake. The correct paragraph should read as follows (corrections in italics):

In Wison's *oxidative dehydrogenation (ODH)* process (flowsheet), butanes and lighter components are first separated in the C4 pre-separation unit. Butenes are then mixed with air and steam and dehydrogenated in the ODH reactor. After recovering the heat, the reaction gas is further cooled and scrubbed to remove acids and other impurities, then compressed. Crude 1,3-butadiene (13BD) is recovered by an absorber/deabsorber unit, and then purified in a 13BD-extraction unit.

The ODH reaction features a new, patent-pending catalyst developed by Wison, which is based on the traditional B-02 (iron-based) catalyst technology. Compared to the traditional catalyst, the new catalyst achieves: a 3–4% increase in the conversion of *butene to butadiene*, to reach a conversion of 77–79% in a single-pass; and a 2–3% increase in the selectivity for 13BD, to reach a final selectivity of 92–94%, says Li. He also adds that the improved heat integration leads to a 15% reduction in utility consumption compared to existing technology.

A revised version of the Chementator can be found at www.che.com/chementator/10566.html.

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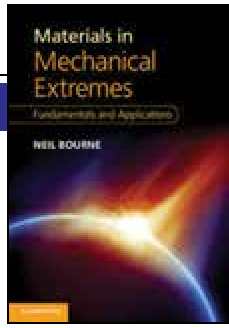
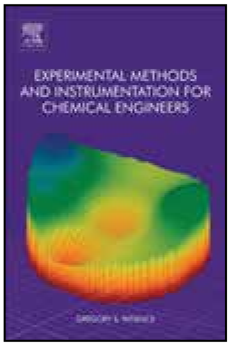
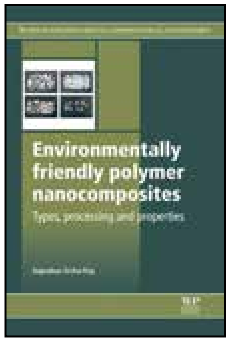


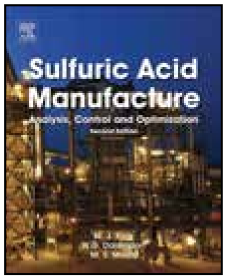
Materials in Mechanical Extremes: Fundamentals and Applications. By Neil Bourne. Cambridge University Press, 32 Avenue of the Americas, New York, NY 10013. Web: cambridge.org. 2013. 539 pages. $155.00.



Experimental Methods and Instrumentation for Chemical Engineers. By Gregory Patience. Elsevier Inc., 225 Wyman Street, Waltham, MA 02144. Web: elsevier.com. 2013. 416 pages. $129.95.



Environmentally Friendly Polymer Nanocomposites: Types, Processing and Properties. By Suprakas S. Ray. Woodhead Publishing Ltd., 80 High Street, Sawston, Cambridge CB22 3HJ, U.K., Web: woodheadpublishing.com. 2013. 506 pages. $270.00.



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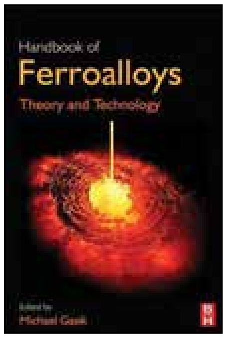

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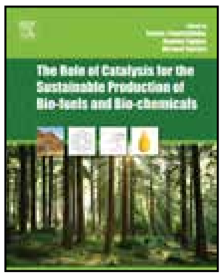

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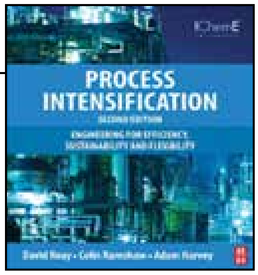
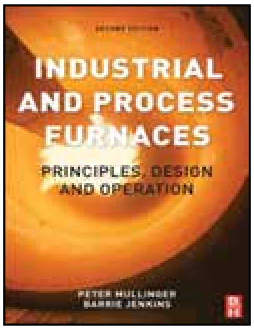
Process Calculations. 2nd ed. (Electronic book) By V. Venkataramani, N. Anantharaman and K.M Meera Sheriffa Begum. PHI Learning Pvt. Ltd. Rimjhim House, 111 Patpargani Industrial Estate, Delhi, 110 092, India. Web: phindia.com. 2013. 259 pages. $4.00.

Ceramics Science and Technology, vol. 4: Applications. Edited by Ralf Riedel and I-Wei Chen. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ 07030. Web: wiley.com. 2013. 544 pages. $405.00.



Process Intensification, 2nd ed.: Engineering for Efficiency, Sustainability and Flexibility. By David Reay, Colin Ramshaw and Adam Harvey. Elsevier Inc., 225 Wyman Street, Waltham, MA 02144. Web: elsevier.com. 2013. 624 pages. $150.00.



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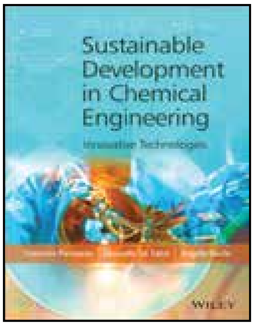
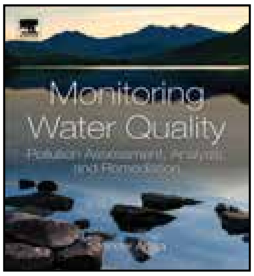


Sustainable Development in Chemical Engineering: Innovative Technologies. By Vincenzo Piemonte, Marcello DiFalco and Angelo Basile. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ 07030. Web: wiley.com. 2013. 384 pages. $115.00.



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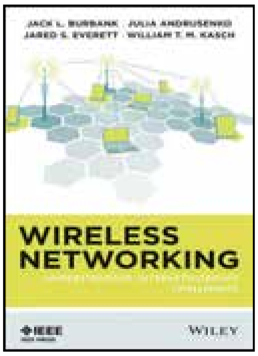
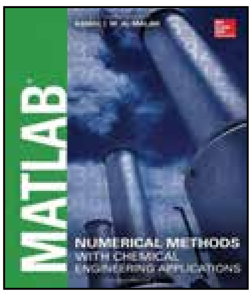


Wireless Networking: Understanding Internetworking Challenges. By Jack Burbank, Julia Andrusenko, Jared Everett, William Kasch. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ 07030. Web: wiley.com. 2013. 712 pages. $135.00.



MATLAB Numerical Methods with Chemical Engineering Applications. By Kamal Al-Malah. McGraw Hill Professional Publishing. 1221 Avenue of the Americas, New York, NY 10020. 2013. 384 pages. $99.00. ■

Scott Jenkins

Editor's Note: If you would like to review a book for this column, contact Scott Jenkins (sjenkins@che.com), senior editor at *Chemical Engineering* magazine.

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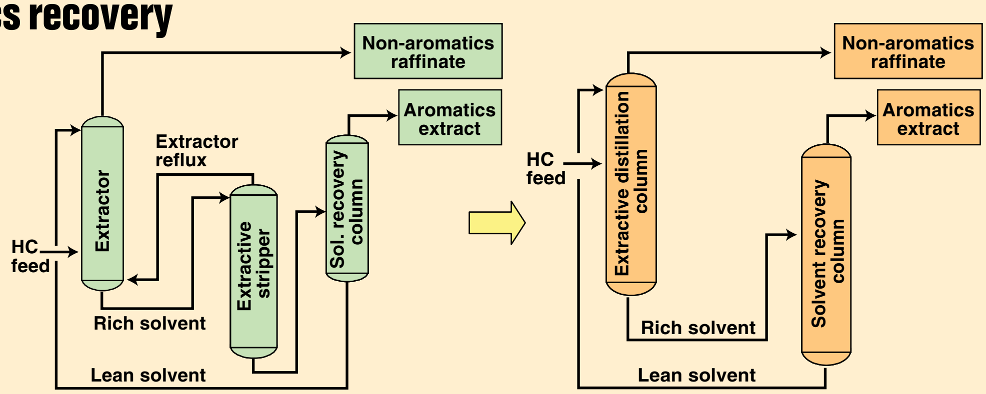
Successful implementation of a new extractive-distillation technology for aromatics recovery



AMT International Inc. (Plano, Texas; www.amtintl.com) and LG Chem, Ltd. (Seoul, Korea; www.lgchem.com) have successfully converted an existing sulfolane liquid-liquid extraction (LLE) unit at LG Chem's Yeosu plant using a new extractive-distillation (ED) process for aromatics recovery. This technology was jointly developed by AMT International Inc. and CPC Corp. (Taipei, Taiwan, R.O.C.; www.cpc.com.tw).

The conversion reused most of the existing equipment, added a new ED column, and reused the original sulfolane solvent without any modifications. The new ED unit, which started up in late April, achieved all revamp objectives, including over 35% savings in energy (compared to the duty of the extractive stripper in the prior LLE unit), over 12% increase in production (only limited by inherent existing equipment capacities), and resulted in on-specification raffinate, benzene and toluene purities and recoveries, says Kuang Wu, vice-president at AMT International. The return on investment for LG Chem is expected to result in a payback period of less than 12 months.

Recovering aromatic hydrocarbons from reformate or pyrolysis-gasoline (pygas) mixtures can be accomplished through LLE (flowsheet, left) or ED processes (flowsheet, right). The ED process typically requires less equipment and lower energy consumption than the conventional LLE process, but it suffers from feedstock boiling-range restrictions, heavy hydrocarbon accumulations in the lean solvent and two-liquid-phase distillation, explains Wu. AMT International, in collaboration with CPC, has conducted a long-term process-technology development program by converting a CPC commercial pygas sulfolane LLE unit at its Kaohsiung plant to an ED unit for BTX (benzene, toluene, xylenes) aromatics recovery. This work has resolved all of the ED process deficiencies and demonstrated significant advantages over the LLE process.

Highlights of this new ED process technology include the following: the effective recovery of BTX aromatics directly from full-range (C6–C8) reformate or pygas feedstocks without pre-cutting C8+ components; the use of the original sulfolane solvent as the ED solvent without modification; the application of proprietary process and mass-transfer equipment designs and operation in an ED column to achieve effective three-phase (L+L+V) fractionation; and the control of heavy hydrocarbons in the lean solvent to maintain optimum solvent performance.

Ceramic membranes and O_3 combine to treat wastewater

High fluxes and micro-contaminant reduction have been achieved in a 2.5-m^3/h pilot plant to test the performance of ceramic membranes and ozonation in treating wastewater at Melbourne Water's (www.melbournewater.com.au) Eastern Treatment Plant. The project, to be completed in a few months, is testing CeraMac technology from PWN Technologies (Velserbroek, the Netherlands; www.pwntechnologies.nl). Although the technology has already been applied in Holland, the U.K., the U.S. and Singapore, the Australian pilot test is unique because it involves secondary effluent. The test results also showed enhanced removal of *Escherichia coli* bacteria.

High-level wastewater treatment usually involves three steps: membrane microfiltration and reverse osmosis followed by advanced oxidation. This is costly when treatment of most surface water can be achieved with membrane filtration alone. The present project achieves the same treatment in a single step. The key feature of the CeraMac technology is that, instead of having ceramic membrane modules in individual stainless-steel casings, up to 192 ceramic elements are now housed in a single stainless-steel vessel. This makes the ceramic membrane system cost-competitive with polymeric membranes, says the company. O_3 can be applied directly on the membrane, destroying micro-contaminants, allowing the system to work at a very high rate (flux) with little water loss.

According to PWN Technologies, cost saving compared with polymeric membranes are

(*Continues on p. 12*)

Solar steam

The Middle East's first solar enhanced-oil-recovery (EOR) project was recently commissioned by Petroleum Development Oman (PDO; Muscat, Oman; www.pdo.co.om). The project uses Enclosed Trough technology from GlassPoint (Fremont, Calif.; www.glasspoint.com) to produce an average of 50 ton/d of steam that feeds directly into existing thermal EOR operations at PDO's Amal West field in Southern Oman. The 7-MW system is 27 times larger than GlassPoint's solar EOR system installed at Berry Petroleum's 21Z oilfield in Kern

(*Continues on p. 12*)

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

Cement technology increases strength and lowers emissions footprint

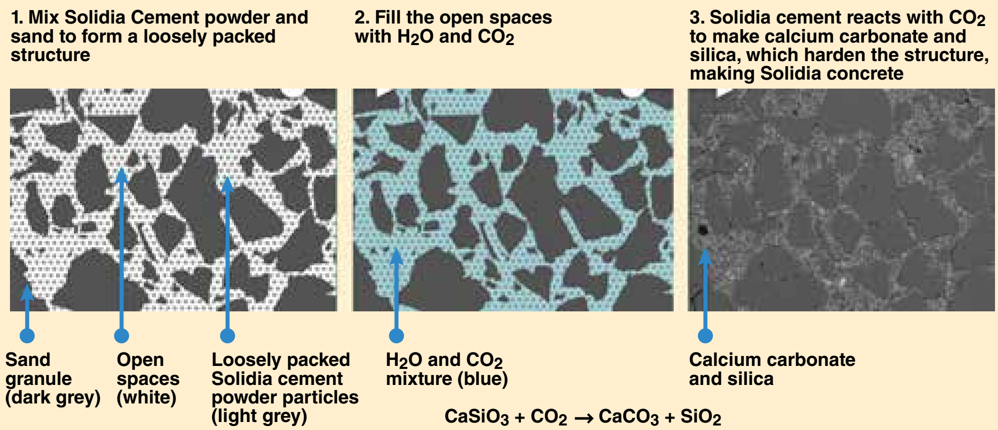
Cement manufacturing is a major source of greenhouse gas emissions due to two factors: carbon dioxide is released when calcium carbonate calcines to lime (CaO) in the cement manufacturing process; and cement kilns are operated at temperatures of 1,500°C, which requires significant fuel consumption. Cement is the agent that binds sand and crushed rock together to form concrete.

Solidia Technologies (Piscataway, N.J.; www.solidiatech.com) has developed technology that can reduce CO_2 emissions in final concrete products by up to 70%, compared to conventional concrete, by using CO_2 as a reactant in the concrete curing process, and by employing cement chemistry that allows lower kiln temperatures (~1,200°C).

Ordinary Portland cement depends on the binding of calcium oxide (from limestone) to silica (from clay) to form di- and tricalcium silicates. These compounds become hydrates when water is added, and the concrete hardens. In Solidia concrete, a patented process called reactive hydrothermal liquid-phase densification (rHLPD) promotes binding between monocalcium silicate ($CaSiO_3$) and CO_2 to cure the material, rather than relying on hydrate formation. To harden Solidia concrete, CO_2 is introduced to a water-containing concrete slurry, where the gas dissolves and begins leaching calcium from the monocalcium silicate. This process forms $CaCO_3$, which precipitates out of solution to lock particles in place (diagram), effectively sequestering CO_2 within the concrete.

Based on the research of Rik Riman at Rutgers University (New Brunswick, N.J.; www.rutgers.edu), the Solidia concrete process has a number of significant advantages over conventional concrete. Aside from its substantially lower carbon footprint, Solidia concrete has higher compressive strength and better abrasion resistance than conventional concrete. "The carbonate is thermodynamically more stable than the hydrates," says Solidia chief technology officer Nick DeCristofaro. Also, curing times are reduced from three weeks to eight hours. Further, "Our process uses the same raw materials and capital equipment as conventional Portland cement, and does not require any changes to the existing concrete supply chain," adds Tom Schuler, Solidia CEO.

Solidia has signed an exclusive licensing agreement with Rutgers for the technology, and is commercializing the technology initially for pre-cast concrete, which constitutes pre-molded shapes including blocks, pavers, railroad ties and building components (as opposed to cast-in-place concrete, which is molded onsite).



CERAMIC MEMBRANES AND O_3

(*Continued from p. 11*)

about 30%. The company says an 18-month trial of a demonstration plant in Singapore treating surface water has led to superior treatment outcomes and savings of up to 40% in comparison with polymeric systems. At the Singapore plant, the daily capacity grew from 1.2 million L/d to 3 million L/d due to the combination of CeraMac with ozone.

The Melbourne Water project is funded by the Australian Water Recycling Center of Excellence and supported by PWN Technologies, Black & Veatch, South East Water and Water Quality Research Australia.

(*Continued from p. 11*)

County, Calif., which has been operating for two years.

Using the sun's energy to make steam can reduce natural-gas use for EOR by up to 80%, says GlassPoint. In the Enclosed Trough design, parabolic mirrors inside a glasshouse enclosure concentrate the sunlight onto water-filled tubes to generate emission-free steam.

Natural N-fixation

A new nitrogen-fixation technology that promises to significantly reduce the need for nitrogen-based fertilizers has been developed by professor Edward Cocking, director of the University of Nottingham's (U.K.; www.nottingham.ac.uk) Center for Crop Nitrogen Fixation. Called N-Fix, the technology involves neither genetic engineering nor bioengineering. Instead, it makes use of naturally occurring nitrogen-fixing bacteria. Plant seeds are coated with these bacteria, which then colonize — intracellularly — as the crop grows. The result is a symbiotic, mutually beneficial relationship between the plant and the bacteria, enabling every cell of the plant to fix nitrogen directly from the atmosphere.

The university has licensed the N-Fix technology to Azotic Technologies Ltd. (Chorley, U.K.; www.azotictechnologies.com) to develop and commercialize N-Fix globally for all crop species. The company anticipates commercialization within the next two to three years.

Resveratrol

Last month, Hosoda Nutritional (Miyuki Fukui City, Japan; www.hosodanutritional.com) introduced Melinjo Resveratrol to the global market. The product — a natural resveratrol (stilbenoid) source extracted from the seeds of the melinjo (Gnetum gnemon) tree — is being produced in a new extraction plant in Java, Indonesia.

Melinjo seed contains an abundance of stilbenoid, mainly in the form of dimers, says the company. The prod-

(*Continues on p. 14*)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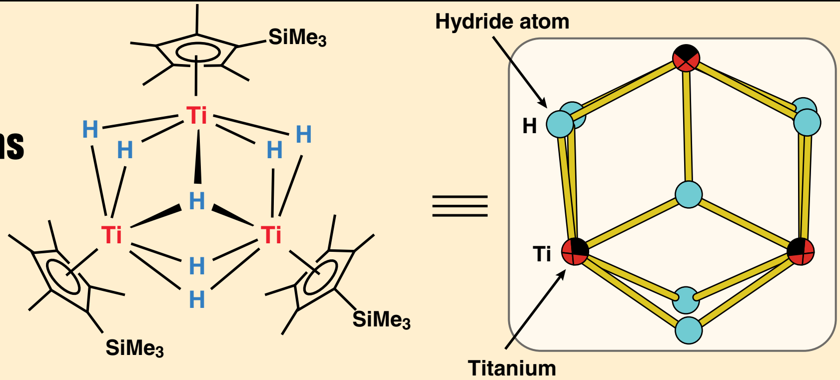
A step toward ammonia production at ambient conditions



Many investigations are ongoing to achieve ammonia synthesis at energy-saving mild conditions instead of the high temperatures and pressures (500°C, 300 atm) required by the commonly used Haber-Bosch process, which consumes more than 1% of the world's power production. Now, Zhamin Hou, Takanori Shima and colleagues at Riken (Saitama, Japan; www.riken.jp/lab-www/organometallic), in collaboration with researchers at Dalian University of Technology, are proposing a new method that uses a titanium hydride system, which is said to be simpler and less expensive than other proposals, because it does not require an electron-donating agent nor a proton source, or expensive chemicals.

The Riken group has reported the reaction of a tri-nuclear titanium polyhydride complex (diagram) with N_2, whereby the N–N bond is broken and nitrogen atoms are partially hydrogenated at ambient temperature and pressure. The researchers expect they can produce ammonia within several hours under these conditions using a simplified and compact reactor. Shima is planning to improve the catalytic system by optimizing the auxiliary ligands and metals, and to collaborate with industry as a side activity.

A direct, one-step enzymatic hydroxylation of benzene to phenol

The selective, one-step biocatalytic hydroxylation of benzene to phenol — at ambient pressure and temperature — has been demonstrated by professors Yoshihito Watanabe and Osamu Shoji at Nagoya University (Nagoya, Japan; http://bioinorg.chem.nagoya-u.ac.jp). The achievement was made using a wild-type of Cytochrome P450BM3 with the simple addition of perfluorinated compounds (PFCs) as "decoy" molecules. The chemists believe the achievement will enable an alternative route to phenol that is simpler, requires less energy and produces fewer byproducts than conventional industrial routes to phenol, such as the multiple-stepped, energy-consuming cumene process, and even R&D processes based on metallic catalyst systems.

The catalytic turnover rates of phenol formation were very much dependent on the alkyl chain length of the PFCs (PFC8 to PFC12, with 8 to 12 carbon numbers were studied). PFC9 and PFC10 afforded the highest turnover rate (120 min^{-1} per P450), using a linear perfluorinated carboxylic acid as decoy, with a phenol yield of 8.4%. Although hydroxylation of phenol is generally accompanied by further oxidation of phenol, the chemists observed exclusive formation of phenol without any over-oxidation products. They believe this is the first demonstration of the exclusive formation of phenol by the hydroxylation of benzene with P450.

The researchers are working to improve the turnover rate by optimizing the structure of the decoy molecules to increase their binding constants toward that of P450BM3. They also expect that they can control the regioselectivity of the hydroxylation of benzene derivatives by changing the structure of the decoy molecules. Watanabe is planning to support P450 on beads for continuous operation in a flow-reactor system.

Non-toxic flame retardants

Researchers from EMPA, the Swiss Federal Laboratories for Materials Science and Technology (St. Gallen, Switzerland; www.empa.ch) have developed organic phosphorous-containing compounds, called phosphoramidates, that show promise as non-toxic alternatives to conventional halogenated flame retardants, such as tri(chloropropyl) phosphate (TCPP) or polybrominated diphenyl ethers. Developed in conjunction with FoamPartner, Fritz Nauer AG (Wolfhausen, Switzerland; www.foampartner.com), the new phosphoramidate-based flame retardants were shown to have no negative effect on the foam manufacturing process for polyurethane foam.

(Continued from p. 12)

uct has been studied for 10 years, with clinical documentation regarding its anti-oxidation and anti-viral properties, and has been marketed in Japan for several years.

Bio-based H_2

Researchers at the Ruhr University of Bochum (RUB; Germany; www.rurh-uni-bochem.de), in collaboration with colleagues from the Max-Planck Institute for Chemical Energy Conservation (Müllhein, Germany) and the Chemistry and Biology of Metals Laboratory (LCBM; Grenoble, France) have discovered an efficient process for making semi-synthetic hydrogenases, which are enzymes that produce hydrogen. The hydrogen-producing enzyme formed spontaneously when the researchers added the protein's biological precursor to a chemically synthesized, inactive iron complex. Only a few organisms are able to produce this so-called iron-iron [FeFe] hydrogenase, whose catalyst is based on an active center with a complex structure that contains iron, carbon monoxide and cyanide, and extracting such hydrolases is extremely difficult, says professor Thomas Happe.

Several milligrams of the hydrogenase's precursor have already been prepared using *Escherichia coli*. And, because commercial processes for cultivating *E. coli* are already established, large-scale production is within reach, says Happe. The findings are described in the August issue of *Nature Chemical Biology*.

Ice pigging for the CPI

Launched this month at drinktec (Trade Fair for the Beverage and Liquid Food Industry; September 16–20; Munich, Germany), Eco-IcePush is a new technology for recovering products during equipment purging, and is being offered by GEA Process Engineering A/S (Søborg, Denmark), a business segment of GEA Group AG (Düsseldorf, Germany; www.gea.com). The Eco-IcePush service requires no capital expenditure, but instead is offered through a service agreement.

Traditional systems use a "pig" that is forced through piping systems to remove residual product from the inner walls and recover product prior to cleaning. But such systems cannot be used on tight bends, through valves, in piping systems with changing pipe diameter or where the product flows through ancillary equipment, such as heat exchangers. With Eco-IcePush, an engineered, two-phase ice slurry is forced through process pipework, and the sharpness of the ice scrapes away product from the inner surfaces for separation and recovery. Because the slurry remains in a fluid state, it can reach every part of the system — even small, complex geometries, says the company.

Although ice-pigging is a technique widely used in the water industry, GEA is now making it available to the chemical process industries (CPI). Potential applications include the reduction of "white water" in dairies; improved product recovery and cleaning in brewery, juice and beverage plants; and similar applications in the food, health and personal-care industries.

A one-pot process to pretreat and saccharify biomass

Researchers from the U.S. Dept. of Energy's Joint BioEnergy Institute (JBEI; Emeryville, Calif.; www.jbei.org) have reported the first demonstration of a one-pot, wash-free process for the ionic-liquid pretreatment and saccharification of switchgrass — a leading potential biofuel feedstock. "By combining ionic liquid pretreatment and saccharification into a single vessel, we eliminate the excessive use of water and waste disposal currently associated with washing biomass that is pretreated with ionic liquids," says chemical engineer Blake Simmons, head of JBEI's Deconstruction Div. "We also drastically simplify the downstream sugar/lignin recovery process and enable the ionic liquid to be recycled," he says.

The researchers developed a compost-derived group of bacteria adapted to grow on switchgrass. Dubbed Jtherm, this mixture of thermophillic microbes is able to thrive at high temperatures and alkaline conditions, enabling the microbes to liberate sugars from biomass in the presence of up to 20% ionic liquids. The one-pot combination of pretreatment with an imidazolium-based ionic liquid and saccharification by Jtherm liberates 81% of the glucose and 87% of the xylose after 70 h processing at 70°C. The sugars could be separated with 90% efficiency.

The group plans to have scaleup tests of the one-pot system at the Advanced Biofuels Process Demonstration Unit (Emeryville, Calif.; abpdu.lbl.gov).

Some bacteria are not inactivated by ultrasound; here's why

Although the inactivation of bacteria by high-power ultrasound has been extensively studied, the relationship between the effectiveness of ultrasound to inactivate bacteria and their physico-chemical properties is not yet well understood, says Muthupandian Ashokkumar, professor at the University of Melbourne (Australia; www.unimelb.edu.au). Hence, a team from the University of Auckland (New Zealand; www.auckland.ac.nz) and the University of Melbourne have investigated how ultrasound inactivation of bacteria might be affected by some physical and biological properties of five microorganisms: *Enterobacter aerogenes, Bacillus subtilis, Staphylococcus epidermidis, S. epidermidis SK,* and *S. pseudintermedius*.

The bacteria for the study were chosen because of their different sizes and gram-status. *E. aerogenes* is a gram-negative, rod-shaped bacterium, which has a size range of 0.3–1.0 × 1.0–6.0 µm. *B. subtilis* is a gram-positive, rod-shaped bacterium with normal size range of 0.7–0.8 × 2.0–3.0 µm. *S. epidermidis* is a gram-positive coccus with sizes of 0.8–1.0 µm in diameter.

These bacteria were sonicated using high-power sound (up to 13 W) with a frequency of 20 kHz at different phases of growth. The team found that high-power ultrasound is very efficient in reducing the number of cells in the case of *E. aerogenes* and *B. subtilis*. The rate of inactivation was also found to be dependent on the growth phase of *E. aerogenes*. The team attributed this to the bacterium's change in morphology from rod-like in the exponential growth phase to a coccus shape in the stationary phase. In contrast, *S. epidermidis* was found to be very resistant to inactivation. This was attributed to the presence of a biopolymer capsule surrounding the bacteria. ■

Amorphous $MgCO_3$

Researchers from Uppsala University (Sweden; www.uu.se) have synthesized a disordered form of anhydrous magnesium carbonate, which has been given the name Upsalite. Making this form of $MgCO_3$ had been thought to be impossible for the last century.

Upsalite has a surface area of 800 m^2/g and has a porous structure with pore diameters of less than 10 nm. The material's adsorption capacity for water is about 50% larger than hydroscopic zeolite-Y at relatively low humidities, and it can be regenerated at temperatures below 100°C, thus making it a potential energy-saving alternative for controlling environmental moisture in the electronics and drug-formulation industries.

The discovery will be commercialized through the university spin-out company, Disruptive Materials (www.disruptivematerials.com). ❑

SPOTLIGHT ON INDIA: PETROLEUM REFINING

Market conditions worldwide create both challenges and opportunities

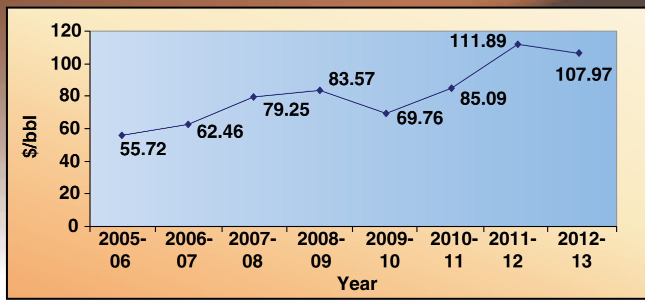


FIGURE 1. The international prices of the Indian basket of crude have steadily risen over time

Source: Petroleum Planning and Analysis Cell (PPAC), Ministry of Petroleum & Natural Gas, Government of India

The petroleum refining sector in India plays a vital role in the country's industrial development and provides a major source to meet India's energy requirements. Today, the refining sector satisfies about 30% of the total energy demand of India [*1*]. As of April 1, 2013, the total installed capacity of Indian refineries was 215 million metric tons per year (million m.t./yr), of which 80 million m.t./yr (37% of total) came from the private sector and 135 million m.t/yr (63% of total) came from the public sector [*2*].

Roughly 80% of crude oil requirements of Indian refineries is met through imports. Therefore, factors that impact imports — such as international crude prices, the exchange rate of Indian rupee (INR) with respect to the U.S. dollar ($), the type of crude available (sweet or sour) and more — have a direct bearing on refinery performance.

India currently has a surplus refining capacity, so some of its refined products are exported to other countries. As such, Indian refiners must compete with refiners in other countries, and meet the strict regulatory requirements of importing countries with regard to quality. And the emergence of non-crude substitutes is another factor. Growing demand for light and middle distillates, coupled with weakening demand for fuel oil, requires Indian refiners to maximize the yield of light and middle distillates and minimize fuel oil yield through better refinery complexity.

Furthermore, in India, the price of fuels such as diesel, PDS kerosene (that is, kerosene sold through public distribution system) and domestic liquefied petroleum gas (LPG) is controlled by the state, which has repercussions for both public- and private-sector refiners. Although the Indian government has partially de-regulated diesel prices recently by allowing public-sector refiners — commonly known as oil marketing companies (OMCs) — to raise the retail prices in small amounts periodically until the entire loss is made up, and by decontrolling bulk diesel prices, the prices are still not fully deregulated. Ongoing price controls force OMCs to sell product at below-cost prices and incur revenue losses. Although the state and state-owned upstream oil-and-gas companies compensate for the losses of the OMCs, the degree and timing of the compensation remains uncertain, and this impacts the availability of funds and the OMCs' ability to invest in plants and machinery.

On the other hand, price control deprives the private-sector refiners of a level playing field. Specifically, private-sector refiners do not get any subsidies or compensation and, therefore, they are at a competitive disadvantage with OMCs, because they cannot sell their products into the Indian retail market at below-cost prices.

However, while the challenges are many, there is no shortage of opportunities for Indian refiners. The opportunities arise from potential demand growth for petroleum products due to thecurrent low per-capita oil consumption, a need for fiscal consolidation, the availability of export markets, the ability to exploit various competitive advantages, better capacity utilization and more.

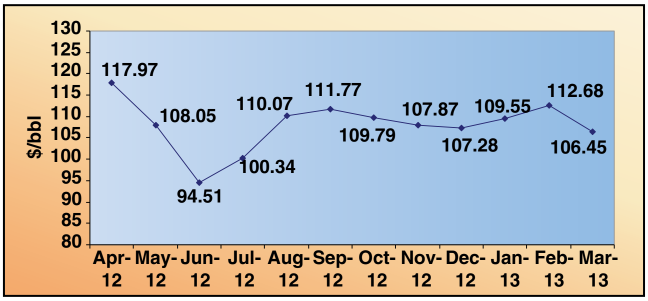


FIGURE 2. The most recent year (2012–2013) has seen some volatility in the international price of the Indian basket of crude

Source: PPAC

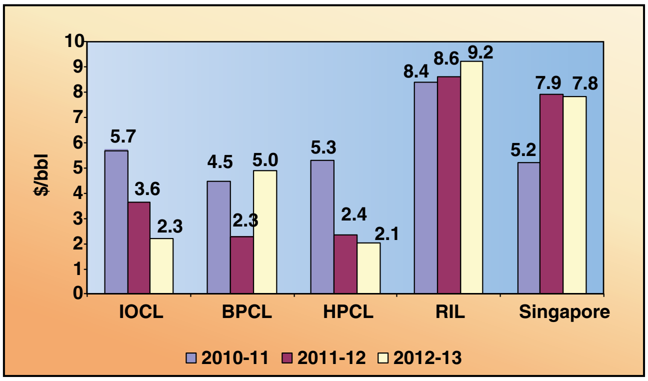


FIGURE 3. There is wide variability in the gross refining margin of Indian petroleum refineries, particularly private- vs. public-sector refineries, due to variability in market conditions and product mixes

Source: Annual Reports/Financial Results of the Companies

Challenges for Indian refiners

International crude prices. International prices of crude oil (Indian basket) have increased approximately two-fold between 2005–06 and 2012–13 (Figure 1), and have been above $105/bbl for most of the period 2012–13, with the peak of above $112/bbl in February 2013 (Figure 2) [*2*]. Because nearly 80% of the crude oil required by Indian refineries is met through imports, and only about 30% of petroleum products are exported, the rising crude prices, coupled with depreciating local currency (INR) against the U.S. dollar, have crippled their gross refining margin (GRM). Depreciating INR with respect to the U.S. dollar increases the cost of crude in INR terms. At the same time, exports of petroleum products from India are not enough to offset increased crude costs, so this weakens the GRM, particularly for public-sector refiners that mainly sell in the domestic market.

The performance of India's major refiners in terms of GRM can be seen in Figure 3. As shown, the performance of GRM of Indian Oil Corp. Ltd. (IOCL), Bharat Petroleum Corp. Ltd (BPCL) and Hindustan Petroleum Corp. Ltd. (HPCL) — all public-sector entities — was mostly below the Singapore benchmark (a regional market for petroleum products). The GRM of RIL (a private-sector entity) was above that of the public-sector refiners, as well as the Singapore benchmark.

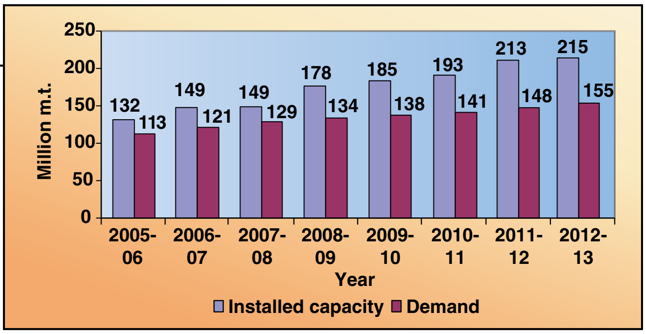


FIGURE 4. The current surplus situation in India — a function of the installed refining capacity in India versus domestic demand — is clearly evident here Source: PPAC

The higher GRM of RIL can be attributed mainly to two factors: 1) higher exports of refined products, coupled with depreciating INR, leading to better realization of products in INR terms; and 2) a higher share of high-margin light and middle distillates in the company's product mix.

Refining surplus. Indian petroleum refineries have surplus capacity beyond domestic demand (Figure 4). Thus, they must export products to other countries in order to utilize their full capacity. But, there is currently a global refining capacity surplus, too [*3*]. As a result, Indian refiners face intense competition from refiners from other countries to sell their products in international markets.

India's major export markets are Asia, Middle East, Africa, Europe, U.S. and Latin America. However, export to the Asian market is likely to be restricted by China's refining expansion plan as well as competition from refiners in South Korea, Japan and Singapore. The Middle East has

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Spotlight on India

also refining expansion plans. For U.S. and Latin American markets, excessive freight costs create a competitive disadvantage for Indian refiners. Meanwhile, in Europe, strict quality requirements by European governments (in the form of Euro V fuel specifications) have the potential to restrict Indian exports there, as only a few of the Indian refineries are able to meet those specifications.

Non-crude substitutes. As India currently has surplus refining capacity and can utilize its full capacity through exports only, any substitution of the petroleum products at the global or domestic level by non-crude alternative products has the potential to impact demand for its products. Non-crude products, mainly ethanol and natural gas liquids (NGLs), are emerging as global substitutes for some refined products, as are gas-to-liquid (GTL) products, coal-to-liquid (CTL) products and methanol. There is a gap between the supply of refined petroleum products and oil de mand, which is filled by these non-refined products.

In 1980, crude-based products from refineries throughout the world covered almost 93% of demand. By the 1990s, this ratio had declined to below 90%, before reaching 85% in 2012. Projections indicate that crude runs will lose another half of one percent share by 2016 [*3*].

Ethanol is projected to play an important role in impacting gasoline demand globally. Driven mainly by the U.S. and Brazil, global ethanol supply is projected to rise from 1.6 million bbl/d in 2010 to 2.4 million bbl/d by 2020, and then accelerate to 5.1 million bbl/d by 2035. Over the same period, worldwide gasoline consumption is projected to rise from 21.3 million bbl/d to 26.1 million bbl/d. Thus, ethanol as a share of the total gasoline pool is expected to grow from 7.5% in 2010 to 19.5% by 2035 globally [*3*]. In India, the government has made it mandatory for the state-owned OMCs to blend 5% ethanol into gasoline.

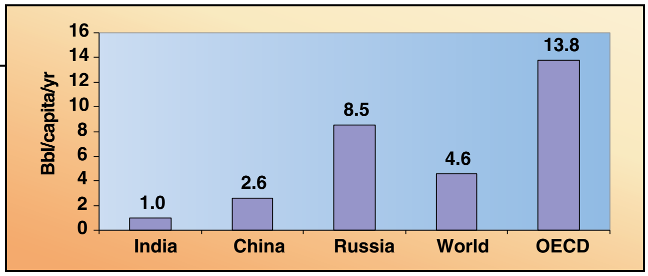

FIGURE 5. While India's per capita oil consumption is relatively small compared to other countries and the rest of the world, it is expected to grow, due to India's expanding economy

Source: Organization of Petroleum Exporting Countries (OPEC), World Bank, Organization for Economic Cooperation and Development (OECD)

Note: Data are based on oil consumption and population in 2011 except for OECD for which population in 2010 has been considered.

Meanwhile, shale gas development in the U.S. has led to increased supply of NGLs produced from natural gas. Increased and cheaper supply of natural gas in the U.S. also increases the feasibility of GTL projects in that country. CTLs are also expected to witness growth, particularly in countries with substantial coal resources, such as the U.S., Australia and China [*3*].

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While currently overshadowed by ethanol, methanol has also been used as a transport fuel for years. In China, methanol from coal comprises a significant percentage of the country's transport fuel pool. And methanol can be produced from many feedstocks, ranging from coal and natural gas to pulp-mill and other byproducts [*3*].

Requirement for cleaner transportation fuel

As noted, Indian petroleum refineries have surplus capacity today. To export their products, they must produce cleaner fuels to meet international limits on sulfur content. For instance, the Euro V fuel specification requires that the sulfur content not exceed 10 ppm by weight in diesel or gasoline. Currently only a few Indian refineries have the capability to produce Euro V fuel.

Today, approximately 70% of crude oil imported by India is of sour grade [*2*]. This requires capacity addition of hydrodesulfurization or hydrotreating, and hydrogen-recovery and sulfur-recovery processes to reduce sulfur levels in petroleum-derived products.

Hydrodesulfurization or hydrotreating is required to reduce the sulfur levels in petroleum-derived products to meet desired levels. The process requires the addition of hydrogen, which reacts with organic sulfur in the presence of a catalyst to produce H_2S, which in turn is absorbed in a solvent. The offgases produced in the process, after removal of H_2S, can be used as fuel in the refinery or can be processed for H_2 recovery. Recovered H_2 can be reused in hydrodesulfurization or hydrotreating processes. The H_2S-rich solution is regenerated into lean solution and H_2S-containing gases are produced during regeneration. Sulfur recovery can be employed to capture sulfur from such gases.

As these processes are highly capital intensive, Indian refiners need to invest huge capital to meet the Euro V standard fuel specifications. Making a huge investment is a challenge in the face of weak refining margins.

Yield maximization of light and middle distillates. Given the nature of domestic and international demand for various petroleum products, Indian refineries have to maximize the yield of high-value light and middle distillates and minimize the yield of low-value heavy ends, such as fuel oil (FO) and low-sulfur heavy stock (LSHS) in order to maximize refining margins. FO/LSHS demand in India has been declining over the years and been less than the production. In 2012–13, demand declined by 17.5% over the previous year and was just 7.7 million m.t. against the production of 15.8 million m.t. [*2*]. FO/LSHS demand in India is expected to continue its declining trend in the near future [*4*]. International FO demand is also expected to decline at a rate of 1.4% per annum between 2011–16 [*3*].

On the other hand, domestic demand for light distillates and middle distillates is likely to grow at a compounded average annual rate of 5.1% and 5.2%, respectively, during the period 2012–13 to 2016–17. Domestic demand for gasoline (a key light distillate) and that for diesel (a key middle distillate) is expected to grow at a compounded average annual rate of 8.8% and 5.8%, respectively, during the period 2012–13 to 2016–17 [*4*]. Global demand for gasoline and that for diesel is expected to grow at 0.9%/yr and 2.1%/yr,

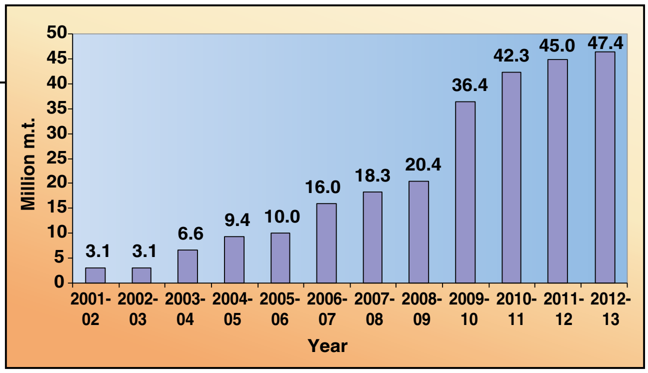

FIGURE 6. In recent years, net exports of petroleum products from India have been rising steadily Source: PPAC

respectively, during 2011–2016 [*3*]. Furthermore, the FO crack spread in Singapore against Dubai crude has been negative (much below that of diesel, gasoline and jet fuel/kerosene) in recent times, and averaged minus-$10.00/bbl in July 2013 [*5*].

The overall yield of light and middle distillates for all Indian refineries is 77.4%. But, low-value FO/LSHS yield is still at 7.3%, which is higher than the yield of high-value LPG (4.5%), aviation turbine fuel (ATF; 4.6%) and super kerosene oil (SKO; 3.7%) [*2*].

Declining demand and poor refining margins of FO require Indian refineries to maximize their yield of light and middle distillates and minimize FO yield to improve margins. Indian refiners would have to make huge capital investments to improve their refinery configurations to optimize product yields.

Lack of a level playing field. The prices of diesel, domestic LPG and PDS kerosene in India are currently controlled (partially or fully) by the government of India. Consequently, the state-owned OMCs — namely IOCL, BPCL and HPCL — are selling those products at below-cost prices. As a result, they suffer revenue losses (under-recoveries) on the sale of those products. But the OMCs are compensated for their under-recoveries by the government in the form of subsidies, and by upstream public-sector oil and gas companies — namely, Oil and Natural Gas Corp. Ltd., Oil India Ltd. and GAIL (India) Ltd. — in the form of discounts on the sale of their products to OMCs. However, similar benefits are not available to private refiners. They cannot sell those products in the Indian retail market and are left with only the options of export or sale to OMCs.

Opportunities for Indian petroleum refiners

Domestic oil demand. Per-capita oil consumption of India is among the lowest in the world (Figure 5), but economic expansion is expected to spur demand. Medium-term oil demand outlook (Table 1*) suggests India's oil demand is likely to grow from 3.4 million bbld/d in 2011 to 4.2 million bbl/d in 2016, at a compounded average annual rate of 4.3%, which is much higher than 1.1% for the whole world and 2.8% for the developing world, and even higher than 4.1% for China [*3*].

Long-term oil demand for India (Table 2*) suggests that oil demand is likely to grow from 3.3 million bbl/d in 2010 to 9.0 million bbl/d in 2035, at a compounded average annual rate of 4.1% — much higher than 0.8% for whole world, 2.2% for developing world, and 2.7% for China [*3*]. Thus, India is likely to show strong growth in oil demand in both the medium and long term. This provides enormous opportunity for the Indian refining industry.

* Note: Tables 1 and 2 can be found in the online version of this article at www.che.com.

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Spotlight on India

Need for fiscal consolidation. As the government of India provides subsidy to OMCs to help offset their under-recoveries, it also widens the government's fiscal deficit. Of the total OMCs' under-recoveries of INR1610 billion in fiscal 2012–13, the government has compensated INR1,000 billion through subsidies. This translates into 19.2% of the estimated fiscal deficit at INR5209 billion in that year. These fuel subsidies are a major contributor to India's fiscal deficit and are not sustainable in the long run.

In order to achieve fiscal consolidation, pruning the fuel subsidy will be the most economically rational option, but this would require decontrol of at least diesel prices. The partial decontrol of diesel prices by the government that was put into effect recently is a step in that direction. Once diesel prices are decontrolled fully, it will provide an opportunity for private refiners also to sell their major products (such as diesel and petrol) in the domestic retail market, which will give them incentive to invest in further capacity addition.

In addition, public-sector refiners will also benefit from decontrolled diesel prices as their finances will be improved, thereby strengthening their ability to generate surpluses and finance the investments through internal accruals instead of relying heavily on external funding.

Export potential. Contribution to export comes mainly from private-sector refiners — namely Reliance Industries Ltd. and Essar Oil Ltd. They have a competitive edge because of their capability to produce Euro V-quality fuels, plus they enjoy economies of scale and the refinery complexity necessary to provide a high-value product slate. In addition, Indian refiners enjoy the geographical advantage to export their products to the markets of nearby Asian countries and Middle East.

Despite the competition from refiners in other countries, Indian refiners have still performed well on the export front. This is evident from the fact that India's net export of petroleum products has been rising steadily since 2002–03 (Figure 6). This indicates the strong potential that exists for the export of Indian refined-petroleum products.

Competitive advantages. To improve profitability, Indian refiners can leverage low costs associated with capital, construction and labor to help offset the impact of high import costs of crude feedstocks. Access to financing and the abundance of skilled labor and high-tech machinery and equipment provides additional competitive advantages.

According to India's Ministry of Petroleum and Natural Gas, several Indian companies have recently announced plans to invest in new refining capacity additions totaling 30 million m.t./yr. All figures are shown in million m.t./yr and expected onstream dates are noted:

- Indian Oil Corp. Ltd.: 15.0; September 2013)
- Nagarjuna Oil Corp. Ltd.: 6.0; January–March 2014
- Hindustan Petroleum Corp. Ltd.: 9.0; January–March 2017

Similarly, according to India's Ministry of Petroleum and Natural Gas, many companies have planned to expand their existing capacity, totalling 50.6 million m.t./yr, during 2012–2017 (All figures are shown in million m.t./yr):

- Indian Oil Corp. Ltd. (4.8)

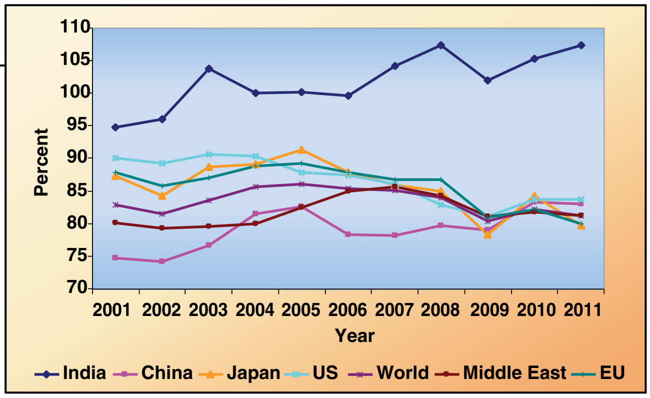

FIGURE 7. India has sustained a capacity-utilization rate near 100% for the past decade, higher than all other major refining countries/regions

Source: "BP Statistical Review of World Energy," June 2012

- Hindustan Petroleum Corp. Ltd. (8.7)
- Bharat Petroleum Corp. Ltd. (7.5)
- Chennai Petroleum Corp. Ltd. (0.6)
- Numaligarh Refinery Ltd. (5.0)
- Manglore Refinery & Petrochemicals Ltd. (3.0)
- Bharat Oman Refinery Ltd. (3.0)
- Essar Oil Ltd. (18.0)

Two foreign companies have also set up petroleum refineries in India in joint ventures (JV) with Indian companies (both onstream during 2011–2012):

- Mittal Energy Investment Pte Ltd., Singapore holds 49% stake in HPCL Mittal Energy Limited, a JV with Hindustan Petroleum Corp. Ltd.
- Oman Oil Co. SAOC holds 26% equity in Bharat Oman Refineries Ltd., a JV with Bharat Petroleum Corp. Ltd.

Capacity-utilization rate. The average capacity-utilization rate of Indian refineries has been well above those of other major refining countries and regions of the world. Whereas the utilization rate in other countries and regions has been in the range of 75–90% for most of the study period, that in India has been near or above 100% throughout the study period (Figure 7) [*6*]. ■

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Pfaudler

FIGURE 1. The modular process-system-design approach was utilized for this evaporator system, shown here being lifted from the truck and righted for plant installation. Modular construction includes mounting all process equipment on a structural steel frame, fabricating all interconnecting process and utility piping and installing all instruments on the module and wiring the instruments to a junction box or control panel. A modular design/build firm provides single-source responsibility for the modular process system

THINKING INSIDE THE BOX

Modular construction offers many benefits. Here's how to decide if it's right for your CPI application

Pfaudler

FIGURE 2. Shop construction is far more efficient than field construction and is not affected by weather or other plant-site activities. Thus, the modular process-system-design approach lowers overall project costs and shortens project schedules. Modular project execution greatly reduces site construction work and its associated plant-site disruptions. This three-module evaporator system was installed at an existing specialty chemical plant in less than two days

Modular construction is slowly, but surely becoming a buzzword in the design/build industry because it provides many benefits to project owners. But does that mean it is the right approach for the chemical process industries (CPI), and specifically, for your application? Here, experts in the industry discuss why and, more importantly, when it makes sense to modularize.

"Modular construction is catching on because of the realized benefits and has become a best-practices methodology in many sectors," says Kim Allen, associate director with the Construction Industry Institute (CII; Austin, Tex.; www.construction-institute.org). "The strategy often makes sense and should be a front-end planning and design premise consideration. This is not to say that all projects fit the bill, but it is a valid question to be asked up front in the project planning phase: What can be modularized on this project, and if we did that, what would the benefits be?"

So what is all the fuss about? In a nutshell, according to Lewis Fabricius, global product director, WFE and reactor systems, with Pfaudler, Inc. (Rochester, N.Y.; www.pfaudler.com), while some people think only of a little pump skid or utility skid when they hear the word "modular," current process modules are much more extravagant than that (Figure 1). "Today's installed modules can be as large as 3,000-gal reactors or large process-system modules that have the same appearance and operation as a stick-build project," he says. "However, the modular approach saves considerable cost and reduces the project schedule by two to three months."

Modular benefits

Supporters of modular construction suggest that there are many benefits to be had. Fabricius mentions single-source responsibility and fixed prices as worthwhile benefits, while David Edwards, vice president, sales and marketing, Zeton, Inc. (Ontario, Canada; www.zeton.com), sees schedule improvements, quality improvements, cost improvements and risk minimization as perks.

Single-source responsibility. One of the main benefits for the client, according to Fabricius, is that the fabricator has sole responsibility for designing the units, building them, providing the equipment and mounting it into the assembly, which ensures the processor that they will receive properly laid out and properly constructed, integrated components and properly functioning systems without any of the usual hassles, says Fabricius.

"No project ever executed has *not* had a problem, but with the single-source responsibility provided by modular fabricators, resolving those issues is taken care of in a way that the customer doesn't have to deal with or solve," explains Fabricius. "In addition to making life easier, it saves time because there is no finger pointing or blame placing from one labor group to the next. If something needs to be corrected, it gets corrected" (Figure 2).

Firm, fixed price. During the upfront engineering design stage, most fabricators will provide a firm, fixed price for the completed project, explains

Zeton

FIGURE 3. Here, a modular shale-oil upgrading demonstration plant is in the shop

Fabricius. "The traditional stick-build approach usually provides only an estimate because when quoting, they don't go to the individual contractors they will be employing on the job or to all the suppliers they will be using," he says. "But with modular construction, we know what is going to go into that box, who is going to be putting it there, and how much it will cost, so we are able to provide a firm price. There won't be any surprises at the end."

Schedule improvements. "When compared to the stick-build approach, modular construction can also speed up a project," says Edwards. "This is because experienced modular fabricators have standardized approaches, which can be applied easily to different situations." He explains that if someone needs a distillation column or a reactor, it is likely that an experienced modular fabricator has dealt with something similar before and will have a pre-designed module in which to place the equipment.

"While there is always a bit of customization, typically each fabricator uses a standard type and size module, and they know how to efficiently place equipment into this standard module. There is no standard with stick-build projects." In addition, since most modular fabrication takes place in a shop environment, schedules are not affected by weather or labor issues. "The shop-build approach provides more efficiency, more flexibility, and more certainty. There is air conditioning in summer, heat in winter, stormy weather doesn't impact the schedule,

FIGURE 4. Due to the remoteness, offshore platforms are almost exclusively built on a modular basis in the shipyard and then floated out to the site

and there are no operating issues in the existing plant to slow progress," says Edwards.

Quality improvements. "Again, compared to the stick-build approach, in a modular shop you have a stable workforce, which makes it easier to control product quality than it is with an onsite labor force," says Edwards. "And, that stable workforce is used to working with the fabricator and knows the level of quality that is expected."

In addition, he says, quality is improved because of the ability to pretest the module in the shop. "We can do leak tests, electrical continuity tests and such before shipping the module, which speeds plant startup and commissioning on site," he says. "Every plant gets 'shaken down' once it's built, but this can happen faster with a module because they are pretested before being shipped to the site" (Figure 3).

Cost improvement. Cost improvements can be found mainly because the cost of operating in a dedicated shop is less than the overhead of an onsite project, where setting up a custom site often requires building access roads and such before construction can begin.

Also, because fabrication can be broken down into subassembly modules that are later put into the large module versus the stick-build approach, which places equipment into the facility as it arrives, it is more efficient, thus lowering costs for the builder and customer, says Edwards.

Space savings. Another advantage that modular design offers is space savings, says James Owen, general manager with EPIC Systems, Inc. (St. Louis, Mo.; www.epicsysinc.com). "When you use a modular frame to build a system, you can layer the piping, equipment and utilities. When designed correctly, it can be easier to service equipment and hook up process connections, while actually fitting the unit in a smaller footprint," he explains.

Risk mitigation. Because modular fabrication requires completing as much of the work as is feasibly possible in a controlled shop environment, it brings the certainty of cost, certainty of quality, and certainty of schedule to the table, which mitigates the risk of a project, says Richard Meserole, vice president, construction with Fluor's Energy and Chemicals Group (Dallas, Zeton

FIGURE 5. This image shows a modular cellulosic-ethanol demonstration plant

Tex.; www.fluor.com). "Risk mitigation is of extreme importance in remote locations where skilled labor is in short supply, and modular construction is a big risk mitigator due to the certainty it provides," explains Meserole.

Modular applications

Modular construction can be equally efficient and beneficial in applications ranging from small skids to large-scale reactor systems, but there are certain applications in which it is most beneficial. For example, Meserole says due to the remoteness, offshore platforms are almost exclusively done on a modular basis. "They are built in the shipyard and then floated out to the site" (Figure 4). Likewise, small process, pilot and demonstration plants are almost exclusively built with modular construction because the equipment is small enough," adds Zeton's Edwards (Figure 5).

However, keep in mind when the application is in an existing structure or plant process that is operational, there may be challenges, says Chris Lamberson, project manager at Skanska USA Civil (New York, N.Y.; www.usa.skanska.com). "Pilot plants demonstrate a need to still tie into the existing process lines that pushes field welding/fitting as well as wiring," he says. "But prefabrication of units in a controlled environment have proven to be the way to go not only from a time/money concern, but in a quality/safety culture as well."

Other popular applications for modular construction include utilities and raw material supply areas," says EPK's Owen. "Often, sets of skids can be engineered to work together in a variety of applications. An example of a complete system could include a raw-material supply skid, a utility skid and a processing unit."

Other considerations

According to Owen, projects that can't use modularization have decreased over the years and there has been a reduction in skepticism on the part of processors. "The need to explain the advantages is decreasing, and we are seeing a higher volume and wider variety of modular opportunities."

However, even though modular opportunities are on the uptick, this is not to say that every chemical processing project is an ideal candidate for modular construction. "The size of the system is a greater factor than the types of operations being performed," says Owen. "It's not practical to 'modularize' a raw-material tank farm with 30,000-gal tanks, for example."

Fluor's Meserole agrees. "The biggest determiner of the ability to modularize is the physical constraints of the plant, as well as the ability to get something of this size to the location where it needs to reside," he says. "There are roadways, bridges, ports [and so on] and then there's the ability to get the module inside a facility if that is where it needs to be placed. That is the number one determining issue — the size of the modules and the ability to move them around. There's a fine line because the larger the module, the larger the benefits, but too large and the project may not be feasible."

Additionally, he explains that trying to force something too big into modules isn't beneficial either. "Sometimes a project would require more than one or two modules, and when there are too many boxes, it may start to diminish the returns the customer was seeking from modularization in the first place," says Meserole.

Additionally, availability of qualified local craftsmen, lead time on


EPIC Systems

FIGURE 6. Melding equipment in a manufacturing environment with chemical processes can be complex. A balanced understanding of modular design, manufacturing objectives and chemical engineering principals is essential. The project must be carefully planned from the concept stage with input from experienced chemical engineers, mechanical engineers, electrical engineers, mechanical designers and project managers

equipment deliveries, specifications on process lines and vessels are also drivers or questions that need to be asked when making the decision to modularize, says Skanska's Lamberson. "Cost and time are always the sticking points, but quality and safety should be the front runners," he says. "The criteria are met when the processor feels right collectively, based on the stability of the pre-design engineering."

The right choice?

The market trend toward modular systems has increased over the past five years, its popularity is growing, and a higher percentage of people have a base knowledge of what modular design is and a general understanding of the benefits. "But designing a modular chemical system requires special attention during the process-engineering phase of the project," says Owen. "Melding equipment in a manufacturing environment with chemical processes can be complex. A balanced understanding of modular design, manufacturing objectives and chemical engineering principles is essential. The project must be carefully planned from the concept stage with input from experienced chemical engineers, mechanical engineers, electrical engineers, mechanical designers and project managers" (Figure 6).

The business case for modularization must also be considered before the determination is made, according to CII's Allen. "Some may think in terms of process plants as being unique and proprietary in nature and that modularization may not apply. But studies show that this is not the case," he says. Therefore, according to Allen, the recommended strategy is to consider modularization during the planning phase and treat this as a design premise throughout. "This is where gains can be made in productivity and quality. In addition, selecting an EPC [engineering, procurement, construction] contractor that embraces modularization and specializes in this methodology can deliver significant results for chemical plant owners and operators," he notes. ■

Joy LePree

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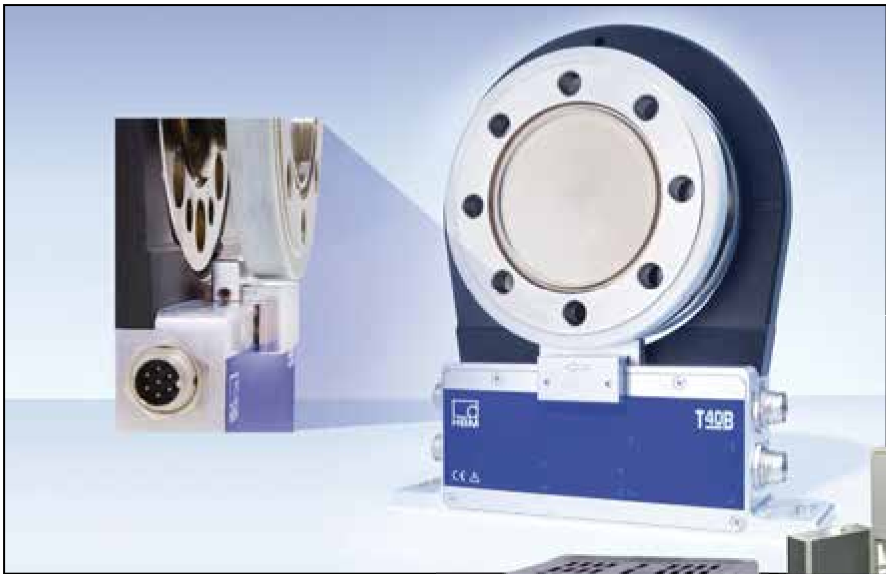

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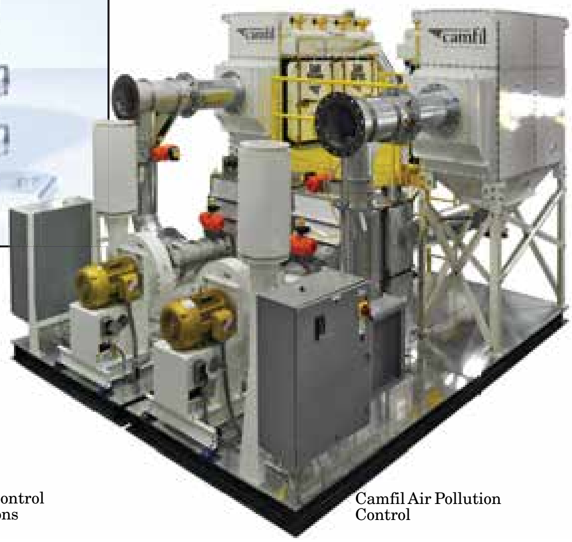

Camfil Air Pollution Control

These transducers can measure torque and speed at the same time

New T40B and T40FM torque transducers (photo) include an integrated speed measurement system that allows them to measure torque and speed simultaneously. Specifically designed for applications in harsh environments, these transducers can operate in locations that contain humidity, condensation, dust, oil and grease, conditions that usually would restrict the use of a traditional optical-speed measurement system. The T40B and T40FM take measurements based on the contactless sensing of an anisotropic magnetoresistive (AMR) sensor, making the transducer signal more robust and stable than that of an optical system. The transducer integrates both the magnetic technology and the speed measurement sensor, saving space and simplifying installation. Other features include a high-resolution 1,024-pulse output and a high tolerance for application-related vibrations. — *Hottinger Baldwin Messtechnik GmbH (HBM), Darmstadt, Germany*
www.hbm.com

A compact skid kit for these dust collectors and accessories

The Farr Gold Series dust collection system (photo) is now available in a simplified skid package. The high-efficiency cartridge dust collectors and all associated equipment are incorporated onto a single platform, for ease of transport and installation. In addition to dust collectors, these customizable skids may contain accessories, such as explosion protection devices, filters, continuous liner discharge, fans, controls and interconnecting ductwork. Equipped with removable electric and pipe connections, the skids can be moved via forklift or crane, and installed anywhere at the end-user's site. — *Camfil Air Pollution Control, Jonesboro, Ark.*
www.camfilapc.com

Accurate lubricant administration in hard-to-access locations

New SKF System 24 LAGD Series single-point automatic lubricators (photo) deliver a pre-set amount of fresh lubricant to machinery bearings used in many industries. Engineered with a gas-driven feed, these lubricators can resolve issues typically associated with hard-to-access or potentially hazardous lubrication points. The automatic lubricator's continuous and controlled supply of fresh and clean lubricant minimizes the ingress of potentially damaging contaminants, prevents the overheating, waste, and seal damage caused by over-lubrication, and eliminates excessive wear from over-lubrication. Featuring user-adjustable dispense settings, the LAGD series lubricators are supplied in two sizes, 60 and 125 mL. — *SKF USA, Inc., Lansdale, Pa.*
www.skf.com

Achieve flexible temperature control in boiler operations

The PMA KS98-1 process temperature controller (photo) is designed to improve the operational economy of steam and hot water boiler applications. Able to manage up to six devices, this controller can reduce energy losses and prevent downtime by selec-

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

Hayward Flow Control

Magnatrol Valve

Watlow Electric Manufacturing

E Instruments International

tive switching of individual devices for maintenance and repair. The configurable, multi-functional KS89-1 can be used to switch smaller units on and off in a defined order, according to energy demand, as determined by a proportional-integral-derivative (PID) controller. A high-resolution LCD screen displays bar graphs and trend curves, while an extensive function library is available to support complex needs, such as analog signal conditioning to digital signal operations, and cascade control systems to complex meshed control loops. — *West Control Solutions, East Sussex, U.K.*
www.west-cs.co.uk

This portable emissions analyzer can house up to five gas sensors

The new E5500 portable combustion analyzer (photo) monitors emissions for regulatory and maintenance use in boiler, burner, engine, turbine, furnace and other combustion applications. The versatile E5500 can measure the temperature of stack gas and ambient air, as well as draft and differential pressure. The E5500 features electrochemical gas sensors for O_2, CO, NO, NO_2 and SO_2, and is low-NOx and true-NOx capable. The analyzer kit also includes an external water-trap assembly, wireless remote printer and real-time PC software package. — *E Instruments International, Langhorne, Pa.*
www.e-inst.com

These solenoid valves are easily serviced while in the pipeline

Type A and AR bronze solenoid valves (photo) are designed for use in water or wastewater and fuel-oil applications. Available for pipe sizes from 0.5 – 3 in., the valves feature cast bronze, globe-pattern valve bodies with NPT ends, as well as packless construction with continuous-duty coils for all voltages. The valves require no differential pressure to open and are easily serviced while in the pipeline, decreasing downtime. Type "A" valves are normally closed (energize to open) and Type "AR" valves are normally open (energize to close). — *Magnatrol Valve Corp., Hawthorne, N.J.*
www.magnatrol.com

Use this compact heat exchanger for high-pressure dry-gas seals

The new Hydrosafe indirect electric heat exchanger (photo) is a complete thermal system designed for use in the harsh environments found in oil exploration and extraction, petroleum refining and petrochemicals. Minimizing potential leaks, the Hydrosafe's one-piece, non-welded design makes this exchanger appropriate for high-pressure situations in dry gas-seal applications. The heating element, vessel, insulation, terminal enclosure, mounting plate and inlet and outlet connections are combined into a complete assembly, for ease of installation. The gas is heated inside a small-diameter seamless tube or pipe, allowing for high-system-pressure capability. The 316L stainless-steel fluid path is independent of the heater sheath, preventing fluid contamination. This also allows sensitive materials to be heated effectively, and assures safety because heater failure will not cause leaks or significant damage. The small diameter and low-volume pressure boundary allow use in many countries without the need for further pressure-vessel certifications. — *Watlow Electric Manufacturing Co., St. Louis, Mo.*
www.watlow.com

This drip-free spray nozzle is made of food-grade materials

The new HydroPulse spray nozzle provides a controlled, intermittent liquid spray using only liquid pressure as the force for atomization. Pneumatically actuated, this low-flow, flat-fan spray nozzle promises drip-free performance in applications requiring overlapping sprays, including petrochemicals, paper, glass, lubrication, automotive and more. The HydroPulse is constructed of food-grade materials, making it appropriate for sensitive processing applications, as well as those requiring corrosive environments and harsh fluids. The flat-fan spray pattern provides spray angles from 0 to 110 deg with flow rates of 0.003 to 24.7 gal/min. — *Bete Fog Nozzle, Inc., Greenfield, Mass.*
www.bete.com

These filter cartridges' low pressure drop yields high throughput

These new pleated filter cartridges (photo) are manufactured in either polypropylene or cellulosic media and provide high surface filtration. Designed for use with this company's CFLV and MFLV cartridge adapter kits, these cartridges are suitable for applications with multiple liquid-purification requirements. The cartridges' larger surface area ensures a longer service life than most filter bags, due to higher flow and particulate holding capacity. Lower pressure drop, reduced processing time and multiple-layered media construction are some additional benefits of these pleated filter cartridges. — *Hayward Flow Control, Clemmons, N.C.*
www.haywardflowcontrol.com ■

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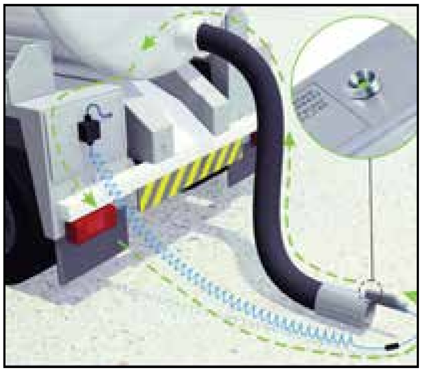


Avert static electricity buildup with this hose-continuity tester

The OhmGuard Hose-Continuity Tester (photo) is designed to continuously ensure that a string of assembled hoses are safely grounded to the transferring vehicle during operations that may produce potentially combustible gas, vapor or dust atmospheres. These testers protect against static electricity that can accumulate to dangerous levels in isolated metal components of commonly used helix-wire transfer hoses. In practice, the new instrument operates as a simple "pass or fail" test, wherein a green LED mounted on the OhmGuard clamp will pulse continuously if the hoses have been properly grounded. If there is a break in the continuity the pulsing will cease, warning the operator of potential danger. — *Newson Gale, Inc., Jackson, N.J.*
www.newson-gale.com

Emergency safety showers offer response to chemical exposure

This company's emergency showers (photo) provide protection for personnel working with hazardous chemicals in industrial, laboratory or academic settings. Compliant with both ANSI and OSHA requirements, the fully assembled showers are constructed of a one-piece fiberglass composite, allowing for simple installation to water supply and drainage systems. This unit is equipped with a pull-rod activated shower and push-handle eye and face wash for immediately drenching of personnel that have been exposed to hazardous chemicals. Optional accessories include grab-bars, hand-held body wash and curtains. — *Hemco Corp., Independence, Mo.*
www.hemcocorp.com

Use this explosion-proof traffic light in hazardous locations

The EPL-TL-3X10W-C LED Traffic Light (photo) provides workers in industrial operations with a durable signaling fixture that can be used in a variety of applications, including routing traffic through refueling stations and indicating a stop, running or caution status during the operation of manufacturing machinery. Featuring three colored LED lamps in red, yellow and green, the unit provides high visibility in a durable package, with each lamp enclosed in a rigid cage capable of withstanding 1,490-psi hydrostatic pressure. The traffic light unit is also explosion-proof and appropriate for use in hazardous locations. The traffic light's customizable mounting assembly is constructed from heavy-gauge aluminum. The LED lamps boast a service life of 50,000 hours. Several voltage configurations are available. — *Larson Electronics, LLC, Dallas, Tex.*
www.larsonelectronics.com

Avoid breathing hazards with this CO-removing filtration panel

The new air-filtration system and disposable respirators from this company expand its personal protective equipment (PPE) portfolio with enhanced breathing protection. The Versaflo AP-600 Series Air Filtration Panel (photo) is designed for applications in a variety of industries including automotive, petrochemical, pharmaceutical and construction. Able to accommodate five to 12 users, the Versaflo AP-600 features a short filter-change time of approximately 5 min. Multiple configurations are available, and the addition of proprietary gold-catalyst technology allows the filtration panel to remove

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

up to 95% of carbon monoxide from a work environment. New FDA-cleared disposable respirators — the VFlex 1805 and the Aura 1870+ — further expand the PPE offerings. Available in two sizes, the VFlex 1805 features a unique pleated design to enhance comfort and ease of breathing. Individually packaged to prevent contamination, the Aura 1870+ is designed with many features to enhance user protection, such as a flat-fold design to ensure fluid resistance, an embossed top panel to accommodate eyewear and reduce fogging and an adjustable chin tab for comfortable positioning. — *3M, St. Paul, Minn.*
www.3m.com

New Pig

This spill kit provides a centrally located response center

The Spill Kit in a Cabinet (photo) is a fully assembled central spill response center. Painted safety yellow, and constructed from heavy-gauge steel, the lockable cabinet comes with many accessories, such as absorbent mats and pillows, wipers, disposal bags and more. The absorbent materials included with the spill kit aid in the containment of fluid spills of oils, coolants, solvents or water. Featuring tamperproof seals, adjustable shelves, lockable drawers and a coat rack, this spill kit can be customized to fit into a variety of locations. — *New Pig Corp., Tipton, Pa.*
www.newpig.com

This acoustic gas leak detector learns to ignore random noise

The FlexSonic Acoustic Gas Leak Detector (photo) analyzes 24 discrete ultrasonic bands, continuously monitoring for the distinct ultrasound emitted by pressurized gas leaks while ignoring nuisance ultrasonic sources. Designed to withstand harsh environments, the FlexSonic features a high-fidelity microphone and can be programmed to discern between gas leaks and environmental noises, such as fans, machinery or vehicles. By diminishing the occurrence of false positive readings, the FlexSonic adds an additional layer of protection in hazardous locations that complements traditional gas-leak detectors. — *Detector Electronics Corp. (Det-Tronics), Minneapolis, Minn.*
www.det-tronics.com

A multi-rotation lock that withstands high temperatures

The MRL Multi-Rotation Lock (photo) is an interlock for multi-rotation handwheel-operated valves. Following the interlocking principle, it only allows the handwheel to be turned when two keys

Netherlocks Safety Systems

are inserted into the lock, ensuring that it can only be operated when it is safe to do so. The MRL has been thoroughly tested and awarded the Fire Test Certificate according to ANSI/API and ISO standards, meaning that the lock will continue to function safely as intended in the event of a fire. Testing has shown that the MRL remains secure and operable, even when subjected to temperatures as high as 1,800°F. — *Netherlocks Safety Systems, Houston*
www.netherlocks.com

Protect personnel from moving equipment with contact mats

These safety contact mats (photo) are used for safeguarding personnel around active machinery in industrial applications including machining centers, robotic work cells, automated cells and conveyor transfer stations. When someone steps on a mat, the surface triggers a control signal to the stop circuit of the nearby equipment. A switch design inside the mat assures that the equipment-motion stoppage is immediate, providing a valuable layer of safety in industrial environments. These safety contact mats feature a dotted polyurethane non-slip surface layer and are impervious to spills from oils, acids or caustic substances. Available in a large range of standard sizes, the mats can be connected in series and mounted to the floor with either aluminum ramp rails or integrated rubber ramp trim. The mats consist of two conductive plates separated by an isolating layer. — *ABB Jokab Safety North America, Westland, Mich.*
www.jokabsafetyna.com.

An online selector tool matches gloves with users' needs

The SafeSpec Glove Selector Tool (www.safespecgloves.dupont.com) is an online-searchable database of more than 300 Kevlar gloves and sleeves from 10 different manufacturers, helping personnel quickly make informed decisions about which gloves will meet their needs. Taking advantage of the tool's dynamic search capabilities, users can conduct a search based on a single factor or multiple requirements. Selection variables include ANSI level for abrasion, cut or puncture; types of coatings; glove construction; and features such as size, weight, cuff type and thumb and finger details. Users can then peruse full-color photographs and detailed descriptions of the items that meet their criteria, as well as contact manufacturers and distributors.— *DuPont, Wilmington, Del.*
www.dupont.com ■

Mary Page Bailey

Steute Industrial Controls

Electro-Chemical Devices

Omega Engineering

Endress + Hauser

Banner Engineering

FOCUS ON Sensors

Inductive sensors for operation in hazardous zones

The new line of ATEX-IECEx-certified inductive sensors (photo) is designed for use in Zone 0 and 20 explosive atmospheres and extreme environments. Units are available in M8, M12, M18 and M30 sizes with a cable or plug-in connector. Models are also available with IP68K or IP69K ratings and for temperatures between –40 and 120°C. Applications include conveyors, food and chemical processing, valve-position monitoring, grains storage and more. — *Steute Industrial Controls, Inc., Ridgefield, Conn.*
www.steutextreme.com

These pressure transducers operate at high speed

The new PX-409-USBH Series of high-speed pressure transducers (photo) features long-term stability, 316L stainless-steel wetted parts and can make 1,000 readings per second. The sensor is "ruggedized" with secondary containment, has an accuracy of ±0.08% and a broad temperature compensation range of –29 to 85°C. The device connects directly to a PC via USB cable. — *Omega Engineering, Inc., Stamford, Conn.*
www.omega.com

A complete system for fluoride monitoring

The combination of the S80 fluoride-specific ion sensor, the AC10 self-cleaning module and the Model T80 universal transmitter (photo) forms a complete fluoride analyzer system, which can be used for monitoring F^- ion levels in water. The Model S80 Intelligent Sensors are available in two designs: insertion/submersion, and valve retractable with flared end to prevent blowout. They feature long-life, replaceable electrode cartridges to lower operating costs, and are available with multiple measurement parameters in the same mechanical configuration: pH, oxidation-reduction potential (ORP), dissolved oxygen, conductivity and resistivity as well as specific ion. — *Electro-Chemical Devices, Irvine, Calif.*
www.ecdi.com

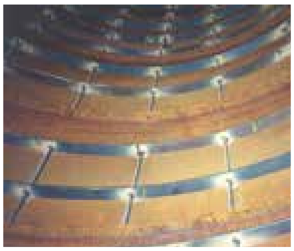
Radar sensors for detecting objects outdoors

Four new models have been added to this company's R-Gage QT50R Radar Sensors (photo) for detecting moving or stationary objects. Designed to meet flexible application requirements and weather conditions, this enhanced line of radar sensors is suitable for collision avoidance on mobile equipment, outdoor crane-to-crane proximity detection, high-volume parking and vehicle detection and flatbed or box truck detection at loading docks. Operating with frequency-modulated continuous-wave (FMCW) radar, the sensors feature IP67-rated housings to withstand harsh environments. — *Banner Engineering Corp., Minneapolis, Minn.*
www.bannerengineering.com

Monitor interface levels with this immersion sensor

The Turbimax CUS71D ultrasonic immersion sensor (photo) is suitable for interface measurements in processes where suspensions are separated into their liquid and solid components by sedimentation. The sensor can continuously monitor the separation and transition zones of the clarification and settling phases. The sensor uses a piezoelectric crystal to generate an ultrasonic signal, and measures the time required for the signal to reflect from solid particles in the separation zone. The sensor is used with the company's Liquiline M CM44x Series of transmitters, which are able to compensate and adjust for changing process conditions, such as temperature

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



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Circle 35 on p. 76 or go to adlinks.che.com/45776-35

Ashcroft

and air pressure. — *Endress + Hauser, Inc., Greenwood, Ind.*
www.us.endress.com

Fittings for sealing sensors into process equipment

These compression fittings provide an efficient, economical means of securing and sealing a variety of sensors into tanks, chambers and pipes. The fittings are available in many different types, sizes and materials of construction, and can be custom-designed to meet the application requirements. — *Electronic Development Labs, Inc., Danville, Va.*
www.edl-inc.com

Tiny pressure transducers that handle extreme pressures

Featuring 1% accuracy, the Model S Series of subminiature pressure transducers fits into tight spaces with little clearance, and measures pressure ranges from 100 to 15,000 psi. These gage-only transducers have a high natural frequency and utilize a flush diaphragm that is manufactured from 17-4 PH (precipitation hardening) stainless steel. Temperature compensation is accomplished by using temperature-sensitive components located inside the transducer. — *Honeywell Sensing and Control, Columbus, Ohio*
www.honeywell.com

Pressure transducers for routine and hazardous service

The A2, A2X and A4 pressure transmitters (photo) are rugged heavy-duty sensors with accuracies of up to ±0.25% of full scale. The A2 has a variety of electrical connections, analog output signals and pressure ports. The A2X (explosion and flame proof) and A4 (intrinsically safe) models are designed for hazardous environments. — *Ashcroft Inc., Stratford, Conn.*
www.ashcroft.com

American Sensor Technologies

New connector options extend pressure-sensor use

This company now offers its pressure transmitters with high-pressure process connections using 316L stainless steel to enable users to integrate products that require liquid or gas compatible with 316L stainless steel, such as hydrogen, natural gas or water. The

two new options — a ¼-in. female NPT and F250C female (photo, p. 39) — are available on all the company's explosion-proof transmitters, and can also be ordered on the AST20HA precision-pressure transducer or AST20SW solid-state pressure switch. — *American Sensor Technologies, Inc., Mt. Olive, N.J.*
www.astsensors.com

Krohne Messtechnika

Analytical sensors with a transmitter built in
SmartSens is said to be the first family of two-wire, loop-powered analytical sensors (photo) with integrated transmitter technology. Prior to this, analytical sensors have required an external proprietary transmitter onsite to deliver the sensor signals to the process control system. The company has miniaturized the transmitter and fitted it into the sensor head, thereby eliminating sources of error caused by false installation, cabling or configuration of the transmitter. The first sensors available are for pH, ORP and conductivity, with other process parameters to follow. These sensors can be connected directly to the process-control system, and feature direct communication via 4–20-mA HART. — *Krohne Messtechnik GmbH, Duisburg, Germany*
www.krohne.com

This portable pressure calibrator is very accurate
The new CA700 Portable Pressure Calibrator is equipped with a silicon resonant sensor that uses the company's proprietary DPharp technology. The CA700 can measure pressures with an accuracy that is within ±0.01 of reading. It can also output and measure current and voltage within ±0.015% of rdg. This highly accurate portable calibrator features a variety of functions, including a wide selection of measuring ranges, "as found/as left" data storage, and memory capacity to store calibration procedures. — *Yokogawa Corp. of America, Newnan, Ga.*
www.yokogawa.com/us

A variety of temperature sensors that can also be customized
This company offers a wide variety of temperature sensor probes, from thermistors and thermocouples, to resistance thermometers. The high-quality sensor probes are easily integrated with other PID temperature controller systems, and have a tolerance of up to ±0.1°C. As a full-service temperature-control-solution provider, the company also has a complete selection of other temperature control products. Each sensor available can also be customized. — *Oven Industries, Inc., Mechanicsburg, Pa.*
www.ovenind.com ■

Gerald Ondrey

ChemInnovations 2013 Conference & Expo

Telular

The ChemInnovations 2013 Conference and Expo will be held September 25 and 26 at the Moody Gardens Convention Center in Galveston, Tex. With eight conference tracks and a number of industry experts (See *Chem. Eng.*, August p. 30–31 for more), the event will also feature exhibits from many vendors who will showcase their newest equipment and technologies on the show floor. The following descriptions are a selection of the exhibitors whose products and services will be on display at ChemInnovations 2013.

This software makes deliverables from laser-scanned 3D plant data

Kubit USA

New PointSense Plant software (photo) produces crucial deliverables for plant and piping design from point clouds. Used for industrial facility design, this software provides solutions for evaluation and post-processing of laser-scanned data in AutoCAD. Capabilities include three-dimensional piping and structural extraction, recognition of tie-in points, tank analysis and creation of AutoCAD Plant 3D deliverables. Booth 413 — *Kubit USA, Houston*
www.kubitusa.com

A rectangular explosion vent with non-fragmenting opening

Fike

The CV-S Explosion Vent, now available in a rectangular version (photo), provides a non-fragmenting opening when protecting industrial processing equipment in applications including air-material separation, drying and conveyance. The CV-S is specially designed to support robust cycling, applications where operating pressure approaches burst pressure, or where moderate vacuum pressure exists. Available in a wide range of standard metric and custom sizes, the rectangular CV-S also has optional accessories, such as burst indicators, weather covers and atmospheric insulation kits. Booth 713 — *Fike Corp., Blue Springs, Mo.*
www.fike.com

Use this ceramic DP sensor with corrosive media

The new TankLink90 with a ceramic differential pressure (DP) sensor (photo) is a wireless remote tank monitoring system designed for use with highly corrosive chemicals. It allows chemical manufacturers, distributors and end users to monitor their corrosive chemicals with an easy-to-install monitor and a ceramic differential pressure sensor that sits near the bottom of the tank and out of the way of chemical vapors at the top that can cloud measurement readings. Unlike ultrasonic sensors, the ceramic DP sits near the bottom of the tank so vapors are completely avoided, resulting in highly accurate level readings. By accessing the TankDataOnline Web-based data portal, users can improve scheduling and delivery. Booth 513 — *Telular Corp., Chicago, Ill.*
www.telular.com

Restore glass-lined steel vessels on-site with this system

The patent-pending Mobile On-site Restore System (MORS) from this company is a new glass repair-and-restoration system that allows for in-place restoration of glass-lined vessels. Developed by highly experienced enameling experts, the MORS process has a one-year warranty, and is more cost-effective than shipping vessels to external locations for re-glass services. Other on-site service products require a three-day curing process, but MORS provides a much faster turnaround.
Booth 211 — *Glasslined Technologies, Inc., Greensboro, Ga.*
www.glasslined.us

This flexible hose is both anti-static and fire resistant

New Corroline+ smoothbore PTFE hoses (photo, p. 45) are designed to be extremely kink-proof, and have the flexibility, durability and chemical re-




Aflex Hose USA

CEJN Industrial

sistance required for chemical transfer applications. Featuring a proprietary tube design and stainless-steel braid reinforcement, the Corraline+ also incorporates a rubber cover that is both anti-static and fire-resistant. Lined fittings are available for critical applications that require all-PTFE wetted surfaces. Both non-conductive and conductive (anti-static) PTFE tubes are available. Booth 511 — *Aflex Hose USA LLC., Pipersville, Pa.*
www.aflex-hose.com

An alternative method for leak repair in aboveground tanks
Portable Friction Forge Bonding (PFFB; photo) technology is designed for mechanical repairs to in-service aboveground storage tanks (AST) in order to mitigate leaks, cracks and other damage. Specifically adapted for safe use within the AST normal work environment, this technology is useful for installation of mechanically joined, engineered repair plates suitable for most floating-roof leaks. When compared to traditional joining and welding methods for tank repair, PFFB features stronger bonds, lower operating temperatures and the ability to join dissimilar metals. Booth 204 — *Forge Tech, Inc., Kemah, Tex.*
www.forgetechinc.com

Forge Tech

This service offers tube repair and restoration in-situ
This company's condenser and heat-exchanger restoration services can extend the life of damaged or failed fin-fan bundles and shell-and-tube heat exchangers. These repairs are achieved in-situ and have been applied in many refineries and chemical plants. Using an eddy current or iris exam to determine where the failure is most severe, either a thin metallic shield or full-length liner is inserted in the partial or entire length of the damaged tubes, forming a sleeve. These sleeves are then expanded with 2,000–10,000 lb water pressure to create a metal-to-metal pressurized fit of the sleeve to the parent tube. This process can add years of service life, depending on metals of construction. Booth 605 — *CTI Industries, Inc., Orange, Conn.*
www.cti-ind.com

These couplings are specially designed for fluid service
This company's non-drip couplings (photo) are designed for broad use in low-pressure fluid and vacuum applications. The couplings are constructed to eliminate spillage, pollution and air inclusion during connection and disconnection for a wide range of fluid lines, including electronic coolant, saltwater, oil transfer and beverage. All coupling components have standardized dimensions with a common interface, enabling numerous combinations and configurations, making them highly adaptable for many applications. Booth 815 — *CEJN Industrial Corp., Gurnee, Ill.*
www.cejn.us

Goodway Technologies

These products remove scale deposits from a variety of materials
Scalebreak and Scalebreak SS biodegradable scale removers (photo) quickly and safely dissolve mineral deposits, such as lime, rust and lithium carbonate from water passages in equipment that is cooled or heated by water. While Scalebreak SS is intended for use on stainless-steel surfaces, Scalebreak is safe for use on steel, iron, brass, copper, plastic and rubber. Fortified with low-foaming wetting and penetrating agents, these descalers are idea for use in boilers, chillers, condensers, heat exchangers, oil coolers, cooling towers, furnaces and water piping systems. Booth 423 — *Goodway Technologies Corp., Stamford, Conn.*
www.goodway.com

Use these rubber seals for natural gas applications
This company offers a range of Underwriters Laboratories (UL) tested rubber compounds specifically designed for natural gas and liquid polypropylene applications, with low extraction characteristics, low compression set and low temperature capabilities. The rubbers have multiple end-uses and operating temperatures ranging from –60 to 105°C. Among the company's products are innovative composite seals including rubber bonded to metal, plastic or nylon material. Also offered are brass-to-rubber bonded products to decrease valve assemblies and increase valve reliability. Booth 219 — *Apple Rubber Products, Inc., Lancaster, N.Y.*
www.applerubber.com ■

Mary Page Bailey

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

PVC and CPVC Plastics for CPI Equipment

Chemical processing equipment made from thermoplastics can have distinct advantages for equipment corrosion, fluid contamination and flame retardancy. When purchased in the form of heavy-gauge sheets, these thermoplastics can be machined, fabricated and formed into a virtually unlimited variety of process equipment components that may address chemical processing challenges that other materials cannot.

The following represents a brief look at properties, possible applications and available methods of fabrication for heavy-gauge thermoplastics sheets of polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC).

Heavy-gauge thermoplastic sheet products are available in an ever-widening selection of grades, thicknesses, sizes, opacities and surface finishes, with stringent fire ratings and outstanding physical properties. They provide ready-made alternatives to lesser — and often costlier — materials in contact with caustic, acidic and contamination-sensitive fluids.

Corrosion and contamination

Chemical and manufacturing plants that handle acids and caustics face an ongoing battle against the corrosion of valves, pumps, tanks, fixtures, enclosures, clean rooms and other equipment and surfaces that are either in constant or incidental contact with corrosive fluids. Plants handling reagent-grade chemicals and ultrapure liquids must prevent the ionization of fluids contacting metal anywhere in the process stream.

Stainless steel and high-performance alloys employed for these applications cannot fully eliminate corrosion and ionization, but certain thermoplastic materials can, and the price can be much lower.

Thermoplastics are available that are 100% inert to corrosive chemicals across the entire pH range, enabling processors and equipment manufacturers alike to preempt corrosion and contamination, while significantly cutting cost, weight and maintenance.

PVC and CPVC

A variety of sheet grades are available to provide the chemical resistance, physical properties, fire ratings, thicknesses and opacity or clarity required by the application in which it is used.

Type I PVC. For chemical and corrosion resistance and flame retardancy

Type II PVC. For chemical and corrosion resistance and flame retardancy with higher impact strength

CPVC. For chemical and corrosion resistance and flame retardancy for use in higher-temperature environments

PVC AND CPVC PROPERTIES		Type I PVC	Type II PVC	CPVC
Property	**Test method**	**Typical values**	**Typical values**	**Typical values**
Mechanical				
Specific gravity	ASTM D-792	1.37	1.35	1.51
Tensile strength (psi)	ASTM D-638	7,400	5,600	7,600
Elongation				
Ultimate (%)	ASTM D-638	132	122	37
Yield (%)	ASTM D-638	3.5	4	-
Modulus of Elasticity (psi)	ASTM D-638	4.0×10^5	3.2×10^5	4.0×10^5
Flexural strength (psi)	ASTM D-790	12,000	8,000	11,000
Flexural modulus (psi)	ASTM D-790	4.2×10^5	3.0×10^5	3.5×10^5
Izod impact				
(ft-lb/in. of notch)	ASTM D-256	1–3	10–15	1–2
Hardness Rockwell R	ASTM D-785	116	116	118
Hardness Shore D	ASTM D-2240	82	80	82
Compression Strength (psi)	ASTM D-695	10,830	8,000	11,400
Shear Strength (psi)	ASTM D-732	9,240	6,500	9,220
Water Absorption 24 h (%)	ASTM D-570	0.032	0.056	0.035
Thermal				
Thermal Expansion				
(in./in.°F)	ASTM D-696	2.95×10^{-5}	3.20×10^{-5}	4.40×10^{-5}
Heat Deflection (°F)				
264 psi (annealed)	ASTM D-648	165	160	212
Thermal Conductivity				
(Btu/(hr × ft² × °F/in.))	ASTM C-177	0.72	0.74	0.641
Flammability				
UL (Underwriters Laboratories)	UL-94	V-0	V-0	V-0

Applications

Applications for heavy-gauge thermoplastic sheet can be found in all industry sectors in which acidic, caustic or ultrapure fluids are handled. These include: chemical and pharmaceutical processing; semiconductor manufacturing; biomedical products manufacturing; pollution control; power generation; industrial and municipal wastewater treatment; and others.

Within those industries, the applications for flat, machined and thermoformed heavy-gauge thermoplastic sheet include the following:

- Tanks and baffles used for corrosive chemicals
- Metal tank linings
- Acid etching equipment
- Wet benches
- Fume scrubber hoods, ducts and parts of all types
- Cleanroom walls, partitions and doors
- Window glazing in cleanroom walls and doors
- Transparent guards and panels of cleanroom equipment
- Enclosures for electrical and mechanical equipment of all types
- Machined parts, including pumps, valves and flanges
- Numerous other new and retrofit applications in which equipment corrosion and fluid contamination must be eliminated

Production methods

The heavy-gauge thermoplastic-sheet products described above can be manipulated in various ways using a wide variety of production methods. These methods enable them to suit an equally wide range of applications, both for new and retrofitted equipment.

Flat laminating. All gauges of metal, wood, composite, masonry and other substrates can be clad with these sheet products using commercially available adhesives

Two-dimensional forming. Thin- to medium-gauge sheet can be brake-formed to generate seamless corners, as well as post-formed onto routed substrates to eliminate sharp outside corners and seams

Thermoforming (three-dimensional). Thin- to medium-gauge sheet can be thermoformed to create three-dimensional enclosures, housings, guards and parts of unlimited shapes

Machining. These sheet products can be saw-cut, drilled, tapped, routed, ground, sanded and otherwise machined using conventional tools

Welding, fastening and bonding. These thermoplastics can be heat welded, bonded using commercially available adhesives, and mechanically fastened using screws, bolts and rivets without the cracking associated with composite materials and certain other thermoplastics, allowing rapid fabrication of components that are easily connected to one another and to other equipment.

Editor's note: Content for this edition of "Facts at your Fingertips" was supplied by Kevin Asti, VP of operations for Boltaron (Newcomerstown, Ohio; www.boltaron.com).

GENERAL SESSIONS

KEYNOTE SESSION

"The Shale Gale is Blowing: Plotting a Course That Avoids the Shoals and Rocks"

WEDNESDAY, SEPTEMBER 25,
10:45 - 11:30 A.M.

Shale gas has revitalized the Chemical Industry in the U.S. The economic benefits have been widely described, but there is little discussion if the impacts of the great increase in ethane cracking. The shifting feedstock slate creates both challenges and opportunities for new technologies. The shoals and rocks caused by the shale gale will be detailed and a course described that can provide an even brighter future for the industry will be presented.

David S. Bem, Ph.D.
Global R&D Director
The Dow Chemical Company

PLANT MANAGER'S ROUNDTABLE

THURSDAY, SEPTEMBER 26,
10:45 - 11:30 A.M.

Hear what challenges are being faced due to the booming renaissance that is impacting the chemical process industries from the perspective of a panel of Plant Managers. Check www.cpievent.com for updates

Moderator: Dorothy Lozowski,
Executive Editor,
Chemical Engineering

CONFERENCE PROGRAM

TRACK 1: PROCESS AND OCCUPATIONAL SAFETY

Session 1A: Process Safety in the Chemical Process Industry-Part 1

WEDNESDAY, 8:30 – 10:00 A.M.

Chair: Philip Hoang, Operations Director, Lloyd's Register Energy Americas, Inc.

Risk Analysis and Optimization for Laboratory Operation in the Chemical Industry
Tianxing Cai, Research Assistant, Lamar University

Team Situation Awareness and Process Safety: Lessons Learned from Process Industry Incidents
Peter Bullemer, Senior Partner and Dal Vernon Reising, Senior Partner , Human Centered Solutions, LLC

Innovation in H_2S Removal Technologies for the Oil & Gas and Chemical Processing Industries
Scott Williams, Engineer and David Engel, Managing Director & Senior Engineer, Nexo Solutions

Session 1B: Process Safety in the Chemical Process Industry-Part 2

WEDNESDAY, 1:00 – 2:30 P.M.

Chair: Anthony Fregosi, Mfg. System Engineer, Cornerstone Chemical Company

Control of Static Electricity in Combustible Dust and Flammable Liquid Hazards
Richard Puig, Regional Manager, Newson Gale

Developing and Maintaining Relief System Design Documentation as an Evergreen Process
Marie Baker, Technical Manager, Lloyd's Register Energy Americas, Inc.

Pressure Safety: Power Failure Scenario for Flare Header Sizing
Steve Kostos, Pressure Safety Consultant, Bayer Technology Services

Session 1C: Occupational Safety in the Chemical Process Industries

WEDNESDAY, 3:15 – 4:45 P.M.

Chair: Stan Zisman, Technical EHS Manager, ChevronPhillips

CSB Updates on Chevron in Richmond, California, the Fertilizer Plant in West, Texas and How Incidents Drive Recommended Guidelines
Beth Rosenberg, ScD, MPH, Board Member, U.S. Chemical Safety and Hazard Investigation Board

Methods of Managing Fatigue
Tom Narbit, Plant Manager, Axiall Corporation – La Porte

What is an OSHA Challenge? Getting Ready for the Voluntary Protection Program (VPP)
Cindy Lewis, Director, Gulf Coast Safety Institute/ College of the Mainland

TRACK 2: INDUSTRIAL WATER MANAGEMENT

Session 2A: Industrial Water Management in the Gulf Coast Region

WEDNESDAY, 8:30 – 10:00 A.M.

Chair and Moderator: Lori Traweek, Operations Manager, Gulf Coast Waste Disposal Authority

Climate Is What We Get: Long-Term Changes in Water Availability
John Nielsen-Gammon, Regents Professor and Texas State Climatologist, Texas A&M University, Atmospheric Sciences

Drought Impacts to Fish, Wildlife and Recreation along the Texas Coast
Cindy Loeffler, P.E., Water Resources Branch Chief, Texas Parks and Wildlife Department

Water Supply Planning in Texas
Dan Hardin, Ph.D., Interim Deputy Executive Administrator, Texas Water Development Board

For complete session descriptions, visit www.cpievent.com

Session 2B: Industrial Water Conservation, Use and Reuse

WEDNESDAY, 1:00 – 2:30 P.M.

Chair: Dorothy Lozowski, Executive Editor, Chemical Engineering

New Decision-Making Tool for Sustainability

Brittany Hohman, EIT, Process Engineer, Veolia Water Solutions & Technologies

Confronting the Water Challenge: Dow Technologies Increase the Flow

Abhishek Shrivastava, Ph.D., Engineering Manager, Clean Filtration Technologies, Dow Water & Process Solutions

Trends in Water Reuse/ Sustainability in the Chemical Industry

Thomas Schultz, Director of Sales and Marketing, Siemens Energy, Inc.

Session 2C: Industrial Water Treatment and Discharge

WEDNESDAY, 3:15 – 4:45 P.M.

Chair: Warren Springer, North American Engineering Manager, Braskem America

Advanced Oxidation Technologies for Industrial Wastewater Treatment

James Yates, Principal, Yates Environmental Services

Holistic Review of Water Treatment Program Design with Respect to Water Minimization and Unit Reliability Goals

Kenneth Cygan, Director, DMS, E&PD, Nalco-An Ecolab Company; Rudy Thorgeson, Technical Consultant and Lance Cox, Regional Marketing Manager-Water, Nalco Champion

Zero Liquid Discharge Technology for Industrial Wastewater Treatment

Russell Vandenberg, Sr. Technical Advisor, GE Water & Process Technologies, Thermal Products

TRACK 3: MAINTENANCE AND RELIABILITY

Session 3A: Preventative Maintenance for Chemical Plants

WEDNESDAY, 8:30 – 10:00 A.M.

Chair: Paul Meiller, Asset Manager, Polyamides and Intermediates, BASF AG

Risked Based Inspection Applied to Instrumentation

Robert Borut, Senior Consultant, Lloyd's Register Energy Americas

Implementing a Corrosion Under Insulation (CUI) Program

Russ Davis, AIMS COE Manager, Mistras Group

Supplementing Risk Basked Inspection Programs with Integrity Operating Windows

Vishal Lagad, Sr. Corrosion Engineer and Vibha Zaman, Pipeline Integrity Management Lead, Lloyd's Register Energy Americas, Inc.

Session 3B: Managing Reliability at Chemical Plants

WEDNESDAY, 1:00 – 2:30 P.M.

Chair: Jonathan Tan, Process Engineer, KBR

The Future of Managing Asset-Intensive Businesses

John Keefe, Technical Manager, Lloyd's Register Energy Americas, Inc.

Case Study – Large Gulf Coast Chemical Plant: Using an Outside Contractor to Create and Implement a Sustainable Reliability Centered Maintenance (RCM) Program

Jay Hurt, Executive Vice President Field Reliability Maintenance and Christopher Tomerlin, Channel Manager Petrochemical and Refining, RelaDyne

Applying Fitness-for-Service Techniques to Extend Service Life

Devon Brendecke, P.E., Quest Integrity Group

Session 3C: Practical Solutions for Chemical Plant Operations

WEDNESDAY, 3:15 – 4:45 P.M.

Chair: Jim Powers, Vice President, Process Technology, WorleyParsons

Discovering Vacuum Leaks under Insulation

Karl Hoffower, Director, Condition Monitoring Solutions, Inc.

Mechanical On Line Repair

Robert Buckley, Consultant, Forge Tech Inc.

Continuous Monitoring for Gas Leaks using a Gas Cloud Imaging (GCI) Video Camera

Robert Kester, Chief Technology Officer, Allison Sawyer, Chief Executive Officer, and Nathan Hagen, Senior Imaging Scientist, Rebellion Photonics

TRACK 4: REGULATORY ISSUES AFFECTING THE CPI

Session 4D: Current Issues Impacting the Chemical Process Industries

THURSDAY, 8:30 – 10:00 A.M.

Check www.cpievent.com for the finalized regulatory session topics and speakers.

TRACK 5: CRITICAL WORKFORCE ISSUES

Session 5E: Developing and Managing a Strong Workforce

THURSDAY, 1:00 – 2:30 P.M.

Chair: Jim Armstrong, Operations Manager Aroma Performance, Solvay - Baton Rouge

Molding, Developing, Mentoring, and Training the Next Generation of Technical Leaders

Will Lehmann, Manager Engineering Development, Hess Corporation

A Customized Career Framework for Engineers

Anthonie Lombard, VP Global Engineering, Xylem

Accelerated Operator Development

Jerry Isch, Partner and Kevin Smith, Managing Partner, KBC Advanced Technologies, Inc.

Session 5F: Recruiting and Hiring Key Employees

THURSDAY, 3:15 – 4:45 P.M.

Chair: Alan Chapple, Director, Corporate Communications and Public Relations, Axiall Corporation

Strategic Solutions for Hiring Foreign Nationals

Kelly Cobb, Partner, FosterQuan, LLP

How to Attract and Keep Top Talent

Keith Wolf, Managing Director, Murray Resources

Community Engagement - Working wth Schools

Steven Horton, ED.D., Schools Program Director, Construction & Maintenance Education Foundation

TRACK 6: AUTOMATION AND CONTROL SOLUTIONS AND STRATEGIES

Session 6D: Adopting New Automation and Control Technologies

THURSDAY, 8:30 – 10:00 A.M.

Chair: Ashley Dufrene, Engineering Manager, Central US, Honeywell Process Solutions

A Tutorial on Model Based Loop Tuning

James Beall, Principal Control Consultant, Emerson Process Management

13 Ways Through a Firewall - What you don't know WILL hurt you.

Andrew Ginter, VP Industrial Security, Waterfall Security Solutions

Are You Ready for your Modernization Project?

Laurie Ben, Director, Modernization & Migration, Emerson Process Management

Session 6E: Wireless use in the Chemical Process Industries

THURSDAY, 1:00 – 2:30 P.M.

Chair: Zafar Taqvi, Ph.D., Life Fellow ISA

Wireless at Axiall Corporation, Lake Charles Complex: the Good, the Bad and the Ugly

Robert Brooks, Process Control Manager, Axiall Corporation – Lake Charles

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Innovative Uses for New PID Features Developed for Control with Wireless
James Beall, Principal Control Consultant, Emerson Process Management

Industrial Wireless Network Security
Andrew Nolan, Americas OneWireless Leader, Honeywell Process Solutions

Session 6F: Technology Trends for the Chemical Process Industries

THURSDAY, 3:15 – 4:45 P.M.

Chair: Zafar Taqvi, Ph.D., Life Fellow ISA

Virtual Training that Generates Real Results
Steve Turner, Sr. Technical Advisor, Kellogg Brown & Root

Modernize Your Control Functionality, Easy Steps to Start Process Optimization
Laurie Ben, Director, Modernization & Migration, Emerson Process Management

Piping the Point Cloud: A Review of 3D Laser Scanning for Industrial Facilities
Scott Diaz, Managing Director and John Bunn, Technical Sales Manager, kubit USA

TRACK 7: PROJECT SPENDING OUTLOOK, ENERGY OPTIMIZATION AND EFFICIENCY

Session 7D: U.S. Spending Outlook and Efficiencies for Plant Operations

THURSDAY, 8:30 – 10:00 A.M.

Chair: Conrad Gamble, Sr. Engineering Associate, Eastman Chemical Company

Chemical Processing Industry - Project Spending Outlook for the United States
Trey Hamblet, VP of Research - Chemical Processing, Industrial Info Resources

From Integrated Automated Plant Design to Excellence in Operational Optimization through Energy Efficiency
Jeffrey Goetz, P.E., LEED AP, Fluor Fellow, Director of Operations and Sustainability and Ashish Shah, Project Director, Fluor Corporation

Combined Heat and Power (CHP) - A Common Sense Solution for Industrial Boiler MACT
Suresh Jambunathan, Director of Business Development, Recycled Energy Development

TRACK 8: PRACTICAL TOOLS FOR CPI PROFESSIONALS

Session 8E: Practical Tools for Engineers - Non Technical

THURSDAY, 1:00 – 2:30 P.M.

Chair: Juan Hinojosa, Process Specialist Projects & Studies, Shell Oil Products US

Enabling Operational Excellence Based on Real Time Knowledge of the Performance of Critical Assets
Ahmed Albarrak, DCS Engineer, ARAMCO

Essential Elements of Effective Communication
Alan Chapple, Director, Corporate Communications and Public Relations, Axiall Corporation

Reliability Cultures, Observations, and Getting Effective Investigations Done Quickly
Loyd Hamilton, Cause Mapping RCA Investigator & Instructor and Mark Galley, Cause Mapping RCA Investigator & Instructor (President), ThinkReliability

Session 8F: Practical Tools for Engineers - Technical

THURSDAY, 3:15 – 4:45 P.M.

Chair: Juan Hinojosa, Process Specialist Projects & Studies, Shell Oil Products US

Troubleshooting Pumps
David Ogra, Maintenance and Reliability Leader and Chris Bounds, Reliability Engineer, Solvay - Baton Rouge

Statistical Process Control in the Chemical Industry
Michael Marcon, Vice President and James Callahan, Principal, InControl Technologies

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Polypropylene Bulk-Phase Process

By Intratec Solutions

Polypropylene (PP) is a thermoplastic polymer formed by the polymerization of 10,000–20,000 monomers of propylene. With a global market of about 60 million metric tons per year, PP is the second most-used polymer globally.

More than 35% of the world's total PP is produced using LyondellBasell's (Houston; www.lyondellbasell.com) Spheripol technology.

The process

In Spheripol technology, polymerization is carried out in liquid propylene (a bulk-slurry process) in tubular loop reactors. This type of reactor has a high heat-removal capacity and avoids polymer deposition on reactor walls.

A polypropylene homopolymer production process via a bulk-slurry process similar to LyondellBasell Spheripol is depicted in the flowsheet (Figure 1). The process shown is capable of producing both homopolymer and random copolymer PP. For impact copolymer production, the addition of a gas-phase reactor is required. In this process, liquid propylene contacts a solid catalyst inside a loop reactor. The process can be separated into three main areas: purification and reaction; polymer degassing and pelletizing; and monomer recovery.

Reaction and purification. In this stage, fresh polymer grade (PG) propylene is sent to fixed-bed dryers for removal of water and other potential catalyst poisons. The catalyst and part of the purified propylene are continuously fed to the prepolymerization reactor. This forms a protective shell around the catalyst particle, which decreases the occurrence of fouling. The remaining fresh and recovered propylene are fed into two loop reactors in series. In the case of copolymer production, ethylene comonomer is also added to the reactors.

Polymer degassing and pelletizing. The slurry from the reactor is discharged into two pressure vessels to separate the unreacted monomer from the polymer. The polymer receives a steam treatment to deactivate the catalyst, and is then dried. Following that, the product is combined with additives and then flows to the pelletizing unit. The polymer pellets are cooled and sent to a product blending-and-storage system. The monomer stream that is recovered from the steam-treatment vessel is sent to a scrubber for water removal.

Monomer recovery. The gas from the high-pressure degasser is directly sent to the propylene scrubber. The propylene-recovered streams from the steam scrubber and low-pressure degasser are washed with an anti-fouling agent before being compressed and sent to the propylene scrubber, where the monomer is separated from polymer residues and recycled to the reaction area. A fraction of the recycle monomer stream is sent to a propylene-propane splitter column (inside the purification area of the propylene supplier, if the plant is part of an integrated petrochemical complex) for purification.

Economic performance

An economic evaluation of the bulk-phase polypropylene process was conducted, based on data from the fourth quarter of 2012. The evaluation concerns a plant with a nominal capacity of 350,000 ton/yr erected in the U.S. Gulf Coast region (the required process equipment is represented in the simplified flowsheet). Two scenarios were analyzed:

1) Integrated scenario. This case corresponds to a PP plant that is linked to a propylene supplier. This nearby unit continuously provides PG propylene at prices below the market average, and receives impure propylene for purification. Thus, no storage for propylene is required. However, storage of products is equal to 20 days of operation.

2) Non-integrated scenario. This case corresponds to a grassroots unit. Thus, 20 days of operation was considered for both products and raw materials. In addition, this scenario includes a propane-propylene splitter.

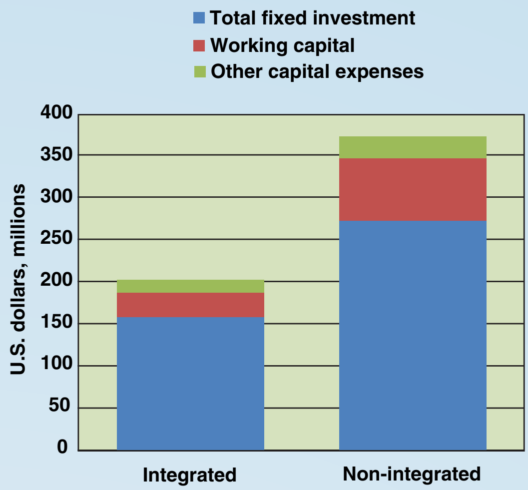

FIGURE 2. An economic comparison of polypropylene production can be made between an integrated and non-integrated scenario

The level of integration with nearby facilities significantly impacts the capital expenses required for the construction of a PP plant. The chart (Figure 2) shows the evaluation of capital expenses for both scenarios. Furthermore, the elevated market prices for propylene makes it unprofitable to operate a stand-alone PP unit in the U.S., when compared to the propylene production cost of integrated plants. ■

Edited by Scott Jenkins

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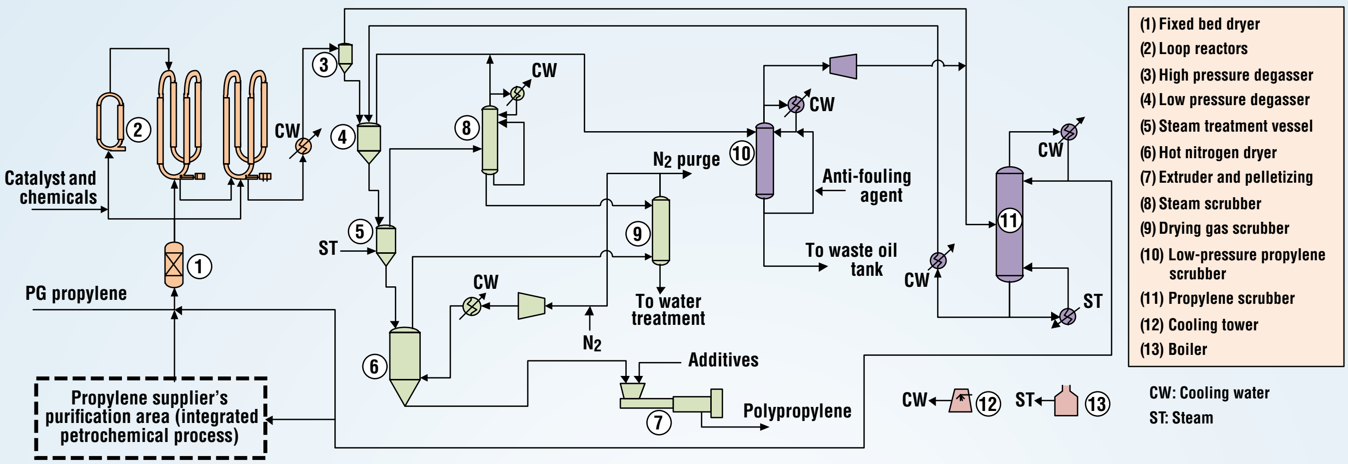

FIGURE 1. Over 35% of the world's polypropylene is produced using LyondellBasell's Spheripol (similar to the bulk-phase process shown)

Improve Rotary Equipment Reliability with Checklists

Design selection and commissioning of rotary equipment can benefit by following a structured, checklist-based method and by promoting end-user involvement

Sourav Kumar Chatterjee
Hindustan Petroleum Corp.

Rotary equipment, such as centrifugal pumps, often represent the heart of plants in the chemical process industries (CPI). A critical factor in the longterm reliability of such equipment is a high-quality design and commissioning process, so that initially, the rotary equipment will have the maximum built-in strength to survive upset operating conditions, yet not be overdesigned in a way that leads to higher overall lifecycle costs. To sucessfully design and commission plant assets, two critical objectives come into play: establishing a culture of cohesive teamwork among the consultant, project and end-user teams; and following a structured procedure with the help of equipment-specific checklists.

The teamwork component of this approach is intended to systematically capture "on-the-ground" realities of the plant and to realize longterm benefits by incorporating improvements into the design, construction and commissioning processes. To do this, the active participation of the end-users is essential throughout the process (Figure 1). The second component, following a structured set of detailed checklists, is intended to optimize the equipment design and setup at the outset, to allow maximum reliability.

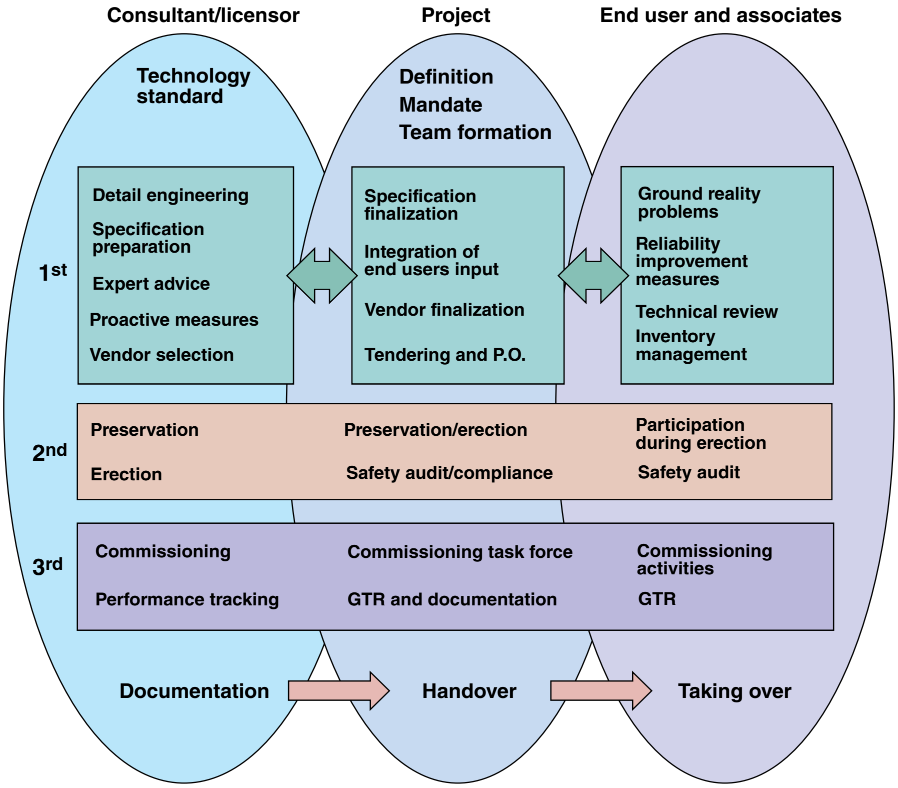

FIGURE 1. Nurturing a culture of cohesive teamwork among consultants, project teams and end-users is difficult, but can generate benefits for equipment reliability

End-user interactions

The end-users of the plant asset can provide a great deal of data to the engineering and construction team, and that information should be captured in the right perspective, and then formalized and structured in a way that promotes understanding. If that is achieved, the result is a high degree of practicality and flexibility in the way the information is implemented. During the data collection process between the engineering and end-user groups, there is potential for a great deal of irrelevant and impractical information to be exchanged. Hence, the organization and use of the data must be carried out by a team of subject-matter experts with visionary wisdom, so that the basis of action items is justified from an economic, as well as a reliability, point of view.

The mode of interaction among the end-users and project-management group for the information transfer described above is of immense importance, because the two groups have different core objectives to achieve. It is often a difficult task to align the mindset of both groups and to bring them under a common umbrella of understanding, so that the exchange of knowledge becomes collaborative, focused and effective, resulting in realization of an integrated common goal. In other words, a mutually agreed-upon structured methodology must be in place for communication and knowledge management that takes into account the profile of participating teams, the nature of the information available, and the areas where that information will be applied. When this structured methodology is established, the project workflow will remain on a progressive track.

This process of value addition by effectively merging end-users' experience from the design selection stage to commissioning of the asset is unique for each project and has to be engineered to allow for modifications to accommodate the systems and procedures for different organizations. If the goal of smooth knowledge transfer is achieved, a safe, on-time, cost-effective execution of the design and installation process will translate into a sustained reliable and productive operation thereafter.

Defining the 'five Gs'

While several methodologies can be derived for the interaction of end-users and project management consultants (PMCs), it is extremely important to convert the information into executable tasks that keep the inherent values intact. The most popular and effective roadmap for structuring these interactions is to develop checklists and procedures for the design selection, pre-commissioning and commissioning activities and to assign responsibility to the teams in the loop. Such checklists play vital roles in ensuring that proactive measures are taken for all asset-reliability issues, operability issues and maintainability issues. To the extent that those measures can be taken, a more trouble-free commissioning is possible, and an enhanced effective service life of the equipment will follow. The process flow can be expressed as the five "Gs":

1) ***Get***. Get end-users' expertise and participation
2) ***Gather***. Gather information and data on reliability, operability, maintainability and safety issues. Develop procedures and a checklist system to incorporate proactive mitigating measures in design, erection and commissioning of the new asset or facility, in consultation with the PMC, licenser or OEM (original equipment manufacturer)
3) ***Grow***. Grow the new facility by commencing the design, erection and pre-commissioning in line with the developed system and procedures
4) ***Gain***. Gain an on-time, safe and smooth commissioning by closely

TABLE 1. GENERAL MAINTENANCE-REDUCTION CHECKLIST FOR ACHIEVING BUILT-IN RELIABILITY FOR CENTRIFUGAL PUMPS

no.	Description of check point	Adequate		Remark
		Yes	No	
1	Design provides the suitable materials of construction of major components, surface sealing materials and hardware to withstand the most adverse operating conditions possible in the system, including all mechanical and hydraulic forces acting upon it			
2	Design provides inherent protection to components from corrosive or erosive environments to which it is, or can be, exposed as a part of the operating process			
3	Design provides a correct and realistic input process condition for the equipment			
	Design provides a correct and realistic equipment output performance within the limit of specified input condition			
4	Design provides the most suitable hydraulic balancing for equipment, so as to minimize the forces acting on components			
5	Design provides a specified trouble-free operating zone without affecting the desired performance and component life			
6	Design provides correct and robust shaft-sealing system that can withstand the most adverse operating conditions possible in the system without failure			
7	Design provides an appropriate bearing-support system to provide maximum stiffness to the rotating mass at minimum frictional loss			
8	Design provides proper lubrication system that is most suitable to protect the bearings at minimum friction loss			
9	Design provides the most suitable lubricant for the bearing system, considering the load and service conditions			
10	Design provides for bearings and seals with wear- or failure-monitoring capability to permit scheduling of maintenance prior to actual component failure or component damage			
11	Design provides suitable casing design pertinent to service conditions to provide highest built-in reliability			
12	Design provides that all running clearances are minimized with applicable tolerances for thermal expansion			
13	Design provides monitoring facilities for crucial performance and physical dynamic parameters of the equipment, so as to assess the health of the machine			
14	Design provides suitable bearing-housing seals to avoid ingress of contamination and leaking of the lubricating oil			
15	Design provides the base frame that enforces adequate rigidity to dampen the vibration generated in the system and prevent the transmitted vibration from other sources to enter			
16	Design provides an appropriate piping support system that prevents piping stress to the equipment and also to eliminate the potential of generating unsymmetrical dynamic forces in the system during operation			
17	Design provides suction, discharge and auxiliary piping system that will not cause excitation of flow-related problems and sizing shall not be over-designed or under-designed in relation to the maximum rated flow, NPSH (net positive suction head) required			
18	Design provides a coupling assembly between the driver and driven system that should be rated for a minimum of 1.5 times the service factor and above the maximum starting torque required, as per the speed–torque curve of the machine			
19	For single-stage rotor, the entire assembled rotor, along with coupling hub mounted, should be balanced in accordance with API 684 or ISO 1940 grade 2.5			
20	For multistage rotors, individual impellers should be balanced before assembly. The assembled rotor should be balanced thereafter			
21	Design provides the driver rating for end-of-the-curve operation			
22	Design provides adequate external protection from weather and harmful interference from other equipment and systems			
23	Design provides a firm identification tag posted at a suitable location close to the equipment that mentions rated operating parameters, allowable physical operating parameters and alarm limits of critical performance parameters			
24	Design provides applicable interlocks, alarm annunciation and a trip system for crucial parameters to mitigate unplanned catastrophic failure of equipment			
25	Design provides color-coding of equipment and connected piping to identify its service media			
26	Design provides vortex breakers in the suction and discharge nozzles to avoid separation			
27	Design provides a provision for an oil-mist lubrication system for antifriction bearings of pumps			

following the commissioning procedure framed earlier. It should be enriched with workarounds for all probable hurdles and hitches
5) ***Give***. Give the end-user a trouble-free plant asset or facility

Checklists for pumps

The series of tables included in this article (Tables 1–9*) were developed and have been used as part of a program of proactive reliability management. The checklists shown here are specifically designed for installing and commissioning centrifugal pumps, but they can also be applied to other pieces of rotary equipment beyond pumps.

The purpose of the checklists found in these tables is to provide a summary of the design review points for assessing the maintainability of new or existing rotary equipment for petroleum refineries or other CPI facilities. The checklists specifically focus on the identification of equipment-design features, tasks, or procedures that impact equipment downtime, repair costs, labor hours and the skill level requirements for maintenance staff. The specific objectives for each table are as follows:

- Table 1. General maintenance reduction
- Table 2. Safety and environmental system design features
- Table 3. Design standardization features
- Table 4. Design features for routine maintenance
- Table 5. Design features for troubleshooting
- Table 6. Design features for repair and replacement
- Table 7. Accessibility for visual inspections and monitoring
- Table 8. Design for physical accessibility
- Table 9*. General precommissioning checklist and commissioning procedure for centrifugal pumps

The "Description of check point" column in each table covers the essential features for completion of items required for the safe and "first-time-right" commissioning of rotary equipment in the given category.

TABLE 2. SAFETY AND ENVIRONMENTAL SYSTEM-DESIGN FEATURES FOR CENTRIFUGAL PUMPS

no.	Description of check point	Adequate Yes	Adequate No	Remark
1	Design provides non-sparking, non-gulling metallurgy for close-clearance areas and dynamic components that probably will impact the static component of the assembly under operating conditions other than normal. For instance, throat bush, bearing guard, coupling guard			
2	Design ensures that sealing materials for all components are compatible with safety procedures and can function safely as required by service conditions			
3	Design provides a safe shaft-sealing system for the pertinent service conditions, including all possible adverse operating conditions			
4	Design provides service-specific alarms and protection systems for hydrocarbons, toxic media, smoke detection and fire			
5	Design provides monitoring, alarm annunciation and protection systems for all parameters that are crucial for human, equipment and environment safety			
6	Design provides all drain and vent points of the pump casing, bearing housing and seal-oil system are connected to the designated closed drain and vent systems with proper isolation and anti-reverse-flow devices			
7	Design provides an applicable in-built protection system for electrical equipment and instruments in line with hazardous area classification API RP 500, IS 5572, IEC 79-10 :1995, NFPA 69			
8	Design provides that service-specific emergency handling for safety equipment and systems are readily available and stepwise procedures are displayed close to equipment			
9	Design provides a data historian system for critical process and environment safety information			
10	Design provides for automatic actuation of safety-protection systems for equipment that handles flammable, toxic, auto-igniting and other hazardous media			
11	Design provides equipment-specific safe operating and maintenance procedures			

TABLE 3. DESIGN STANDARDIZATION FEATURES FOR CENTRIFUGAL PUMPS

no.	Description of check point	Adequate Yes	Adequate No	Remark
1	Design provides interchangeability of equipment that is in similar or nearly similar service to all new pieces of equipment that are under procurement			
2	Design provides for interchangeability of equipment that functions similarly with equipment that already exist in the operating facility			
3	Design describes the full scope of standardization and interchangeability of components, such as shafts, impellers, wear parts, mechanical seals, seal spares, bearings, couplings, gaskets, hardware, valves, connectors and others			
4	Design provides vendor-qualification criteria for maintaining standardization as a nodal decision-making point			
5	Design provides for interchangeability of monitoring, control instruments, piping support system and so on			

Implementing the five Gs

The remaining portion of this article elaborates on the methodology, and provides examples of checklists using centrifugal pumps as the asset. There are three broad phases for the process.

Phase 1 — Get and gather. Each participating group should prepare its own objectives to share, depending upon the project type. The project-management department prepares the project details, including the background, business objectives, location, mandate and so on. This would be the primary input and the basis for selecting the consultant, technology licenser or plant-equipment system or asset involved. The consultant would prepare the basic specifications and execution plans, while the licensor would provide the most applicable technology and operating profiles.

Under the guidance of a company's management, one or more teams from various disciplines would be formed, making sure to involve the relevant knowledgeable persons and having that particular project department as the principal facilitator.

In the first phase, the end-users' feedback and participation comes into play in the form of input to the project management consultant on the practical problems of reliability, operability, maintainability and safety, so that the weak points can be addressed at the

***Editor's note:** Table 9 can be viewed in the online version of this article (www.che.com)

TABLE 4. DESIGN FEATURES FOR ROUTINE MAINTENANCE

no.	Description of check point	Adequate		Remarks
		Yes	No	
1	The equipment and all mechanical adjustment and check points are located in primary maintenance zones with permanent identification tags			
2	The base frame is provided with jack bolts for moving drivers within the slotted zone for hold-down bolts			
3	Coupling guard has a window for condition monitoring while in operation			
4	The suction and discharge piping is provided with spectacle blinds for positive isolation without disturbing the piping and casing orientations during dismantling of the rotor assembly			
5	Quick-connect connectors are installed on frequently changed lines, for cooling-water seal flushing lines and cables			
6	Routine service and inspection points are not located behind other components or structural members, in enclosed spaces or in the secondary maintenance zone			
7	All components subject to routine maintenance are immediately accessible; for example, bearing housing, seal-flushing system, cooling-water system, suction strainer, coupling			
8	The drain- and vent-line isolation valves are immediately accessible			
9	All block valves, control valves, control instruments, spring hangers, monitoring gages, seal-flush system valves, strainers and transmitters are in immediately accessible locations			
10	Procedures for routine maintenance and checklists for each component and system are displayed close to the maintenance point			
11	Procedural and personal safety precautions applicable for each activity of routine maintenance are displayed close to the maintenance point			
12	A lubrication cart — consisting of a tagged lubricant, seal-flush media, tools and tackle — is available at the maintenance point			
13	Display of personal protective gear required for routine maintenance and also for unit area entrance is available at the maintenance point			
14	Procedure and facilities for housekeeping and waste disposal by category are available at a designated place outside maintenance point			

TABLE 5. DESIGN FEATURES FOR TROUBLESHOOTING OF CENTRIFUGAL PUMPS

no.	Description of check point	Adequate		Remarks
		Yes	No	
1	Details of designed and rated operating specifications, including media density, flow pressure, temperature range, minimum flow, load-specific normal power, are available at the site			
2	Manufacturer-defined roto-dynamic parameters, such as allowable bearing temperature, vibration level and noise level are available at the site			
3	Equipment-specific normal startup and shutdown procedures and check points as per OEM manual are displayed at the site			
4	Mechanical seal specific allowable operating parameters and checklists with procedure are available at the site			
5	General layout facilitates visual inspection of major components, connections, couplers, interfaces and potential damage points			
6	All mechanical interfaces are visible from the sides or end of the machine			
7	Manual test points are located in the primary maintenance zone for all critical components of equipment and its auxiliaries			
8	Test points are designed to eliminate or minimize the need to remove components for testing			
9	Test points are labeled and located close to the control or display with which they are associated			
10	General design and layout provides for rapid and positive identification of component malfunction, such as leakages, high vibration, temperature rise, deterioration of performance, in terms of low pressure, loss of flow, cavitation, high power consumption, abnormal noise and so on			
11	A guide chart for equipment-specific problems, as per the manual, is available			
12	Shop-test data and baseline data during the performance test at the site are available			
13	Performance curves, data sheets, cross-sectional and assembly drawings for the pump and mechanical seals are available			
14	Common potential failure modes with threshold values are available			

design stage. The goal is to achieve trouble-free commissioning and long lifecycle with minimum resource utilization and downtime.

Phase 1 also includes several value-adding activities that help meet the project mandate. A few follow:

- Interactive sessions to identify idle assets that can be reused in a project — a cost- and time-saving measure
- Examination of the possibilities for standardizing assets for the new equipment that may have operating conditions that are close to equipment from the existing operating plant — a cost-saving and inventory-reduction measure
- Technical review of specifications to ensure the inclusion of measures to mitigate potential problems faced previously in the plant's operation
- Finalization of the vendor-selection criteria to ensure reliable equipment and after-sales service. Preference must be given to vendors with proven track records for similar equipment and assets, and those who have local service centers
- Examination of interchangeability of spare parts for the new and existing equipment — an inventory-reduction measure

Phase 2 — Grow. This is the execution phase, which comprises erection and pre-commissioning activities. Here, the execution team will work under the supervision and guidance of the primary team, who will carry out quality control activities and ensure adherence to safety rules during erection.

The following represent key objectives for the project:

Preservation. Proper preservation of the equipment that arrives for erection, as advised by the respective manufacturers or as per standard procedures.

Erection. Erection of equipment in a way that adheres to the applicable

no.	TABLE 6. DESIGN FEATURES FOR REPAIR AND REPLACEMENT OF CENTRIFUGAL PUMP Description of check point	Adequate Yes	Adequate No	Remarks
1	All pump components are labeled to positively identify part type, mounting location, type of lubricant required, direction of rotation and other pertinent information			
2	The dismantling and assembly procedures for each part and component are provided and available			
3	Equipment-specific procedure for isolation and depressurization should be available to ensure safe and swift repair. Procedure for replacement of parts should also be available			
4	A monorail with trolley-mounted pulley block should be available over the pump slab for removing and installing pumps and components without interfering with adjacent equipment, pipelines, cables, cable racks, valves and so on			
5	Sufficient free headroom over the pump and driver is provided for unhindered movement of the pump and components as they are lifted in the pulley block, out to the dropdown area outside the unit			
6	The weightlifting capacity of the pulley block along with the rail for travel should be 1.5 times the weight of the heaviest single piece of equipment installed within the pulley's range of travel			
7	The pulley-block travel rail shall be extended to the designated dropdown place outside the unit			
8	For equipment at higher elevations, the deck floor should allow the equipment or components to access the dropdown location safely			
9	All heavy components should have lifting lugs or eye bolts of the required working-load capacity			
10	The equipment assembly should be provided with the best possible self-cleaning and self-draining systems for leakage of fluids, such as lubricants and service media, without spilling or splashing into the adjacent area outside the equipment frame			
11	All interface assembly components should be permanently marked with the correct manner of installation, including direction, placement and geometrical orientation			
12	Design should not require special tools or jigs unless they are the same as what is included in the scope of supply by the OEM			
13	Spare consumables for overhaul and repair should be available from a local vendor or OEM office to minimize lead time			
14	Equipment should be provided with jack bolts for shifting movable equipment for alignment			

no.	TABLE 7. DESIGN FEATURES FOR VISUAL INSPECTION AND ACCESSIBILITY POINTS Description of check point	Adequate Yes	Adequate No	Remarks
1	All maintenance points should be visually accessible from all sides, or the end of the machine, and should provide line-of-sight inspection capability			
2	Design provides for clear and rapid visual identification of parts and safe access for checking with key monitoring checklist and checking procedure during operation and when idle, so as to assess the health of the equipment as a whole			
3	Any unsafe points should be clearly identified and provided with protective guards and covers. The guard covers shall comply with applicable design and safety standards to achieve maximum built-in reliability			
4	Access openings should be large enough to permit visual contact with the component while the work is being performed on it (OISD 118 compliance)			
5	Visual access points on the machine should have adequate space for inspection and monitoring by the operator without introducing ergonomic stress. A minimum of 48 in. of free space above equipment is suggested			
6	Visual access to openings should not be located underneath the equipment body or behind other components that restrict visibility			
7	For less frequently performed maintenance tasks, the maintenance point may be located behind a protective cover. The component, however, should be directly visible when the protective cover is removed			
8	Maintenance and service points should be located no further than 91 cm (36 in.) from the maintenance worker's head at the time of inspection			
9	Monitoring and check points should enable free access and be protected by a toe guard, hand railing and slip-proof flooring			

engineering procedure, without creating operability and maintainability hindrances. Here, the team members from operation, maintenance and technical departments have major roles to play in pointing out issues and providing advice for practical solutions to the project and execution groups.

Safety. Safety audits by a multidisciplinary team to identify the potential safety gaps and to track the implementation of corrective measures that have been recommended.

Tracking. Tracking of progress with respect to scheduled timelines to identify any lagging portion and to determine a practical pathway for expeditious progress.

Pre-commissioning. All pre-commissioning activities of asset equipment systems and preparation for commissioning ensuring completion of the following: procedures and checklists; safe work practices; integrity and completeness checks; contractor management modalities; training and performance assurance; management of change; operational readiness; sequence of activities; measurement and metrics indexes; audit recommendations compliances; management review; emergency management procedures.

Phase 3 — Gain

Once pre-commissioning activities are complete, the door is open for step-wise commissioning of units, as per the process-flow requirements. The essential features of commissioning equipment are the following:

- Ensure availability of startup and shutdown procedures
- All protective functions and interlocks should be checked for proper configuration and functionally tested
- All systems and subsystems should be checked for completeness
- Integrity plan and records should be

TABLE 8. DESIGN FOR PHYSICAL ACCESSIBILITY

no.	Description of check point	Adequate		Remarks
		Yes	No	
1	All components are accessible from the side or the end of the machine			
2	All drain valves for casing, reservoirs and sumps are accessible from the side or end of the machine			
3	All valves for equipment operation (for example, suction, discharge, cooling-water system, seal-flush system, steam-quench system) are freely accessible and operable. Valves above 65 in. from ground or the level of the base frame of the equipment should have a firm and protected platform			
4	All components weighing 23 kg or more should be removed from the side or end of the machine and should not have to be lifted up and over the machine frame or other components			
5	Access openings should be sufficiently large to permit removal and replacement of all components contained within that area			
6	For enclosed equipment, hinged or quick-release access opening covers should be used where practical with the hinges on the side or bottom so that the door will remain open during maintenance			
7	The minimum number of bolts or fasteners should be used on access covers, equipment bay doors or other protective shielding			
8	For components weighing more than 45 kg, access openings and workspaces should be sufficient to permit the attachment of hoisting and lifting devices			
9	Screws, nuts and bolts should be located to allow free access and space for the use of hand tools required to remove or replace them			
10	Access openings should be sufficiently large to permit removal and replacement of all components contained in that area			
11	Non-hinged access opening covers should be designed with built-in handles or lifting-device attachment points			
12	Design provisions are made to support components weighing over 23 kg while they are being unbolted or bolted into place			
13	All components can be removed and replaced in a straight line from their place of attachment, so that components do not have to be maneuvered around or over structural features or components			
14	Illumination around the equipment should be sufficient at all access points, so that no accessibility hindrance occurs due to invisibility			

reviewed. These include construction and testing records for interconnected piping, systems, electrical circuits and control loops
- Ensure adequacy of fire protection systems, for example, fire-water system, gas-leak detection system, fire extinguishers, and so on
- Ensure safe movement and approach of equipment
- Note equipment-specific hazards
- Determine deployment of trained manpower
- Ensure use of personal protective equipment (PPE)
- Ensure that equipment installation procedures are consistent with respective equipment standards

Apart from technical activities, the most important areas that the project management team must strive to implement are the following:
- Preparing a daily activity list and review of progress
- Adhering to safety guidelines throughout the process
- Establishing an effective good-housekeeping procedure
- Maintaining 360-deg communications with all stakeholders
- Holding a toolbox meeting to appraise the respective execution personnel on the scope of the job, safety rules, job-specific safety precautions and PPE
- Adhering to the work permit system, without exception
- Documenting and record keeping for commissioning activities and incidents with absolute transparency
- Managing progress updates

Benefits of 'giving'

The benefits for following through on the "giving" component of the process are felt by end-users, and also extend to the the organization as a whole. The benefits include the following:
- Improved reliability
- Increased safety
- On-time delivery of quality product
- Higher customer confidence
- Improvement through learning
- Fostering long-lasting mutual respect among teams
- Solidifying ownership concept among the post-commissioning team
- Fostering collaborative culture
- Increased plant familiarity and hands-on training of end-user personnel (competency development)
- Optimize inventory management through standardization and interchangeability of asset-equipment system spare parts

In addition, another benefit of end-user participation in precommissioning and commissioning is that, because end users hold good rapport with internal and external local resource providers, they can guide the executing contractor on the availability of quality fabricators in cases where urgent site modifications or hardware changes are required. This can save a great deal of time and money.

Closing comment

The process described here has become an inherent part of any project management because it nurtures a "win-win" bond between the project group and end-users group deriving substantial benefit for the organization. Without such a structured approach, projects could draw displeasure from the end users as well as from management for any design, operability and maintainability issues in the newly commissioned plant. Futhermore, end-users could struggle to sustain the operation with a problematic system, resulting in a state of unreliability. With this system in place, projects are likely to have reduced post-commissioning problems and more reliable plants. ■

Edited by Scott Jenkins

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How To Properly Size A Steam Trap

Don't confuse the size of a steam-trap's end connection with the internal discharge orifice for condensate

Kelly Paffel
Swagelok Energy Advisors

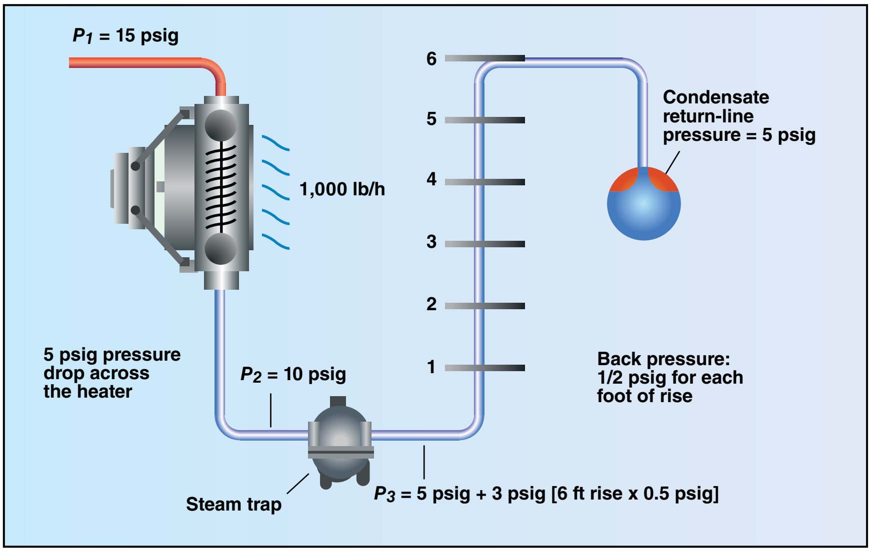

FIGURE 1. Shown here is the setup and data for Process Example No. 1: Unit heater

Proper steam-trap sizing is critical to efficient and reliable steam-trap operation. Incorrect steam trap sizing can undermine the design and function of the steam trap, create installation issues, and cause condensate backup, steam loss, or both.

Steam-trap sizing refers to the internal discharge orifice for condensate. Unfortunately, it is sometimes confused with the size of the end connection or piping, which is entirely different. It's true that for low-pressure steam heating systems, manufacturers will produce steam traps with connection sizes that correlate directly to capacity or orifice size, but for industrial applications, there is no such correspondence. A steam trap with 2-in. end connections can have the same condensate capacity as a steam trap with ½-in. end connections.

When sizing a steam trap, the first order of business is to determine the required condensate capacity or size of the internal discharge orifice. This is a fairly complex undertaking, which will be explained below. Then, a relatively simple matter is determining the end connection size or installation requirements.

Information needed for sizing

To determine the correct orifice size, the following information is required:

Application. Is your system a process or non-process application? Process applications employ a heat exchanger, which means there will be a loss of pressure as energy is transferred. Pressure in a process application, therefore, will be different at different points in the system. By contrast, non-process applications do not have a heat exchanger. They are simply delivering steam to a system. Therefore, pressure does not modulate (not by design at least).

Maximum pressure. The maximum steam pressure of your steam system is determined either by the design specifications of the system or by the pressure setting of the safety valve, which protects the steam system. In all cases, your steam trap must be rated for this maximum pressure (or greater), even if the pressure modulates downward before it reaches your steam trap.

Maximum temperature. In all cases, your steam trap must be rated for the maximum steam temperature of your steam system.

Operating pressure. The operating pressure of a steam system is always different from the maximum pressure. Your system may be designed for 250 psig, but it may operate at only 150 psig. Operating pressure can be obtained from plant information or an installed pressure gage.

Inlet steam pressure. In a process application, the operating pressure will be different at different points in the system. Pressure may start at 75 psig, but at the inlet to the steam trap, the pressure may be only 50 psig. In a non-process application, the operating pressure will remain the same. In other words, the operating pressure and the inlet pressure at the steam trap will be the same.

Maximum condensate capacity. The maximum condensate capacity of the steam system may be documented either in the system design specifications or on equipment nameplates. If the condensate capacity is not shown, it will be necessary to calculate the condensate capacity by using a heat-transfer formula. Keep in mind that one pound of steam condenses to one pound of water (condensate). If the

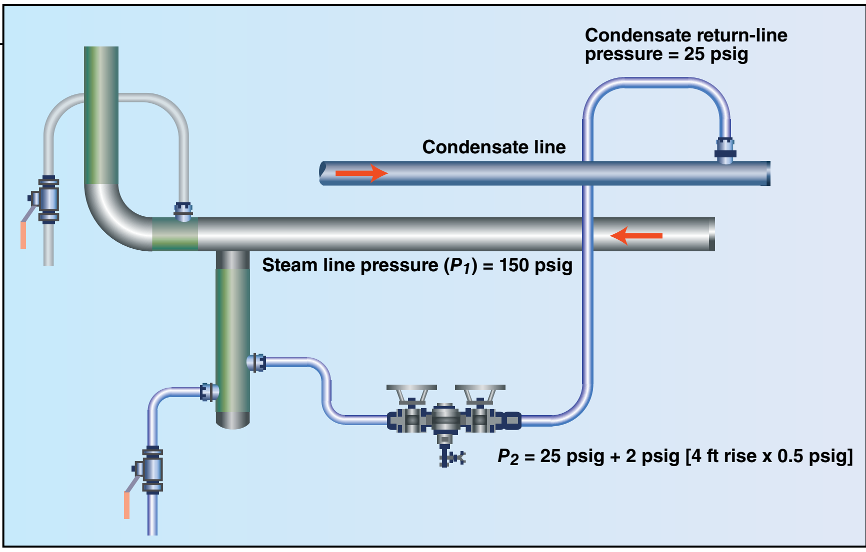

FIGURE 2. This diagram shows the setup and data for the non-process example: Steam line drip leg or steam lock

TABLE 1. STEAM-TRAP SIZING FACTORS	
Types of steam traps	Sizing factor
Inverted bucket	3
Float and thermostatic	2
Thermostatic	3
Thermodynamic	3

pounds per hour of steam is known, the condensate capacity is the same. If heat-transfer equipment is rated in Btu/h, the capacity in lb/h can be approximated as follows: The heat transfer energy requirement is rated in Btu/h; therefore, it is necessary to divide the Btu/h by the latent heat energy of the steam at the operating pressure of the equipment.

Here is one more option if a control valve controls steam flow to the process. The rated capacity of the valve (in terms of *x* pounds per hour of steam) would generate an equivalent amount of condensate. (Again, one pound of steam equals one pound of condensate.)

Condensate flow condition. Is the condensate flow modulating? Is it turning on or off? Or is it in continuous operation?

Minimum differential pressure. The minimum pressure difference, $\Delta P = P_1 - P_2$, between the inlet to the steam trap, P_1, and the outlet pressure, P_2, is a key variable in sizing your steam trap. An initial system operating pressure can be taken from a gage. Then, you will need to subtract from that figure for any known pressure drops in the system leading up to the steam trap inlet, P_1. We will provide examples of how to do this later in this article.

Steam-trap outlet pressure, P_2, may have many sources, and these pressures may be referred to variously as steam-trap discharge pressure, condensate-return-line pressure, or back pressure. A high percentage of steam-trap applications will have back pressures above atmospheric. The back pressure may be intentional or unintentional. It may be caused by pressure in the return system or by a vertical rise in the pipe (following the steam trap). Main condensate-return lines are typically installed at elevations above the steam traps; therefore, it is necessary to pipe the condensate up to the condensate mains. As a rule of thumb, every foot of rise results in an additional 0.5 psig back pressure at the steam trap discharge.

Undersized condensate lines can also cause back pressure on the steam trap, and this variable must also be considered when sizing steam traps. Condensate lines need to be sized for two-phase flow (condensate and flash steam).

Back pressure may be created intentionally in some cases to increase thermal cycle efficiency. For more information on high-pressure condensate systems, see Ref. 1.

The sizing factor

In the manufacturers' product literature, steam-trap tables provide the condensate capacity of various discharge orifices at various operating pressures (maximum differential pressure). The condensate capacities in these tables indicate maximum continuous discharge. In other words, they assume that the discharge orifice never closes. Since steam traps are designed either to cycle on and off, or to modulate, we must apply a sizing factor to these tables to ensure we select a steam trap with sufficient condensate capacity. You must multiply the system's maximum condensate capacity by the sizing factor (Table 1) to arrive at the condensate capacity required when selecting your steam trap. This is one of several figures that is used to select a properly sized steam trap.

As shown in Table 1, sizing factors range between 2 and 3 for different types of steam traps. If startup loads are heavy or fast, heat-up is required. A sizing factor of 4 is more appropriate.

The selection of sizing factors is different for each operational steam-trap design. Follow manufacturers' instructions when selecting the sizing factors.

Steam-trap sizing examples

Following are three examples of how to size a steam trap. Two are process examples and one is a non-process example. For all three, our goal is to arrive at the following three pieces of information:

- Differential pressure across the orifice
- Condensate capacity
- Maximum steam pressure in the system

With these three pieces of information, you can consult with the manufacturer's sales representative or product literature and arrive at a properly sized steam trap (with the proper orifice size) for your application. In addition, when selecting your steam trap, you will also need to reference maximum system temperature (see above section "Information needed for sizing").

Process example No. 1: Unit heater. First, we need to determine the differential pressure across the steam trap. According to Figure 1, the pressure delivered to the heater unit is 15 psig (P_1). Pressure drop across the unit heater is 5 psig, so the inlet pressure to the steam trap is 10 psig (P_2).

15 psig (P_1) – 5 psig (pressure drop across the unit heater) = 10 psig (P_2 or inlet pressure to the steam trap)

Back pressure in the condensate line is 5 psig. However, to arrive at P_3 (pressure at the steam-trap outlet or total back pressure), we must account for additional back pressure resulting from the rise in the piping after the steam trap. In this case, the rise is 6 ft. There is a 0.5-psig increase for each foot of rise. So we have an additional 3 psig in back pressure: 3 psig + 5 psig = 8 psig (P_3 or pressure at the steam trap outlet).

To arrive at the differential pressure across the steam trap, we subtract P_3 from P_2.

Finding #1: 10 psig (P_2) – 8 psig (P_3) = 2 psig minimum differential pressure across the steam trap

Second, we will determine the condensate capacity for the steam trap. The condensate capacity of the system is 1,000 lb/h. We will be using a float and thermostatic steam trap for this application so, based on Table 1, we must multiply the system condensate capacity by 2.

Finding #2: 1,000 lb/h (system condensate capacity) × 2 (size factor from Table 1) = 2,000 lb/h condensate capacity

Third, we must identify the maximum rated pressure for the system. See the system's design specifications or the pressure setting on the system's safety valve.

Finding #3: 20 psig maximum rated pressure

The safety valve on the steam system is set for 20 psig; therefore, the steam trap orifice must be rated for a maximum steam pressure rating of 20 psig.

Non-process example: Steam line drip leg or steam lock. For this example, we will use Figure 2. First, we need to determine the differential pressure across the steam trap. According to Figure 2, pressure in the system is 150 psig. This is a non-process application, so there is no modulation in system pressure. Therefore, the inlet pressure at the steam trap is the same as the system pressure (P_1), which is 150 psig.

Back pressure in the condensate return line is 25 psig. However, to arrive at P_2, we must account for additional back pressure due to the rise in the line, which is 4 ft. There is a 0.5-psig increase for each foot of rise, so we must add 2 psig: 25 psig + 2 psig = 27 psig (P_2).

To arrive at the differential pressure across the steam trap, we must subtract P_2 from P_1.

Finding #1: 150 psig (P_1) – 27 psig (P_2) = 123 psig differential pressure across the steam trap

Second, we will determine the condensate capacity of the steam trap. The condensate capacity of the steam system (or flow) is 120 lb/h. We will be using a thermostatic steam trap for this application so, based on Table 1, we must multiply the condensate capacity of the system by 3.

Finding #2: 120 lb/h (condensate capacity of system) × 3 (sizing factor from Table 1) = 360 lb/h condensate capacity of steam trap

Third, we need to identify the maximum rated pressure for the system. See the system design specifications or the pressure setting on the system's safety valve.

Finding #3: 200 psig maximum rated pressure

The safety valve on the steam system is set for 200 psig; therefore, the steam trap orifice must be rated for a maximum steam pressure rating of 200 psig.

Process example No. 2: Heat exchanger. In this example, we will use Figure 3. First, we need to determine the differential pressure across the steam trap. Some plants document steam pressure at the steam control-valve inlet, but we cannot assume that the steam-line operating pressure will equal the steam pressure at the control valve. We need to consider pressure drops in the steam line. In Figure 3, P_1 (75 psig) is the pressure at the control-valve inlet. The pressure drop across the control valve is available from the manufacturer's valve-performance information. In this case, the pressure drop is 15 psig.

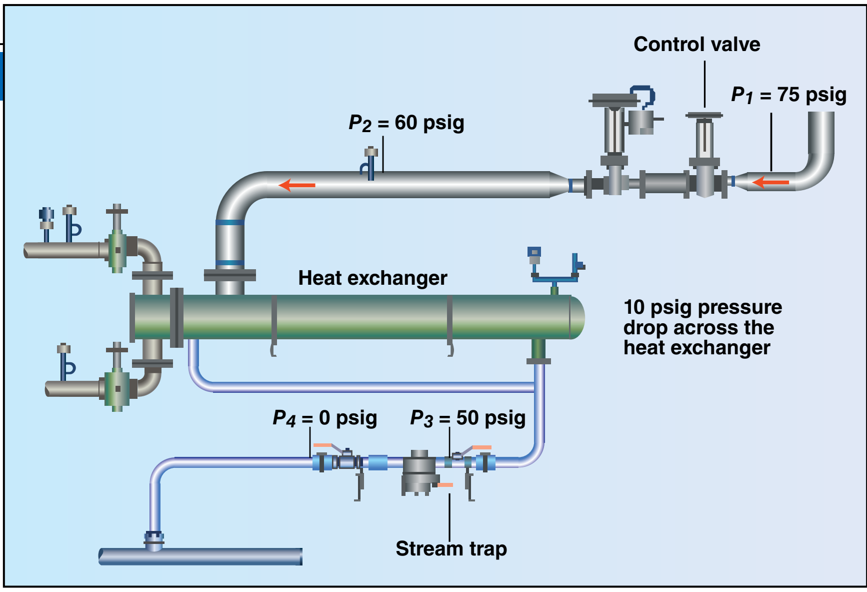

FIGURE 3. The setup and data for process example No. 2 (heat exchanger) is shown here

75 psig (P_1) – 15 psig (pressure drop) = 60 psig (P_2 or pressure entering the heat exchanger)

All heat transfer components have a pressure drop, and this can be obtained from the transfer performance sheets. In this case, the pressure drop is 10 psig.

60 psig (P_2 or pressure entering the heat exchanger) – 10 psig (pressure drop) = 50 psig (P_3 or pressure outlet from the heat transfer unit)

P_3 (50 psig) is the outlet pressure from the heat transfer unit or the inlet pressure for the steam trap. There is no back pressure (0 psig), so the differential pressure is 50 psig.

Finding #1: 50 psig (P_3) – 0 psig (P_4) = 50 psig pressure drop across the steam trap

Second, we will determine the condensate capacity for the steam trap. The condensate capacity of the system (or flow) is 3,624 lb/h. We will be using a float and thermostatic steam trap for this application, so, based on Table 1, we must multiple the system condensate capacity by 2.

Finding #2: 3,624 lb/h (condensate capacity or flow) × 2 (sizing factor from Table 1) = 7,248 lb/h condensate capacity

Finally, we need to identify the maximum rated pressure for the system. See the system's design specifications or the pressure setting on the system's safety valve.

Finding #3: 100 psig maximum rated pressure

Sizing end connections

Once you have determined the steam-trap orifice size, you can move on to the end connections. Always select steam-trap end connections that are equal to or larger than the heat-transfer outlet connection. For example, if the heat transfer equipment has a 2-in. piping outlet, don't select a ½-in. steam trap, as condensate flow will be restricted. In this case, select a 2-in. end connection.

Note that many industries use ¾-in. steam trap piping as a minimum size to provide piping rigidity. Three-quarter-inch piping is also used when standardizing components.

Summary

Steam-trap sizing refers to the internal discharge orifice for condensate, not to be confused with the size of the steam trap's end connections. Three pieces of information will assist you in finding a steam trap with a properly sized orifice: differential pressure across the orifice, condensate capacity, and maximum steam pressure in the system. When consulting tables or approaching the manufacturer's sales representative, you will need this information. Also, you should have on hand your maximum system temperature. Finally, you will specify the end connection or piping size (for instance, ¾-inch).

To increase your chances of succeeding, consider training in sizing and installation. Further, standardize wherever possible within your plant. For example, limit the number of manufacturers of steam traps in your plant to no more than two. ■

Edited by Gerald Ondrey

Reference

1. Follow the link to Best Practice #8 at www.swagelokenergy.com/practices/practices.aspx

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Understanding Finned Heat Exchangers

Fin geometry affects many aspects of boiler, evaporator and heater selection

Viswanathan Ganapathy
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FIGURE 1. Serrated (left) and solid (right) fins are used in boiler and heater applications

Solid and serrated fins (Figure 1) are widely used as heat transfer surfaces in boilers and heaters. The use of finned tubes makes heat exchanger equipment compact. The fluegas pressure drop is also decreased relative to a comparable plain-tube design, resulting in lower operating costs. Fin geometry, such as fin density (fins/in.), fin height and fin thickness, should be selected with care as it impacts the thermal design and performance of the exchanger. However, engineers often select fin geometry without understanding the implications on tubewall temperatures, heat flux, pressure drop or fin temperatures.

This article highlights the importance of selecting proper fin geometry for heat transfer equipment and the implications of poor fin selection. There are common misconceptions among engineers when evaluating fins regarding surface area. Many engineers assume that more fin surface area will always equate to a better design and that designs with smaller surface area will not be sufficient. Selecting a finned heat exchanger design based on surface area alone can lead to long-term problems including higher heat flux, increased tubewall temperatures and even tube failure. This article uses examples of boiler and steam superheater designs to illustrate the proper considerations when selecting fin geometry.

Why finned tubes?

Finned tubes are widely used in clean fluegas heat exchangers and heat recovery systems in petroleum refineries, chemical plants and power plants. In boilers or heaters, fin density ranges from 1 to 6 fins/in., height from 0.5 to 1 in. and thickness from 0.05 to 0.12 in. Fin or tube material can be made of carbon or alloy steel. Typical applications of finned tubes are in turbine exhaust heat-recovery steam generators (HRSG), incineration plant heat-recovery boilers, thermal fluid heaters or fired heaters that process natural gas or recover energy from clean fluegas.

Fin geometry should be carefully selected in fuel-fired applications, as the ash in fuel-oil can cause fouling or deposition of dust on finned tubes. Fins are generally avoided in solid fuel-fired applications, or tubes with very low fin density may be used based on experience. This article discusses heat recovery from clean fluegas applications where restrictions on fin geometry selection are minimal. An understanding of the thermal performance of finned tubes is helpful in optimizing the design and performance of the heat exchanger.

Users of finned heat exchangers experience many benefits. Using finned tubes results in a compact unit with low gas-side pressure drop. Fabricating smaller units results in lower labor costs. In gas turbine HRSGs, multiple pressure modules are used, such as superheaters, evaporators, economizers and condensate heaters. With finned-tube design (Figure 2, left), these modules are more compact, and can be easily assembled in a small space. With a traditional plain-tube design (Figure 2, right), the boilers or heat recovery equipment will be larger and may not fit into more confined spaces.

Example 1: Waste-heat boiler

Table 1 presents the performance of a waste-heat boiler with 150,000 lb/h of 1,000°F fluegas that must be cooled to 535°F in a waste-heat boiler generating saturated steam at 600 psig, with water entering near its saturation temperature. Table 1 shows six different exchanger design cases for this scenario. Some important observations can be made based on these results.

Fin geometry and the ratio of external surface area to tube internal area affects the overall heat-transfer coefficient. Figure 3 shows the behavior of gas-side heat transfer coefficients (h_g) at varying fin height (h) and fin density (n), as mass velocity (G) increases.

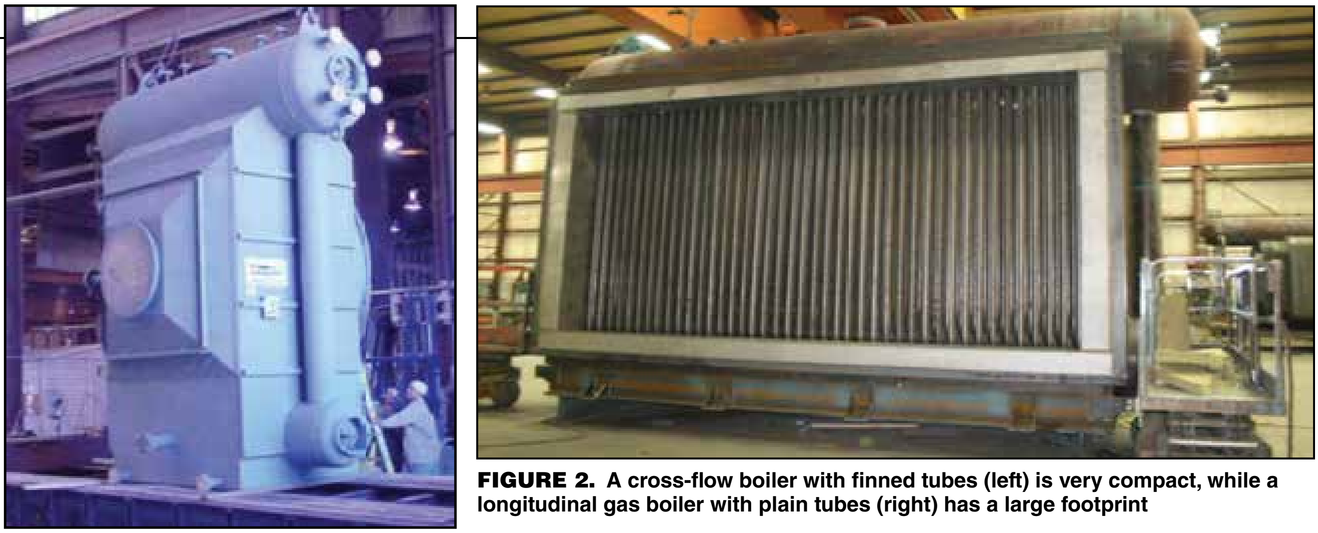

FIGURE 2. A cross-flow boiler with finned tubes (left) is very compact, while a longitudinal gas boiler with plain tubes (right) has a large footprint

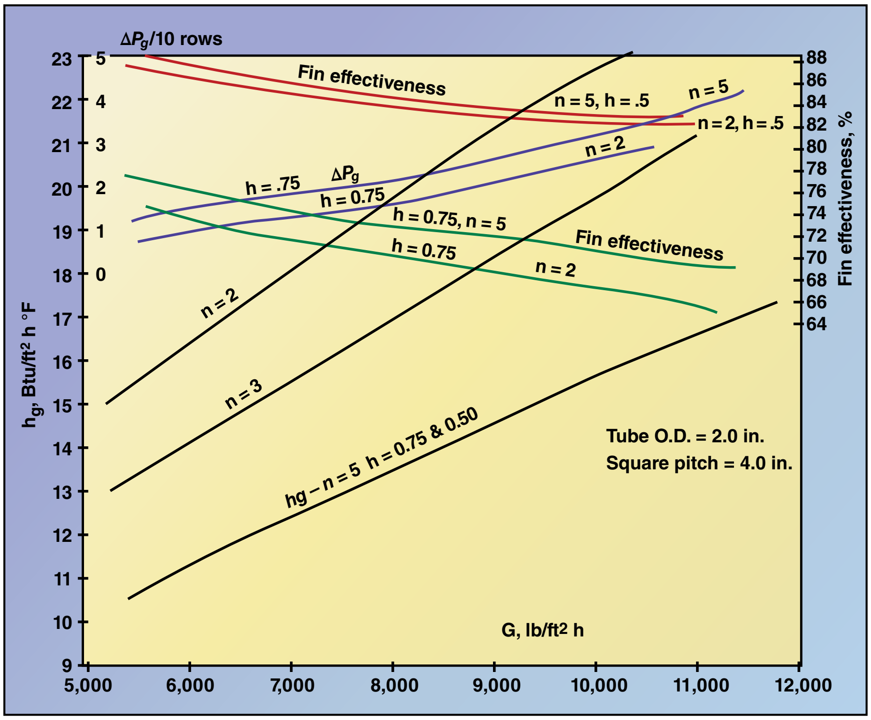

FIGURE 3. Geometry affects gas-side heat-transfer coefficients; as fin density (n) increases, the gas-side heat transfer coefficient (h_g) will decrease. In this figure, h is fin height in inches

Most notably, as fin density increases, the gas-side heat transfer coefficient will decrease. Also, as the ratio of external to internal area increases, the heat-transfer coefficient decreases. This further demonstrates that more surface area does not necessarily translate into a better design. The results in Table 1 show that the surface area of the designs in Case 2 (2 fins/in.) and Case 4 (6 fins/in.) varies by about 50%, and yet the exchanger performance is similar. The surface area of the plain-tube boiler for the same duty (Case 1) is much lower due to the higher overall heat-transfer coefficient compared to the finned-tube boiler. The lower surface area exhibited in Case 1 when compared to finned-tube designs also means that more tubes are required to achieve the same heat transfer. Table 1 shows that the plain-tube design will need 72 tubes, while the finned-tube designs only require 14 to 24 tubes. Thus, plain-tube designs have a much larger footprint than finned designs. This illustrates how crucial it is that purchasing managers and engineers are aware of the effect that fin geometry has on surface area and exchanger performance.

As seen in Table 1, finned tubes have a higher tubewall temperature compared to plain-tube designs. Tubewall temperature also increases as fin density increases. In this example, tubewall temperatures reached nearly 650°F, so it is important to choose an appropriate material of construction. Carbon-steel construction is assumed for this example. Higher heat flux causes the increased tubewall temperatures in finned tubes, since heat flux is a function of surface area.

$$q_i = U_o \frac{A_t}{A_i}\left(T_g - T_i\right) \quad (1)$$

where:

q_i = heat flux, $\frac{\text{Btu}}{\text{ft}^2\text{h}}$

U_o = overall heat transfer coefficient, $\frac{\text{Btu}}{\text{ft}^2\text{h°F}}$

A_t = surface area of finned tube, ft^2

A_i = surface area inside tube diameter, ft^2

T_g = gas temperature, °F

T_i = fluid temperature, °F

It is also apparent in this example that the pressure drop changes with fin geometry. In comparing Case 1's plain-tube design with Case 4 (6 fins/in.), the pressure drop is much lower for the finned design. This is because the finned exchangers require fewer tubes, even though the resistance of the finned tube to gas flow is much higher on a per-tube basis.

Finally, the effects of fouling are also examined. Cases 5 and 6 show the effect of tubeside fouling on the tubewall temperature and boiler duty. With plain tubes, the effect of increasing the tubeside fouling proved insignificant. Small changes are seen in exit gas temperature, duty and tubewall temperature. However, compared to the finned-tube design, the effect is minimal. With the finned-tube boiler, the duty decreases significantly with tubeside fouling; duty increases by 5.5% with fins, compared to only 1% with plain tubes. The tubewall temperature in the plain-tube design increases by only 24°F while in the finned bundle it

TABLE 1. BOILER DESIGNS WITH VARYING FIN GEOMETRY							
		Design with plain and finned tubes					
Case		1	2	3	4	5	6
Description	Units	Plain tubes	2 fins/in.	4 fins/in.	6 fins/in.	6 fins/in. with fouling	Plain tubes with fouling
Gas flowrate	lb/h	150,000	150,000	150,000	150,000	150,000	150,000
Inlet gas temperature	°F	1,000	1,000	1,000	1,000	1,000	1,000
Outlet gas temperature	°F	537	536	535	536	564	542
Specific heat	Btu/lb°F	0.2791	0.2791	0.2791	0.2791	0.2796	0.2792
Heat loss (assumed)	%	1	1	1	1	1	1
Heat duty	MM Btu/h	19.21	19.25	19.26	19.21	18.12	18.99
Gas pressure drop	inch wc	3.46	2.22	2.20	2.47	2.52	3.47
Steam flowrate	lb/h	26,250	26,307	26,307	26,331	24,769	25,959
Steam pressure	psia	600	600	600	600	600	600
Heat transfer coefficient (overall)	Btu/ft^{2}h°F	15.95	9.90	7.82	6.51	5.31	15.27
Tube outer diameter	in.	2	2	2	2	2	2
Tube inner diameter	in.	1.773	1.773	1.773	1.773	1.773	1.773
Fin density	fins/in.	n/a	2	4	6	6	n/a
Fin height	in.	n/a	0.75	0.75	0.75	0.75	n/a
Fin thickness	in.	n/a	0.05	0.05	0.05	0.05	n/a
Fin serration	in.	n/a	0.172	0.172	0.172	0.172	n/a
Fin conductivity	Btu/fth°F	n/a	25	25	25	25	n/a
Pitch	in.	4	4	4	4	4	4
Tubes per row		20	20	20	20	20	20
Number of tubes		72	24	17	14	14	72
Effective length	ft	8	8	8	8	8	8
Tubewall temperature	°F	500	526	543	554	647	524
Fin tip temperature	°F	n/a	726	709	696	760	n/a
Surface area	ft^2	6,032	9,796	12,453	14,797	14,797	6,032
Heat flux inside tubes	Btu/ft^{2}h	16,391	49,608	70,306	84,432	68,909	15,694
Fouling factor	ft^{2}h°F/Btu	0.0005	0.0005	0.0005	0.0005	0.003	0.003

increases by 93°F. These results demonstrate that finned-tube designs are much more susceptible to fouling and that care must be taken to ensure that tubeside fluids are clean and devoid of deposits. Otherwise, high tubewall temperatures — and even failures — can occur. This is especially important with superheater design, as tubeside heat-transfer coefficients are smaller, and a large fin density will contribute to higher heat flux and possible failure. Heat flux does not create as many issues for steam-generating evaporators since the tube-side boiling coefficient is very high. This further proves that careful examination must take place when selecting finned exchangers — one cannot judge on surface area alone. Heat flux and fouling considerations must also be taken into account when evaluating fin geometry.

The next example presents the importance of heat flux and fin geometry in an HRSG superheater.

Example 2: HRSG superheater

Steam superheaters (Figure 4) present a unique situation when determining fin geometry, since they exhibit much lower tubeside heat-transfer coefficients than evaporators and economizers, whose heat transfer coefficients can be up to ten times higher than those seen in a superheater. Consider two designs for a superheater that is to heat 100,000 lb/h of saturated steam at 600 psia to 840°F, with 150,000 lb/h clean fluegas at 1,300°F available from an incinerator. Case 1 features a design with a fin density of 5 fins/in., while Case 2's design has 2 fins/in. Table 2 presents all of the data required to evaluate this scenario.

As expected, the most significant difference between Cases 1 and 2 is surface area. The surface area required in Case 1 is 68% higher than that in Case 2, due to the higher fin density. Once again, the design should not be judged on surface area alone. Upon further examination of the results in Table 2, it is seen that Case 1 exhibits a much larger heat flux inside the tubes, resulting in a higher tubewall temperature of 1,007°F, compared to only 952°F for Case 2. Higher tubewall temperature is detrimental to the superheater's predicted operating life.

Figure 5 shows the typical Larson-Miller parameter (LMP) chart for estimating the life of superheater tubes based on stress. LMP is defined as follows:

$$\frac{(T+460)(20+\log t)}{1{,}000} \quad (2)$$

where:

T = tubewall temperature, °F

t = predicted tubelife, h

LMP is useful for estimates of tube life or for studying the effect of tube temperature on equipment lifetime. First, the stress must be calculated. As stress is a function of operating

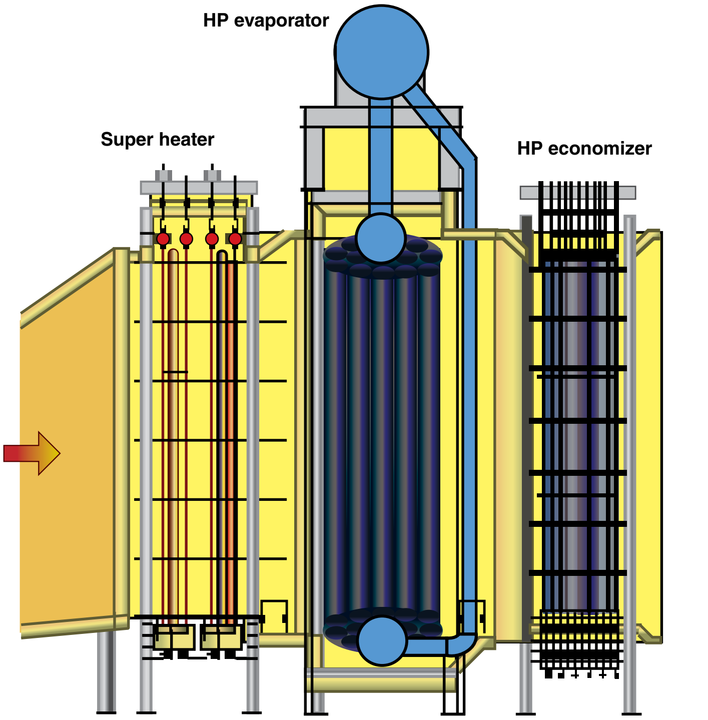

FIGURE 4. A typical HRSG consists of several elements, including a superheater

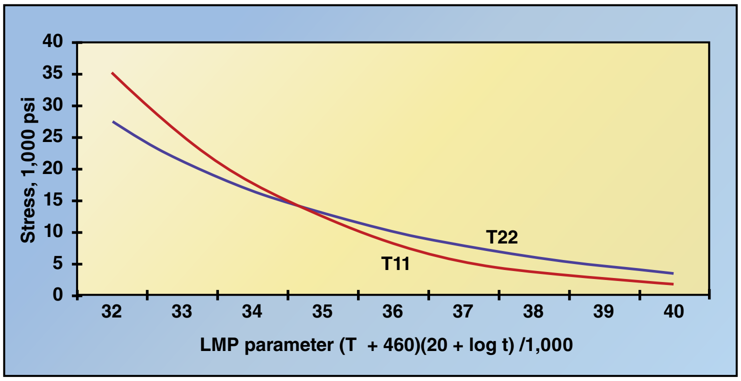

FIGURE 5. The Larson-Miller parameter allows for calculation of superheater tube life

TABLE 2. EFFECT OF FIN GEOMETRY ON SUPERHEATERS

		Case 1	Case 2
Gas flowrate	lb/h	150,000	150,000
Inlet gas temp.	°F	1,300	1,300
Outlet gas temp.	°F	773	773
Specific heat	Btu/lb°F	0.2884	0.2885
Heat duty	MM Btu/h	22.59	22.58
Heat transfer coefficient (overall)	Btu/ft^{2}h°F	5.74	9.66
Tubeside coefficient	Btu/ft^{2}h°F	254	254
Gas pressure drop	inch wc	2.23	1.76
Tubeside conditions			
Tubeside flowrate	lb/h	100,000	100,000
Inlet temperature	°F	486	486
Outlet temperature	°F	840	839
Pressure drop	psia	16	23
Operating pressure	psia	600	600
Inlet wall temp.	°F	590	556
Outlet wall temp.	°F	1,007	952
Inlet fin temp.	°F	655	631
Outlet fin temp.	°F	1,111	1,073
Tubeside velocity	ft/s	80.17	80.16
Surface area	ft^2	10,737	6,374
Tube outer dia.	in.	2	2
Tube inner dia.	in.	1.738	1.738
Fin density	fins/in.	5	2
Fin height	in.	0.75	0.625
Fin thickness	in.	0.05	0.05
Fin serration	in.	0.172	0.172
Fin conductivity	Btu/fth°F	25	25
Pitch	in.	4	4
Tubes per row		20	20
Number of tubes		12	18
Effective length	ft	8	8
Number of streams		20	20
Arrangement		inline	inline
Configuration		counter-flow	counter-flow
Heat Flux	Btu/ft^{2}h	32,467	21,625

temperature and pressure, this value will be the same for Cases 1 and 2. For this example, T11 is the selected material of construction. Assuming a stress of approximately 5,000 psi (based on operating pressure of 600 psig), the resulting LMP for T11 material is 37,500. Using the tubewall temperatures shown for the two cases in Table 2 and applying a 25°F margin, the predicted life can be calculated. For Case 1, the predicted lifetime is approximately 135,000 h, while for Case 2, the predicted lifetime is 1.2 million h. The LMP's logarithmic scale means that even incremental changes to tubewall temperature can greatly affect tube lifetime. This example further illustrates the dramatic difference fin geometry can have on heater operation and lifetime. Obviously, despite its smaller surface area, Case 2's fin geometry presents a much more economical option.

Final remarks

Finned tubes are an excellent option to achieve efficient heat transfer in evaporators, boilers and superheaters, but a clear understanding of finned exchanger design is important. Fin geometry affects the surface area of heat-transfer equipment significantly. The heat flux inside the tubes, the tubewall temperature and the equipment lifetime are also impacted. Hence a better understanding of the thermal performance aspects of finned tubes will help plant engineers to select a better HRSG or boiler and also to ask proper questions of vendors. ■

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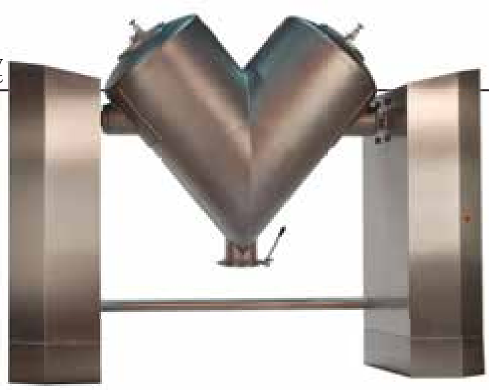

FIGURE 1. The tumbler blender comes in a V-shaped configuration

Fundamentals of Bulk Solids Mixing and Blending

Learn about mixing technology, types of blending equipment and key sampling practices to meet today's requirements for robust processes

Eric Maynard
Jenike and Johanson

Mixing and blending of bulk solids is a common processing step in many industries. For example, in pharmaceutical manufacturing of solid dosage formulations (tablets or capsules), small amounts of a powdered active drug are carefully blended with excipients, such as sugar, starch, cellulose, lactose and lubricants. With foods, many powder-form consumer products result from custom mixed batches; consider cake mix, ice tea and dry seasonings. Thousands of processes in the chemical process industries (CPI) involve mixing or blending of specialty chemicals, explosives, fertilizers, glass or ceramics, detergents and resin compounds.

Today's production operations require robust mixing processes that provide fast blend times, recipe flexibility, ease of equipment cleaning for minimizing grade change-over time, and assurances that de-mixing (segregation, for example) does not result with a blended material [*1*].

Over the past two decades, mixing and blending technology has greatly improved to address needs for larger batch sizes, faster blend times and segregation minimization. Though many blenders are capable of mixing all kinds of powders, the process of selecting a blender remains an "art form" because of the many variables involved. There are many types of solids blenders available, and while one blender may have a lot of flexibility, others may be highly specialized for a difficult blending application. Knowledge gains in the area of sampling and segregation have allowed a more holistic approach to the typical blending unit operation, thereby often preventing problems with the uniformly blended material once it has been discharged from the mixer.

This article provides an overview of basic powder-blending technology and sampling considerations.

Mixing versus blending

The terms "mixing" and "blending" can be synonymous to some, however, they technically can be considered slightly different. Mixing is defined as the process of thoroughly combining different materials to achieve a homogenous mass. In most cases, the mixture is a combination of dissimilar materials (such as polyethylene pellets and black pigment to make trash bags) using significant agitation. A mix can also be made with a chemically homogenous material that requires uniform distribution of its particles.

Blending, like mixing, is an act of combining materials. This operation, however, usually occurs in a gentle fashion with multiple components (such as blending fertilizer ingredients without generating fines). For the scope of this article, we will use the terms mixing and blending interchangeably.

The goals of producing an acceptable blend, maintaining it through additional handling steps, and verifying that both the blend and the finished product are sufficiently homogeneous can be difficult to achieve on the first attempt. The costs for troubleshooting a poorly performing blending system can far outweigh the initial investment costs. For example, an inadequate blend or segregation of a pharmaceutical "blockbuster drug" can cause the batch to fail, which could lead to costs in the millions of dollars, even though the equipment used to blend and transfer the powder can be a small percentage of this cost.

Batch versus continuous

Blenders come in all shapes, sizes, arrangements and modes of operation, but they fit into one of two categories: batch or continuous.

Batch blending. A batch blending process typically consists of three sequential steps: weighing and loading blend components; mixing; and discharge of the blended product.

In a batch blender, solids motion is confined only by the vessel, and directional changes are frequent. The retention time in a batch blender is carefully controlled, while for a continuous blender, this is generally not the case. Blending cycles can take from a few seconds with high-intensity units to 30 min or more where additional processing, such as heating or cooling, may be involved. Blender discharge may be rapid or take substantial time, particularly if the blender is used as a surge vessel to feed a downstream process. Ideally, a blender should not be used for storage capacity, because this can create a process bottleneck, given that the blender cannot perform operations of storage and blending concurrently. Batch blenders [*2*] are often used in the following situations:

- When quality control requires strict batch control

TABLE 1. TYPICAL BLENDER FEATURES						
Blender	Typical capacity	Typical speed	Power required	Lump breaking	Jacket vessel	Ability to add liquid
Ribbon, plow	30–28,000 L (1–1,000 ft^3)	15–100 rpm	High	Good	Yes	Yes
Tumble	15–5,000 L (0.5–175 ft^3)	5–30 rpm	Moderate	Poor	Difficult	Difficult
In-bin tumbler	750–3,000 L (25–100 ft^3)	5–30 rpm	Moderate	Poor	Difficult	Difficult
Planetary	30–28,000 L (1–1,000 ft^3)	15–100 rpm	Moderate	Good	Yes	Yes
Fluidized	2,800–85,000 L (100–3,000 ft^3)	0.03–0.33 m/s (0.1–1 ft/s)	Low	Poor	Yes	Yes
High shear	30–10,000 L (1–350 ft^3)	Tip > 3 m/s (600 ft/min)	High	Excellent	Yes	Yes

TABLE 2. BLENDER COMPARISONS					
Blender	Range of materials	Can handle cohesive materials	Blending time	Easy to clean	Gentle blending
Ribbon, plow	Wide	Yes	Fast	Moderate	Moderate
Tumble	Moderate	With intensifier	Long	Yes	Yes
In-bin tumbler	Moderate	With intensifier	Long	Yes	Yes
Planetary	Moderate	Yes	Moderate	Moderate	Yes
Fluidized	Narrow	No	Fast	Yes	Moderate
High shear	Moderate	Yes	Fast	Moderate	No

FIGURE 2. With tumbling in-bin blenders, the storage container itself becomes a blender

- If ingredient properties change over time
- When the blender cannot be dedicated to a specific product line
- When production quantities are small
- When many formulations are produced on the same production line

Major advantages of batch over continuous blending include the following:

- Lower installed and operating costs for small to medium capacities
- Lower cleaning costs when product changes are frequent
- Production flexibility
- Pre-blending of minor ingredients is easily accomplished
- Control of blending time

Continuous blending. In a continuous blending process, the weighing, loading, blending and discharge steps occur continuously and simultaneously. Blending occurs during transport of the material from the in-feed point toward the mixer outlet. Unlike batch blenders where product retention time is carefully controlled, material retention time with continuous blenders is not uniform and can be directly affected by blender speed, feedrate, blender geometry and design of internals. Continuous blending [2] is typically used under the following conditions:

- A continuous, high production rate process is required
- Strict batch integrity is not essential
- Combining several process streams
- Smoothing out product variations

Some of the advantages of a continuous blending system are the following:

- Ease of equipment integration into continuous processes
- Less opportunity for batch-to-batch variation caused by loading errors
- Automation can improve quality and reduce labor costs
- Higher throughputs are often possible

Blending mechanisms

There are three primary mechanisms of blending, namely: convection, diffusion and shear. *Convective blending* involves gross movement of particles through the mixer either by a force action from a paddle or by gentle cascading or tumbling under rotational motion. *Diffusion* is a slow blending mechanism and will pace a blending process in certain tumbling mixers if proper equipment fill order and method are not utilized. Lastly, the *shear* mechanism of blending involves thorough incorporation of material passing along high-intensity forced slip planes in a mixer. Often these mixers will involve dispersion of a liquid or powdered binder into the blend components to achieve granulation.

Achieving a uniform blend is the goal of any industrial process involving mixing, and defining uniformity strongly depends upon the scale of uniformity. For instance, loading two components into a tumble blender does not guarantee blend uniformity across the range of sample sizes. If the entire quantity in the blender were analyzed, then uniformity may be present. However, taking smaller samples from either side of the blender will result in substantial differences, which clearly does not meet uniformity requirements.

Think of a tumble blender containing a side-by-side loading of salt and pepper. Perhaps after 20 revolutions of the blender, the salt remains predominantly on the left side while the pepper resides on the right side of the blender. Though diffusion has allowed some intermixing, in general, there is a large-scale non-uniformity in the blender that indicates additional blend time is required. As sample size is reduced, even with a good blend of salt and pepper, there is a chance that random selection will yield some samples mostly composed of salt and others of pepper. This example illustrates why it is important to collect sample sizes representative of the final product size when evaluating uniformity.

There are two types of blend structures: random and ordered. A *random blend* occurs when the blend components do not adhere or bind with each other during motion through the blend vessel. In this case, dissimilar particles can readily separate from each other and collect in zones of similar particles when forces such as gravity, airflow or vibration act on the blend. An example of a random blend is salt and pepper.

More commonly, *ordered* or *structured blends*, result in most industrial processes. This occurs when the blend components interact with one another by physical, chemical or molecular means and some form of agglomeration or coating takes place. The process of granulation involves this approach, whereby larger particles are created from smaller building-block ingredient particles, and each "super" particle has ideally the correct blend uniformity. A blend of perfect super

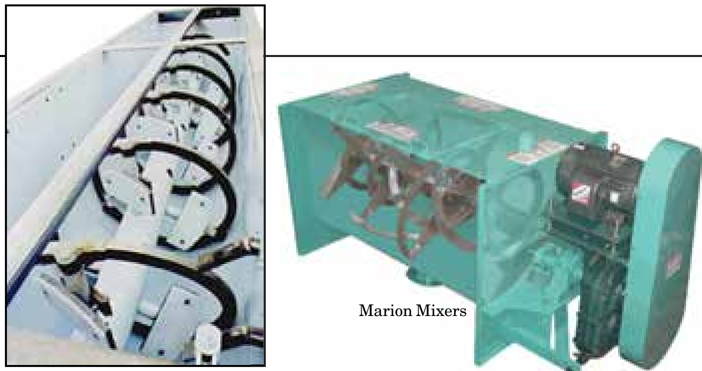

FIGURE 3. Paddle (left) and ribbon (right) blenders are convection-type units

particles of identical size will not segregate after discharge from the blender, which is clearly an advantage over a random blend. However, if these particles are not mono-sized, then segregation by size may occur and induce problems with bulk density, reactivity or solubility in post-blend processing.

A word of caution regarding blend structure: There are cases where some ingredients have a tendency to adhere only to themselves, without adhering to dissimilar ingredients. This often happens with fine materials, such as fumed silica, titanium dioxide and carbon black. At times, a blend can reach "saturation," where minor fine components will no longer coat larger particles, and concentrations of the fine component will build (and segregate from the blend). Fortunately, some blender manufacturers have recognized this problem and have developed technology, like chopper blades placed in dead-zone locations, to mitigate its harmful effects.

Types of blenders

There are four main types of blenders: tumbler; convective; hopper; and fluidization. A general description of each blender type, including its typical operation and possible concerns follows. Tables 1 and 2 also provide an at-a-glance feature comparison for each blender.

Tumbler. The tumble blender is a mainstay in the pharmaceutical and food industries because of its positive attributes of close quality control (batch operation only), effective convective and diffusive mechanisms of blending, and gentle mixing for particles prone to breakage. This type of rotating blender comes in double-cone or V-shaped (Figure 1) configurations, and in some cases, these geometries are given asymmetric features to reduce blend times and improve blend uniformity. Typical tumble blender features, speeds and capacities are given in Table 1.

Rotational speed is generally not as much of a factor on achieving uniformity as loading method and blend time (number of rotations). Though there is no proven method of calculating required blender run time, there is a preferred loading method for tumble blenders, especially with symmetric geometries. A top-to-bottom component loading is better than a side-to-side loading. In this case, ingredients are allowed to cascade into one another with diffusive effects occurring perpendicular to the main flow. This approach yields far faster blend times than side-to-side loading.

It is also important to prevent ingredient adherence to the walls of the blender. This is common with fine additives, such as pigments and fumed silica. Component loss can occur with the blend if the material does not leave the wall surface. In some cases, the sticky ingredient can be pre-blended into another component (called master-batching) to help pre-disperse the material and avoid wall adherence. It is also important to consider blend cohesiveness, which directly correlates to a material's tendency to form a bridge over the blender's outlet. Highly cohesive blends should not be handled in tumble blenders if bridging or ratholing flow obstructions have been experienced in past processing equipment. Additionally, cohesive material mixing in a tumble blender takes significant time, usually requires an internal agitator (called an intensifier), may not achieve intimate mixing, and thus may not be the most suitable equipment.

In-bin tumbler. To reduce blending process bottlenecks and segregation potential, tumbling in-bin blenders (Figure 2) have been developed where the storage container itself becomes a blender. Blend components can be loaded into the container, blended and transferred in the container to point-of-use or to a storage area. This process leads to highly flexible production and has been popular in the pharmaceutical, food and powdered metal industries. Typical in-bin blender features, speeds and capacities are given in Table 1.

In-bin tumble blending is likely the foremost solids-mixing technology improvement that has occurred in the past 25 years [*3*]. The greatest benefit of this technology is its elimination of a transfer step from a blender into a container, by which segregation by various mechanisms can result. Additional benefits include: no cleaning between batches; and the blend is stored in a sealed container until use. Optimum in-bin tumble blenders incorporate mass-flow technology (all of the material is in motion whenever any is discharged) to ensure the blend does not segregate during container discharge.

Ribbon, paddle, plow. Convection blenders use a fixed U-shaped or cylindrical shell with an internal rotating element (impeller) like a ribbon, paddle, or plow (Figure 3). Due to the action of the impeller, the particles move rapidly from one location to another within the bulk of the mixture. The blending action can be relatively gentle to aggressive, depending on the agitator design and speed and the use of intensifiers (choppers).

Ribbon and paddle blenders tend to create cross-wise, recirculating cutting planes within the vessel to allow rapid mixing at an intimate uniformity level. With fine powder mixtures, the action of the ribbons induces a near fluidized state with minimal interparticle friction, thereby allowing fast blend times.

Plow blenders operate slightly differently. The main plows divide the powder bed and have back-side plows that fold in the remaining powder behind the main plow segments. This effectively blends highly cohesive materials without inducing particle breakage. Additionally, the plow blender is renowned for having minimal dead zones since the clearance between the plows and the blender shell is very small. Ribbons and paddles, on the other hand, tend to have larger dead zones due to the requirement for the clearances to be bigger.

The convective blenders work well with cohesive materials, which nor-

Young Industries

FIGURE 4. Tube-type blenders are well-suited for free-flowing, granular solids mixing

Hosokawa Bepex

FIGURE 5. A conical screw, or Nauta-type mixer is commonly used for cohesive powder blending

mally take substantially longer blend times in tumbling-type mixers. They also have the advantages of taking up less headroom, allowing liquid addition, heating and/or cooling, and potential for continuous operation instead of only batch mixing as with tumble blenders. Also, these blenders are less likely to experience blend segregation during discharge because the impellers typically operate during this process. Typical convective blender features, speeds and capacities are given in Table 1.

Hopper. Hopper blenders are usually cone-in-cone to tube-type units, where particles flow under the influence of gravity in a contact-bed without moving parts (attractive for highly abrasive bulk materials given their wear potential). With the former unit, the inner cone produces a pronounced faster flow through the inner hopper as compared to the outer annulus section, thereby allowing moderate blending of material. These hoppers typically require two to four passes with a recirculation system to achieve proper uniformity. Tube blenders (Figure 4) utilize open pipes within a bin; the pipes have notches in them to allow pellet or granular material to partially flow in and out of the tubes over the height of the bin, or for reintroduction into a lower portion of the bin (such as in a mixing chamber).

These blenders can handle much larger volumes of material than tumbling or convective blenders, since no free-board space is required, and their technology can be applied to storage bins or silos. Typical gravity-flow hopper blender features and capacities are given in Table 1.

Planetary. Another type of hopper blender, called a planetary or conical-screw mixer (Figure 5), is commonly used for cohesive powder blending. The planetary screw is composed of a near-vertical screw conveyor inside a conical hopper. The screw is located so that one end is near the apex of the cone and the other end is near the top of the hopper, with the tip of the flights near the wall of the hopper. The screw rotates while revolving around

Dynamic Air

FIGURE 6. Fluidization mixers rapidly blend components using high gas flowrates

Forberg

Dynamic Air

FIGURE 7. These high-shear mixers combine fluidization and convective features

the walls of the hopper, pulling material up from the bottom. Advantages include the ability to handle a wide range of materials, from free-flowing to highly cohesive.

Potential concerns with this blender include possible segregation during blend discharge and a dead region at the bottom of the cone during blending. These blenders are commonly jacketed for heating and/or cooling of a material during the blend cycle. Typical convective blender features, speeds and capacities are given in Table 1. The Nauta-type blender can also be fitted with a vertically oriented ribbon blender, though there are limitations on its capacity given the high level of operating torque and horsepower.

Fluidization. Fluidization mixers (Figure 6) use high flowrates of air or inert gas to fully fluidize powders in order to rapidly blend components. The gas can also be used to process (heat or cool) the blend. Not all powder blends are well-suited for fluidization mixing. Ideal candidates are fine, free-flowing powders that have a narrow size distribution and are close in particle density. Highly cohesive powder blends may experience channeling and non-uniform blend quality.

High shear. These mixers (Figure 7) combine fluidization and convective features, yielding rapid blend times with a high degree of blend uniformity. This type of blender consists of twin counter-rotating paddled agitators that mechanically fluidize the ingredients. Rotation is such that the blend is lifted in the center, between the rotors. Mixing is intensive, producing intimate blends in a short period of time. Blend cycles are often less than a minute, and "bomb-bay" doors allow rapid discharge of the entire blend. These features combine to give this blender a high throughput capacity relative to its batch size, and highly cohesive materials can be readily blended.

In another type of high-shear blender, a rapidly rotating impeller with integral choppers creates high-intensity blending. The impeller clearance is very small to avoid blender dead zones. This type of blender is routinely used for blending highly cohesive powders and for agglomeration processes, such as the manufacture of dry laundry detergent. Rapid blend times are common with this type of mixer.

Sampling of blends

Effective sampling is essential in determining the state of the blend in a mixer and in downstream equipment, such as a bin, hopper or packaging system. To achieve a high level of confidence in the quality of the samples extracted from a process, consider these five points regarding sampling (see Refs. 4 and 5 for good technical articles on sampling).

1. A perfect blend does not guarantee uniform product. Consider that every time a transfer step occurs in a powder handling process, the mix or blend has the potential to segregate. Common segregation mechanisms [*6*] occurring during industrial powder handling applications include sifting (Figure 8), fluidization and dusting. Depending upon which mechanism of segregation occurs, the fine and coarse particles will concentrate in different locations in the bin or hopper, thus rendering location-specific sampling results. Sample at each piece of equipment that the powder has transferred into to evaluate if segregation has resulted due to powder transfer.

2. Beware of thief. A sample thief is commonly used to collect powder samples from a stationary bed of material in a blender, drum or bin. A thief is a metal rod with recessed cavities capable of receiving powder after being inserted into a powder bed. Care must be made with thief-collected samples, because this method will disturb the powder sample in-situ and some components may or may not flow into or stick to the thief cavity. Numerous studies have shown that thief sampling results can be dependent on operator technique (such as thief insertion angle, penetration rate, angle and twisting). I am not proposing that thief samplers be abandoned. Rather, I suggest that the resulting data be carefully scrutinized and observations (for example, static cling, agglomeration and smearing) of the thief cavity and extracted powder sample be recorded.

3. Use stratified sampling. Improve the quality of thief sampling with a stratified (nested) approach and statistical analysis to differentiate blend variability from sampling error (from the thief, laboratory analysis or collection method). Instead of sampling only once from a given location in a blender, multiple (minimum of three) thief samples should be extracted from the same location. This should then be repeated throughout several distinct locations, especially in known "dead-zones" like at the blender walls. After analysis of these samples, assessments can be made to within-location versus between-location variability. If the three samples collected at the same point have large variability, then questions should be raised regarding the thief or analytical testing method. If large variability exists between the samples collected around the blender, then it is likely that the blend is not yet complete and additional time or agitation will be required; it is also possible that segregation may have occurred within the blender due to over-blending. Nested sampling is also effective for thief sampling of bins, hoppers, drums or other vessels containing the bulk-solid mixture.

4. Collect full-stream samples. Consider an alternative sampling approach, such as full-stream sampling during blender discharge. This technique provides a true "snapshot" of blend uniformity exiting the blender and overcomes many of the pitfalls common to the sample thief. If a full-size sample is extracted, it may re-

FIGURE 8. Sifting is a common segregation method

quire reduction in size for analysis. In this case, a rotary sample splitter — also called a rotary or spinning riffler — should be used to properly distribute fine and coarse particles to the reduced sample quantity.

5. Handle collected sample carefully. Ideally, use the entire collected sample for analysis. However, in many cases, the gross sample will be required to be split down to a smaller size for the analysis (such as chemical assay, pH and particle size). For example, imagine that a 500-g sample is collected from a hopper, and it segregates in the sample container. If the laboratory technician then collects a small 5-g grab sample for analysis, this smaller sample may not represent the true particle size distribution of the entire sample, and error results. In this case, a sample splitter, such as a rotary riffler, can be used to accurately reduce the sub-sample size. Avoid using error-prone splitting methods like cone and quarter or chute riffling. Additionally, samples collected over time and combined into a composite sample can only tell you at-best what is the quality of material over that period. Furthermore, if the composite sample is not well-mixed, sampling bias can result. ■

Edited by Dorothy Lozowski

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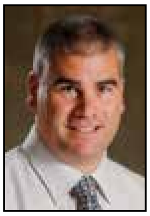

Eric Maynard is the director of education and a senior consultant at Jenike & Johanson, Inc. (J&J; 400 Business Park Dr., Tyngsboro, MA 01879; Phone: 978-649-3300; Fax 978-649-3399; Email: epmaynard@jenike.com; Website: www.jenike.com). The firm specializes in the storage, flow, conveying, and processing of powders and bulk solids. During his 18 years at J&J, Maynard has worked on nearly 500 projects and has designed handling systems for bulk solids including chemicals, plastics, foods, pharmaceuticals, coal, cement, and other materials. He is the principal instructor for the AIChE courses "Flow of solids in bins, hoppers, chutes, and feeders" and "Pneumatic conveying of bulk solids." He received his B.S. in mechanical engineering from Villanova University and an M.S. in mechanical engineering from Worcester Polytechnic Institute.

Fractionation Column

The science of droplets

Many chemical engineers study or employ distillation trays, gas-liquid separators and spray nozzles. Most of those engineers have studied or employed force balances around liquid droplets suspended in upward-flowing vapor streams. Considering a droplet of size "*d*," for the droplet to be suspended motionless, the summed forces of drag and buoyancy must equal exactly the force of gravity. At higher vapor velocities, the droplet is carried upward; at lower velocities, downward. Who was the first to develop these force balances? Was it Stokes? Souders-Brown? Or Archimedes after he stepped, dripping, out of the bathtub?

Most of the force balance manipulations lead to the same two conclusions: 1) The suspension vapor velocity is a function of the liquid and vapor densities; and 2) The droplet sizes are almost totally unknown. Hydraulics engineers use *C*-factors, and *F*-factors, that employ this density function to design distillation columns and separators. What if we knew the droplet size distributions associated with such equipment, and the velocity distributions of the entrained droplets? Air/water information would be nice but hydrocarbon/organic data would be ten times better.

A Phase Doppler Particle Analyzer (PDPA) is a laser-based diagnostic tool that can provide such droplet size and velocity data. It was invented by Will Bachalo in 1982 and soon became the worldwide droplet-sizing technique across spray-related industries as wide ranging as gas-turbine fuel injection and medical nebulizers. In September of last year, Bachalo and Chad Sipperley visited Stillwater to demonstrate Artium Technologies' Phase Doppler Interferometer (PDI) — an updated version of the PDPA — at Oklahoma State University (OSU) and at FRI. At OSU, they focused the two green laser beams beneath a spray nozzle. At FRI, using FRI's new kettle-reboiler windows, they focused the beams on the spray above the boiling pool. They then moved the PDI to the operating distillation column and focused the beams on the rain beneath a packed bed and on the spray above that packed bed. The OSU professors (Rob Whiteley and Clint Aichele) and the FRI researchers were very impressed by the droplet distribution information that was very quickly gathered. FRI and OSU decided to jointly purchase a PDI.

OSU graduate students are now studying droplet distributions in an acid-gas absorption column beneath a spray nozzle. They will evaluate droplet size distributions and velocities for a variety of solvents and conditions over a range of applications including absorption, distillation and packing characterization. FRI engineers will use the PDI for at least three things: 1) to further study droplet sizes above boiling pools in the FRI kettle (up to 165 psia); 2) to study entrainment above tray froths; and 3) to collect distribution data beneath and above de-entrainment devices. The FRI studies

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

will cover a very broad range of fluid physical properties, from xylenes at 75 mm Hga to C4s at 500 psia. Regarding the latter, surface tensions will sometimes be closer to zero than to 1.0 dyne/cm. The partnership between OSU and FRI will lead to advanced understanding of sprays by combining laboratory measurements at OSU with pilot-scale measurements at FRI.

Someday soon, distillation tray engineers will have a fairly good knowledge of droplet distributions above tray froths. Flood points will be more predictable. Surely a complete understanding of gravitational forces cannot be too far behind — assuming that you have not already adopted the String Theory. ■

Mike Resetarits

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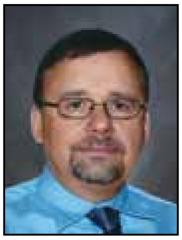
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Hans Schonemann becomes president of **Phasex Corp.** (Lawrence, Mass.), which specializes in supercritical fluid extraction. He replaces Phasex founder *Val Krukonis*, who becomes director, R&D programs *James Camasso* becomes plant manager.

Netzsch Pumps North America LLC (Exton, Pa.) names *Robert Kisler* national sales and product manager for the Tornado product line.

Markus Tacke is named CEO of the Wind Power Div. of **Siemens Energy Sector** (Erlangen Germany). He replaces *Felix Ferleman* who is leaving the company.

Devin International (Houston), a subsidiary of Greene's Energy Group and equipment supplier for oil-and-gas operations, names *J.H. (Trey) Miller III* U.S. sales manager. *Andrew Riojas* becomes location supervisor in the firm's the Lafayette, La., location.

Gulfstream Services Inc. (Houston), an oilfield rental company, names *Fred Bailey* as operations manager in its Sealy, Tex., facility.

Karim Hajjar becomes CFO of **Solvay S.A.** (Brussels, Belgium), replacing *Bernard de Laguiche*, who will remain a non-executive board member.

Precision Polymer Engineering (Blackburn, U.K.), a maker of molded elastomer seals, names *Jamie Hill* regional OEM sales manager for the U.K. ■

Suzanne Shelley

BUSINESS NEWS

PLANT WATCH

Chevron Phillips receives key permits for large Gulf Coast project

August 14, 2013 — Chevron Phillips Chemical Company LP (The Woodlands, Tex; www.cpchem.com) has received key permits from the Texas Commission on Environmental Quality, and the U.S. Environmental Protection Agency (EPA) for its planned ethane cracker and polyethylene units. Pending final board approval, the 1.5-million metric tons per year (m.t./yr) ethane cracker would be built at Chevron Phillips Chemical's Cedar Bayou facility in Baytown, Tex., while the two new polyethylene facilities, each with a capacity of 500,000 m.t./yr, would be built on a site near the Chevron Phillips Chemical Sweeny facility in Old Ocean, Tex. Estimated completion for this project is 2017.

One of the world's largest ammonia plants to be built in Saudi Arabia

August 8, 2013 — The Saudi Arabian Mining Company (Ma'aden) will use ammonia technology from ThyssenKrupp Uhde GmbH (Dortmund, Germany; www.thyssenkrupp-uhde.de) in its new ammonia plant Ma'aden II, being built near the port of Ras al Khair, which is in the Arabian Gulf. The 3,300-m.t./d plant is scheduled for completion in 2016 and is said to be one of the largest of its kind worldwide.

Dow and Johnson Matthey Davy license LP Oxo Technology to PetroChina

August 5, 2013 — Johnson Matthey Davy Technologies (JM Davy; London, U.K; www.davyprotech.com) and The Dow Chemical Company (Midland, Mich; www.dow.com) announced that PetroChina Guangdong Petrochemical Co. has selected LP Oxo Technology for its petrochemical complex in Jieyang, Guangdong, China. The new LP Oxo unit will produce 85,000 m.t./yr of 2-ethylhexanol, 235,000 m.t./yr of n-butanol and 33,000 m.t./yr of iso-butyraldehyde.

Sibur and Sinopec establish a JV to produce synthetic rubbers

August 5, 2013 — Sibur (Moscow, Russia; www.sibur.com) and China Petroleum and Chemical Corp. (Sinopec) entered into a joint venture (JV) developed on the site of the Krasnoyarsk Synthetic Rubber Plant (KZSK). Sinopec purchased 25% + 1 share of KZSK. The deal was approved by Russian and Chinese regulators. The shareholders will also consider expanding the KZSK capacity from 42,500 to 56,000 m.t./yr.

BASF to build a new plant for high-performance polyamide in China

July 29, 2013 — BASF SE (Ludwigshafen, Germany; www.basf.com) is building a new polymerization plant for the high-performance polyamide Ultramid. With a capacity of 100,000 m.t./yr, the new plant is planned to start up in 2015. The plant will be built at China's Shanghai Chemical Industry Park in Caojing.

Sasol and Ineos sign agreement for high-density polyethylene JV

July 24, 2013 — Sasol (Johannesburg, South Africa; www.sasol.com) and Ineos Olefins & Polymers USA (Ineos) have announced their intent to form a JV to manufacture high-density polyethylene (HDPE). The plant will produce 470,000 m.t./yr of bimodal HDPE. The final investment decision is expected in the 1st half of 2014 with expected startup in late 2015.

MERGERS AND ACQUISITIONS

Clariant and Tasnee establish masterbatches JV in Saudi Arabia

August 9, 2013 — Clariant (Muttenz, Switzerland; www.clariant.com) and Tasnee, an industrial conglomerate in Saudi Arabia, have announced the signing of an agreement to establish a masterbatches JV in Saudi Arabia. Tasnee will acquire a 40% stake in Clariant's masterbatches operations in the country, operating under the name Clariant Masterbatches (Saudi Arabia) Ltd. The JV will be operational following completion of customary merger-control-clearance procedures.

Edwards to acquire ultra-high vacuum pump specialist Gamma Vacuum

August 9, 2013 — Edwards Group Ltd. (Crawley, U.K.; www.edwardsvacuum.com), a manufacturer of vacuum products and abatement systems has entered into a definitive agreement to acquire Gamma Vacuum, which specializes in ultra-high vacuum pumps. The transaction is expected to be completed in the 3rd quarter of 2013 and is subject to standard closing conditions.

Altana acquires specialty coatings business from Henkel

August 8, 2013 — The specialty chemicals group Altana (Wesel, Germany; www.altana.com) has acquired the specialty coatings business of Henkel. The products are sold under the brand names MiraFoil and Miracure and are mainly supplied to the packaging industry in North America. The business' estimated sales were $15 million in 2012. Within the Altana group, the business will be integrated into Actega Kelstar Inc. in the U.S. and into Actega Terra GmbH in Germany, both belonging to the Actega Coatings & Sealants division.

Ametek acquires Controls Southeast for $160 million

August 7, 2013 — Ametek, Inc. (Berwyn, Pa.; www.ametek.com) has acquired Controls Southeast, Inc. (CSI), a manufacturer of custom-engineered thermal solutions, from Industrial Growth Partners for approximately $160 million. Based near Charlotte, N.C., Controls Southeast has annual sales of approximately $50 million.

Nordson to acquire Kreyenborg Group's polymer processing businesses

July 31, 2013 — Nordson Corp. (Westlake, Ohio; www.nordson.com) has entered into a definitive agreement to acquire Münster, Germany-based Kreyenborg Group's Kreyenborg GmbH and BKG Bruckmann & Kreyenborg Granuliertechnik GmbH companies. The transaction is expected to close during the 3rd quarter of 2013, pending customary closing conditions and regulatory reviews. Revenues for fiscal year 2012 were approximately €62 million.

Pexco acquires Scandia Plastics, deepens specialty plastics machining capability

July 30, 2013 — Pexco LLC (Atlanta, Ga.; www.pexco.com) has acquired Scandia Plastics, Inc. of Plaistow, N.H. Scandia is a custom extrusion business that sells to the filtration, medical, environmental, defense, and other industrial markets, and process a variety of high-end engineering resin materials.

Altana to acquire rheology modifier business from Rockwood

July 28, 2013 — Altana has signed a definite agreement to acquire the global rheology business of Rockwood Holdings Inc., of Princeton, N.J. The purchase price amounts to $635 million. The closing of the transaction is expected to take place in the 4th quarter of 2013. ■

Mary Page Bailey

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

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

2011 — 2012 — 2013

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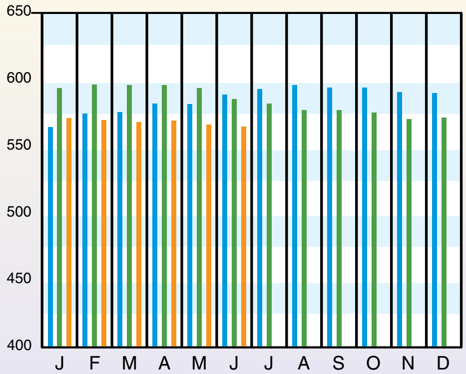
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Jun.'13 Prelim.	May '13 Final	Jun.'12 Final
***CE* Index**	564.9	566.5	585.6
Equipment	684.1	685.4	713.9
Heat exchangers & tanks	626.7	624.3	661.4
Process machinery	654.4	655.1	666.5
Pipe, valves & fittings	859.3	863.4	917.7
Process instruments	410.2	410.6	425.1
Pumps & compressors	919.2	919.3	927.0
Electrical equipment	512.7	513.1	513.7
Structural supports & misc	730.9	741.7	759.9
Construction labor	317.6	319.7	322.6
Buildings	530.8	534.0	527.1
Engineering & supervision	324.4	325.5	327.9

Annual Index:

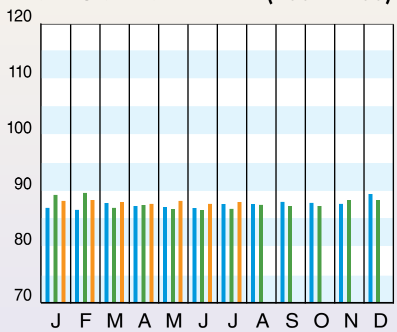
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6



CURRENT BUSINESS INDICATORS

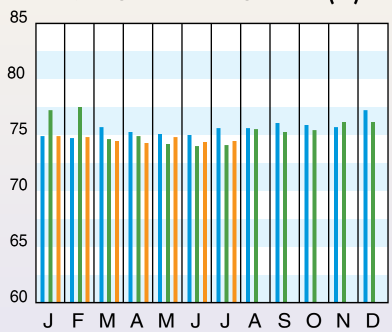
	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2007 = 100)	Jul.'13	=	88.0	Jun.'13	=	87.7	May.'13	=	88.2	Jul'12	=	86.8
CPI value of output, $ billions	Jun.'13	=	2,109.8	May.'13	=	2,124.9	Apr.'13	=	2,098.1	Jun'12	=	2,035.5
CPI operating rate, %	Jul.'13	=	74.5	Jun.'13	=	74.4	May.'13	=	74.8	Jul'12	=	74.1
Producer prices, industrial chemicals (1982 = 100)	Jul.'13	=	299.6	Jun.'13	=	304.0	May.'13	=	301.7	Jul'12	=	294.8
Industrial Production in Manufacturing (2007 = 100)	Jul.'13	=	95.4	Jun.'13	=	95.5	May.'13	=	95.3	Jul'12	=	94.2
Hourly earnings index, chemical & allied products (1992 = 100)	Jul.'13	=	156.4	Jun.'13	=	156.0	May.'13	=	156.7	Jul'12	=	157.6
Productivity index, chemicals & allied products (1992 = 100)	Jul.'13	=	104.4	Jun.'13	=	104.5	May.'13	=	104.7	Jul'12	=	105.6

CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)

CPI OPERATING RATE (%)



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

CURRENT TRENDS

Preliminary data for the June 2013 *CE* Plant Cost Index (CEPCI; top; the most recent available) indicate that the composite index decreased by 0.3% from the final May value. The value for the Heat Exchangers & Tanks subindex rose slightly, while the other subindex values decreased. The June 2013 preliminary PCI index value stands at 3.5% lower than the corresponding final PCI value from June 2012. Meanwhile, the latest Current Business Indicators from IHS Global Insight (middle) once again moved in both directions, with the CPI output index edging slightly upward, while the CPI value of output decreased from the previous month. The hourly earnings index and CPI operating rate changed little. ■