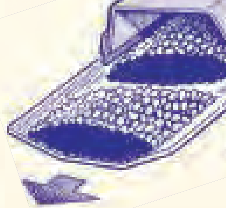
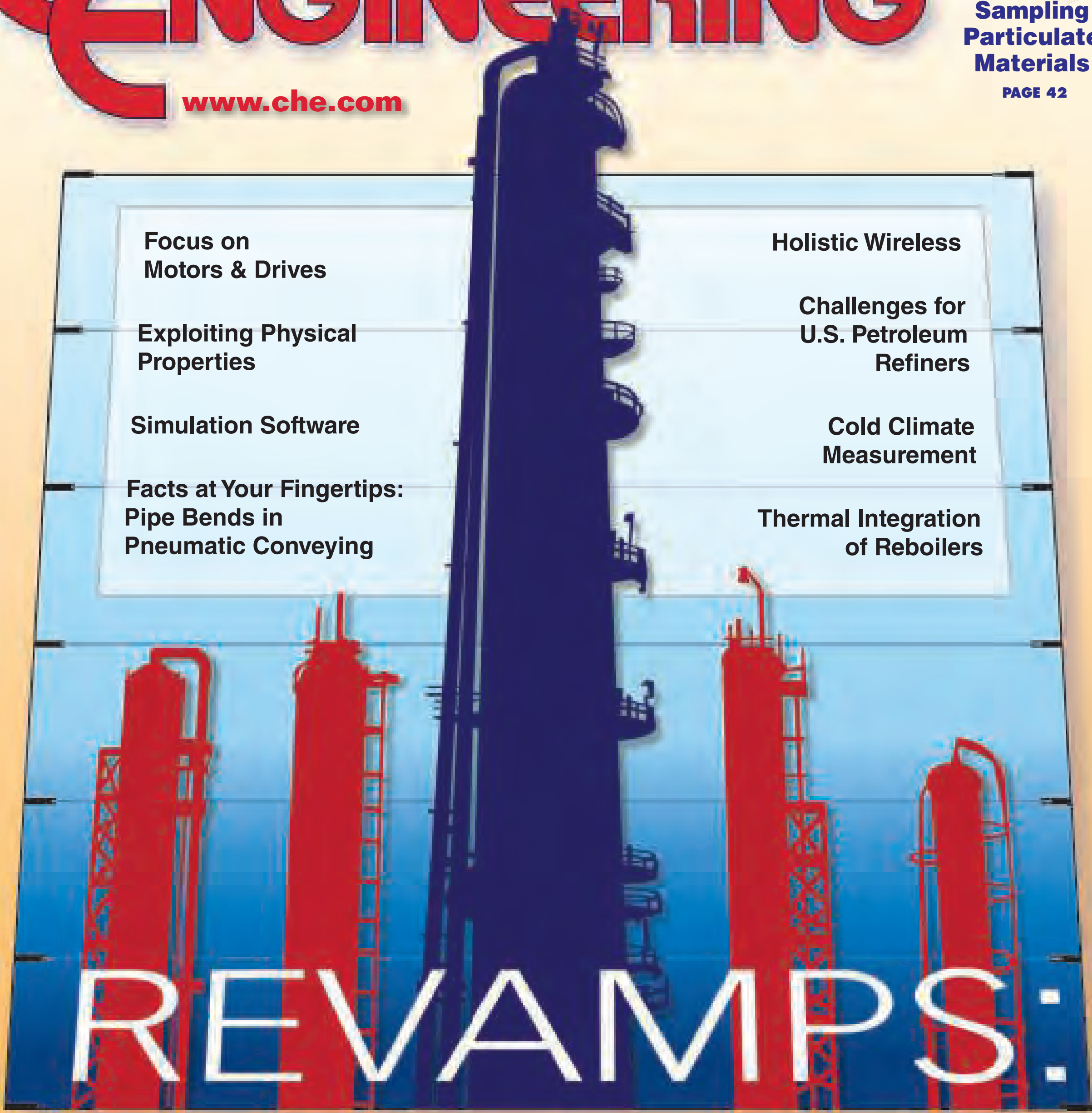
CHEMICAL ENGINEERING

April 2012

www.che.com



Sampling Particulate Materials
PAGE 42



Focus on Motors & Drives

Exploiting Physical Properties

Simulation Software

Facts at Your Fingertips: Pipe Bends in Pneumatic Conveying

Holistic Wireless

Challenges for U.S. Petroleum Refiners

Cold Climate Measurement

Thermal Integration of Reboilers

REVAMPS: Boosting Capacity

PAGE 36

Access Intelligence

Give your next pneumatic conveyor the PNEUMATI-CON® advantage:

The pneumatic conveying expertise you need for top efficiency, plus the broad process experience you need for seamless integration with your upstream and downstream equipment.

It takes more than a great pneumatic conveyor to deliver your bulk material with top efficiency. It also takes process engineering experts who know, in advance, how your process equipment, storage vessels, and material will affect your conveying results.

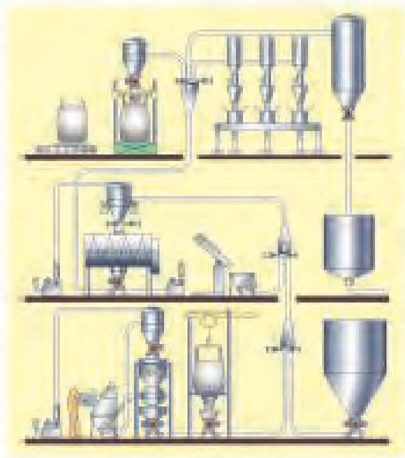
Which is why you should rely on Flexicon.

Under one roof you will find a comprehensive line of robust pneumatic conveyor components from filter receivers and rotary airlock valves to cyclone separators and blowers, and the in-depth pneumatic experience it takes to size and configure them to yield maximum efficiency, longevity and cost effectiveness.

As importantly, you will find experienced process engineers who draw on Flexicon's 15,000+ installations integrating conveyors, screeners, grinders, crushers, blenders, weigh hoppers, bulk bag unloaders/fillers, bag/drum dump stations, and/or storage vessels—experts who understand how your upstream and downstream equipment can impact, and be impacted by, the operation of your pneumatic conveyor.

Going the extra mile to outperform competitive pneumatic conveyors is what the PNEUMATI-CON® advantage is all about.

It's what enables Flexicon to guarantee top results, and you to make pivotal improvements to your process with absolute confidence.



When you convey with Flexicon, you convey with confidence™

Flexicon® .com

See the full range of fast-payback equipment at flexicon.com: Flexible Screw Conveyors, Pneumatic Conveying Systems, Bulk Bag Unloaders, Bulk Bag Conditioners, Bulk Bag Fillers, Bag Dump Stations, Drum/Box/Container Dumpers, Weigh Batching and Blending Systems, and Automated Plant-Wide Bulk Handling Systems

USA
sales@flexicon.com
1 888 FLEXICON

CHILE	+56 2 415 1286
UK	+44 (0)1227 374710
AUSTRALIA	+61 (0)7 3879 4180
SOUTH AFRICA	+27 (0)41 453 1871

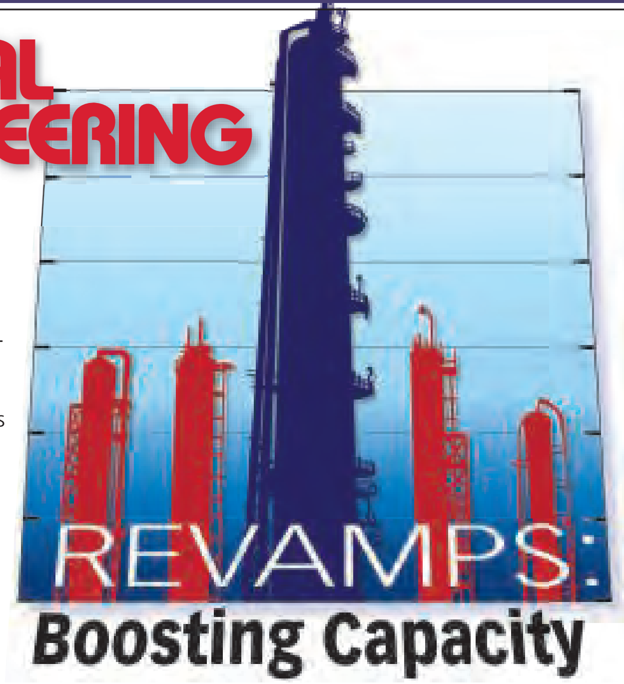
AA-0491

Circle 14 on p. 82 or go to adlinks.che.com/40266-14

Circle 24 on p. 82 or go to adlinks.che.com/40266-24

CHEMICAL ENGINEERING

www.che.com



COVER STORY

NEWS

ENGINEERING

EQUIPMENT & SERVICES

***ONLY ON CHE.COM**

- Web exclusive: Plant Perspectives
- New Products, Show Preview
- Latest news and more

COMMENTARY

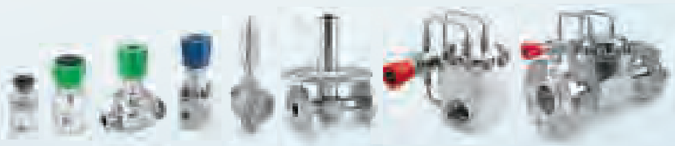
DEPARTMENTS

ADVERTISERS

COMING IN MAY

Look for: **Feature Reports** on Centrifugal Compressors for the CPI; and Water Savings; **Engineering Practice articles** on Pipe Vibration Analysis and Avoiding Problems During Distillation Tower Startup; An **Solids Processing article** on Pneumatic Conveying Systems; a **News article** on Sensors; a **Technology Showcase article** on Absorption and Adsorption; an Achema **Show Preview**; and more

Cover: David Whitcher



Winner of Eight Jesse H. Neal Awards for Editorial Excellence

CHEMICAL ENGINEERING

Published since 1902
An Access Intelligence Publication

PUBLISHER

BRIAN NESSEN
Group Publisher
bnessen@accessintel.com

EDITORS

REBEKKAH J. MARSHALL
Editor in Chief
rmarshall@che.com

DOROTHY LOZOWSKI
Managing Editor
dlozowski@che.com

GERALD ONDREY (Frankfurt)
Senior Editor
gondrey@che.com

SCOTT JENKINS
Associate Editor
sjenkins@che.com

CONTRIBUTING EDITORS

SUZANNE A. SHELLEY
sshelley@che.com

CHARLES BUTCHER (U.K.)
cbutcher@che.com

PAUL S. GRAD (Australia)
pgrad@che.com

TETSUO SATOH (Japan)
tsatoh@che.com

JOY LEPREE (New Jersey)
jlepree@che.com

GERALD PARKINSON
(California) gparkinson@che.com

INFORMATION SERVICES

CHARLES SANDS
Senior Developer
Web/business Applications Architect
csands@accessintel.com

MARKETING

JAMIE REESBY
Marketing Director
TradeFair Group, Inc.
jreesby@che.com

JENNIFER BRADY
Marketing Coordinator
TradeFair Group, Inc.
jbrady@che.com

ART & DESIGN

DAVID WHITCHER
Art Director/
Editorial Production Manager
dwhitcher@che.com

PRODUCTION

STEVE OLSON
Director of Production &
Manufacturing
solson@accessintel.com

JOHN BLAYLOCK-COOKE
Ad Production Manager
jcooke@accessintel.com

AUDIENCE DEVELOPMENT

SARAH GARWOOD
Audience Marketing Director
sgarwood@accessintel.com

GEORGE SEVERINE
Fulfillment Manager
gseverine@accessintel.com

JEN FELLING
List Sales, Statlistics (203) 778-8700
j.felling@statlistics.com

EDITORIAL ADVISORY BOARD

JOHN CARSON
Jenike & Johanson, Inc.

DAVID DICKEY
MixTech, Inc.

MUKESH DOBLE
IIT Madras, India

HENRY KISTER
Fluor Corp.

TREVOR KLETZ
Loughborough University, U.K.

GERHARD KREYSA (retired)
DECHEMA e.V.

RAM RAMACHANDRAN
(Retired) The Linde Group

HEADQUARTERS

88 Pine Street, 5th Floor, New York, NY 10005, U.S.
Tel: 212-621-4900 Fax: 212-621-4694

EUROPEAN EDITORIAL OFFICES

Zeilweg 44, D-60439 Frankfurt am Main, Germany
Tel: 49-69-9573-8296 Fax: 49-69-5700-2484

CIRCULATION REQUESTS:

Tel: 847-564-9290 Fax: 847-564-9453
Fullfillment Manager; P.O. Box 3588,
Northbrook, IL 60065-3588 email: clientservices@che.com

ADVERTISING REQUESTS: see p. 70

For photocopy or reuse requests: 800-772-3350 or info@copyright.com
For reprints: Wright's Media, 1-877-652-5295, sales@wrightsmedia.com

ACCESS INTELLIGENCE, LLC

DON PAZOUR
Chief Executive Officer

ED PINEDO
Executive Vice President
& Chief Financial Officer

MACY L. FECTO
Exec. Vice President,
Human Resources & Administration

HEATHER FARLEY
Divisional President,
Access Intelligence

ROBERT PACIOREK
Senior Vice President,
Chief Information Officer

SYLVIA SIERRA
Senior Vice President,
Corporate Audience Development

MICHAEL KRAUS
Vice President,
Production and Manufacturing

STEVE BARBER
Vice President,
Financial Planning and Internal Audit

GERALD STASKO
Vice President/Corporate Controller

Access Intelligence
4 Choke Cherry Road, Second Floor
Rockville, MD 20850 • www.accessintel.com

Editor's Page

Do challenges for an industry mean hard times for ChEs?

Given that readers of this magazine are employed across a wide spectrum of the chemical process industries (CPI), our editors go to great lengths to keep most of our content as broadly applicable as possible. In our technical articles, especially, we try to present information that focuses on unit operations, for instance, as opposed to a CPI niche, such as pharmaceutical processing or cement manufacturing. The reason for this policy is that it increases the likelihood that each reader will find more articles that appeal to him or her, whether in a current job or a future one.

Occasionally, however, our news department will focus on a significant trend affecting or coming out of one CPI segment or another. That said, there is one segment that we give attention to on a regular basis because it employs so many chemical engineers and has so much influence on the rest of the CPI. That segment is petroleum refining, which gets its annual update this month on pp. 19–22.

The headline of that story is "Challenges for U.S. Petroleum Refiners," and since part of my job is to wonder how industry trends are affecting our readers, it makes me ask myself: Do challenges for a CPI segment — even an inordinately influential one — automatically threaten the job market for chemical engineers? The answer depends on what the challenges actually are: in this case, essentially the effects of high crude-oil prices and severe increases in the prices of rare-earth metals, which are used in fluid catalytic cracking (FCC) catalysts and FCC additives. At least three U.S. petroleum refineries on the East Coast have shut down since last fall, and one more is planned for July.

The news of multiple refinery closures alone could easily lead a person to argue that, yes, challenging times for U.S. petroleum refiners means hard times for chemical engineers. Indeed, for the chemical engineers employed at the closed facilities, there surely have been (or will be) hard times. But, stopping at that conclusion would ignore some other, very significant parts of the bigger picture.

The big-picture view is related to the fact that CPI plants spend money on capital equipment when profit can be made or costs can be saved by doing so. As a general rule of thumb, plants start spending significant amounts of money on capital equipment when operating rates (in terms of percent capacity) are in the high-80s. Today, U.S. petroleum refineries are operating at around 90%. On top of that, there is a decent possibility that a new pipeline could soon be approved and built to bring more low-cost, heavy crude oil to the U.S. Gulf Coast. Either situation on its own would signal the need for expanded Gulf Coast refining capacity and the additional need for chemical engineering prowess. One can only imagine what both would mean.

In fact, chemical engineers are already in short supply in that region, partly because of the demand for them in petroleum refining. From his plant visits with engineers and plant managers in and around Baton Rouge, Louisiana, Scott Jenkins, associate editor, reports that recruiting technically trained engineers, especially those with process experience is a significant challenge (for more, see Regional Plant Perspectives at www.che.com under the heading Web Exclusives).

All in all, it would be ridiculous to say that tough challenges for an industry *never* threaten the job market, but there is one caveat that should not be forgotten. It is safe to say that without significant challenges to solve, the CPI wouldn't need *as many* chemical engineers. ■

Rebekkah Marshall

Letters

2012 CE Awards

Chemical Engineering and ChemInnovations (New Orleans, Nov. 13–15; www.cpievent.com) are issuing an industry-wide call for nominations for the 2012 awards program. Awards will complement *Chemical Engineering's* flagship award for 2012, the Personal Achievement Award (for more, see www.che.com/paAward), which has a nomination deadline of April 15.

Nominations in the following categories will be reviewed for the joint *Chemical Engineering* and ChemInnovations awards:

- Unit Operation Awards
- Innovative Energy Use Award
- "Jack of All Trades" Award
- Best Plant Improvement Award
- The Safety Award
- Plant Manager of the Year
- Top 30 Under 30
- People's Choice Awards
- Community Service Award
- Early Adopter Award

Award nominations will go through two rounds of judging. First, the ChemInnovations Advisory Committee will review nominations and rate each based on specific and measurable criteria. After receiving ratings, the nominations will go through the second round of judging to be completed by the editors of *Chemical Engineering*. If your plant is selected as an award finalist, a *Chemical Engineering* editor will contact you to develop an article that will be published in *Chemical Engineering* to inform the rest of the industry of your achievement. The award finalists will receive an invitation to the 2012 Industry Awards Banquet, scheduled to take place during the ChemInnovations event on Tuesday, November 13, 2012 at the Morial Convention Center in New Orleans, La. All winners will be announced and presented during the Industry Awards Banquet.

How to enter. Visit www.che.com/CE_CI_Awards to find out more details about the categories and instructions on submitting your entry.

Questions. Contact Cassie Davie:
CassieD@tradefairgroup.com 713-343-1891.

Postscripts, corrections

March 2012 (pp. 43–47): In the article, Distillation Optimization By Vapor Recompression, an error appeared in the print and digital magazines. The author's photo for Jayant D. Divey was incorrect. The correct photo appears in the online version of the article found at www.che.com.

Do you have —

- Ideas to air?
- Feedback about our articles?
- Comments about today's engineering practice or education?
- Job-related problems or gripes to share?

If so — Send them, for our Letters column, to
Rebekkah Marshall
Chemical Engineering, Access Intelligence,
110 William St., 11th floor
New York, NY 10038; letters@che.com

Calendar

NORTH AMERICA

Responsible Care Conference & Exhibit. American Chemistry Council (ACC; Washington, D.C.). Phone: 202-249-7000; Web: americanchemistry.com/about/meetingsconferences
Hollywood, Fla. **April 29–May 2**

103rd AOCS Annual Meeting & Expo. American Oil Chemists Soc. (AOCS; Urbana, Ill.). Phone: 217-359-2344; Web: annualmeeting.aocs.org
Long Beach, Calif. **April 29–May 2**

3rd International Conference on Stem Cell Engineering. AIChE's Society for Biological Engineering (New York, N.Y.). Phone: 646-495-1339; Web: stemcell.aiche.org
Seattle, Wash. **May 1–3**

Interphex. Reed Exhibitions (Norwalk, Conn.). Phone: 203-840-5648; Web: interphex.com
New York, N.Y. **May 1–3**

3rd Opportunity Crudes Conference. Hydrocarbon Publishing Co. (Philadelphia, Pa.). Phone: 610-408-0116; Web: opportunitycrudes.com
Houston **May 6–8**

ChemSpec USA. Quartz Business Media Ltd. (Surrey, U.K.). Phone: +44-1737-855-000; Web: chemspecevents.com/usa
Philadelphia, Pa. **May 8–9**

PTXi International/Powder and Bulk Solids International. UBM Canon (Los Angeles, Calif.). Phone: 310-455-4200; Web: canontradeshows.com
Chicago, Ill. **May 8–10**

Electric Power 2012 Conference. The TradeFair Group (Houston). Phone: 832-242-1969; Web: electricpowerexpo.com
Baltimore, Md. **May 15–17**

2012 PRB Coal Users Group Conference (co-located with The Electric Power 2012 Conference; above). The TradeFair Group (Houston). Phone: 832-242-1969; Web: electricpowerexpo.com/prb/
Baltimore, Md. **May 15–17**

Fundamentals of Shale Natural Gas. PGS Energy Training (Hilton Head, S.C.). Phone: 412-521-4737; Web: pgsenergy.com
Pittsburgh, Pa. **May 17**

2012 ACC Annual Meeting. American Chemistry Council (ACC; Washington, D.C). Phone: 202-249-7000; Web: americanchemistry.com
Colorado Springs, Colo. **June 4–6**

A&WMA 2012 Annual Conference & Expo. Air & Waste Management Assn. (Pittsburgh, Pa.). Phone: 412-232-3444 Web: awma.org
San Antonio, Tex. **June 19–22**

International Union of Pure and Applied Chemistry (IUPAC) World Polymer Congress. Virginia Polytechnic University (Blacksburg, Va.). Phone: 540-231-7832; Web: macro2012.org
Blacksburg, Va. **June 24–29**

Recycling Metals from Industrial Waste. Colorado School of Mines (Golden, Colo.). Phone: 303-279-5563; Web: mines.edu
Golden, Colo. **June 26–28**

Semicon West. SEMI (San Jose, Calif.). Phone: 408-943-6978; Web: semiconwest.org
San Francisco, Calif. **July 10–21**

EUROPE

IFAT/Ensorga. Messe München GmbH (Munich, Germany). Phone: +49-89-949-11358; Web: ifat.de
Munich, Germany **May 7–11**

ChemSpec Europe. Quartz Business Media Ltd. (Surrey, U.K.). Phone: +44-1737-855-000; Web: chemspecevents.com/europe
Barcelona, Spain **June 13–14**

Achema 2012. Dechema e.V. (Frankfurt am Main, Germany). Phone: +069-7564-277-296; Web: achema.de
Frankfurt am Main, Germany **June 18–22**

ASIA & ELSEWHERE

ChemSpec India. Quartz Business Media Ltd. (Surrey, U.K.). Phone: +44-1737-855-000; Web: chemspecevents.com/india
Mumbai, India **April 26–27**

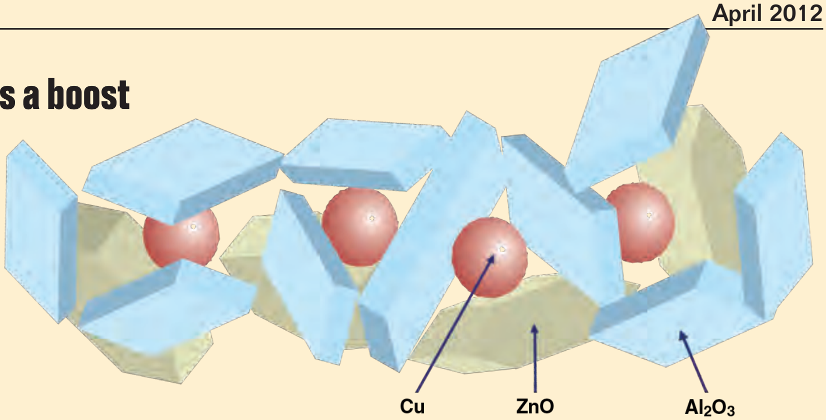
Power & Energy Kenya 2012. Expogroup Worldwide (Dubai, UAE). Phone: +971-50-4730490; Web: expomesse.com
Nairobi, Kenya **May 10–12** ■

Suzanne Shelley

Circle 28 on p. 82 or go to adlinks.che.com/40266-28

Edited by Gerald Ondrey April 2012

This new LTS catalyst delivers a boost for H_2 and NH_3 production



In conventional hydrogen and ammonia plants, the final conversion of CO to H_2 occurs across the low-temperature shift (LTS) catalyst. This makes the LTS catalyst one of the most important catalysts in the plant — even small changes in its performance will have a significant impact on operating costs, says Kristina Svennerberg, marketing manager, shift and synthesis catalysts at Haldor Topsøe A/S (Lyngby, Denmark; www.topsoe.com). Last month, Topsøe commercialized LK-853 Fence, a new generation of low-methanol LTS catalyst that delivers higher conversion rates, increased poison resistance to sulfur, low methanol formation and prolonged catalyst lifetime when compared to its predecessor, she says.

The basis for the new catalyst, explains Svennerberg, is Topsøe's Fence technology, in which finely dispersed, nano-sized particles of the active copper crystals are separated from each other by a "picket fence" of metal oxide crystals (zinc oxide and alumina). This inorganic fence reduces sintering of the copper particles during operation — a major deactivation mechanism in conventional catalysts — and thus extends the catalyst's activity. The Fence technology also leads to a larger available copper surface area for poison uptake, thereby prolonging the catalyst lifetimes, she says. The LK-853 Fence catalyst also has an optimized amount of promoter (alkali metals), which reduces methanol formation (and the associated loss of H_2) during the shift reaction.

The above benefits (and more) combine to increase production. For a 1,500 metric ton (m.t.) per day ammonia plant, for example, the higher activity, stability and sulfur capacity of LK-853 Fence will lead to increased NH_3 production compared to the benchmark catalyst. For an operating period of five years, this would add up to a production gain of around 7,000 m.t. of NH_3, which corresponds to a value of around $2.8 million, says Svennerberg. Reduced methanol formation for the same-sized plant would have a daily NH_3 production gain of 1.0–1.9 m.t. (worth about $0.6–1.3 million over five years).

Two charges of the new LK-853 Fence catalyst were installed in a North American ammonia plant and commissioned last October, and another charge for installation this spring has been ordered by the same producer.

Integrated energy-efficient design boosts aromatics production

A Samsung petrochemicals facility in South Korea will be the first to feature a suite of energy efficiency technologies developed by UOP LLC (Des Plaines, Ill., www.uop.com) for improved aromatics production.

A number of UOP aromatics-processing design features and materials will be integrated to allow the facility to reduce its energy consumption by 33%. The facility will produce 1 million m.t./yr of *para*-xylene and 500,000 m.t./yr of benzene The products will be used in the manufacture of synthetic fibers and resins, such as polyethylene terephthalate (PET).

Part of the energy efficiency gain results from a hardware design scheme that maximizes energy recovery across the unit as a whole. "We integrated the process components, such as reforming, isomerization and heavy aromatics conversion, in a way that allows us to maintain the degrees of freedom to start each sub-operation independently," says Keith Couch, UOP's senior business leader for aromatics.

Other energy savings are realized with a more efficient catalyst in the reforming reaction of naptha to BTX (benzene, toluene and xylenes), and an adsorbent material for the separation of *para*-xylene from other eight-carbon aromatic isomers. The UOP engineers developed a new adsorbent that allows 37% more capacity than its predecessors. "The higher capacity of the adsorbent lowers the energy intensity required for the separation," says Couch.

Previous incarnations of UOP's aromatics production process required 1,400 Btu/h in the years from 2004–2008. By 2009, UOP engineers had lowered the total energy required for the process to 1,150 Btu/h. The updated design being rolled out at the Samsung facility, including the integrated technologies, can operate on around 700 Btu/h of required energy, Couch says.

Biobutanol milestones

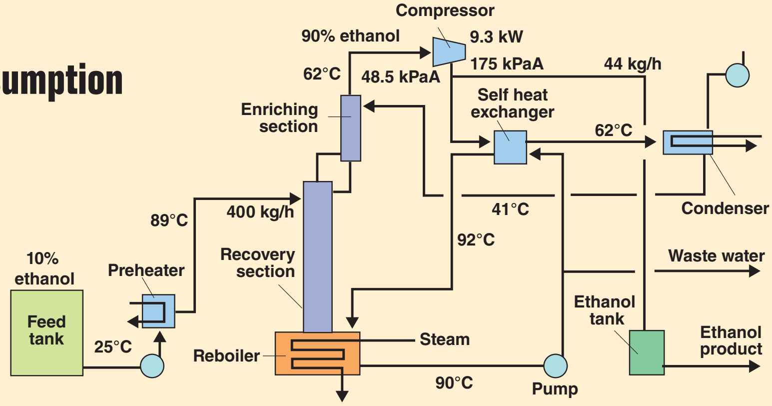
Last month, Cobalt Technologies (Cobalt; Mountain View, Calif.; www.cobalttech.com) announced two achievements toward commercial-scale production of bio-based *n*-butanol: the demonstration of its biomass pretreatment process, and the demonstration of its advanced-strain fermentation process.

In cooperation with Andritz Group (Graz, Austria; www.andritz.com), Cobalt tested its dilute acid-hydrolysis pretreatment process, the first step of Cobalt's process for converting sugars into *n*-butanol for use as a renewable chemical or fuel. Cobalt conducted the testing in the Andritz pulp-and-paper mill demonstration facility in Springfield, Ohio. Cobalt's dilute acid-hydrolysis pretreatment process, which extracts

(*Continues on p. 12*)

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

Drastically reduce energy consumption with exergy recuperation



A distillation process that consumes 85% less energy than traditional methods has been demonstrated by researchers from the University of Tokyo's Institute of Industrial Science (www.energy.iis.u-tokyo.ac.jp) and Nippon Steel Engineering (NSE, both Tokyo, www.nsc-eng.co.jp). The technique, which involves the incorporation of a compressor for self-heat recuperation (exergy recuperation), was first proposed by professor Atsushi Tsutsumi, who performed simulations of the theoretical process that predicts a decrease in energy consumption by one-fifth to one-twentieth that of conventional heating processes. The technique has potential applications for all thermal processes, including distillation, condensation, drying, reaction and separation, and could see commercialization in three to five years.

In self-heat recuperation technology, the heat of steam condensation and the cooling heat are recuperated by compression work. The vapor stream from the top of a column is compressed adiabatically to recuperate the heat of steam condensation as the vaporization heat in a self-heat exchanger.

Now, NSE has applied the self-heat-recuperation concept for the distillation of bioethanol (flowsheet), and demonstrated the theory in pilot-scale experiments. Results of the study found that self-heat recuperation reduced the energy required from 4.6 MJ/L (without recuperation) to 0.7 MJ/L of ethanol (2.3 MJ/L vapor), without affecting the performance of the distillation. The NSE engineers also confirmed that: adiabatic compression can be performed without condensing the water and ethanol vapors from the top of the distillation column; adiabatically compressed vapor is heat-exchangeable with the reboiler and that a part of compressed heat loss is transformed to process vapor; the targeted energy saving was up to 85%; and stable operation without damage to the distillation performance was observed to deliver high-quality, 90 vol.% ethanol. NSE speculates that adding a compressor increases a plant's installation cost by up to 1.5 times, but this additional investment could be recovered in 3.3 years due to a 50% reduction in fuel requirements.

Professor Tsutsumi expects the application of exergy recuperation can lead to significant energy savings in the following sectors: distillation in petrochemicals (86% energy savings), bioethanol and azeotropic distillation (88%); drying of biomass and charcoal (70%); naphtha desulfurization (75%); CO_2 separation by chemical absorption (68%); oxygen plants in iron manufacturing and integrated coal gasification combined cycle (IGCC; 40%). NSE plans to apply this self-heat recuperation technology for cellulose-based ethanol plants because distillation accounts for almost 60% of the total energy consumed in the production process. NSE is also suggesting that the development of high-temperature-tolerant compressors will extend the application possibilities for high-temperature processes.

This new PET process eliminates production steps

A new process for generating sheets of polyethylene terephthalate (PET) eliminates several production steps used in the traditional process, offering greatly reduced energy use and improved polymer properties. Developed by Octal Petrochemicals LLC FZC (Muscat, Oman; www.octal.com), the direct-to-sheet PET (DPET) process avoids the granulation, drying, reheating and extrusion steps that are components of conventional pellet-based PET sheet production.

"A key to the process is being able to control the pressure of the resin melt very precisely," says Joe Barenberg, Octal COO, "so the sheet has extremely consistent properties, and producers can use less plastic to achieve the same performance." The PET resin that directly feeds Octal's DPET sheet-making process is produced in twin Uhde Inventa-Fischer 400-ton/d Discage reactors, which are designed for continuous polymer processes. The plastic produced via the DPET process has improved properties, Barenberg notes, such as improved crack-resistance and clarity. DPET is designed as an alternative to conventionally produced PET in polyester packaging applications, especially in the food and beverage industry.

(*Continued from p. 11*)

sugars from ligno-cellulosic biomass, was validated on woody biomass, bagasse and agricultural residues. Cobalt tested its pre-treatment process on both a batch and continuous basis. These runs, while processing up to 20 ton/d of bone-dry biomass, successfully extracted sugars from the biomass without the use of enzymes to produce the desired liquid hydrolysate. These hydrolysates were successfully fermented into *n*-butanol at Cobalt's facility in Mountain View without the need for any conditioning to remove inhibitory compounds, the company says.

Meanwhile, Cobalt also demonstrated its non-GMO (genetically modified organism) biocatalyst at the Integrated Biorefinery Research Facility of the U.S. Dept. of Energy's National Renewable Energy Laboratory (Golden, Colo.; www.nrel.gov), where multiple fermentation campaigns in a 9,000-L fermenter were performed. Cobalt says it has confirmed that its process to produce renewable butanol is 40–60% less expensive than making petroleum-based butanol using the traditional oxo-alcohol process.

Making a rare terpene

Last month, Allylix Inc. (San Diego, Calif.; www.allylix.com) said it plans to produce commercial quantities of a rare terpene later this year for use in fragrance applications. Tradenamed Epivone, the synthetic epi-beta-vetivone is structurally

(*Continues on p. 14*)

This water-treatment system can aid disposal options for brine

A six-stage water treatment process involving electrocoagulation (EC) and multi-stage flash (MSF) distillation could improve options for the disposal of sludge and brine in applications that include the treatment of water from hydraulic fracturing of oil and gas wells (see also Frac Water Reuse, *Chem. Eng.*, February, pp.14–16), as well as desalination.

The first small-scale demonstration of the Clleen Frac end-to-end system, developed by Clleen Water and Power (Irving, Tex.; www.waterdesalinationplants.com), is expected to start up in May 2012 in North Dakota. A second, larger facility is planned in Pennsylvania.

"In certain shale plays, brine disposal represents the largest water-treatment costs for hydraulic fracturing operations, and can be even higher than the fresh-water costs themselves," says engineer Anthony Migyanka, developer of the Clleen water system. The Clleen system can reduce disposal costs by generating a non-toxic sludge and dry salt that can be resold. The system is appropriate for water with any level of total dissolved solids from 3,000 ppm to 300,000 ppm. The sludge can undergo a further treatment step with specialty enzymes and soil additives to form organic fertilizer.

A key component of the system is the EC step, which is based on technology from Quantum Ionics Inc., a partner of Clleen. The non-chemical EC step separates emulsified oils, organic materials and silt from the water, while killing bacteria. The EC also removes heavy metals by converting the metal ions, such as iron, into their corresponding oxides. The result is a non-toxic sludge and an oil waste stream that is recovered in a vacuum clarifier.

The system's other key technology is an MSF-distillation apparatus that is unique in the way it uses heat. "We heat the air to generate steam, rather than the water, and the hot condensate is used to raise the temperature of the feed water prior to flashing," explains Migyanka. This method requires less energy to generate a pure condensate stream and a brine stream than conventional distillation. The concentrated brine from the MSF distillation enters a crystallizer that produces a dry salt with market value.

Plastics with soy-derived protein reduce petroleum use

New biocomposite plastics that combine soybean-meal protein with conventional plastic resins allow significantly lower use of petroleum-based chemicals in polyethylene (PE) and polypropylene (PP) manufacturing. The new class of bioplastics incorporates soybean-meal protein, which is chemically bound to the PE or PP backbone and replaces between 10 and 40% of the resin in the plastics. The proprietary, single-step process does not require isolation or purification of the soybean meal. The protein unfolds and is functionalized and dispersed into the polymer.

Engineers from the research and development organization Battelle (Columbus, Ohio; www.battelle.org) de-

(*Continues on p. 14*)

(*Continued from p. 12*)

related to beta-vetivone, a key component of vetiver oil. Epivone has never been commercially available because it could not be synthesized cost-effectively, says the company. Now, using its proprietary fermentation technology platform, Allylix plans to be the first company to offer Epivone in a highly purified form.

Also last month, BASF Venture Capital GmbH (Ludwigshafen, Germany;

(*Continues on p. 16*)

This new route to PLA requires no organic solvent or metal catalyst

A process to make polylactic acid (PLA) that requires no solvent or metal catalyst has been developed by Ricoh Co. (Ricoh; Tokyo, www.ricoh.com), in cooperation with Shizuoka University. Ricoh's continuous PLA process is based on a commercially available organic catalyst (1,8-diazabicyclo[5.4.0]-7-undecene), the supercritical (SC) CO_2 technology of professor Takeshi Sako and the organic reaction technology in a SC CO_2 system by associate professor Nobuyuki Mase (both at Shizuoka University).

The combination of high-pressure (5–15 MPa) CO_2 and the organic catalyst enabled the efficient, low-cost continuous production of high-purity PLA at low temperatures (40–60°C), with reaction times of less than 15 min. In contrast, conventional batch PLA processes use a tin-based catalyst, organic solvents and operate at temperatures over 200°C, with reaction times of several hours, says Ricoh.

The Ricoh process is performed in a compact tubular reactor (10-mm I.D., 3-m length) and produces 600 g/h of PLA. The organic catalyst is easily separated after the reaction, and no residual solvent or catalyst remains in the product. The company also demonstrated that heat-resistant PLA can be produced by consecutive addition of different stereo-specific monomers, and that the technology can be used for ring opening polymerizations, such as those of ϵ-caprolactam and propylene carbonates, as well as co-polymerization with lactic acid. Ricoh is now developing highly durable, flame-resistant PLA, and plans to start collaborating with partners for a wide range of applications.

PLASTICS WITH SOY-DERIVED PROTEIN

(*Continued from p. 13*)

veloped the biocomposites, which are designed as comparably priced replacements for PE and PP in a range of applications. The company BioBent Polymers (Marysville, Ohio; www.biobent.com) is commercializing the technology through an exclusive license with Battelle. The two organizations recently received a grant from the United Soybean Board (Chesterfield, Mo.; www.unitedsoybean.org) to improve the thermal stability and optimize the thermal properties of the biocomposites.


What's your
LEVEL
of confidence?
Now featuring
reveal
wide indicator
patent pending
EXPERIENCE MATTERS. With thousands of installations across the globe in some of the world's toughest conditions and applications, Orion Instruments® proves daily that we are the leading supplier of magnetic level indication. Contact us today to find out how we can apply ORION INSTRUMENTS technology to help solve your level applications.
• CHEMICAL • Power • Military • Wastewater
• Oil & Gas Exploration & Production • Refining • Pulp & Paper
ORION INSTRUMENTS
A Magnetrol® Company
GET TOUGH
Jupiter
Magnetostrictive Level Transmitter
Atlas
Basic, high-performance MLI suitable for a variety of applications.
Aurora
Redundant MLI with integrated Guided Wave Radar level transmitter.
Scan to learn more about REVEAL™
Schedule a visit to our manufacturing facility
www.orioninstruments.com • 2105 Oak Villa Boulevard • Baton Rouge, Louisiana • 70815 • 866-55-ORION • 225-906-2343 • f: 225-906-2344
HART® is a registered trademark of the HART Communication Foundation. | FOUNDATION fieldbus™ is a trademark of Fieldbus Foundation.
Circle 21 on p. 82 or go to adlinks.che.com/40266-21
ISO 9001

Growing algae with fluegas CO_2

Construction of a 1-hectare (ha) carbon-capture and recycling "synthesizer" demonstration plant has started at Tarong Power Station near the town of Nanango in southeast Queensland, Australia. Tarong Power Station comprises four coal-fired units with a gross generating capacity of 1,400 MW. The plant — a joint initiative between MBD Energy Ltd. (Melbourne, Australia; www.mbdenergy.com) and the Queensland government-owned Stanwell Corp. — is expected to be operational later this year.

The aim of the project is to determine whether waste industrial CO_2 emissions can be recycled to produce algal biomass on a commercial scale and cut net CO_2 emissions. The project will also help determine whether algal biomass grown with the assistance of captured and recycled waste CO_2 is suitable for the production of animal feed, fertilizers and solid and liquid fuels. The plant is expected to capture 700 m.t./yr of CO_2 and produce 1 m.t./d of algal biomass.

Algal synthesis involves the injection of captured fluegases into a water growth medium contained in large, elongated plastic membranes to produce a rapid increase of algal biomass — doubling about every 24–48 h. MBD Energy says this algal biomass is grown from locally selected strains of micro algae to protect local biodiversity, and may be harvested daily.

One of the company's technologies, its Biological Algal Growth System (BAGS) allows synthesizing captured smokestack CO_2 emissions on a continuous basis. The rapid algal growth is enhanced by a constant flow of captured CO_2 (and other gases such as NOx and SOx) that are dissolved into nutrient-rich wastewater that slowly circulates through the membranes. The algal biomass is dewatered and processed according to intended end use (biofuels, nutrition or fertilizer production).

MBD Energy aims to build an algal synthesizer of about 80 ha, with a CO_2 supply of 70,000 m.t./yr of fluegas emissions, and algae production capacity of 100 m.t./d (35,000 dry m.t./yr). An even larger plant is planned, to 1,600 ha, with an algal biomass production capacity of 2,000 m.t./d (700,000 dry m.t./yr).

(*Continued from p. 14*)

www.basf-vc.de) invested \$13.5 million in Allylix, part of a \$18.2-million financing round, joined by existing investors Tate & Lyle Ventures, Avrio Ventures and Cultivian Ventures.

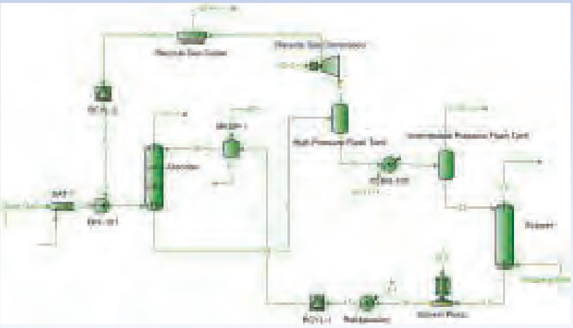
Hygienic gas bottles

Air Products and Chemicals, Inc. (Lehigh Valley, Pa.; www.airproducts.com) has launched Freshline Plus, a gas cylinder with a built-in barrier technology to drive hygiene and safety standards in the food-packaging industry. Developed specifically for use in modified-atmosphere packaging (MAP) applications, the gas cylinder has an antimicrobial coating that is designed to minimize the risk of contamination in food-processing areas. The coating inhibits the growth of microbes, bacteria and mold on the cylinder's surface.

Process Insight: *Comparing Physical Solvents for Acid Gas Removal*

Physical solvents such as DEPG, NMP, Methanol, and Propylene Carbonate are often used to treat sour gas. These physical solvents differ from chemical solvents such as ethanolamines and hot potassium carbonate in a number of ways. The regeneration of chemical solvents is achieved by the application of heat whereas physical solvents can often be stripped of impurities by simply reducing the pressure. Physical solvents tend to be favored over chemical solvents when the concentration of acid gases or other impurities is very high and the operating pressure is high. Unlike chemical solvents, physical solvents are non-corrosive, requiring only carbon steel construction. A physical solvent's capacity for absorbing acid gases increases significantly as the temperature decreases, resulting in reduced circulation rate and associated operating costs.

Typical Physical Solvent Process



DEPG (Dimethyl Ether of Polyethylene Glycol)

DEPG is a mixture of dimethyl ethers of polyethylene glycol. Solvents containing DEPG are marketed by several companies including Coastal Chemical Company (as Coastal AGR®), Dow (Selexol™), and UOP (Selexol). DEPG can be used for selective H_2S removal and can be configured to yield both a rich H_2S feed to the Claus unit as well as bulk CO_2 removal. DEPG is suitable for operation at temperatures up to 347°F (175°C). The minimum operating temperature is usually 0°F (-18°C).

MeOH (Methanol)

The most common Methanol processes for acid gas removal are the Rectisol process (by Lurgi AG) and Ifpexol® process (by Prosernat). The main application for the Rectisol process is purification of synthesis gases derived from the gasification of heavy oil and coal rather than natural gas treating applications. The two-stage Ifpexol process can be used for natural gas applications. Methanol has a relatively high vapor pressure at normal process conditions, so deep refrigeration or special recovery methods are required to prevent high solvent losses. The process usually operates between -40°F and -80°F (-40°C and -62°C).

NMP (N-Methyl-2-Pyrrolidone)

The Purisol Process uses NMP® and is marketed by Lurgi AG. The flow schemes used for this solvent are similar to those for DEPG. The process can be operated either at ambient temperature or with refrigeration down to about 5°F (-15°C). The Purisol process is particularly well suited to the purification of high-pressure, high CO_2 synthesis gas for gas turbine integrated gasification combined cycle (IGCC) systems because of the high selectivity for H_2S.

PC (Propylene Carbonate)

The Fluor Solvent process uses JEFFSOL® PC and is by Fluor Daniel, Inc. The light hydrocarbons in natural gas and hydrogen in synthesis gas are less soluble in PC than in the other solvents. PC cannot be used for selective H_2S treating because it is unstable at the high temperature required to completely strip H_2S from the rich solvent. The FLUOR Solvent process is generally limited to treating feed gases containing less than 20 ppmv; however, improved stripping with medium pressure flash gas in a vacuum stripper allows treatment to 4 ppmv for gases containing up to 200 ppmv H_2S. The operating temperature for PC is limited to a minimum of 0°F (-18°C) and a maximum of 149°F (65°C).

Gas Solubilities in Physical Solvents

All of these physical solvents are more selective for acid gas than for the main constituent of the gas. Relative solubilities of some selected gases in solvents relative to carbon dioxide are presented in the following table.

The solubility of hydrocarbons in physical solvents increases with the molecular weight of the hydrocarbon. Since heavy hydrocarbons tend to accumulate in the solvent, physical solvent processes are generally not economical for the treatment of hydrocarbon streams that contain a substantial amount of pentane-plus unless a stripping column with a reboiler is used.

Gas Component	DEPG at 25°C	PC at 25°C	NMP at 25°C	MeOH at -25°C
H_2	0.013	0.0078	0.0064	0.0054
Methane	0.066	0.038	0.072	0.051
Ethane	0.42	0.17	0.38	0.42
CO_2	1.0	1.0	1.0	1.0
Propane	1.01	0.51	1.07	2.35
n-Butane	2.37	1.75	3.48	-
COS	2.30	1.88	2.72	3.92
H_2S	8.82	3.29	10.2	7.06
n-Hexane	11.0	13.5	42.7	-
Methyl Mercaptan	22.4	27.2	34.0	-

Choosing the Best Alternative

A detailed analysis must be performed to determine the most economical choice of solvent based on the product requirements. Feed gas composition, minor components present, and limitations of the individual physical solvent processes are all important factors in the selection process. Engineers can easily investigate the available alternatives using a verified process simulator such as ProMax® which has been verified with plant operating data.

For additional information about this topic, view the technical article "A Comparison of Physical Solvents for Acid Gas Removal" at http://www.bre.com/tabid/147/Default.aspx. For more information about ProMax, contact Bryan Research & Engineering or visit www.bre.com.

Expanded certifications for industrial virtualization

Invensys Operations Management (IOM; Plano, Tex.; iom.invensys.com), a division of Invensys, has expanded its certification for virtualization technology, making its industrial automation systems the first to be certified for high availability, disaster recovery and fault tolerance in supervisory control applications using both the VMware and Microsoft Hyper-V virtualization platforms.

The traditional way to relocate or create a redundant control server requires buying new hardware to duplicate the system. Now, virtualization software can transform or "virtualize" a computer's hardware (the CPU, hard drive and network controller) to create a virtual computer that can run its own operating system and applications just like a "real" computer. By sharing hardware resources with each other, multiple operating systems can run simultaneously on a single physical computer. Eliminating the dependency between the physical hardware and software yields two important advantages for control systems: 1) cost savings; and 2) the ability to move the systems between host computers, so for example, there can be fast recovery in disaster situations.

Virtualization software is available from companies such as Microsoft and VMware. Invensys' software (ArchestrA System Platform 2012 and Wonderware InTouch 2012) are the first industrial automation systems to be certified for use with both Microsoft and VMware's virtualization software.

Maryanne Steidinger, IOM's director of product marketing says "Historically, high-availability and disaster-recovery solutions in supervisory control systems were expensive to implement, not only because of hardware and software costs, but also because of additional administrative burdens." Now, she says, the Invensys platforms are certified for disaster recovery and high availability using virtualization software from two different vendors and "All this is possible on commercial operating systems using off-the-shelf hardware, further reducing cost and easing implementation of mission-critical applications." ■

Pyrolysis demo plant

Last month, Metso Corp. (Helsinki, Finland; www.metso.com) and Fortum Power and Heat (www.fortum.com) signed a contract for the delivery of a bio-oil production plant and a related automation system to the Fortum power plant in Joensuu, Finland. Scheduled for startup in the fall of 2013, the demonstration plant will have a nominal output of 30 MW oil production, and the planned production will be 50,000 ton/yr of bio-oil. The bio-oil production plant will be integrated into a fluidized-bed boiler, in which uncondensed gases and coke will be combusted. The demonstration plant will utilize 225,000 m^3/yr of forest residue and sawdust.

The bio-oil will be produced by a fast pyrolysis process, which Metso developed in collaboration with the Technical Research Center of Finland (VTT), Fortum and UPM. The development work is based on the basic research and patents of VTT. ❏

CHALLENGES FOR U.S. PETROLEUM REFINERS

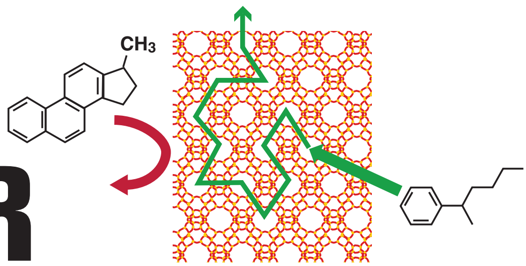


FIGURE 1a. In conventional Y-type zeolites, the pores are too small for large molecules to enter and be cracked. Also, product diesel and gasoline molecules have difficulty exiting the zeolite micropores and are prone to "over-cracking" to coke and gases before escaping

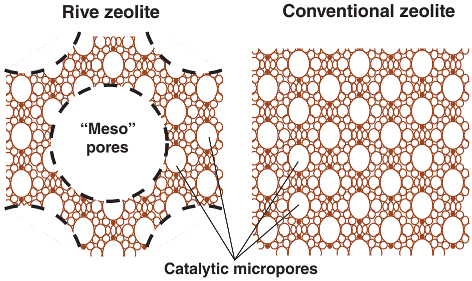


FIGURE 1b. Rive's Molecular Highway technology creates a network of larger mesopores to overcome the limitations of the small pore sizes in conventional zeolites (Figure 1a)

Future hinges on heavy oil pipelines, domestic rare-earth supply and more

The closure of several U.S. petroleum refineries over the past few months carries a simple message: petroleum refining is a tough business to be in these days. Paradoxical as it may seem to consumers, the recent rapid increase in fuel prices does not represent higher profits for refiners, which are generally operating with low margins, but is simply due to the higher cost of crude oil.

Sunoco, Inc. (Philadelphia, Pa.; www.Sunoco.com) announced its intention to exit the refining business last September and focus instead on its profitable logistics and retail businesses. The company's two refineries, with a combined crude capacity of 505,000 bbl/d, were put up for sale, but despite rigorous efforts Sunoco has found no buyers. The company stopped processing crude at its Marcus Hook (Pa.) refinery last December and plans to idle the main processing units at its Philadelphia refinery by July.

Also, ConocoPhillips (Houston; www.conocophillips.com) shut down its 185,000-bbl/d refinery in Trainer, near Philadelphia, last fall and is seeking a buyer for it. Hovensa, a joint venture between Hess Corp. (New York City; www.hess.com) and Venezuela's state-owned oil company, Petróleos de Venezuela (Caracas), closed its 350,000-bbl/d refinery in St. Croix, U.S. Virgin Islands in February. The refinery sold most of its product on the U.S. East Coast.

The biggest issue for the U.S. refining sector is a combination of poor profitability and an expected ongoing weak demand for fuels, both of which stem from high crude-oil prices, says Blake Eskew, vice president, downstream industry consulting for IHS Purvin & Gertz (Houston; www.purvingertz.com). Most of the closures are on the East Coast, he says, because this is the most competitive area in the U.S. for refiners. For one thing, the refineries were designed to handle costly light, sweet crude, and for another they have to compete with gasoline imports from Western Europe, which has a surplus of gasoline because of a growing demand for diesel fuel.

[U.S.] Gulf Coast refiners are more profitable, says Eskew, because they depend more on lower-cost heavy crude from Mexico and Venezuela. However, he notes that the production of heavy oil in Mexico and Venezuela has been dropping in recent years and continues to decline. Thus, Gulf Coast refiners, having made substantial investments in heavy-oil upgrading equipment and cokers, are having to use increasing amounts of more costly light crude.

In contrast, refiners in Midwestern and Rocky Mountain states are the most profitable in the U.S. because there is a regional surplus and growing supply of low-priced domestic crude, plus Canadian crude oil. The reason for this situation is that much of the oil is "trapped" in the region because there is a lack of transportation to move it elsewhere.

Despite its economic problems, the refining industry has been operating at roughly 90% of its approximately 17,736,000-bbl/d capacity, according to the U.S. Energy Information Administration (EIA; Washington D.C.; www.eia.gov). Also, the U.S. is becoming more and more self-sufficient in liquid fuels, due to an increased use of ethanol, higher domestic oil production, and a growing volume of biofuels and biofeedstocks that can be integrated with conventional refinery feeds. Imports as a share of total U.S. liquid fuel use fell from a high of 60% in 2005–2006 to about 50% in 2010, and are predicted to reach 36% in 2035, according to an EIA report.

Gasoline use is in a long-term decline for three basic reasons: the Federal Government's promotion of ethanol and other biofuels; a growing demand for diesel fuel, and the increasing fuel efficiency of autos. The Renewable Fuels Standard (RFS) of the U.S. Environmental Protection Agency (EPA; Washington D.C.; www.epa.gov) calls for the industry's use of ethanol to increase from 13.8 billion gal last year to 36 billion gal by 2025.

Heavy oil pipeline

Another preoccupation of refiners is a dispute that has delayed the construction of a 1,660-mile, 36-in.-dia pipeline that would bring 1.3-million bbl/d of heavy oil from Canadian oil sands from Hardisty, Alta., to the Texas coast. The pipeline, called the Keystone XL project, is of particular concern to Gulf Coast refiners because of the decline in imports of heavy oil.

The pipeline dispute came to a head in January, when President Barack Obama denied a Presidential Permit (cross-border permit) application for the project from TransCanada Corp. (Calgary, Alta.; www.transcanada.com), saying there had been insufficient time for a proper review. A major point at issue was that the pipeline route would cross the environmentally sensitive Sandhills in Nebraska.

Then, on February 27, TransCanada informed the U.S. Dept. of State that it plans to file a new application for a Presidential Permit, using a new route through Nebraska. A statement from the White House said the application would receive "the important assessment it deserves" and that the President's decision in January "in no way prejudged future applications."

At the same time, the President welcomed a TransCanada plan to build what would have been the final stretch of Keystone XL, from Cushing, Okla., to Nederland, Tex., although this project does not require a Presidential Permit. Oil production has been growing rapidly in the Midwest, as noted earlier, and the pipeline will relieve a transportation bottleneck at Cushing that has restricted the movement of "trapped" Midwestern oil to Gulf Coast refineries. Pending regulatory approvals, TransCanada expects to have the pipeline in operation by mid-to-late 2013.

However, these developments offer small comfort to Gulf Coast refiners. A spokesman for Valero Energy Corp. (San Antonio, Tex.; www.valero.com) says that while the proposed pipeline from Cushing is a positive sign, "we are looking to replace heavy oil from Mexico and South America with Canadian oil and any delay in the construction of the Keystone XL pipeline is expensive for us."

Catalysts and rare earths

Another concern to refiners has been a stratospheric increase in the prices of rare earth metals, used in fluid catalytic cracking (FCC) catalysts and in FCC additives. The increase resulted from a restriction on exports by China, which has a virtual monopoly on rare earths production. "Prices for lanthanum oxide (used in catalysts) went from $5–8/kg to as high as $140/kg last fall, and cerium oxide prices (for sulfur-control additives) got to around $175/kg," says Joe McLean, global technology manager for refining catalysts with BASF Corp.'s Catalyst Division (Iselin, N.J.; www.basf.com). More recently, he says, the prices for both materials have been "in the low thirties."

Initially, catalyst manufacturers responded by imposing a surcharge on their products to cover the cost of rare earth elements, which has fluctuated wildly from month to month. More recently, several manufacturers have come out with new FCC catalysts and additives that contain no, or a lower amount, of the metals. They include Albemarle Corp. (Baton Rouge, La.; www.albermarle.com), BASF, and Grace Davison (Columbia, Md.; www.grace.com).

Conventional FCC catalysts typically contain 1–5% lanthanum-based rare earth oxides, while SOx-control additives contain 10–15% cerium oxide, says Alan Kramer, global FCC additives specialist for Albemarle. The main function of the rare earth in an FCC catalyst is to stabilize the zeolite in the catalyst, which increases activity. In the case of additives, cerium oxidizes SO_2 to SO_3, which is adsorbed by metal oxides on the additive. The captured sulfur is released as hydrogen sulfide in the FCC riser.

In general, each catalyst manufacturer has developed several products to cover various FCC needs, but declines to identify the rare earth substitutes. Grace Davison, for example, offers five FCC catalysts and two additives under the name Replacer. The catalysts use two new zeolites and formulations and consist of two rare-earth-free catalysts and three low-rare-earth formulations, the latter for resid, heavy feed and vacuum gas oil.

In full-scale tests at Montana Refining Co.'s refinery in Great Falls, Mont. last year, Replacer catalysts maintained unit conversion with a catalyst volume similar to that of the conventional catalyst, says Rosann Schiller, Grace Davison's product manager for refining technologies. "We maintained gasoline selectivity, bottoms conversion and coke selectivity, with no loss in yield," she says.

In the meantime, Grace Davison has sold Replacer rare-earth-free catalysts to 52 refineries and has 13 users of its new additives. "Normally, refiners are hesitant to try new products," says Schiller, "but in this case market acceptance has been swift."

Albemarle produces two rare-earth-free sulfur-control additives: SoxMaster, which reduces SOx emissions from the FCC regenerator, and Scavenger, used to remove sulfur compounds from the FCC naphtha. Both consist of a hydrotalcite (magnesium-aluminum hydrate) base and proprietary, non-rare-earth catalytic metals.

As it happens, SOxMaster was not designed to get around the rare earths problem, but was developed some years ago (Scavenger came later) for use in partial-combustion FCC units, where not all the carbon monoxide is burned in the regenerator. "We wanted to avoid cerium because it promotes combustion of CO, which can lead to a buildup of coke on the catalyst," says Kramer. However, because of the rare earths situation "we have lots of refiners that have switched to SOxMaster from cerium-containing additives." Typically the addition rate for SOxMaster is higher than that of a traditional additive, he says, but the

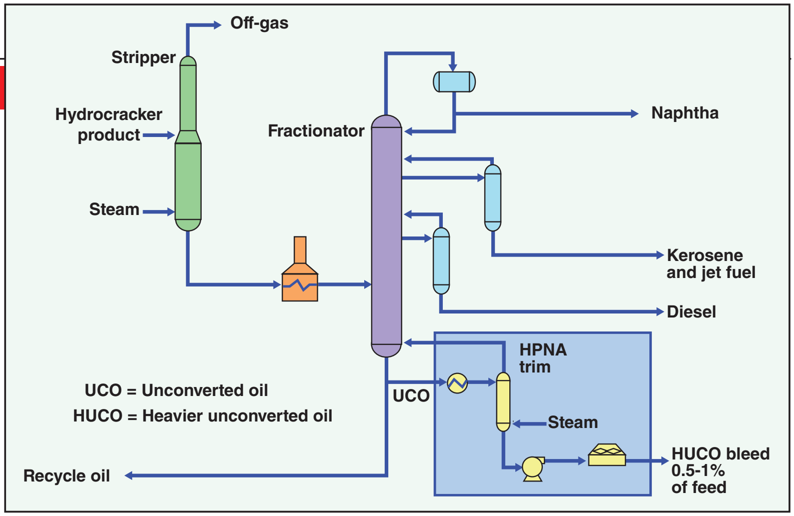


FIGURE 2. The HPNA Trim process reduces the ultimate UCO bleed by as much as 80%

cost is so much lower that it is much more cost-effective.

Meanwhile, Molycorp., Inc. (Greenwood Village, Colo.; www.molycorp.com) is ramping up production dramatically at its rare earths mine and process plant in Mountain Pass, Calif. The expansion will increase production from about 3,500 metric tons (m.t.) this year to 19,050 m.t./yr of ten rare earth materials (total U.S. consumption of rare earths is 15,000–18,000 m.t./yr).

In another catalyst development, an FCC catalyst system designed in a collaboration between Grace Davison and Rive Technology, Inc. (Monmouth Junction, N.J.; www.rivetechnology.com) has reduced undesirable bottoms production by 7% in a full-scale test at Country Mark's 27,000-bbl/d refinery in Mount Vernon, Ind. The improved conversion rate amounts to a profit improvement of $0.72/bbl, says Larry Dight, Rive's senior vice president for research and development.

The catalyst system integrates Rive's "molecular highway" zeolite technology (Figure 1) with Grace Davison's knowhow in zeolite manufacturing and catalyst formulation. The "highways" consist of a tunable percentage of interconnected mesopores of about 40 Å dia. These mesopores allow the cracking of large molecules that are too large to enter the standard micropores of <10 Å that make up the bulk of the zeolite. They also permit the passage of large product molecules of gasoline or light cycle oil that might otherwise be trapped and overcracked in the micropores.

Dight says the partners have now developed a more robust and less expensive manufacturing process and have produced a "substantial quantity" of the catalyst in preparation for a second test in a different refinery this fall, prior to commercialization. The catalyst will likely cost more than a standard catalyst, he says, but this will be more than offset by the increased performance.

Hydrocracking

An undesirable side reaction of hydrocracking, used to obtain middle distillate fuels from heavy vacuum-gas oils, is the production of heavy polynuclear aromatics (HPNAs), which build up in the unconverted recycle oil stream and can deactivate the catalyst and foul cold heat-exchanger surfaces. Normally, the buildup is controlled by purging 2–5 vol.% of the unconverted oil (UCO) stream, says Mike Hunter, a principal engineer with Haldor Topsoe, Inc. (Orange, Calif.; www.topsoe.com). The company has developed a method that reduces the ultimate UCO bleed by as much as 80%.

The process, called HPNA Trim (Figure 2), takes a normal bleed stream, but feeds it to the top of a small, packed stripper column (see diagram). Steam is injected into the bottom of the column and strips out the lighter portion of the UCO, which is returned to the bottom of the hydrocracker's main fractionation tower. The heavier portion of the UCO stream, containing the HPNAs, is recovered from the bottom of the stripper column. Hunter says the process is being offered commercially, with an estimated payback time of four to seven months.

Two hydrocracking processes that had for long been considered uneconomical prior to today's high oil prices are now being commercialized. One is the Veba Combi Cracker (VCC) process, offered by KBR (Houston; www.kbr.com) in collaboration with BP (London; www.bp.com), and the other is a slurry hydrocracking process from UOP LLC (Des Plaines, Ill.; www.uop.com).

VCC had been more or less in waiting for nearly 60 years — it was used in Germany to produce liquid fuel from coal during the Second World War, then to upgrade heavy oil residue (resid) in the 1950s. BP acquired the technology in 2001 and has since improved it.

Now, KBR has contracts for three plants, one to be built for TAIF Group (Kazan, Russia) and two plants for Yangchang Petroleum Group (Beijing, China). The Russian plant is scheduled to go onstream in 2015 and will convert 50,000 bbl/d of vacuum residue into naphtha and diesel fuel. The Chinese plants, each of about 10,000 bbl/d, are set for startup in 2013 and 2014. One will produce diesel fuel from coal tar (from a coking plant), and the other will make diesel fuel from a mixture of refinery vacuum resid and pulverized coal.

VCC has two stages. First, feed is slurried with a proprietary additive in a slurry phase reactor at 200 bar and more than 400°C, then it is hydrotreated. The second stage employs a combination of standard nickel-molybdenum and zeolite catalysts in a fixed bed. John Derbyshire, president of KBR Technology, says the process achieves better than 95% conversion of heavy oil, and the naphtha and diesel products require no further downstream processing.

UOP's process, called Uniflex, will be commercialized by National Refinery Ltd. (Karachi, Pakistan). When the facility goes onstream in 2016 it will produce 40,000 bbl/d of diesel fuel and 4,500 bbl/d of lube base oils.

Uniflex is an upgraded version of technology acquired years ago from Natural Resources Canada (Canmet; Ottawa). Heavy oil or vacuum resid is slurried with fine particles of a base metal catalyst and fed into the bottom of an upflow reactor. Hydrogen reacts with the feed at 1,800–2,000 psig and 800–880°F, converting about 90% of the oil to distillate and naphtha. ■

Gerald Parkinson

Circle 19 on p. 82 or go to adlinks.che.com/40266-19

Newsfront

TAKING A HOLISTIC APPROACH TO WIRELESS

Wireless technology is not just for instrumentation anymore. Smart processors rely on a blend of technology as they move toward plant-wide installations

Emerson Process Management

FIGURE 1. The CSI 9420 Wireless Vibration Transmitter connects economically to any machine. It delivers vibration information over a highly reliable, self-organizing wireless network for use by operations and maintenance personnel

Phoenix Contact

FIGURE 2. WirelessHart makes the HART protocol more usable, flexible and cost-effective. The WirelessHart gateway (left) can connect up to 250 WirelessHart field devices and convert HART data to Modbus TCP for easy integration into a host system. A WirelessHart adapter (foreground right) connects an existing wired HART device into a WirelessHart network for more flexible field connections

While some initially worried that the lack of a single wireless instrumentation standard — currently WirelessHart and ISA 100 both exist — would deter end users from embracing any wireless technology, it seems that's not the case. "The benefits of wireless technology are too great to ignore," says Hesh Kagan, senior consultant with Invensys Portfolio Group (Foxboro, Mass.). "The cost of wireless instruments and implementing a wireless solution are not that big, but the benefits of these solutions can be huge and often provide an ROI [return on investment] in four or five months in many applications." For this reason, many chemical processors started slowly employing wireless in applications that could give a leg up to their processes, such as temperature measurements or tank level. "They simply are not using the lack of a single standard as an excuse or barrier to acceptance for fear that if they don't take advantage of this low cost form of measurement, their competitors will."

Plant-wide wireless network

As a matter of fact, wireless instruments and technologies, and the related benefits, have gone over so well and proven to be reliable, robust and secure enough that many processors who started with point-by-point wireless trials are methodically working toward large-scale adoption. "Many chemical processors are interested in employing full wireless coverage across an entire site because it allows them to add devices wherever and whenever they need to without having to create a new infrastructure for each point they want to measure or monitor," explains Lara Kauchak, director of wireless sales and marketing with Emerson Process Management (Austin, Tex.).

Steven Toteda, vice president and general manager for the wireless business unit with Cooper Bussmann (St. Louis, Mo.) agrees. "What began as setting up a device with an antenna on it that shot a signal across the air to another device with an antenna on it, quickly developed into wireless mesh networking," he explains. Via wireless mesh-networking technology, the sensors themselves can send signals from where the reading is taken along to the next sensor and then the next across the plant until it reaches its destination. He says this capability has created a digital overlay of the plant, which allows processors to drop a sensor anywhere and have it connect into the network, creating an overall deployment of wireless.

Ray Rogowski, director of marketing for Honeywell's (Morristown, N.J.) HPS wireless programs says having an existing wireless network in place and dropping in devices as needed provides a significant cost savings over adding point-by-point applications each time a need arises. "A big advantage here is that once the infrastructure exists, there are minimal incremental costs to expand when compared to continually adding applications on a point basis," he says. "If you just put in one sensor network, you will eventually want or need to put in another one someplace. Eventually you will want Wi-Fi or wireless security and then you will have to continue to invest and reinvest in multiple networks versus investing in one plant-wide network that can handle incremental applications. The value here is lower cost."

Surprisingly, though, Kauchak says cost savings aren't the only reason processors are interested in plant-wide wireless networks. "We honestly thought the cost savings was going to be the impetus to 'go wireless,' but what we learned is that while it's still very important, the speed of deployment and low manpower requirement is often the biggest attraction."

"It is so much faster to place a sensor or instrument into a wireless network. It requires less engineering, less installation, fewer contractors onsite and minimal disruption to workflow," she says. "That's what is driving wireless today."

The ability to "drop" in devices is also inviting opportunities to go wireless for more than simple process measurements. For instance, Kauchak says more diagnostics are being taken wirelessly than would have been possible in the wired world. "Things like vibration monitoring or acoustic monitoring of steam traps where wired wasn't an alternative are now being done wirelessly, which makes it easier to view your whole system," she explains.

Cooper Bussmann

FIGURE 3. Capable of operating as a data concentrator, the Elpro 315-WH-DC offers node-to-node deterministic mesh network repeatability to further range, coupled with multiple channel spacing options to increase network scalability of HART-based networks. Modbus server capability allows seamless integration into legacy systems that do not support HART protocol

Another area getting a lot of attention is in the realm of security, safety and emergency response. "Chemical processors are being hit really hard with mandates centered around safety and security," says Sarah Prinster, vice president of marketing with Apprion (Mountain View, Calif.). "There are a lot of vendors out there with wireless speakers, cameras and strobes, which are required for physical and perimeter security and safety purposes. When you have a wireless network in place, it's very easy to purchase these devices and simply drop them into the network."

She adds that there are mandates

Invensys

FIGURE 4. The SmartGlance mobile application from Invensys Operations Management gives fast access to manufacturing management information and displays it on Apple iPad; Apple iPhone, Blackberry or other handheld devices

regarding emergency response and mustering if there is an event in the plant. By having security devices and alarms wirelessly connected, you can be notified immediately if an event causes an alarm, see via the cameras if the area is occupied, use handheld mobile devices to track the locations of employees to determine who is in the area and who is not, provide mustering instructions via speakers or handhelds and know who has reached the destination and who is still missing. "The wireless umbrella is helping to solve huge safety issues at a low cost," she explains. "It requires a few applications and a good wireless umbrella to make it super seamless and easy to meet security and safety mandates."

A blended approach

While the ability to track process components, safety, security and numerous other applications via wireless technology has obvious speed, efficiency, operational, safety and cost benefits, there still remains the issue of how to tie it all together in a useful, easy-to-access manner. "It's getting to the point where it's less about the wireless devices and technology itself and more about what to do with the information being brought in by these devices," says Rogowski. "The focus now is on taking all that information and providing a way to get it to a dashboard viewed by workers and operators so they can make better, more informed decisions."

Jeremy Bryant, manager of communications and identification business with Siemens (Alpharetta, Ga.), says this should be done using a combined technology method. "As standards get developed, we will start to see users blend a variety of different technologies," he says. For example, wireless instrumentation will be used to obtain data from the equipment, another component will process that information and then a different technology, such as Wi-Fi, may be used to move it along the backbone (an industry term for getting data from the middle component to the control system) and perhaps an entirely different technology will be used to sort the information in this central location and send it to the appropriate destination.

Typically, says Justin Shade, wireless product marketing specialist, with Phoenix Contact (Middletown, Pa.), wireless devices such as measurement instrumentation or cameras (often, Siemens

FIGURE 5. The Siemens Industry Automation division has developed a package of coordinated industry-compatible components for wireless communication complying with the WLAN (Wireless LAN) standard IEEE 802.11n. The new range consists of the access points Scalance W786 and W788, the client module Scalance W748 and the IWLAN controller Scalance WLC711. The main advantage of the components is the data rate of up to 450 MB/s

existing wired devices may be made wireless through the use of a wireless adapter) are joined to a gateway product, which has both a wireless device radio (this could be either Wireless Hart or ISA based, depending on the instrument and technology being used) and Wi-Fi or another networking protocol built into one housing. The information from all the wireless devices joined to that gateway enters and is managed by the gateway. At the same time, the gateway provides a Wi-Fi point or other networking protocol and uses that to wirelessly link and send the harvested information to an access point, such as a PLC or other control system, the IT infrastructure, plant historian or wherever the user wants the information.

In plant-wide installations, it is not uncommon to have hundreds of gateways, each of which may have dozens of wireless devices associated with it, all sending information to the single, centralized access point. The gathered data from all the wireless devices and gateways are then organized and firewalled to the appropriate person or department. The information is usually presented on a dashboard that provides key views and data. Via these dashboards, maintenance people would see key measurements for asset management, operators would see process data, safety and security people would see data related to their needs, and so on.

Because there is currently no standard on how to integrate all these systems and get the information sorted onto appropriate dashboards, some users prefer to go with one company that can handle all their networking needs from control system down to instrumentation. Others do not wish to be locked into one technology (either ISA 100 or Wireless Hart) or one company, so they opt to pick and choose which instruments and applications they want and use a gateway that can support either or both technology platforms, as well as their control system.

"Users need to keep in mind that it doesn't have to be all one technology or one network. You have to look at it from the perspective of different technologies having different advantages and serving different purposes," says Rogowski. "The important thing is that the network is expandable for the future so it can support updates and be used holistically throughout the plant for any additional applications or security needs as they arise. And it's also crucial to find a way to manage all the data that is coming into the network and get it to the people who need to see each pocket of data. It's not just the applications, it's what you do with the information provided by those applications that counts." ■

Joy LePree

POLYSILICON PLANT MEETS PROJECT DEADLINE, IMPROVES OPERATIONAL EFFICIENCY VIA BLENDED TECHNOLOGY APPROACH

Woongjin Polysilicon manufactures polysilicon, the base material for solar batteries. Construction at the South Korean plant began in 2008 and had a goal of a two-year start date in order to maintain its jump on the competition.

The major challenge the company faced was getting its plant up and running in a very short timeframe, so it was necessary to find a technology partner to provide not only control solutions, but to do so within the manufacturer's aggressive schedule. The partner also had to be well versed in Foundation Fieldbus since the company wished to employ this technology.

Woongjin selected Honeywell based on its blended variety of solutions and the ability to address the startup and commissioning schedule needed. The solution included the following:

- Three Experion PKS R311 Systems
- Eleven EPKS Console Stations
- Two Safety Managers
- One Process Historian Document (PHD)
- Sixteen C300 Controllers with Series C-I/O
- Ninety-five Foundation Fieldbus Interface Modules
- 165 Fieldbus Temperature Multiplexers
- One FDM Server
- One Digital Video Manager (DVM) Server with sixteen CCTV cameras
- Thirteen Wireless Mobile Stations
- Six Large Wall Screens for graphic and camera monitoring

Through a blended process-network design, Woongjin was provided with a secure and high-performance network environment. Some of the highlights of this installation included the OneWireless mobile station solution instead of field operator stations. Using the mobile station, operators are able to monitor process operations anywhere in the work environment, allowing Woongjin to save the installation and maintenance costs of an installed field station and improve the flexibility and efficiency of its operators.

Polysilicon CVD reactor sequences also presented a challenge, but a best performance and optimized sequence was developed that provided operators with the ability to operate multiple reactors while increasing efficiency. A stable integration solution for peer-to-peer communications was provided by a Peer Control Data Interface (PCDI) that enabled secure third-party communications.

The integration of CCTV with a DVM solution was another unique technology approach. The CCTV, along with the field sensors, connect to the control systems, which transfer alarms to the EPKS system and can help trigger pre-defined actions.

The benefits of a blended approach using these technologies in conjunction with Foundation Fieldbus were many, according to Joo Taek Lim, electrical and instrumentation team leader with Woongjin Polysilicon. The Foundation Fieldbus technology permitted the change of instrumentation life from analog to digital and provided the ability to centrally check instrument status. Personnel can be more efficient and operate more reactors simultaneously with fewer trips to the field. And, an advanced control system allows personnel to operate more reactors than initially planned or expected. ❒

Acid gas absorption expert

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

I will bet that many readers are familiar with a Teddy Roosevelt quote that includes the following: "It is not the critic who counts…the credit belongs to the man who is actually in the arena..." Ralph Weiland has been in the arena for many years, doing chemical engineering work that has benefitted many people. At the Spring AIChE meeting this month (Houston; April 1–5), the Distillation and Absorption Group will be honoring Ralph's myriad contributions to the profession.

Along with his former colleague, Ross Taylor, of Clarkson University, Weiland has been one of the world's foremost advocates of rate-based modeling and simulation of multi-stage separation processes. This approach is particularly advantageous in acid-gas-absorption and regeneration columns, where McCabe-Thiele type constructions and conventional computer simulations often show that the number of equilibrium stages required is very small, and not a whole number — such as 1.7 or 2.3 equilibrium stages.

Ralph Weiland regards mass and heat transfer rate-based modeling as one of his life-long hobbies. One of his other hobbies is acid gas absorption. Weiland, and Nate Hatcher, recently authored a book entitled, "Advanced Gas Treating: The Engineering Science." As a former Union Carbide acid-gas absorption expert, I feel sufficiently well qualified to say that their book is one of the three best all-time acid gas books, along with the Robert Maddox and Giovanni Astarita books. The Weiland/Hatcher book is particularly well-timed considering the attention that carbon capture and sequestration is receiving globally and the recent industry focus on shale gas. The book leans toward amine solvents, including blends and additives. The chemistries of physical absorption, chemical absorption, regeneration and heat-stable salt effects are well covered. Along with his former Ph.D. students Chakravarty and Phukan, Ralph was one of the very first engineers to propose the use of blended or promoted amines. Also in the acid-gas absorption realm, at the 2009 Laurence Reid Gas Conditioning Conference, he explained how the spray regime on trays could be used to promote the selective absorption of H_2S over CO_2. Weiland has presented annually at that conference for the past seven years.

Weiland has also contributed to the world of conventional distillation. He has authored articles on cocurrent flow trays, especially Ultra-Frac trays from Koch-Glitsch LP. While working at Koch-Glitsch, Weiland and his colleagues converted a 6-ft-dia. industrial depropanizer into a tray-and-packing test column. At a 2001 AIChE meeting, he explained why dual-flow trays are inherently unstable with low efficiencies. He is the only modeler I know who tackled mass transfer efficiencies on two-liquid extractive distillation trays. He is also a glycol dehydration and sour water stripping expert.

Besides mass transfer rate-based modeling, acid gas absorption and distillation, Weiland has experimented with developing a theoretical approach to catalyst self poisoning, especially the deactivation of enzymes. He has at least two other hobbies that I know about. He sails on Lake Texoma. He raises cattle. During his spare time, he sleeps — a full eight hours per day. ■

Mike Resetarits
resetarits@fri.org

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Pipe Bends in Dilute-phase Pneumatic Conveying

Pneumatic conveying of solid material provides advantages over mechanical conveying systems in many applications, including those that require complex routing, multiple source-destination combinations and product containment. Routing of pneumatic piping offers process operators great layout flexibility, but taking advantage of such design flexibility requires a strong understanding of the complex behavior of pneumatically conveyed solids in bends, such as elbows and sweeps, between straight sections.

Bends are likely the least understood components of a dilute-phase pneumatic conveying system, and can present problems for process operators. If not properly selected and designed, bends in a pneumatic conveying system can experience line-plugging, excessive product attrition (degradation), unacceptably high bend wear and higher-than-expected pressure drop. Bend wear and material attrition commonly occur at the impact zones.

Research findings on solids flow through bends are often inconsistent, and do not match field experience in some cases. Even generalizing the findings for basic pipe bends is difficult, since most data still reside with vendors, and understanding the physics of more innovative pipe-bend designs can be more complex.

Bend designs

Basic long-radius bends are the most commonly used by designers of pneumatic conveying systems, because they provide the most gradual change in direction for solids, and because the angle of impact on the pipe wall is relatively small, which helps to minimize the risk of attrition or erosion.

Common-radius bends. Common-radius bends (Figures 1 and 2) are made by bending standard tubes or pipes. The radius of curvature R_B may range from 1 to 24 times the tube diameter. Common-radius bends can be loosely classified as follows: Elbow (R_B/D = 1 to 2.5); Short radius R_B/D = 3 to 7; Long-radius (R_B/D = 8 to 14; Long sweep (R_B/D = 15 to 24).

Common fittings. The most commonly used fitting for a change in flow direction is a blind-tee bend (see Figure 3). In this design, the path is blocked in the straight direction, and open at a 90-deg angle to the original path. The benefit of this design is that an accumulated pocket of material cushions the impact of the incoming material, so the potential for wear and for product attrition is reduced. The disadvantage to blind-tee designs is that the conveyed solids lose most of their momentum upon impact, so they must be reaccelerated downstream of the bend. Pressure drops across a blind tee can be three times as much as that for a long-radius bend.

Special bend designs. A variety of specialized bend designs are available to control flow within the bend, in order to minimize attrition and wear. This is often achieved by creating a self-cleaning or replenishing pocket or layer of material upon which the incoming stream lands. Wear inside the piping is minimized by redirecting the gas-solid suspension away from typical wear points.

Evaluating bend performance

A number of key metrics can be used to evaluate bend performance in a pneumatic conveying system.

LEGEND FOR FIGURES 1 AND 2

Ricocheting Pattern (dotted line)
Sliding Pattern (solid line)

D = Pipe diameter
R_B = Bend radius

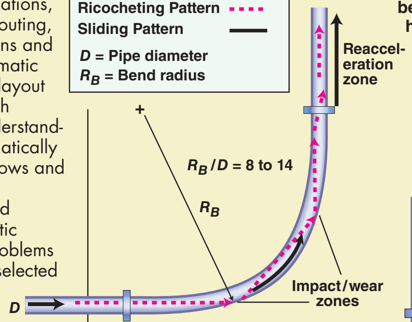


FIGURE 1. Flow in a standard, long-radius bend is illustrated here, with typical flow patterns, wear points and reacceleration zone shown

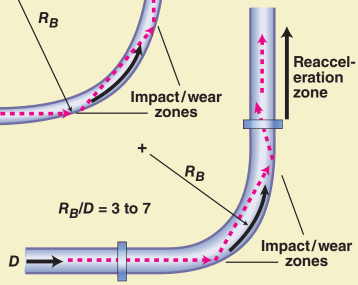


FIGURE 2. Flow in a standard, short-radius bend shows typical flow patterns, wear points and reacceleration zone

Pressure drop related to bend. The pressure drop in a bend depends on the ratio of bend radius to pipe diameter (R_B/D), the gas velocity (U_g) and the internal roughness (k) of the pipe. When a two-phase, gas-solid suspension undergoes a directional change, as in a bend, the bend naturally acts as a segregator of the two phases. Centrifugal forces act on the particles, concentrating them near the outer wall of the bend. Depending on material properties, solids loading, gas velocity and pipe-wall interactions, the particles may have multiple impacts within the body of the bend. Pressure drop in a bend is attributable to the combination of frictional loss in the bend itself plus the energy required to reaccelerate the solids back to the steady-state velocity. Friction coefficients within the bend will be different than that in the adjacent straight section.

When particles impact pipe walls, energy is transferred to the point of impact. Depending on the comparative strength of particle and pipe-wall materials, either the particle will be damaged or the pipe wears out.

Attrition or product degradation. Defined as the formation of unwanted species in the conveyed material, attrition can manifest itself in a number of ways, including a change in the distribution of particle size and shape, surface abrasion of particles, undesirable loss of surface coating, degradation of product due to impact heating, and others. Generation of fines can impact downstream processing, such as by increased caking tendency.

Bend wear. The major factors associated with erosion in bends are as follows: bend geometry, orientation, flow pattern inside bend, material of construction, particle hardness, shape and size. Bend geometry and pipe orientation affect the number and location of particle impact zones, while the flow pattern inside the bend determines the penetration rate and uniformity of wear (Figure 4). Pipe erosion rate is directly proportional to particle hardness and inversely proportional to the hardness of the bend material. The specific

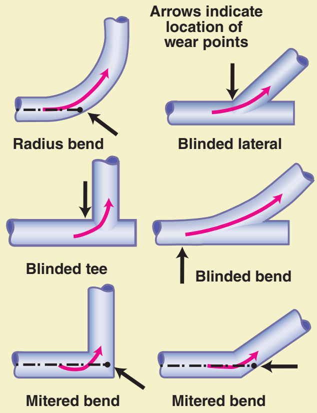


FIGURE 3. Several variations of common fittings are shown here, with typical wear points highlighted

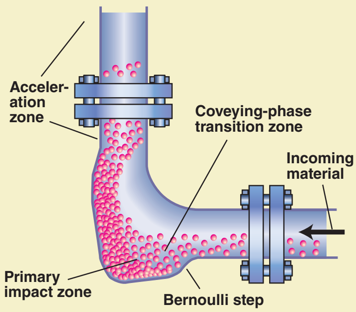


FIGURE 4. Some bend geometries allow the formation of a pocket of material at the primary impact zone, helping to minimize attrition and erosion

erosion rate increases with particle size until critical value, after which the rate does not change. Angular particles increase erosion rate, and smaller particle size hastens bend failure from penetration. In addition, erosion rate is a strong function of gas velocity.

Key concepts

The following concepts should be considered when designing and installing pneumatic conveying systems with bends:

- Bends located toward the end of the conveying system will experience higher gas and particle velocities than those closer to the pickup location
- The increase in gas velocity from pickup to destination is greater with a vacuum system than a pressure system
- Minimize the number of bends in a transfer system, and avoid back-to-back bends, if possible
- Consider directional changes earlier in the layout, if possible
- Misaligned bends will increase attrition and wear
- Install critical bends such that they can be easily serviced

References

1. Dhodapkar, S., Solt, P. and Klinzing, G. Understanding bends in pneumatic conveying systems. *Chem. Eng.*, April 2009, pp. 53–60.

WHO'S WHO


Cassidy


Nguer


Gutjahr


Doornbos


Hammer

Robert Gulotty becomes technical manager for **Applied Catalysts** (Doraville, Ga.), a developer of catalysts for chemical processing and pollution-abatement applications.

Kevin Cassidy is named chemical and monitoring solutions general manager, water and process technologies, for **GE Power & Water** (Trevose, Pa.).

Momar Nguer is now senior vice president, Africa/Middle East, at the Total Supply & Marketing subsidiary of oil-and-gas company **Total S.A.** (Paris). The company's Board appoints *Gérard Lamarche* as director.

Tobias Gutjahr becomes marketing director **Procentec GmbH** (Karlsruhe, Germany), a provider of products, services and training focusing on Profibus and Profinet.

Richard Doornbos retires as CEO of **Hemlock Semiconductor Group** (Hemlock, Mich.), which is owned by Dow Corning, Shin-Etsu Handotai and Mitsubishi Materials Corp.

Intelligrated (Cincinnati, Ohio), a provider of automated material-handling solutions, names *Howard Hammer* sales manager for the southern operations team, based in Alpharetta, Ga.

Flowserve (Dallas, Tex.), a provider of flow-control products, promotes *Thomas Pajonas* to chief operating officer. *Thomas Ferguson*, senior vice president and president of the company's Flow Solutions Group, will retire at the end of 2012. ■

Suzanne Shelley

Process Technology for Industry
PTXi international
INTERNATIONAL
Powder & Bulk Solids

Piab

Cardinal Scale Manufacturing

Admix

Kuriyama of America

Pawling Engineered Products

The PTXi / Powder and Bulk Solids Exhibition and Conference will take place from May 8–10 at the Donald E. Stephens Convention Center in Rosemont, Ill.

The conference is organized into four tracks: pneumatic conveying; material storage and handling; particle technology; and dust collection and safety. The pneumatic conveying track will cover dilute- versus dense-phase conveying, as well as system design, troubleshooting, scaling up and components. In the material storage and handling track, flow fundamentals will be covered, including design details of silos, conveyers, chutes and feeders. The particle technology track will focus on sizing, drying, agglomeration, segregation, mixing and characterization, while the dust track will target dust capture, filter selection, duct layout, safety and environmental standards and explosion implications.

For the first time, the conference will include Tech Innovations Sessions, which are interactive conference modules showcasing new powder- and bulk-solid-related technology. Participants will be able to watch live technology demonstrations and learn how the leading-edge technologies may help their operations.

Over 300 exhibitors will feature products on the tradeshow floor. Descriptions of some of them follow; others can be found online at www.che.com.

This weight indicator is designed for harsh environments

The 190 Storm digital weight indicator (photo) is built for extreme-use applications in the chemical, pharmaceutical and food-processing industries. Its IP69K-rated polycarbonate enclosure can withstand high-temperature, high-pressure washdowns. The 190 Storm features capacitive touch keys, highly visible LCD digits and a RS232 communications port. It can be powered by a.c., d.c or by a rechargeable battery. Booth 2649 — *Cardinal Scale Manufacturing Co., Webb City, Mo.*
www.cardinalscale.com

Prevent static buildup with this hose

The Voltbuster (photo) is a material-handling hose with an innovative design that dissipates static to ground, helping to prevent static buildup and thus reducing the potential for dangerous electrostatic discharges when transferring powders, pellets or granular materials. The hose is constructed with abrasion-resistant, food-grade polyurethane. The grounding wire is encapsulated in a rigid helix on the exterior of the hose, eliminating the risk of contamination for transferred materials. Booth 2411 — *Kuriyama of America, Inc., Schaumburg, Ill.*
www.kuriyama.com

This inflatable seal has built-in antimicrobial properties

The AMS Series silicone seal material (photo) has antimicrobial properties, and is designed for applications where inhibiting microbial contamination is critical, such as pharmaceuticals, medical products and sterilizer seals. The material is available in this company's standard inflatable profile, but the silicone seal can be customized to suit any inflatable or compression-sealing application. Internal tests have shown that the material maintains its integrity after two million cycles of standard sealing conditions, the company says. Booth 1360 — *Pawling Engineered Products Inc., Pawling, N.Y.*
www.pawlingep.com

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

Electro-Sensors


Kason

Pelletron


Tiger-Vac

Add dry ingredients ergonomically with this unit
The Fastfeed Powder Induction and Dispersion system (photo, p. 33) is designed to help operators avoid injuries as they add dry ingredients to vessels. The system offers consistent powder delivery even at high solids levels and high viscosity, ensuring that the system does not plug or foul. Controlled powder feed rates from 3 to 400 lb/min are available, and the system can handle viscosities up to 2,500 cP and solids levels up to 78%. Booth 2803 — *Admix Inc., Manchester, N.H.*
www.admix.com

This vacuum conveyor is easy to use
The piFlow-I (photo, p. 33) is an easy-to-use vacuum conveyor that maintains top technical performance. It is designed with a full opening, making it possible to maximize material throughput and production. The piFlow-I design makes it possible to double the conveying capacity for many materials, making it a cost-effective alternative to mechanical conveying equipment, the company says. The piFlow is ATEX dust classified, and equipped with this company's COAX cartridges. Booth 1906 — *Piab AB, Taby, Sweden*
www.piab.com

Design changes in this dust removal device increase efficiency
The RC DeDuster (photo) features a proven electromagnetic coil for breaking the electrostatic charges between plastic pellets and small dust particles. And design changes introduced recently improve the efficiency of dust removal, the company says. For example, an adjustable inlet funnel distributes product evenly to the central conical wash deck and provides smooth flow. The wash air is provided by a high-efficiency fan that removes dust and streamers. The unit can clean up to 600 lb/h of pellets, depending on the bulk density. The newly updated design maintains the low height of previous related models, and is suitable for cleaning all kinds of granular products, plastic pellets, regrind, dry food, minerals and others. Booth 3725 — *Pelletron Corp., Lancaster, Pa.*
www.pelletroncorp.com

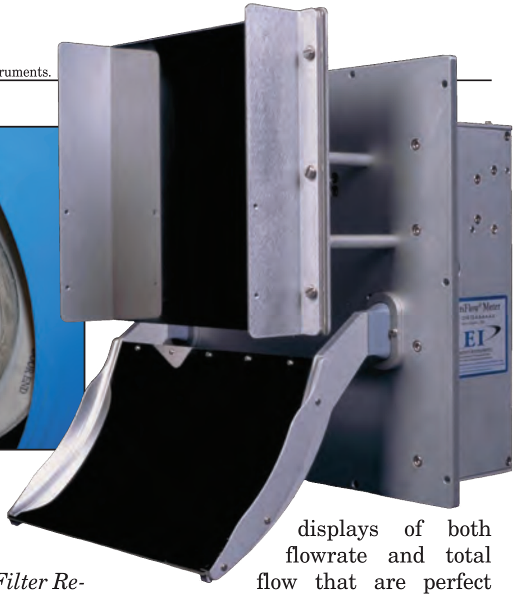
Separation using vibratory screening and airflow
The Vibro-Air Size/Density Separator (photo) employs vibratory screening to remove undersize particles, and airflow to simultaneously remove low bulk-density materials. The equipment is suitable for separating fines and chaff from grain products, strands and film scrap from plastic pellets, saw dust from wood chips and other undersize and low bulk-density material from on-size products. Material is fed through a port on the unit's hood, and cascades over a series of strategically placed internal trays, onto a vibrating, fine mesh screen that moves on-size particles outward. Simultaneously, air flows upward, drawing balance of the low-density material into a cyclone or dust collector. This company will also feature an insulated, quick-clean centrifugal screener on the show floor. Booth 1224 — *Kason Corp., Millburn, N.J.*
www.kason.com

Get feedback for valve position with this monitor
The SG1000A Slide Gate Monitor (photo) provides independent feedback of slide-gate or valve position to an external device, such as a PLC or a slide-gate display. With a rugged, explosion-proof cast-aluminum housing, the device is dirt-, dust-, grease- and waterproof. Easy to install and calibrate, the SG1000A is said to offer ruggedness and versatility not found in alternative valve and gate monitors. The company

Arizona Instrument

TDC Filter and Midwesco Filter Resources

Eastern Instruments.



offers an optional display that decodes the signal from the monitor and shows the percentage open between zero (fully closed) and 100 (fully open), allowing the gate to be more accurately positioned. Booth 2731 — *Electro-Sensors Inc., Minnetonka, Minn.*
www.electro-sensors.com

Safely recover combustible dusts with this vacuum

The SS-35L EX HEPA (photo, p. 34), single-venturi vacuum cleaner is specifically designed to safely recover combustible and conductive dusts. The unit is constructed of stainless steel, and is pneumatically operated. It features a detachable, 9-gal recovery tank, and has a four-wheeled cart that can dissipate static buildup. The vacuum includes either a HEPA (high-efficiency particulate air) filter or a ULPA (ultra-low particulate air) filter. The filter and chamber can be washed with water and mild detergents. Booth 2702 — *Tiger-Vac Inc., Dania, Fla.*
www.tiger-vac.com

Convert oval-shaped dust collectors to round with this kit

The O-kit (photo) is a retrofit kit for oval-shaped dust collector cartridge filters. The kit is said to be easy to install, and allows you to use this company's cost-effective standard cylindrical cartridge filters, leaving the oval-shaped dust collector in tact. The O-kit will be exhibited alongside the Rust-Grip corrosion coating, which is made by the sister company of the O-kit manufacturer. Rust-Grip encapsulates rust, corrosion, lead-based paint, asbestos and bio-hazardous materials. The product can be used to address the most severe corrosion issues in the harshest industrial environments. It serves as effective insulation on boilers, ducts, pipes and baghouses. Booth 2502 — *TDC Filter and Midwesco Filter Resources Inc., Bolinbrook, Ill.*
www.tdcfilter.com
www.midwesco.com

Grind materials to sizes as small as 10 µm with this mill

The PolarFit ultrafine grinding mill is a unique technology for reducing hard-to-grind materials to smaller particle sizes than can be achieved with conventional impact mills. The PolarFit grinding system can generate consistent yields of particles between 45 and 240 µm, and in some cases, as small as 10 µm. The mill uses a combination of size-reduction mechanisms, including impact, attrition and particle-particle collisions to achieve smaller particle sizes than alternate technologies. PolarFit is ideal for cryogenic reduction of a wide range of materials, including pigments, plastics, powder coatings, thermoplastic elastomers, waxes, pharmaceuticals, food products and others, the company says. Booth 2845 — *Air Products Inc., Allentown, Pa.*
www.airproducts.com

Accurate metering and control with these mass flowmeters

The CentriFlow solid-particle mass flowmeter (photo) can accurately measure a variety of bulk solids continuously in a process, and will typically offer an accuracy of within ±0.25% of full scale. A related product, the CentriFeeder, combines the patented flow measurement technology and can accurately measure and control the flow of any granular, free-flowing solids. Both instruments utilize large, color, touch-screen HMIs that feature easy, push-button calibration and real-time displays of both flowrate and total flow that are perfect for a variety of applications, including batching, blending, ratio control, bag filling, multiple-product-recipe blending and more. Booth 2702 — *Eastern Instruments Inc., Wilmington, N.C.*
www.easterninstruments.com

A device for fast, accurate moisture sensing

This company's Computrac line (photo) of moisture analyzers is designed to produce fast, accurate and repeatable results during a manufacturing process. They are precise enough for laboratory use, but durable enough for production use. The company's rapid loss-on-drying and relative-humidity sensor technology provides a more desirable method of moisture measurement compared to Karl Fischer titration. This company offers free trials, customer support and free method development over the lifetime of the instrument. Booth 2445 — *Arizona Instrument LLC, Chandler, Ariz.*
www.azic.com

Features on this level sensor make it failsafe

The SafePoint rotary-paddle level sensor has a self-validating design that monitors its own ability to fuction while detecting material in bins and silos. The self-analysis features, which include sensor health and system power failure, make the unit failsafe, the company says. The Safepoint also has a collapsible, two-vane, paddle that can be inserted from the outside of a bin or silo through a 1.25-in. coupling. Booth 2407 — *Monitor Technologies LLC, Elburn, Ill.*
www.monitortech.com ■

Scott Jenkins

Revamping Your Process Plant

An overview of some options to consider for increasing capacities

Siddhartha Mukherjee
Air Liquide Engineering and Construction, Lurgi India

When a process plant is set up, an owner has several things in mind; the market demand for his product and hence the plant capacity, the plant cost, the space availability, space for future expansion and so on. Once a plant has been built, there is equipment that has additional design margins. For example, columns and pumps are specified with 10% margins. Control valves are specified with approximately a 20% margin. Heat exchangers are also designed with about a 10% margin on the surface area.

In addition, there are sometimes differences between what is specified and what is finally procured. A 5–10% design margin on area is a standard practice for heat exchangers. However, depending on standard tube diameters available, standard shell diameters per project standards and standard tube lengths per client standards, we might end up designing exchangers with even higher design margins. The point to emphasize here is that there are margins available in various equipment beyond what is required to run the plant at 100% load.

It is these margins that are utilized when a client decides to revamp his plant for capacity augmentation. It is here that we study what margins are available and where the bottlenecks are. Debottlenecking a process plant begins with a process study that involves evaluating the plant in its entirety and identifying the obstacles that come in the way of an increase in the capacity. It could be a restricted pipe size that could come in the way of a required increased flow, or a heat exchanger where the surface area falls short of the required, future heat-load requirements. It could be a column, where increased vapor-liquid traffic leads to an unacceptable pressure drop. It could be a control valve, which even at full open condition, allows only a portion of the intended flow. In most cases, it is a combination of some or all of these factors.

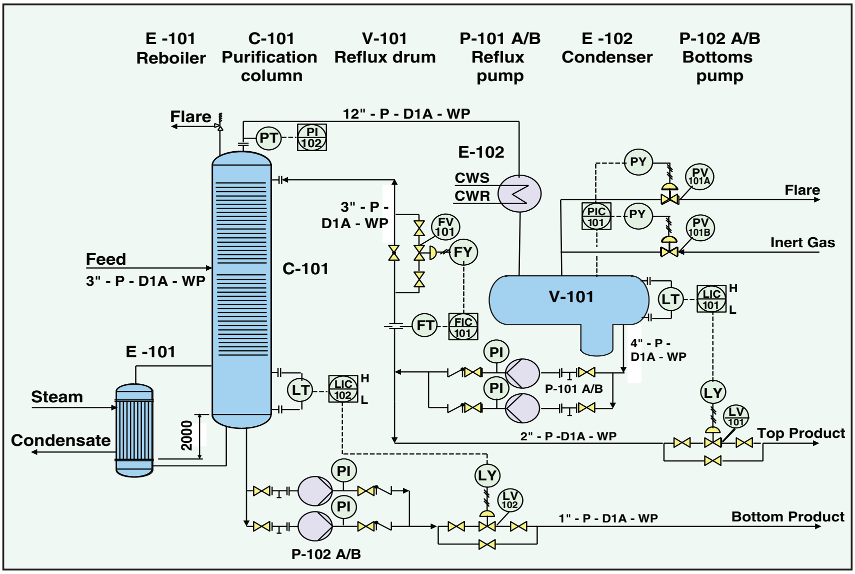


FIGURE 1. Shown here is the piping and instrumentation diagram for the example distillation process discussed in the text

Freezing the design basis

This article presents the example of a typical distillation column in a process complex. The column splits an impure hydrocarbon cut into a pure top product and a bottom heavy product. The column is associated with the overhead condenser, the reflux drum and pumps, the reboiler, associated piping and instrumentation. The piping and instrumentation diagram (P&ID) for this example is shown in Figure 1.

The owner now wishes to expand the capacity by 40%. There is not enough space in the existing plant to add new equipment trains. It is therefore envisaged to minimize the addition of new equipment, keeping in mind cost considerations. The owner desires to maximize debottlenecking options in existing equipment to achieve the desired capacity. Further, all utility conditions, such as steam and cooling water, will remain unchanged.

With this as the background, we will consider the equipment one by one and identify debottlenecking options. The piping and instrumentation will also be looked into for possible bottlenecks. We will also consider other debottlenecking options outside this P&ID.

The column

We take the case of the distillation column C-101 in the above plant. The column has two sections, namely, Trays 1–20 and 21–40 (see the tray data

NOMENCLATURE

- A Required effective discharge area of valve, in.^{2}
- c_p Heat capacity at constant pressure, J/kg-K
- c_v Heat capacity at constant volume, J/kg-K
- C Coefficient determined from an expression of the ratio of the specific heats [5]
- k heat capacity ratio, c_p/c_v
- K_b Capacity correction factor due to back pressure [5]
- K_d Effective coefficient of discharge = 0.975 [5]
- K_c Combination correction factor for installations with a rupture disc upstream of the pressure relief valve
- Q Flowrate, gpm
- G Specific gravity relative to water
- M Molecular weight of the gas or vapor
- ΔP Pressure drop across valve, psi
- P_1 Upstream relieving pressure, psia
- T Relieving temperature, °R
- W Required flow through the valve, lb/h
- Z Compressibility factor at relieving conditions

TABLE 1. TRAY GEOMETRY AND HYDRAULICS

01	Item		C - 101									
02	Designation		Final distillation column									
03	**Case No.**		1a		1b		1c		1d		1e	
04	Case		Original traffic		Revamp traffic		Revamp traffic		Revamp traffic		Revamp traffic	
05	Tray geometry		Original geometry		Original geometry		Original geometry		Original geometry		New geometry	
06							More valves		New valves		New valves	
07	Column section number		1		1		1		1		1	
08	Tray section		1 – 20		1 – 20		1 – 20		1 – 20		1 – 20	
09	Type of tray		Floating valves		Floating valves		Floating valves		Proprietary valves		Proprietary valves	
10	Percentage load	%	50	110	50	110	50	110	50	110	50	110
11	Vapor to tray	kg/h	15,866	34,908	22,212	48,871	22,212	48,871	22,212	48,871	22,212	48,871
12	Density	kg/m^3	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
13	Vapor viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	Liquid from tray	kg/h	11,957	26,309	16,740	36,833	16,740	36,833	16,740	36,833	16,740	36,833
15	Density	kg/m^3	770	770	770	770	770	770	770	770	770	770
16	Surface tension	N/m	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2
17	Liquid viscosity	cP	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
18												
19	Column diameter	mm	1,600		1,600		1,600		1,600		1,600	
20	Tray spacing	mm	500		500		500		500		500	
21	Tray passes		1		1		1		1		1	
22	Active area	m^2	1.61		1.61		1.61		1.61		1.68	
23	Flow path length	mm	1,100		1,100		1,100		1,100		1,160	
24	Downcomer chord height top/bottom	mm	250/250		250/250		250/250		250/250		200/200	
25	Number of valves	mm	160		160		225		175		195	
26	Downcomer clearance	mm	40		40		40		40		40	
27	Exit weir height	mm	45		45		45		45		45	
28	Weir load	m^3/h·m	13.4	29.4	18.7	41.2	18.7	41.2	18.7	41.2	19.7	43.4
29	Downcomer backup liquid	mm	90	135	98	195	101	155	82	145	84	137
30	Downcomer flood	%	13	29	18	42	18	42	18	42	22	50
31	Jet flood percent	%	22	50	32	69	32	69	31	68	30	66
32	Dry tray pressure drop (per tray)	mm liq.	21.9	58.6	24.2	113.2	21.9	59.1	14.8	71.6	12	58
33	Total tray pressure drop (per tray)	mm liq.	55.4	93.3	59.6	146.8	60	100.2	42.7	95.2	42.8	83.1
34	Total tray pressure drop (all trays)	kg/cm^2	0.085	0.144	0.092	0.226	0.092	0.154	0.066	0.147	0.066	0.128
35	Alloweable tray pressure drop (all trays)	kg/cm^2		0.15		0.15		0.15		0.15		0.15

sheet in Table 1). We will consider here the tray section 1–20 for our study. Consider Case 1a for this section with the existing vapor-liquid traffic and the existing tray geometry. The column diameter is 1,600 mm with a tray spacing of 500 mm. The existing trays are fitted with 160 floating valves. The allowable pressure drop across the whole column is 0.3 kg/cm^2. The allowable pressure drop across each section is 0.15 kg/cm^2.

Since it is proposed to increase the capacity of this plant by 40%, the vapor-liquid traffic in this column would also increase by approximately 40%. The column diameter cannot be increased, because this would mean procuring a new column. So what is the solution?

Now, consider revamp Case 1b. Here, the increased vapor-liquid traffic has first been tried with the same column diameter and same tray geometry. It can be seen that while the other parameters (namely jet flood, downcomer flood and downcomer backup) are within reasonable limits, the pressure drop at 110% load is 0.226 kg/cm^2 which exceeds the allowable limit of 0.15 kg/cm^2.

We now try with increased number of valves in the tray. Let us try with 225 valves instead of the existing 160 (Case 1c of Table 1). We still find that while the jet flood, downcomer flood and the downcomer backup are within reasonable limits, the pressure drop at 110% load has reduced to 0.154 kg/cm^2 but is still greater than the limit of 0.15 kg/cm^2.

We now try with special valves that are more expensive, but give low pressure drops (Case 1d of Table 1). We take 175 of these valves per tray. We now find that all parameters are within acceptable limits. The pressure drop is 0.147 kg/cm^2.

Consider an academic case where even after going for the low-pressure-drop valves it was not possible to get the pressure drops to within limits. One available option would be to further increase the number of these valves per tray. However the tray active area does not permit increasing the number of valves beyond a limit. In such a case, there is a way to increase the tray active area by reducing the downcomer width and without having to weld new bolting bars for new downcomers. There are adapters available that can be fitted to the old bolting bars [*1*]. The new downcomers can then be bolted to these adapters (Figure 2). The trays would now be in a position to accommodate a higher number of valves, since they now have a larger active area. Case 1e shows such a situation where the active area has increased from 1.61 m^2 to 1.68 m^2, the number of valves increased from 175 to 195 and the pressure drop has decreased from 0.147 to 0.128 kg/cm^2.

Heat exchangers

Modifications in heat exchangers have a more limited scope than in columns where we can go for a host of changes in the internals to suit the hydraulics. For floating head exchangers some modifications are possible, while in fixed tube-sheet exchangers options are further limited. Following are some of the feasible modifications in a revamp scenario:

Changing from series to parallel operation. Consider a heat exchanger train having four exchanger shells in series. Under the revamp scenario of 1.4 times the throughput, the pressure drop across the train would increase more than two fold. The configuration could be suitably altered to two shells in series and two shells in parallel. This will lead to a reduced pressure drop and provide scope for a higher throughput [*2*].

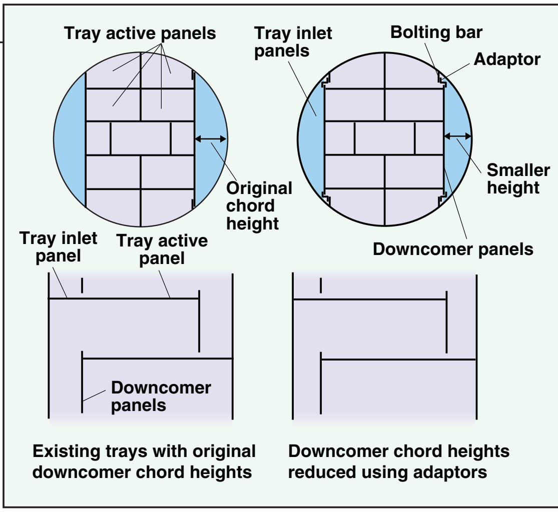


FIGURE 2. Adjusting downcomer chord heights with adapters increases the active area

Replacing tube bundles. To save costs, instead of replacing the entire heat exchanger, sometimes only the tube bundle, with improved baffle designs can be replaced. In this option, the piping and foundation are left unaltered. Such options are useful when handling fluids with low shell-side heat-transfer coefficients [*2*]. The idea is to increase the overall heat transfer coefficient, thus resulting in a larger heat duty for the revamp case with the existing exchanger surface area.

Tube side modifications. Such changes are carried out when handling fluids with low tube-side heat-transfer coefficients. The industry today has come out with various types of tube designs that create turbulence in tubes, thus reducing the film resistance and increasing the tube-side heat-transfer coefficients. In this option too, the piping and foundation are left unaltered.

Interchange of shell- and tube-side fluids. Changing a more viscous fluid from tube side to shell side is effective in a revamp scenario since it leads to higher turbulence and therefore a higher heat-transfer coefficient [*2*].

For scale-up factors within the range of 1.1 to 1.3, such tube bundle or tube side modifications could be useful. However, for a larger capacity increase, parallel heat exchangers (or in case of space constraints), new exchangers would need to be installed.

Pumps

Two types of changes are required in pumps during plant revamps, namely the flow and the head. Let us take the case of the revamp under consideration. Consider the reflux pump P-101 for the distillation column. The existing pump has the following specifications:

Rated flow:	48 m^3/h
Head:	73 m
Liquid density:	770 kg/m^3
Liquid viscosity:	0.28 cP

Consider the pump characteristic curves shown in Figure 3. With the existing pump the above specifications are met with an impeller diameter of 200 mm.

While doing a revamp, several options are possible. The easiest option would be to go for a higher diameter impeller. In this way, both the increase in flow as well as head are met. However, in such cases while we save the pump, we may need to go for the motor of the next higher rating in case the increase in power requirement is substantial. Therefore, ideally one should aim at replacing only the impeller while keeping the motor and pump unchanged.

While increase in the flow requirement is inevitable in revamp activities, it may be worth trying to minimize the increase in the head requirement of pumps in order to avoid unnecessary increases in power consumption. In order to do so, we need to decrease the frictional losses. Frictional losses in pipes in typical process plants are hardly of the order of 0.10–0.15 kg/cm^2. Hence, unless pipes in the existing plant are on the upper end of allowable velocities, pipes can normally take higher flows with acceptable in-

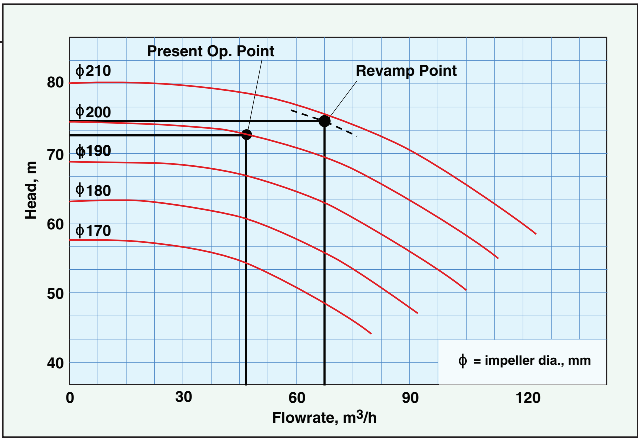


FIGURE 3. This pump characteristic curve shows the original pump and that considered in the revamp

TABLE 2. VALVE CHARACTERISTICS

Flow Characteristic	Valve Size	Valve Opening, % of Stroke Range									
		10	20	30	40	50	60	70	80	90	100
Equal Percentage	in.	C_v									
	1	0.35	0.5	0.7	1.1	1.9	3.6	5.6	7.5	9.1	10
	1 1/2	0.74	1.1	1.5	2.3	4	7.6	12	16	19	22
	2	1.9	2.7	3.8	6	10	20	31	41	48	54
	3	3.3	4.7	6.6	11	18	35	54	72	84	95
	4	5.9	8.5	12	18	32	61	96	128	153	175
	6	13	18	25	40	68	130	203	271	324	360

creases in frictional losses. This leaves us with losses across control valves. The existing reflux pump P-101 has two routes, namely the product route to battery limit, and the reflux route to Tray No. 1 of the column. The second route happens to be the controlling route (that is, this route has the higher resistance and hence determines the pump differential head). The prospect of decreasing the allowable pressure drop across the control valve FV-101 was examined. It was found that in the existing unit, an allowable pressure drop of 1.0 kg/cm^2 across the valve was specified. It could still be brought down to 0.85 kg/cm^2 in the revamp. With all the above, we arrive at the revamp conditions of the pump.

Under the revamp conditions, the pump has the following specifications:

Rated flow:	67 m^3/h
Head:	75 m
Liquid density:	770 kg/m^3
Liquid viscosity:	0.28 cP

The flow has increased by 40%. The head has increased marginally. The other parameters have remained unchanged.

Referring back to Figure 3 again, we find that the revamp figures of flow and head can be met with an impeller of diameter of 208 mm. Hence we need to procure a standard impeller of 210-mm dia. and get it trimmed to 208 mm.

Control valves

Consider the control valve on the reflux line, that is, FV-101 in Figure 1. For the existing plant, the control valve parameters are as follows :

Maximum flow: 37 m^3/h (162.9 gpm)
Minimum flow: 17 m^3/h (74.8 gpm)
Pressure drop at maximum flow:
1.0 kg/cm^2 (14.22 psi)
Pressure drop at minimum flow:
1.7 kg/cm^2 (24.17 psi)
Specific gravity relative to water: 0.77

The C_v of a control valve in liquid service is defined as the number of gallons of water that would pass through a valve with a 1-lb/in.^{2} pressure drop, and is given by the following equation [3]:

$$C_v = Q\sqrt{\frac{G}{\Delta P}} \qquad (1)$$

At maximum flow, C_v =
162.9(0.77/14.22)$^{1/2}$ = 37.9
At minimum flow, C_v =
74.8(0.77/24.17)$^{1/2}$ = 13.4

The existing valve has a C_v of 54 and a size of 2 in. It has an opening of 77% of stroke range at maximum flow and 53% at minimum flow (see Table 2, which is a typical chart similar to those supplied by manufacturers).

Now consider the following specifications of the same control valve under revamp conditions :

Maximum flow: 52 m^3/h (229.0 gpm)
Minimum Flow: 24 m^3/h (105.7 gpm)
Pressure drop at maximum flow:
0.7 kg/cm^2 (9.95 psi)
Pressure drop at minimum flow:
1.5 kg/cm^2 (21.33 psi)
Specific gravity relative to water: 0.77

Note that while the flow has increased, a reduced pressure drop across the control valve has been specified in order to minimize the increase in pump head.

At maximum flow, C_v =
229.0(0.77/9.95)$^{1/2}$ = 63.7
At minimum flow, C_v =
105.7(0.77/21.33)$^{1/2}$ = 20.08

At a C_v of 63.7 (at maximum flow), the existing 2-in. control valve will not be adequate since its rated C_v is 54. Hence we need to go for the next higher size valve, which is 3 in. (see Table 2).

For a 3-in. valve, with a rated C_v of 95, the openings shall be 75% at maximum flow and 51% at minimum flow. (In normal practice, we operate control valves between 10 and 80% of stroke range). In other words, we need to replace the existing 2-in. valve with a new 3-in. valve.

Pressure relief valves

Like all other equipment in a plant, elements of the pressure relief system also need to be evaluated for bottlenecks. The safety equipment generally consist of pressure relief valves, and in some cases, rupture discs.

Consider the pressure relief valve mounted on C-101 in the plant under discussion (Figure 1). The size of a relief valve is determined by its orifice size, which in turn gives the inlet and outlet flange sizes of the relief valve. API 526 provides details of various standard orifice sizes of relief valves as well as the inlet and outlet flange sizes [4].

Per the present rating, the parameters for this relief valve in the existing plant are as follows:

Required relieving rate:
23,000 kg/h (50,706 lb/h)

Molecular weight: 78

Compressibility factor: 0.90
Set pressure: 5.9 kg/cm^2g (6.9 kg/cm^2a)
Relieving pressure: 6.5 kg/cm^2g (7.5 kg/cm^2a, or 106.65 psia)
Relieving temperature: 60°C (600°R)
c_p/c_v: 1.1
Back pressure: 1.0 kg/cm^2, g

The existing relief valve has an orifice size of 4.34 $in.^2$.

According to API 526 [4], it is called an "N" orifice. For a 150# rating piping on inlet and outlet, the nozzles sizes are 4 and 6 in., respectively.

Under the revamp scenario, we have the following process condition:

Required relieving rate: 34,000 kg/h (74,956 lb/h)

All other process parameters remain unchanged.

Now, for pressure relief valves, the effective orifice area for gas or vapor at critical flow condition is given by the following equations (API 520 [5]):

$$A = \frac{W}{CK_dP_1K_bK_c} \cdot \sqrt{\frac{TZ}{M}} \quad (2)$$

Where

$$C = 520\sqrt{k \cdot \left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \quad (3)$$

or, for this case (k = 1.1), C = 326.

The ratio of back pressure to set pressure is less than 30%, hence K_b = 1.0. K_d = 0.975 (when the pressure relief valve is installed with or without a rupture disk in combination, as per API 520 [5]). And since there is no rupture disc, K_c = 1.0 (also per API 520 [5]).

The required effective orifice area of the relief valve of this example is calculated as follows:

A = 74,956/(326×0.975×106.65×1.0) $(600\times0.90/78)^{1/2}$
= 5.81 $in.^2$

According to API 526 [4], the next standard orifice is 6.38 $in.^2$. It is called a "P" orifice. For 150# rating piping on inlet and outlet, the nozzle sizes would still be 4 and 6 in., respectively. (see API 526 for details regarding orifice sizes and types.) Therefore, we will have to procure a new relief valve with a "P" type orifice for the revamp.

1	2	3	4			5		
Sl No	Pump	Parameter	Existing pump characteristics			Revamp pump characteristics		
						(flow unchanged, higher head)		
			max.	normal	min.	max.	normal	min.
1a	P-201	flow m^3/h	53.6	42.8	17.12	53.6	42.8	17.12
		head m	58	64	67	75	83	86
		density kg/m^3	896	896	896	896	896	896
1b	P-201	flow m^3/h	53.6	42.8	17.12	53.6	42.8	17.12
		head m	58	64	67	75	83	86
		density kg/m^3	896	896	896	896	896	896
2	P-202	flow m^3/h	43.7	36.4	15	43.7	36.4	15
		head m	467	470	480	488	488	512
		density kg/m^3	702	702	702	702	702	702
3	P-203	flow m^3/h	28	23.3	9.32	28	23.3	9.32
		head m	138.2	147	162	156	164	178
		density kg/m^3	597	597	597	597	597	597
4	P-204	flow m^3/h	42.3	34.0	13.96	42.3	34.0	13.96
		head m	98.1	102.0	106.0	109.0	111.0	114.0
		density kg/m^3	571	571	571	571	571	571
5	P-205	flow m^3/h	36	31	12.5	36	31	12.5
		head m	45.2	46	47.2	61	62	64.5
		density kg/m^3	778	778	778	778	778	778
6	P-206	flow m^3/h	18	15.4	5	18	15.4	5
		head m	43	43.4	43.6	78.6	80	81
		density kg/m^3	960	960	960	960	960	960

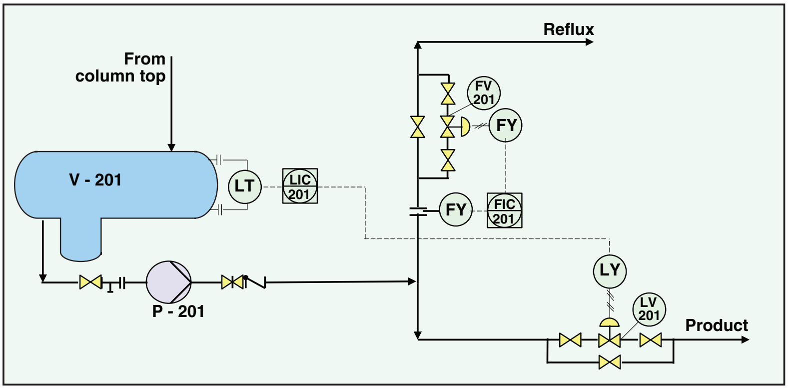


FIGURE 4. A partial revamp scenario similar to the example on the distillation column (Figure 1) that is discussed in the text

Partial revamp activities

A complete revamp of a full-scale process plant may take between two and three months. Often times, owners try to arrive at an optimum solution regarding the time schedule. They go for an interim plant shutdown for 10–15 days during which they carry out certain parallel activities, such as the following:

Column internals. Demolition of column internals and installation of new internals are sometimes carried out during this period. In such cases, proper planning is needed to select only those columns where it could be achieved in this short time period. Further, only those columns should be selected where after the installation of new internals, the columns are able to function satisfactorily at the original throughput. A careful study to this effect needs to be done before carrying out such an activity.

Pump impellers. Changing of pump impellers is sometimes done during an interim shutdown. This is done only for those pumps where the change is only of the impeller and not both the impeller and the motor. The plant is then started-up with the new impellers in pumps but operating at the old throughput. However, before such a revamp is carried out, a detailed analysis of the hydraulics is required, otherwise we could end up in complications as explained below.

Imagine a case of a reflux pump — P-201 in Figure 4 — delivering a normal flow of 42.8 m^3/h. A portion of this flow (34.2 m^3/h) goes as reflux to the top of a distillation column. This reflux is routed on flow control to the top of the distillation column through control

TABLE 3. SUITABILITY OF EXISTING CONTROL VALVES DURING A PARTIAL REVAMP SCENARIO

6		7			8			9			
Control valve	Parameter	Control valve data			Control valve data			Control valve characteristics			
		Before partial revamp			After partial revamp			After partial revamp			
		max.	normal	min.	max.	normal	min.				
FV-201	flow m^3/h	41	34.2	13.7	41	34.2	13.7	% opening	58	53	34
	ΔP kg/cm^2	0.64	0.88	1.24	2.16	2.58	2.94	Calculated C_v	30.84	23.55	8.34
	Rated C_v	95									
LV-201	flow m^3/h	12.6	8.6	3.42	12.6	8.6	3.42	% opening	33	22	< 10
	ΔP kg/cm^2	1.5	1.9	2.8	3.02	3.60	4.50	Calculated C_v	8.02	5.01	1.78
	Rated C_v	95									
LV-202	flow m^3/h	40.5	33.8	11.8	40.5	33.8	11.8	% opening	61	57	39
	ΔP kg/cm^2	24.6	26	30.3	26.1	27.3	32.5	Calculated C_v	7.77	6.34	2.02
	Rated C_v	22									
FV-202	flow m^3/h	8.7	7.2	2.9	8.7	7.2	2.9	% opening	65	59	39
	ΔP kg/cm^2	1.8	2.6	5.2	2.86	3.61	6.16	Calculated C_v	4.64	3.42	1.06
	Rated C_v	10									
FV-203	flow m^3/h	23.0	18.4	7.4	23	18.4	7.4	% opening	54	50	26
	ΔP kg/cm^2	1.65	1.95	3.4	2.27	2.46	3.86	Calculated C_v	13.47	10.35	3.32
	Rated C_v	54									
FV-204	flow m^3/h	14.4	12.3	4.9	14.4	12.3	4.9	% opening	51	47	25
	ΔP kg/cm^2	0.75	0.84	1.04	1.98	2.08	2.39	Calculated C_v	10.55	8.78	3.27
	Rated C_v	54									
LV-203	flow m^3/h	15.5	12.9	2.5	15.5	12.9	2.5	% opening	36	32	< 10
	ΔP kg/cm^2	0.22	0.29	0.37	3.64	3.80	3.96	Calculated C_v	9.31	7.58	1.44
	Rated C_v	95									

valve FV-201. The valve has a rated C_v of 95. The remainder of the flow (8.6 m^3/h) goes as column top product to the battery limit. This flow is routed on level control as top product through control valve LV-201. This valve also has a rated C_v of 95. For some reason, this existing valve appears oversized, but let us not debate on this issue now (see Table 3).

The original pump has a differential head of 64 m of liquid at a normal flow of 42.8 m^3/h. In the post revamp scenario, calculations show that the pump should be upgraded to a head of 83 m of liquid. Based on the partial revamp philosophy, the client wishes to upgrade this pump during an interim shutdown. After the upgrading, the control valves would operate at the original flow. However, in view of the increased head of the pump as a result of the upgrading, it would give a higher pressure at its discharge. This extra pressure would be killed across the control valve, which would close to some extent to relieve this extra pressure.

Table 3 shows the percentage openings of the respective valves under the partial revamp scenario. The table should ideally be explained for better clarity. Section 4 shows the existing pump characteristics (before revamp). Section 5 shows the pump characteristics after partial revamp. It can be seen that the flows have remained unchanged (since it is a partial revamp and the plant will be run at the original throughput). However, the heads have increased since in partial revamp, we would replace the impellers wherever planned. Section 7 shows the control valve data in the existing plant. Section 8 shows the control valve data after partial revamp. It can be seen that the flows have not changed but the pressure drop figures have changed since the control valves would close to "kill" the additional pressure due to change of impellers. Section 9 shows the control valve characteristics after partial revamp in terms of the calculated C_v and the percentage openings at maximum, normal and minimum flowrates.

Table 3 shows that after partial revamp, FV-201, would have an opening of 34% at minimum flow which is acceptable. However LV-201, which is oversized, would have an opening of less than 10%. As explained earlier, we operate valves between 10 and 80% of stroke range.

Thus, under the partial revamp scenario, upgrading of P-201 would not be feasible. Only those pumps can be upgraded where downstream control valves would operate within the acceptable opening ranges.

Concluding remarks

Revamping a process plant is a complicated issue. This article gives the reader a flavor of some of the various options and possibilities that are considered while executing a revamp. The actual execution is much more detailed and complicated. A lot of thinking and experience goes into the successful revamp of such a plant. It is more complicated and difficult compared to a greenfields project. ■

Edited by Gerald Ondrey

References

1. Mukherjee, S., *Indian Chemical Engineer*, Vol. 49, No. 4, October–December 2007, pp. 514–525.
2. Mukherjee, R., *Hydrocarbon Process.*, July 1988, pp. 47-49.
3. Borden, G., and Friedmann P. G., "Control Valves – Practical Guides for Measurement and Control," Instrument Society of America, 1998.
4. "Flanged Steel Pressure Relief Valves", API Standard 526, American Petroleum Institute, 5th edition, June 2002.
5. "Sizing, Selection and Installation of Pressure - Relieving Devices in Refineries, Part I – Sizing and Selection", API Standard 520, American Petroleum Institute, 8th edition, December 2008.

Author

Siddhartha Mukherjee is the head of Refineries and Process Execution Departments at Air Liquide Engineering and Construction, Lurgi India Co. Pvt. Ltd. (A-24/10, Mohan Cooperative Industrial Estate, Mathura Road, New Delhi 110 044, India. Phone: +91–11–4259–5365; Fax: +91–11– 4259–5051; E-mail: siddhartha.mukherjee@airliquide.com). He has worked at Lurgi since 1993 at different levels and has been involved in the design, engineering, precommissioning and commissioning of chemical and petrochemical plants in India and elsewhere. He has also been involved in inorganic and oleochemistry while at Lurgi. Prior to this, Mukherjee worked as an environmental engineer with Development Consultants Ltd. (Kolkata), doing various environmental assessment projects involving thermal power plants. Mukherjee earned his B.Tech. and Ph.D. Ch.E. degrees from the Indian Institute of Technology, Kharagpur. He holds lifetime memberships in India's Institute of Engineers and the Indian Institute of Chemical Engineers.

Sampling Particulate Materials the Right Way

Remi Trottier and Shrikant Dhodapkar
The Dow Chemical Company

To obtain a representative sample for particle size characterization, adhere to the golden rules of sampling and follow these best practices

In the chemical process industries (CPI) it is often necessary to verify material specification at various points in the process. In that effort, it is usually impossible — or at the very least impractical — to measure the whole production. Instead, small samples must be extracted from a parent population. Such is the case in particle size characterization of bulk solids, process streams and slurries.

While truly representative sampling has long been an important goal, a number of current trends are driving the incentive for rapid implementation of top-notch sampling strategies to be the standard, rather than the exception. These trends include the ever-increasing demand for superior material quality in the high-technology industries, more-stringent pharmaceutical regulations and higher environmental standards, to name a few.

Unfortunately many sampling strategies in use today do not take into account the most modern sampling theories (for more on the history of sampling strategies, see box, p. 45), which leads to inaccurate test results and unrealistic material specifications that are impossible to verify properly.

The best practices outlined in this article provide guidelines for collecting representative samples from most solids handling and processing equipment and then reducing the sample to the proper size for the analytical technique used in the measurement. In addition, an assessment of sampling errors, based on simple statistical theories, illustrates the pitfalls of sampling methods.

One of the everyday examples of sampling that all of us can relate to is when a medical doctor orders blood to be drawn for routine laboratory analysis. In this example, we can all appreciate the two main, necessary characteristics of the sample:

1. That a relatively small sample is taken (much smaller than the total available)
2. That the sample be representative of the whole (so that the correct diagnosis can be made)

Although both points are extremely simple concepts, a great deal of diligence is usually necessary to achieve them. Careless sampling of powders or slurries often results in a faulty conclusion, regardless of whether good analytical techniques are employed. In that respect, the first item that should be considered for a particle-characterization study is a sampling protocol that insures a representative sample of the proper size.

STATISTICS OF SAMPLING

The first necessary step for a good sampling program is to define the sample that is needed and clearly specify how the sample is taken, including equipment specification. It is important to keep in mind that in particulate material sampling, the best we can ever achieve is a random sample where all particles within the parent population have an equal chance of being sampled, thereby assuming that no systematic bias exists in the sampling process. Since there is no such thing as two identical samples, a perfectly extracted sample (random sample) will always be inflicted by a residual error, called the fundamental error (FE), as first postulated by Gy [1]. This is due to the heterogeneity of any particulate sample that has a distribution of particle sizes. This notion that individual particles are not identical is referred to as constitutional heterogeneity (CH). The higher the upper end of the distribution, the higher the heterogeneity. The Gy sampling theory can estimate the variance of this fundamental sampling error due to the CH, using Equation (1), [2]:

$$Var(FE) \approx \left(\frac{1}{M_S} - \frac{1}{M_L}\right) f \rho \left[\left(\frac{1}{c_L} - 2\right) d_1^3 + g d^3\right] \quad (1)$$

Where M_S is the mass of the sample, M_L is the mass of the parent population from which the sample is taken, f is a shape factor (0.5 for spheres, 1 for cubes, 0.1 for flakes), ρ is the particle density, c_L is the mass fraction of material in the size class of interest, d_1 is the average particle diameter in the size class of interest, g is the granulometric factor [ratio of the diameter corresponding to the 5th percentile of the size distribution to the diameter corresponding to the 95th percentile of the size distribution (d_{05}/d_{95})], d is the diameter corresponding to the 95th percentile of the distribution (d_{95}). This allows the calculation of the fundamental error for any size class in a distribution. If the mass of the parent population is much greater than the sample mass, the term $1/M_L$ can be dropped from the equation. A few important highlights from the above equation:

1. The variance of the fundamental error decreases as the sample size

EXAMPLE OF A SAMPLING PROBLEM, WITH SOLUTION

After several customer complaints, an engineer is assigned the responsibility of setting up a sampling protocol for a ground product that frequently does not meet the specification that no more than 5% of the mass, or volume distribution should be greater than 250 microns (Figure 1). This product is sold in lots consisting of several tons. This specification should be measured at the 99% confidence level. This product has a density of 2.5 g/mL. Assuming that correct sampling techniques were used to obtain a random sample, what is the minimum sample size that needs to be collected and analyzed?

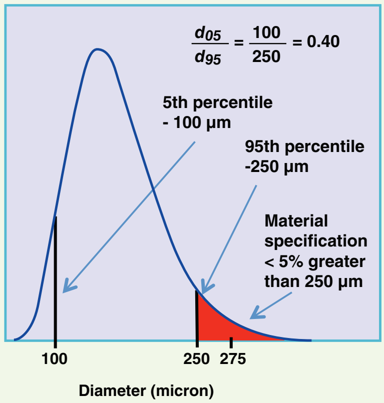


FIGURE 1. Example of size distribution with information necessary to calculate minimum sample mass

Solution:

1. Since the mass of the sample is much smaller that the mass of the lot, the equation for the fundamental error estimation [Equation (1)] can be rearranged as follows to solve for the minimum sample mass

$$M_S \approx \left(\frac{1}{Var(FE)}\right) f\rho\left[\left(\frac{1}{c_L}-2\right)d_1^3 + gd^3\right] \tag{4}$$

2. Measure the size distribution on a volume, or mass basis to obtain the diameters corresponding to the 5th and the 95th percentile (Figure 1)
3. The 99% confidence level implies that the value of *FE* is 0.01. The variance of the fundamental error, *Var*(*FE*), is 0.01^2, or 0.0001. The shape factor (f) can be set at 0.5, assuming that the particles can be approximated by spheres. The particle density (ρ) is 2.5 g/cm^3. The fraction of material in the size class of interest c_L is 0.05 (5% > 250 microns). The average diameter in the size class if interest (d_1) can be taken as 275 microns (see Figure 1). The granulometric factor (g) is defined as d_{05}/d_{95} (see Figure 1) is 0.40 for this distribution. Finally, d, defined as the 95th percentile of the distribution (see Figure 1) is 250 microns. Changing all units to CGS units to obtain the sample mass (M_S) in grams, we obtain the following:

$$M_S \approx \left(\frac{1}{0.0001}\right)(0.5)\left(\frac{2.5\text{g}}{\text{cm}^3}\right)\left[\left(\frac{1}{0.05}-2\right)(0.0275\text{cm})^3+(0.40)(0.025\text{cm})^3\right]=4.8\text{ g} \tag{5}$$

Please note that not only a sample of 4.8 g is needed, but an analysis technique that can analyze the whole sample needs to be utilized. ❑

increases. Since the variance is equal to the square of the fundamental sampling error, the fundamental sampling error decreases in proportion to the square root of the sample mass

2. The variance of the fundamental error is a strong function of the coarse end (95th percentile) of the size distribution as dictated by the d^3 term.

The above equation can easily be rearranged to provide the minimum sample mass to be used in an analysis. The sample mass estimate is the minimum sample size, since additional sources of error will contribute to the variance of the total sampling error. It should be noted that these additional contributors can be minimized through good sampling practices, and therefore are controllable to a large extent. Gy broke down the total sampling errors into seven basic components as listed in Table 1.

The mass required to meet a product specification is related to the inherit degree of heterogeneity in the material and the desired level of accuracy and precision. In addition to sampling error, analytical error will also add to the uncertainty of the measurement. With modern particle-characterization instrumentation, the sampling error will typically become much larger than the expected analytical error as the top end of the distribution (95th percentile) exceeds 100 microns. Gy defined each of the seven error components as an additive model where the variance of the total error is as follows:

$$TE = FE + GE + CE_2 + CE_3 + DE + EE + PE \tag{2}$$

If correct sampling practices are utilized, the terms GE, CE_2, CE_3, DE, EE, and PE are minimized, and are much smaller that the FE term, for particles sized greater than about 100 microns. This minimization of the sampling error can only be accomplished through appropriate selection of sampling equipment for all phases of the sampling and sub-sampling process. For smaller particle sizes, where the heterogeneity of the system decreases as the third power of particle size, sampling typically becomes less of an issue, and analytical errors take over. Table 2 outlines the basic steps for correct sampling.

Grab samples should not be used even if one attempts to mix the bulk specimen prior to sampling — for example, bulk bags or perhaps a sample brought to the laboratory. It is simply not possible to obtain a homogeneous mix from blending alone, and therefore such a practice should not be used to properly minimize grouping and segregation errors. Pitard [2] showed that the variance of the grouping error can be compared to the variance of the fundamental error as follows:

$$Var(GE) \approx \frac{Var(FE)}{N} \tag{3}$$

As a rule of thumb, at least 30 sample increments (N) are recommended to minimize GE errors.

CORRECT SAMPLING

Correct sampling implies following a few simple rules throughout the sampling process as well as using appropriate sampling tools to minimize the errors identified in the previous section. Correct sampling practices include the following:

- Taking many samples at regular or random time intervals (>30 samples), and sub-dividing into smaller samples for analysis to minimize grouping and segregation error (*GE*)
- Using correctly designed sampling tools to minimize delimination and extraction errors (*DE* and *EE*).
- Using common sense and diligence to minimize sample preparation and analysis errors (avoid particle settling, agglomeration, dissolution, and swelling) (*PE*)

In this section, we will introduce sampling equipment designed to sample from various solids systems including static bulk materials, gravity flow systems, mechanical conveying systems, pneumatic conveying systems, solids-processing unit operations and slurry systems. The sampling techniques in different systems are discussed and recommendations for proper sampling are provided.

TABLE 1. SEVEN BASIC SAMPLING ERRORS

	Name	Description / Mitigation
1	Fundamental Error (*FE*)	Caused by constitutional heterogeneity (CH). Reduce *FE* by increasing sample size. Note that this is the sample size that not only needs to be sampled, but analyzed in its entirety
2	Grouping and Segregation Error (*GE*)	Incremental samples can be different from each other. Reduce *GE* by collecting and combining several random sub-samples, taken correctly from the parent lot
3	Long-Range Heterogeneity Fluctuation Error (CE_2)	Fluctuations in size distribution over time contribute to the heterogeneity. Reduce CE_2 by collecting a large number of sub-samples at random or regular intervals to form a composite
4	Periodic Heterogeneity Fluctuation Error (CE_3)	Periodic fluctuations in size distribution over time contribute to the heterogeneity. Reduce CE_3 by collecting a large number of sub-samples at random or regular intervals to form a composite
5	Increment Delimitation Error (*DE*)	Delimitation errors occur when the sampling process does not give an equal probability of selecting all parts of the parent lot. As an example, a grab sample will only sample from accessible parts of the lot, usually the surface. Reduce *DE* by using properly designed sampling tools and strategies
6	Increment Extraction Error (*EE*)	Since particles are discrete elements of various sizes, they will be forced in or out of the sampling device — *even if they are on the sample target boundary*. If a particle's center of gravity is within the sampling boundary, it should be part of the sample, otherwise it should not be part of the sample. Reduce *EE* by using properly designed sampling tools
7	Preparation Error (*PE*)	Sample degradation error caused by inadequate preparation where particles settle, dissolve, aggregate, break or swell during preparation or analysis. Use proper sample handling and dispersion techniques

Sampling process overview

There are usually several stages in particulate matter sampling, and it is of paramount importance to maintain the integrity of the sample until the analysis is carried out. Figure 2 takes us through the stages of a sampling process. Several increments are taken from the bulk lot using properly designed sampling equipment as outlined in the next section. The gross sample may be too large to be sent to the laboratory, and may need to be reduced to a more practical weight. Depending on the measurement technique, and the amount of sample required by the instrument sample delivery system, the laboratory sample may need to be further sub-divided to the test sample to be used in its entirety by the instrument. Even at the laboratory-sample level, which is the last step before analysis, the common practice of simply scooping material out of the container is likely to introduce bias. The overall goal of any sampling procedure is simple: it is to obtain a sample with a total sampling error similar to that expected from the fundamental sampling error, which is solely governed by the heterogeneity of the material — grab sampling at any level will almost guarantee that this goal will not be achieved.

Gross sample extraction

Consistent with Gy's sampling theories, Allen [*3*] independently proposed two "Golden Rules" of sampling:

1. Sample a moving stream — sampling of bulk solids at rest should be avoided.
2. The whole of the stream of powder should be taken for many small increments in time in preference to part of the stream being taken for the whole time.

Applying Gy's principles and Allen's recommendations, extraction of a gross sample consists of properly extracting several increments from the parent lot during processing or handling using properly designed tools. Each increment can be defined as the group of particles extracted from the parent lot during a single operation cycle of the sampling device. The final gross sample should consist of at least 30 such increments.

Static material sampling

Ideally, the sampling should have been carried out before the material became a static bulk, which is much more difficult to correctly sample. The degree of inhomogeneity will depend on the powder's history. In the case of free-flowing material, it is a safe bet to assume segregation has taken place during the transfer, and for non-free flowing material, the degree of inhomogeneity will largely depend on its history.

The inherent problem with sampling static material is that no equipment

HISTORY OF SAMPLING TECHNIQUES

Sampling became a common, but non-scientific practice first in the mining industry, then in the pharmaceutical and chemical industries shortly after the industrial revolution. Back in those early days of sampling, although no rigorous theory existed, scientists and engineers used a common-sense approach based on their intuition and their experience to guess at the requirements on what constituted a good sample. In the mid-19th century, Vezin was the first to introduce the concept of a minimum sample size necessary for obtaining a representative sample, without the benefits of modern sampling theories. He also invented a sampler that bears his name, and is still in use today. It was not until the 1950s that the guessing game in sampling was replaced by a more rigorous discipline, thanks to Gy's [*1*] development of the statistical theories behind sampling. This offered a structured approach to sampling from which all sampling errors are broken down to basic components.

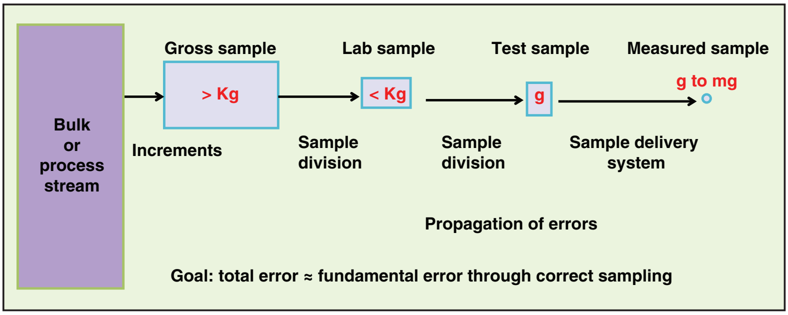


FIGURE 2. In this sampling process, incremental sampling throughout the sampling and sample reduction process is practiced to minimize propagation of sampling errors

TABLE 2. BASIC STEPS FOR CORRECT SAMPLING

1. Define sample quality	Data Quality Objective – precision and accuracy required for product specification, or quality
2. Define sample size	Sample size: gross sample, lab sample, actual amount analyzed
3. Define sampling strategy	Equipment, sampling location, sampling frequency, sample reduction
4. Preserve sample integrity	Sample reduction, prevent particle aggregation, attrition, dissolution, and swelling
5. Verify that the required data quality can be achieved	Is the equipment and strategy used adequate to meet data quality objective? Is the sample size analyzed large enough?

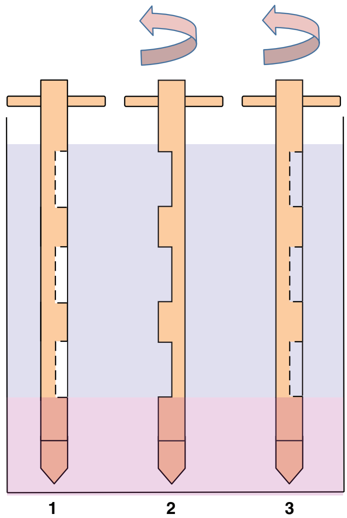


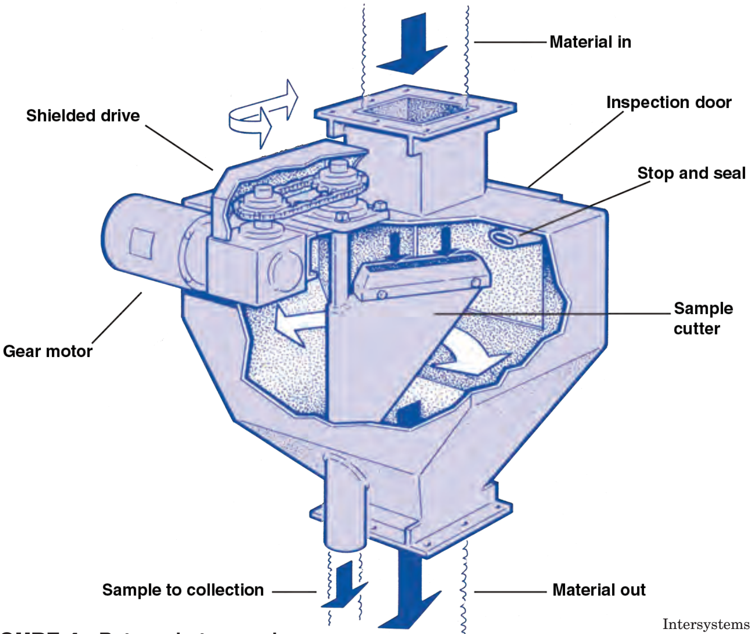
FIGURE 3. The sampling thief is one of the simplest devices to extract powder from a static bulk

exists that can take a sample where every particle has an equal chance of being sampled. There will always be parts of the bulk that will not be accessible to the sampler.

The workhorse of the bulk sampling domain remains the thief sampler (Figure 3), which provides several increments taken at random throughout the bulk material. This device consists of a co-axial outer sleeve and an inner hollow tube with matching grooves to allow powder flow in the core of the inner cylinder. In the first step of the sampling procedure, the inner tube is rotated so that the matching groves are on opposite sides, then the probe is inserted in the powder. The second step consists of twisting the inner tube to align the two sets of grooves, thereby allowing powder to flow into the sampler. Thirdly, the inner tube is twisted to lock the powder into the sampler, which is then withdrawn from the bulk. This procedure is repeated several times to extract several increments to make up the bulk sample ready for splitting. The shaded region at the bottom of Figure 3 indicates the region where there is no chance of sampling, which illustrates a weakness of this device. Another source of error to be aware of when using this type of device occurs as the material is being displaced down by the probe moving through the bulk material, thereby causing segregation and preventing equal probability for all particles to be sampled.

Sampling free-falling streams

The rotary chute sampler, also referred to as the Vezin sampler, is a multi-purpose device that collects representative samples from materials (dry powders or slurries) that are free-falling from pipes, chutes or hoppers. This sampler is generally a good choice for installation on loading and unloading equipment, or at the entrance or exit of material transfer equipment. Various versions of the Vezin sampler are available in several sizes from multiple manufacturers. This device, shown in Figure 4, operates by one or more cutters revolving on a central shaft, passing through the sample stream and collecting a fixed percentage of the total material. A Vezin sampler is totally enclosed to minimize spillage or leakage problems. The area between the sample cutter and the discharge chute is sealed to prevent possible contamination or sample loss.



Intersystems

FIGURE 4. Rotary chute sampler

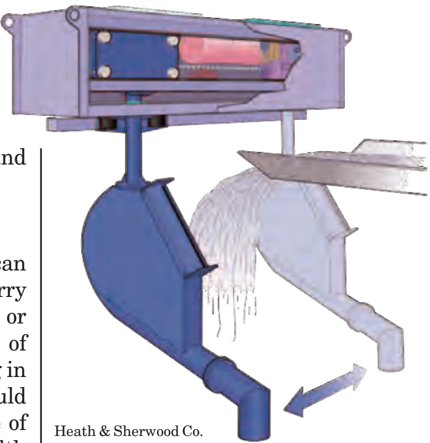
TABLE 3. LIST OF QUESTIONS TO CONSIDER WHEN SELECTING A SAMPLER

Materiel properties	Is the material free-flowing?
	Is the material abrasive?
	Is the material friable?
	Does the material have a broad size distribution?
	Is the material dusty?
	What is the largest particle diameter
	Is the material temperature sensitive?
Process conditions	Is the process enclosed?
	Are the particles dispersed in gas phase?
	Is the process in a pressurized enclosure?
	Is the process at elevated temperature?
	Is the process wet or dry?
	Is the powder in motion?
Sample requirements	What sample size is required?
	Are there any sanitary requirements?
	Is automatic sampling required?
	Is a composite sample required?
	Is the sample sensitive to moisture?

As a rule of thumb, incremental extraction errors can be minimized by limiting the cutter speed to 0.6 m/s, an inner-wall sampler three times the particle diameter (3*d*) for coarse material, where $d > 3$ mm, and at least 10 mm for finer material.

Sampling from gravity flow

As shown in Figure 5, gravity flow can be any free-flowing powder or slurry from a conveyor, hopper, launder or unit operation under the influence of gravitational forces. When sampling in such systems, each increment should be obtained by collecting the whole of the stream for a short time. The width of the receiver should be made at least 10 mm or three times the diameter of the largest particles — whichever is larger. The volume of the receiver must be large enough to ensure that the receiver is never full of material. The length of the receiver should be sufficient to ensure that the full depth of the stream is collected. The ladle or receiver should cross the whole stream in one direction at constant velocity. For heavy mass flow, a traversing cutter as a primary sampler together with a Vezin sampler as a secondary splitter can usually be applied.



Heath & Sherwood Co.

FIGURE 5. Linear gravity flow samplers collect samples from free-flowing powders under the influence of gravity

Mechanical conveying systems

The conveyor types for mechanical and pneumatic conveying of bulk solids include belt conveyor, screw conveyor, bucket conveyor, vibrating conveyor, and dense- or dilute-phase conveyers. The best position for collecting the samples is where the material falls in a stream from the end of the conveyor. One can then follow the procedure for gravity flow or free-falling streams as noted above. However, if the situation is such that samples have to be taken directly from within the conveying line, several types of sampler have been developed. An example of such samplers designed to extract samples from belt conveyor systems is illustrated in Figure 6. The mid-belt sampler uses a rotating scoop that makes a pass across the moving belt, thereby cutting a clean cross section of material.

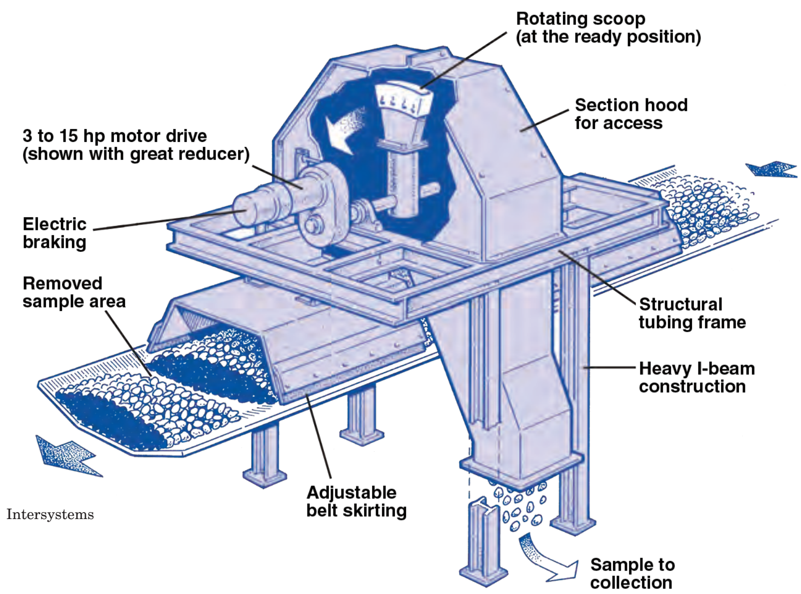


FIGURE 6. Automatic mid-belt samplers are used with belt conveyors

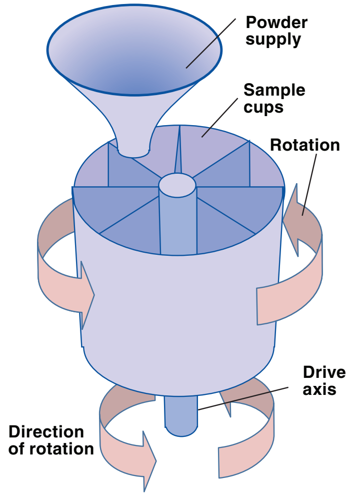


FIGURE 8. The spinning riffler is comprised of a ring of containers rotating under a powder stream

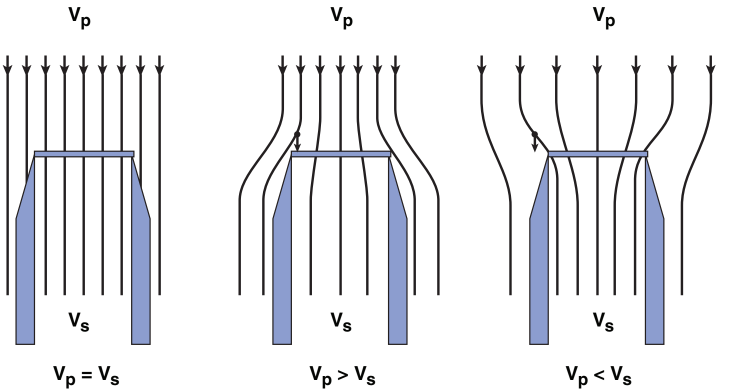


FIGURE 7. These illustrations of isokenetic sampling from a pipeline show the sampling velocity (V_s) equal to the process velocity (V_p; left), V_p greater than V_s (middle), and V_p less than V_s (right)

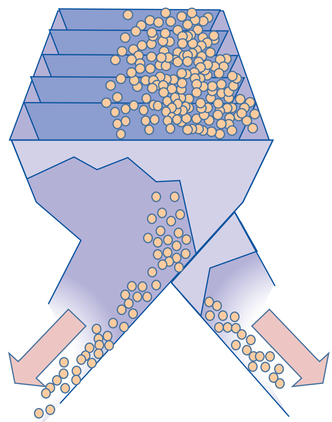


FIGURE 9. The chute riffler splits a sample using a series of alternate chutes

Slurry sampling

The same basic sampling rule where all particles have an equal chance of being sampled must also be followed when sampling from slurries. Knowledge of slurry properties and behavior is essential to insure proper sampling strategies. For instance, sampling a slurry from a point in a tank, or flowing through a pipeline requires the presence of a homogeneous suspension at the point of sampling, which is dependent on such parameters as particle size and density, fluid density and viscosity, flowrate and pipe diameter [*4*]. Turbulent flow, which provides mixing, is typically required to keep the slurry well mixed before sampling. Pipelines can be sampled isokinetically using nozzles provided the slurry is well mixed at the sampling point. Isokinetic sampling (Figure 7) occurs when the average fluid velocity in the sampling tube (V_s) is the same as the surrounding fluid velocity (V_p). No sampling bias is expected during isokinetic sampling. If the process flow velocity is greater than the sampling velocity, particle inertia causes an excess of larger particles to enter the sampling probe while a process flow velocity smaller than sampling velocity will cause an excess of larger particles to avoid the probe. Therefore, non-isokinetic sampling will introduce a bias based on the particle size distribution.

RELEVANT STANDARDS ON SAMPLING OF PARTICULATE MATERIALS

ASTM Standards:

ASTM B215 - 10 Standard Practices for Sampling Metal Powders

ASTM C322 - 09 Standard Practice for Sampling Ceramic Whiteware Clays

ASTM C50 - 00(2006) Standard Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

ASTM C702 / C702M - 11 Standard Practice for Reducing Samples of Aggregate to Testing Size

ASTM D140 / D140M - 09 Standard Practice for Sampling Bituminous Materials

ASTM D1799 - 03a(2008) Standard Practice for Carbon Black—Sampling Packaged Shipments

ASTM D1900 - 06(2011) Standard Practice for Carbon Black Sampling Bulk Shipments

ASTM D1900-06(2011) Standard Practice for Carbon Black Sampling Bulk Shipments

ASTM D197 - 87(2007) Standard Test Method for Sampling and Fineness Test of Pulverized Coal

ASTM D197 - 87(2007) Standard Test Method for Sampling and Fineness Test of Pulverized Coal

ASTM D2013 / D2013M - 11 Standard Practice for Preparing Coal Samples for Analysis

ASTM D2234 / D2234M - 10 Standard Practice for Collection of a Gross Sample of Coal

ASTM D2590 / D2590M - 98(2011)e1 Standard Test Method for Sampling Chrysotile Asbestos

ASTM D345 - 02(2010) Standard Test Method for Sampling and Testing Calcium Chloride for Roads and Structural Applications

ASTM D346 / D346M - 11 Standard Practice for Collection and Preparation of Coke Samples for Laboratory Analysis

ASTM D460 - 91(2005) Standard Test Methods for Sampling and Chemical Analysis of Soaps and Soap Products

ASTM D75 / D75M - 09 Standard Practice for Sampling Aggregates

ASTM D979 / D979M - 11 Standard Practice for Sampling Bituminous Paving Mixtures

ASTM E105 - 10 Standard Practice for Probability Sampling Of Materials

ASTM E122 - 09e1 Standard Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

ASTM E141 - 10 Standard Practice for Acceptance of Evidence Based on the Results of Probability Sampling

International Standards:

BS 3406: Part 1: 1986 British Standard Methods for Determination of particle size distribution Part 1. Guide to Powder Sampling, British Standards Institute, London (1986).

ISO/WD: 14888 Sample Splitting of Powders for Particle Size Characterisation International Organization for Standardization, Geneva.

ISO 2859-Statistical Sampling. http://www.iso-9000.co.uk/9000qfa9.html, International Organization for Standardization, Geneva (2000).

It is better to sample from a vertical pipe so that particle segregation by gravity can be avoided. In such a situation, the sampler should be located at least ten pipe diameters downstream from any bends or elbows in the pipe.

Particle diameter has a strong influence on particle segregation by gravity since the settling velocity is proportional to the square of the particle diameter. Gravity starts to play an important role at particle diameters greater than roughly 50 microns. The best approach, if possible, is to sample at the discharge where a cross-stream sampler (Figure 5) may be used as a primary sampler followed by a Vezin sampler cutter to reduce sample size. This allows sampling even in the non-ideal case where some segregation may have occurred in the pipe. A large number of cuts (>30) for both the primary and secondary samplers needs to be extracted. Not all situations are alike, and therefore, these samplers need to be installed and designed properly to fit the application.

Selection of the proper sampling equipment may not always be trivial, and may depend on material properties, type of process, and sample requirements. Table 3 provides a list of questions to consider when designing a sampling protocol.

Sample reduction

Powder sampling is typically done at two levels, a gross sample taken directly from the process, and then sub-divided into samples suitable for the laboratory. The spinning riffler, as illustrated in Figure 8, has been widely used for reducing the amount of powder to be analyzed to a smaller representative sample. In this commercially available device, a ring of containers rotates under a powder flow to be sampled, thereby cutting the powder flow into several small increments so that each container consists of a representative sample. The spinning riffler is a versatile device that can handle free-flowing powders, dusty powders and cohesive powders. The operating capacity of this device varies from 25 mL to 40 L. If only the small capacity spinning riffler is available, the Vezin sampler can be used to reduce the gross sample to the appropriate quantity suitable for the spinning riffler. The spinning riffler, when properly used, is the most efficient sample divider available.

Another commonly used device for sample reduction of free-flowing powders is the chute riffler as shown in Figure 9. It consists of alternating chutes where half of the material discharges on one side and the second half on the other. The total number of chutes represents the number of increments defining the sample. Although the sample can be processed several times to increase the number of total increments, it will likely not match the number of increments performed by the spinning riffler. As such, the spinning riffler is the best device for sample reduction and should be used whenever possible.

Several standards dealing with powder sampling are available from a number of organizations. A comprehensive list is provided in the box, p. 48.

Summary

Appropriate attention to sampling, sample size reduction and data analysis is the first step towards obtaining reliable analytical results from a batch [5]. To obtain a representative sample, one must adhere to the golden rules of sampling and follow the best practices as outlined in this article. ■

Edited by Rebekkah Marshall

References

1. Gy, Pierre, "Sampling Theory and Sampling Practice. Heterogeneity, Sampling Correctness, and Statistical Process Control", 2nd Ed., CRC Press, Boca Raton, 1993.
2. Pitard, Francis F., "Pierre Gy's Sampling Theory and Sampling Practice: Heterogeneity, Sampling Correctness, and Statistical Process Control", CRC Press, Boca Raton, 1993.
3. Allen, T., "Particle Size Measurement", 4th Ed., Chapman & Hall, London, 1990.
4. Turian, R.M., and Yuan, T.F., Flow of Sluries in Pipepines, 3, 1977, *AIChE J.*, Vol. 23, 3, pp. 232–243.
5. Trottier, Remi and Dhodapkar, Shrikant, and Wood, Steward, Particle Sizing Across the CPI, *Chem. Eng.*, April 2010, pp. 59–65.

Authors

Remi Trottier is a research scientist in the Solids Processing Discipline of Engineering & Process Sciences at The Dow Chemical Co. (Phone: 979-238-2908; Email: ratrottier@dow.com). He received his Ph.D. in chemical engineering from Loughborough University of Technology, U.K,, and M.S. and B.S. degrees in Applied Physics at Laurentian University, Sudbury, Ont. He has more than 20 years of experience in particle characterization, aerosol science, air filtration and solids processing technology. He has authored some 20 papers, has been an instructor of the course on Particle Characterization at the International Powder & Bulk Solids Conference/Exhibition for the past 15 years.

Shrikant V. Dhodapkar is a fellow in the Dow Elastomers Process R&D Group at The Dow Chemical Co. (Freeport, TX 77541; Phone: 979-238-7940; Email: sdhodapkar@dow.com). He received his B.Tech. in chemical engineering from I.I.T-Delhi (India) and his M.S.Ch.E. and Ph.D. from the University of Pittsburgh. During the past 20 years, he has published numerous papers on particle technology and contributed chapters to several handbooks. He has extensive industrial experience in powder characterization, fluidization, pneumatic conveying, silo design, gas-solid separation, mixing, coating, computer modeling and the design of solids processing plants. He is a member of AIChE and past chair of the Particle Technology Forum.

Thermal Integration Of Reboilers

How to incorporate reboilers into composite curves, and more suggestions are given

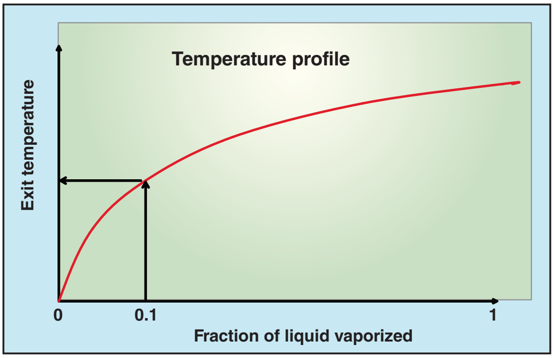


FIGURE 1. The temperature at the reboiler exit that is equal to 10% vaporization of the mixture being evaporated can be obtained from the heat demand curve

G. T. Polley,
E. E. Vazquez–Ramirez,
M. Riesco Avila,
and D. Jantes Jaramillo
University of Guanajuato, Mexico

The approaches currently used by process integration specialists to assess the opportunities for the integration of reboilers are frequently erroneous and lead to proposals that have to be rejected at the detailed engineering stages or worse, to commissioned reboilers that do not perform properly.

This article examines the integration of both vertical and horizontal thermosiphon reboilers, and covers the following topics: incorporating the heat-load-temperature characteristics into a "pinch analysis"; matching the hot stream with the reboiler duty; minimum and maximum temperature differences for the reboiler; and effects of distillation column control and startup on the integration.

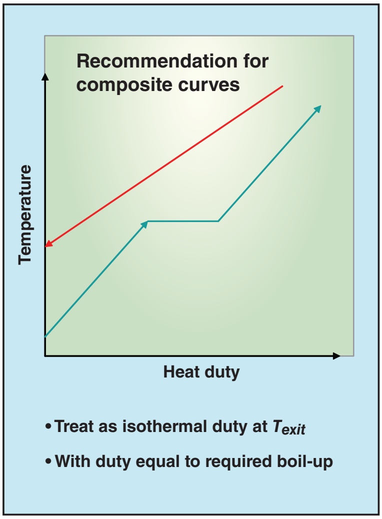


FIGURE 2. Vaporization duty can be incorporated into a cold composite curve by treating it as an isothermal operation

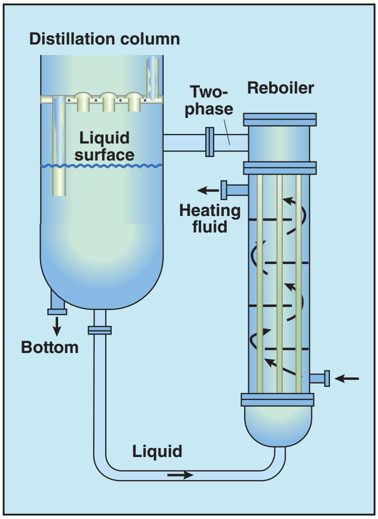


FIGURE 3. When hot liquids are used to heat vertical thermosiphon reboilers, a potential problem is excessive generation of vapor in the lower parts of the tube

Reboiler exit temperature

Consider the vaporization of a binary mixture. If we ignore (for the moment) the temperature difference required to initiate vapor generation, the vaporization of a liquid mixture commences once the "bubble point" of the mixture is exceeded. As vapor is generated, the concentration of the less volatile component increases, and this leads to an increase in saturation temperature. If the design of the reboiler is such that liquid and vapor are in contact throughout the vaporization process (achieved in vertical tubes), then the vaporization process could continue until all of the liquid is evaporated, at which point the saturation temperature has reached the "dew point" of the mixture.

If the design of the reboiler is such that liquid and vapor flows are separated (as occurs in horizontal tube bundles, see Ref. 1), then vaporization is complete at the boiling point of the less volatile component.

These scenarios describe limiting values. In practice, even in once-through designs, the feed to a reboiler is not equal to the quantity of material that is to be vaporized. With a vertical thermosiphon reboiler the maximum amount will rarely exceed 20% of the feed, and in most applications it will be less than 10% of the feed (Figure 1). In horizontal thermosiphons the fraction of feed vaporized should be lower. This will be discussed later in this article.

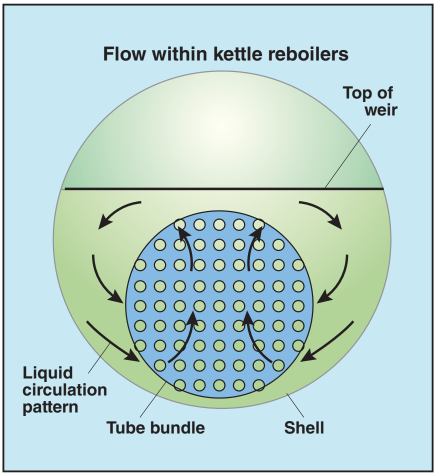


FIGURE 4. This schematic shows the operation of a kettle reboiler, where liquid enters the tube bundle from the base and sides

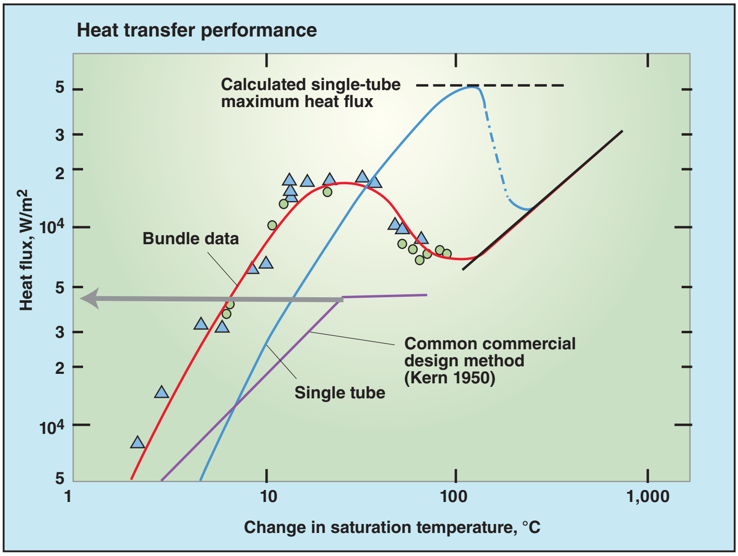


FIGURE 5. The thermal behavior of kettle reboilers has led the authors to conclude that this type of unit is best avoided when hot liquid is used as the heat source

The cold composite curve

In pinch analysis, the concept of "composite curves" is based upon the assumption of counter-current flow. As will be shown below, co-current flow should be used in a thermosiphon reboiler. So, how can such heat demand be represented in a composite curve? The option recommended here is that it is represented as an "isothermal" operation conducted at the vapor exit temperature (Figure 2). (For more on composite curves, see Energy Optimization Using Pinch Analysis, *Chem. Eng.,* November 2011, pp. 36–41.)

Matching of reboiler streams

If the stream being used to provide heat to the reboiler is a liquid, then its flow should be co-current with the flow of the stream being vaporized. This is particularly important with vertical thermosiphon reboilers (Figure 3).

The mixture being vaporized flows through the tubes of a vertical thermosiphon. It enters the tubes as a subcooled liquid (the liquid in the reservoir will be at saturation temperature, but the surface of the reservoir can be 3–4 m above the lower tube-sheet of the reboiler). The point at which nucleation (the formation of bubbles of vapor) first occurs within the tube is dependant upon both the temperature of the liquid and the temperature of the hot wall. Maximizing the temperature driving force reduces the length of tube prior to the onset of nucleate boiling. This driving force is maximized if the hot liquid flows co-currently.

The heat transfer coefficient on the cold-side of the unit increases rapidly once two-phase flow has been established. Consequently, there is a large variation of heat transfer coefficient along the length of the tube. This variation is "stabilized" if co-current flow is used. If the hot liquid flows counter-current to the vaporizing mixture, then its temperature profile is affected by changes in the heat transfer distribution on the cold-side. These changes affect the point at which nucleation commences and the heat transfer distribution on the cold-side. So, the use of counter-current flow can result in instability and control difficulties.

Startup and control

Startup and control are important considerations that must made when evaluating reboiler integration. While a plant may be designed to operate at a given condition (such as a specific throughput), it will be operated under a range of conditions. This means that reboiler load will be subject to variation, and therefore control will be required.

In many situations it will be found that startup and control cannot be undertaken using an integrated unit, and that the overall duty must be undertaken using two separate reboilers: an integrated unit having a fixed duty and an non-integrated unit used for both startup and for control functions.

The engineer needs to determine the following two items:

1. The load required for startup purposes (this is set by the minimum loading on the column not the ultimate operating condition);
2. The variation in load required for the control function

The design of the non-integrated reboiler will involve identifying a geometry that will provide either the startup performance or the load associated with maximum control load (whichever is the larger) at a point that is at least 20% below the maximum operating condition for the design (set by critical heat-flux conditions).

This reboiler needs to be onstream all of the time that the plant is operational. Consequently, its load will never be zero. The minimum value should be set at a value that is around 20% above the lowest stable condition (the minimal sustainable reboiler load).

The load for the integrated unit will be the total load minus that required at the minimum throughput minus that needed by the non-integrated unit operating at its minimum load.

Minimum temperature

While the reboiler is represented by an isothermal line set at the tempera-

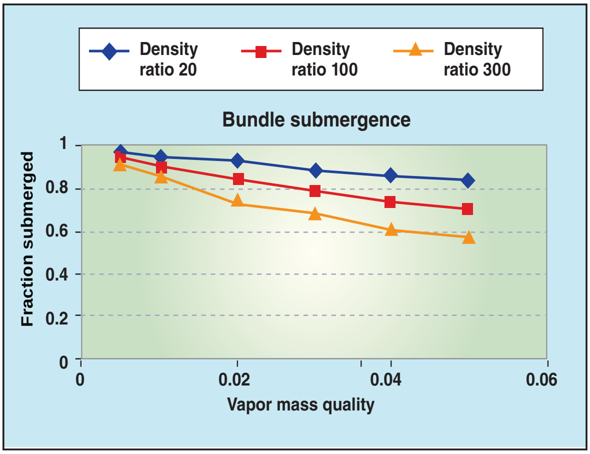


FIGURE 6. Bundle submergence during horizontal flow is presented for a range of inlet quality (the mass fraction of the liquid that is vaporized)

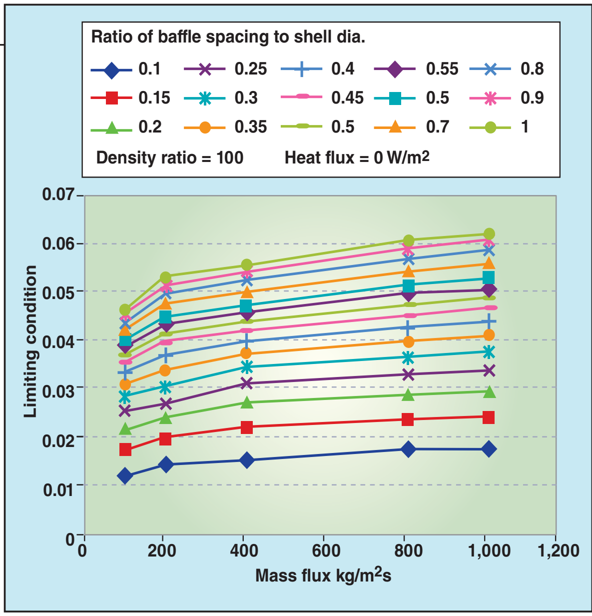


FIGURE 7. For a fluid having a density ratio of 100 (typical of an organic substance with a molecular weight of 100 being vaporized at a pressure of 2 bar absolute), in vertical flow, large baffle spacing is favored

ture at which the boiling mixture exits the reboiler, checks do need to be made that the temperature of the hot stream entering the reboiler is sufficient for it to operate.

With units handling aqueous mixtures, the minimum wall temperature that has to be achieved within the unit should be at least 15°C above the saturation temperature of the liquid entering the unit. (Note that in vertical thermosiphon reboilers this saturation temperature is higher than that within the reservoir feeding the unit. In the case of units operating under vacuum, the difference can be large.) For units handling organic compounds, the required difference between these temperatures can be taken as 5°C.

Maximum temperature

In some applications, there is a limitation on the maximum temperature of hot fluid used to drive the reboiler. This is set by the rate at which vapor is generated close to entry.

Kettle reboilers. In a kettle reboiler, liquid enters the tube bundle from the base and sides (Figure 4). The tubes at the periphery of the bundle are well wetted. However, as the liquid endeavors to move into the center of the bundle, it encounters an increasing quantity of vapor. The result can be difficulty in wetting the tubes within the core of the bundle.

This gives rise to a relationship between temperature driving force and heat flux that is very different than that observed for a single tube (Figure 5). The "plateau" observed with tube bundles is due to a situation in which the heat transfer coefficients for the tubes at the periphery increase due to increased nucleate boiling, while those for the tubes within the core fall due to liquid starvation.

This has led to a philosophy that bases design on a "limiting heat flux". This limiting heat flux can easily be achieved when steam is used to drive the reboiler (for the pressure within the steam chest reduces until the controlled load is obtained). However, when a hot liquid is to be used, this is much harder to achieve because the actual heat flux is controlled by the inlet temperature of the liquid and

Authors

Graham T. Polley, currently co-supervises a group of research students at the University of Guanajuato, Mexico (gtpolley@aol.com). This group works on the design of integrated systems, fouling in petroleum refinery pre-heat trains, fouling in compact heat exchangers, two-phase flow experimentation and the design of integrated distillation schemes. Polley has Ph.D., M.Sc. and B.Tech (Hons) degrees from Loughborough University of Technology. He has worked on the development of heat-exchanger design methods for around forty years and has published over two hundred technical papers. In 1990 his work on energy saving in oil refineries was recognized by the U.K.'s IChemE through the award of its Moulton Medal. He is a past president of the U.K.'s Heat Transfer Society.

Edgar E. Vázquez-Ramirez holds a M.S.Ch.E. degree working in process integration and a Ph.D. in mechanical engineering working in boiling flow and two-phase flow at the University of Guanajuato, México.

José M. Riesco-Ávila graduated in mechanical engineering from the Instituto Tecnológico de la Laguna, México in 1984. He obtained his M.S. degree in 1986 at the Universidad de Guanajuato, México, and his PhD in 2004 at the Universidad Politécnica de Valencia, Spain. Over the last five years, his research activities have included one project funded by the academic administration and two R&D projects funded by industry. His scientific publications include two book chapters, 13 articles published in international journals and more than 70 papers at scientific conferences.

Dionicio Jantes-Jaramillo graduated in chemical engineering from the University of Guanajuato, Mexico, in 2006. His thesis for obtaining the M.Sc. degree was about the design of compact heat exchangers by using parameter plots. During his Ph.D. studies, he was involved in the design of heat recovery systems. His research has been done in collaboration with the École Polytechnique in Montreal, Canada, and the Norwegian University of Science and Technology (NTNU) in Trondheim. He has obtained the academic merit consecutively from 2007 to 2011 granted by the University of Guanajuato.

the flow conditions on the tube-side of the unit.

Our conclusion is that this type of unit is best avoided when hot liquid is to be used as the heat source.

Vertical reboilers. One potential problem with vertical thermosiphon reboilers that operate with hot liquid as a heat source is excessive generation of vapor in the lower parts of the tube. This can give rise to a "choking" effect where so much vapor is generated that there is insufficient head provided in the down-pipe feeding the unit to drive the two-phase flow through the unit. The result is vapor travelling back through the feed leg. Operation of the unit becomes unstable. Tubes dry out and fouling, erosion or corrosion can occur.

This problem is most commonly encountered when the ratio of the liquid to vapor density is high (found when vaporizing organic compounds of molecular weight less than 200 at atmospheric pressure). The phenomenon is sensitive to reboiler tube length (the longer the tube, the more likely the problem). Any limit on the temperature of the hot stream should be determined through analysis of reboiler behavior ahead of integration analysis.

Horizontal reboilers. The rate of vapor generation is also a consideration that must be taken into account when the design of horizontal units for use in integrated schemes is considered. The generation of a lot of vapor in the first baffle spaces of a unit can give rise to problems from poor phase distribution further along the unit. The problem is more acute for duties involving high liquid-to-vapor density ratios. Curves that allow the engineer to determine these effects have been presented by Vazquez-Ramirez and others [*1*], and are reproduced here in Figures 6 and 7. (For more on these curves and additional information on two-phase flow, see Designing Shell and Tube Heat Exchangers: Consider Two-Phase Flow, *Chem. Eng.*, January 2012, pp. 36–39.) ■

Edited by Dorothy Lozowski

References

1. Vazquez –Ramirez E.E., Riesco Avila M. & Polley G.T. "Two Phase Flow through Horizontal Tube Bundles: Implications for Heat Exchanger Design", AIChE Spring Meeting, 2011.

New Measurement Practices for Cold Climates

New approaches improve reliability and reduce costs in environments with extremely cold temperatures

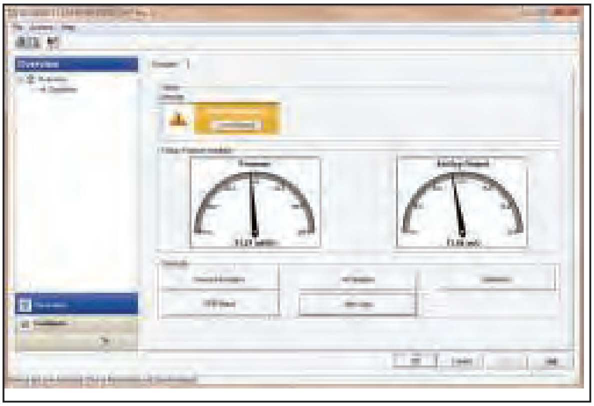
Mark Menezes
Emerson

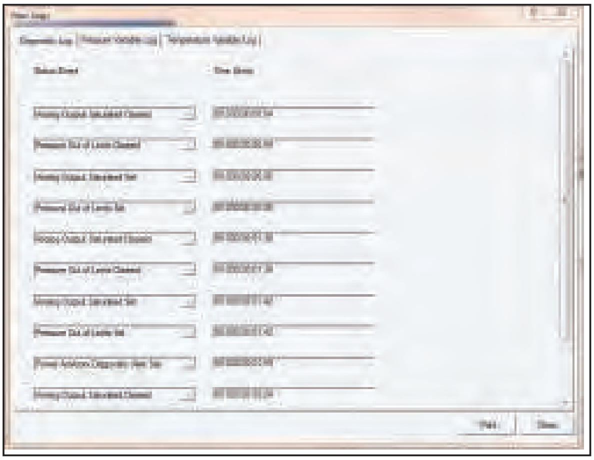
Instrumentation best practices that are taught in colleges and published in standards are intended to be broadly applicable, guiding users in every industry and geography. However, for outdoor applications in cold climates, where the temperature can fall below –40°C, the optimum installation may be very different from those recommended via best practices, to ensure reasonable performance, reliability and lifecycle cost.

New best practices for making measurements in cold climates have been identified using advanced transmitter diagnostics, digital protocols and asset-management software. Together, these new technologies give users and equipment suppliers unprecedented insight into device performance and failure modes in real applications.

As this article demonstrates, many of the traditional practices for managing instrumentation are not ideal for cold climates. For instance, traditionally, transmitters used in cold climates have been:

- Installed in heated enclosures. As an alternative, operators should heat the sensing lines only. This reduces cost and improves reliability
- Mounted below the pipe for steam-flow applications, with a heated wet leg (discussed below). As an alternative, operators should install the transmitter above the pipe and the configuration should have no wet leg. This reduces cost and improves reliability
- Connected to the process via heated capillaries in level applications. Instead, operators should use electronic remote sensors. This reduces costs, improves performance, reduces spares and simplifies installation and maintenance





FIGURES 1A and 1B. Using a device dashboard and time-stamped diagnostic log, complex, diagnostic information about this pressure transmitter is presented in an easy-to-understand format, for easy troubleshooting. All events and failures are logged in non-volatile memory, with date-and-time stamp, for easy post-mortem failure analysis

Diagnostics, digital protocols

Several tools have emerged during the past decade [*1*] to identify and justify improved measurement practices. These include advanced device diagnostics and the proliferation of digital protocols, such as HART, Foundation Fieldbus or Profibus fieldbus or the newer WirelessHART or ISA 100.11a. These advances can help users to detect, predict and even automatically correct for problems in the device sensor and electronics, the power supply and wiring, the environment, the process connections and in the process itself.

Not surprisingly, since a key stressor in a cold climate is low temperature, diagnostics that measure and trend process and device temperature were useful in identifying the new practices described below. For example, in a pressure transmitter, the sensor *temperature measurement* is used internally by the smart transmitter microprocessor to automatically compensate for expansion and contraction of the oil and mechanical components, which improves the accuracy of the *pressure measurement*.

FIGURE 2. The use of transmitters with heating and isolation valving pre-assembled at the factory eases field installation

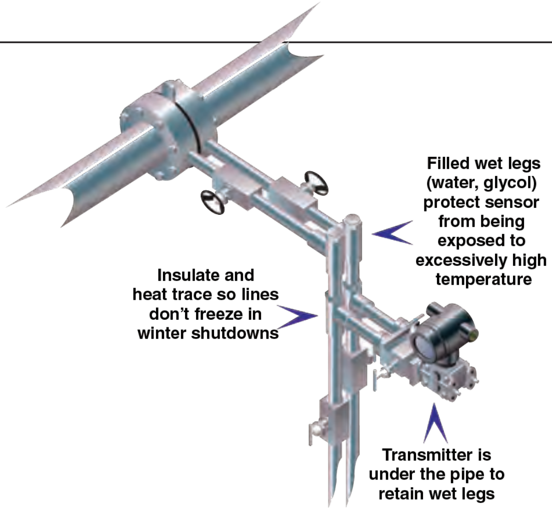


FIGURE 3. In a traditional steam flowmeter installation, wet legs are sensing lines filled with condensate. They protect the sensor against over-heating, but need to be insulated and heat-traced in a cold climate to avoid freezing in case of shutdown

While some of this diagnostic information is available directly from the transmitter's local display, the greatest utility comes when devices are connected via digital protocols to a central asset-management station, as shown in Figure 1. Realtime and historical diagnostic information are made available in a user-friendly dashboard format, and the user can easily troubleshoot suspected problems using pre-configured wizards.

Benefits for the user include faster troubleshooting, improved process safety, and reduced unscheduled downtime. These diagnostics and logs that can help users maximize uptime also allow equipment suppliers to improve their equipment designs and recommended installation practices, as they provide added insight into how the devices perform and why they fail over an extended time frame in a variety of actual installations.

Heated sensing lines

User experience and post-mortem diagnostic failure analysis reveal that many transmitters typically suffer from three problems when exposed to extremely cold environments:

- The electronics may fail, or may not restart after a shutdown
- The sensor may exhibit large errors due to ambient temperature effects [2]
- The local display may stop updating or go blank (although it usually recovers when the temperature increases)

To avoid these problems, users should install the transmitters inside an enclosure that is equipped with a thermostat-controlled heater. While this installation and assembly can be done by the user or their contractor in the field, supplier engineering and factory pre-assembly minimizes cost and risk from field installation. In the factory environment, the supplier can better ensure that all openings and valves are properly sealed and insulated, and that the heater is correctly sized and installed for the application. An under-sized heater in the enclosure will allow wide temperature swings to occur; an over-sized one can cause rapid, extreme temperature fluctuations. Either can overwhelm the transmitter's ambient temperature circuitry and result in large measurement errors.

Many of today's newer smart transmitters are rated to operate safely to –50°C, and the newest local displays can update to –40°C. Such transmitters can safely be mounted outside of an enclosure, without heating. However, even for these newest transmitters, it is essential to heat the sensing (impulse) lines, which connect the transmitter to the process — up to and including the manifold block.

A review of the process sensor's diagnostic logs from installed and failed transmitters reveals that even hot processes cool surprisingly quickly in cold environments, even with insulated tubing — sometimes an order of magnitude faster than the industry's rule of thumb related to dissipation, which is, on average, 100°/ft. Without appropriate heat tracing, even brief process shutdowns can cause fluid to freeze and harden inside the tubing, and this can be difficult to remove after the process has been restarted. Worse, if the fluid contains even small amounts of water, that water can freeze and expand, possibly bursting the tubing or destroying the sensor.

In the new best-practice installation recommended here, operators would still use heat tracing, but they would heat trace and insulate only the sensing lines and manifold block — not the transmitter itself. This minimizes capital and operating costs, reduces total size and weight and minimizes the risk that a heater that fails "on" will cause overheating and failure of the transmitter. The temperature sensor in the transmitter can be configured to alert maintenance to a failure — on or off — of the heat tracing. If the transmitter is connected digitally to the central maintenance terminal, this alert will be immediate, allowing the user to remedy the problem and prevent equipment failure and unscheduled downtime.

Steam flow in cold climates

Rising energy costs and new environmental regulations are motivating operators to better measure and manage their utility flows — especially steam utility systems, since steam is so widely used in the chemical process industries (CPI) to transport energy. Steam is commonly used for process fluid heat exchange, space heating, and for steam injection. Accurate flow measurements are needed to maintain process efficiency, detect leaks and account for steam consumption. The ability to cost-effectively ensure high accuracy, repeatability and reliability is a challenge in outdoor applications in cold climates. Although vortex flowmetering technology has enjoyed great success in recent years, the most widely used technology for measuring steam flow remains the differential-pressure (dP) flowmeter.

The traditional steam dP-flowmeter is shown in Figure 3. Steam flows through the "primary element" restriction, which causes a pressure drop that is proportional to flowrate. The orifice plate is the most common primary element for steam service, although the averaging pitot tube is usually preferred in larger lines or when users wish to minimize permanent pressure loss through the flowmeter. The dP transmitter is installed under the pipe, and columns of condensate form in each of the impulse lines leading to the transmitter. These so-called "wet legs" of condensate are hot where they contact the steam, and cool by the time they reach the transmitter. This prevents the oil in the transmitter from overheating to past its vapor pressure, which would cause the oil to flash and rupture the thin metal diaphragm in the pressure transmitter. Users manually fill the wet legs with condensate prior to startup, and refill the wet legs after a shutdown.

In outdoor installations in cold climates, the fluid in the impulse lines farthest from the process — that is, nearest the transmitter — can freeze, particularly during planned or unplanned process shutdowns. To prevent this, heat tracing must be used to heat the impulse lines and maintain their temperatures above freezing. This increases cost and complexity.

Figure 3 shows only a single dP transmitter, which measures volumetric flow. Since steam is compressible, the user must compensate for variable density using a line-pressure and process temperature measurement [*3*]. A lower-cost alternative to multiple devices is the multivariable "integrated flowmeter".

Integrated flowmeters, shown in Figure 4, include the primary element,

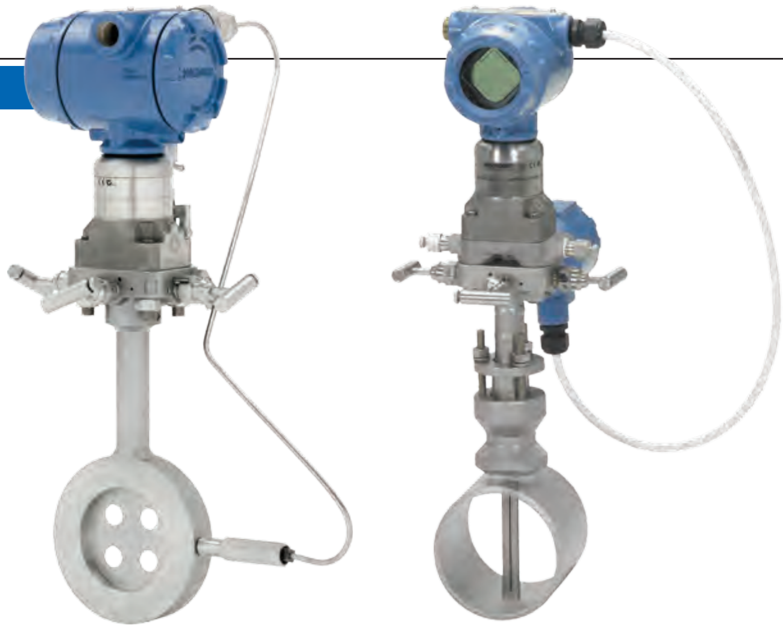


FIGURE 4A and 4B. The integrated dP flowmeter includes the primary element, the flow computer and the sensors needed to calculate mass and energy, dP, pressure and process temperature. As shown in Figure 4A (left), the use of a wafer-style orifice plate as the primary element minimizes cost in smaller lines, and the 4-hole design minimizes the need for straight pipe. By contrast, in larger lines, the use of an averaging pitot tube as the primary element (shown in Figure 4B, right) minimizes total cost and pressure loss

the differential and line-pressure sensors, the process temperature sensor, and any isolation valving that may be required. They arrive pre-assembled, pre-configured and leak-tested from the supplier (Figure 2), which minimizes the overall cost and risk of incorrect field assembly. An integrated flowmeter is consistent — for every line size, the components between the pipe wall and the pressure transmitter are virtually identical. Since the heat dissipating components are the same in every installation, a given process temperature should always result in a given temperature at the transmitter.

Analysis of temperature logs in operating steam-flow installations — from both the diagnostic temperature sensor in the pressure transmitter and the process temperature sensor used for density compensation — has revealed the following:

- Temperature of the fluid at the pressure sensor is difficult to predict in a "traditional" installation, in which the user installs whatever length and diameter of sensing lines best fit the installation
- Temperature of the fluid at the pressure sensor is predictable and found to be consistently lower than expected when using an integrated flowmeter

These field results, and subsequent factory testing, justify the following new practice for low-to-medium-pressure steam-flow measurement. Without risk of damage to the sensors, and using normal insulation for personnel protection, the integrated flowmeter can be directly installed when the steam temperature does not exceed 205ºC. This temperature corresponds to a saturated steam pressure of 235 psig, which is suitable for most industrial applications in the CPI. Higher temperatures and pressures are possible, though users should consult supplier recommendations [*4*] for specific applications.

The new best practice for installing the transmitter above the pipe eliminates wet legs. This results in a simpler, lower-cost installation. By eliminating the risk of wet-leg freezing during shutdown, the need for heat tracing is also eliminated (along with its associated capital and operating costs). Figure 5 shows installations of steam flowmeters in a cold climate (Albany, N.Y.).

Using pressure to infer level

A "bottom-up" pressure measurement can be used to infer level, because the pressure exerted by the fluid is proportional to the fluid height — above the tap — and the fluid density. Thus, for a known fluid density, the measured

FIGURE 5A and 5B. **In field installations with a transmitter on top, as shown in Figure 5A (left), the compact orifice integrated flowmeter is installed between existing flanges and eliminates heated sensing lines. In this installation, the use of wireless communication eliminates field wiring. For larger lines (Figure 5B, right), an averaging pitot tube is used to minimize pressure loss**

pressure can be used to infer level. For dirty or abrasive fluids that might plug or damage the transmitter, very high temperatures, or special process connections, remote seals are used to isolate the transmitter from the process and "repeat" the pressure signal.

In a closed tank, the vapor above the liquid is pressurized, and the level is proportional to the difference in pressure between the top and bottom taps, obtained using a dP transmitter. The transmitter is typically located at grade near the low-side (high-pressure) process connection. The high-side (low-pressure) seal is normally near the top of the vessel, so it must be connected to the transmitter via oil-filled capillaries that hydraulically repeat the pressure signal from the seal to the transmitter (Figure 6).

Although the low-side seal is physically close to the transmitter, users have traditionally specified equal-length capillaries — with the excess lower-seal capillary coiled up at the transmitter. The rationale for including this extra capillary is to "balance" the impact of fill-fluid expansion. An increase in ambient and/or process temperature causes the fill fluid to try to expand. Within the fixed volume of the capillary, this mimics an increase in pressure and hence inferred level. In this balanced system, temperature changes will equally impact both high- and low-side capillaries, with zero net error.

Unfortunately, there is another significant source of error — the head temperature effect. As ambient or process temperatures increase, the specific gravity of the fill fluid decreases. This causes the force on the transmitter from the upper seal to decrease, since head pressure is the product of specific gravity and height, so the inferred level is reduced.

There is no effect on the lower seal, since it is at the same elevation as the transmitter (that is, the height is zero). This means that in a balanced system, the impact of fill-fluid expansion is zero, while the head temperature effect is negative.

A better approach is to direct mount the lower seal with no capillary, as shown in Figure 6, Since the two effects act in opposite directions, the positive effect of expanding fill fluid will partially counteract the negative head temperature effect, thereby minimizing net error. As an additional benefit, eliminating the lower-seal capillary speeds response, since changes in liquid level do not need to travel through the entire capillary before being sensed at the transmitter. The direct-mount installation also reduces cost, since it eliminates one length of capillary.

Since fill fluids have known coefficients of thermal expansion, and since diaphragms and capillaries have known stiffness values and volumes, it is possible for the supplier to quantify these effects in advance. Given these application details and expected ambient and process temperature variation, suppliers can optimize seal and capillary design (in terms of fill fluid, diameter and thickness) so that in the actual installation, the two effects will almost exactly cancel each other out over the widest possible operating range. Today, this optimization is done using sophisticated software, producing a so-called tuned system.

Pressure-based liquid level

One drawback of the tuned system approach is that it can potentially create a unique solution for each application, leading to a large number of unique spare parts. To simplify matters, most users choose to sub-optimize individual applications, balancing the need to achieve acceptable performance with maximum commonality. Even so, if any component of the system is damaged during installation or operation, the entire assembly must be removed and returned to the supplier for repair. This can be particularly challenging in cold climates, where working on devices in the field is uncomfortable and unsafe. Also, many cold climates are remote from repair facilities, and long return shipping times can lead to days or weeks without a working measurement.

Another problem observed in cold

climates is that fill fluids suitable for high process temperatures suffer from very high viscosity in cold ambient conditions. The user must choose a fill fluid that will not vaporize under worst-case vessel conditions — that is, highest temperatures and lowest pressures — to avoid oil boiling and seal rupture.

Table 1 shows maximum and minimum temperatures at atmospheric pressure, as well as viscosities at 25°C, for some commonly used fill fluids from Dow Corning. As shown in Table 1, at atmospheric pressure, DC200 is stable to 205°C (400°F). If the vessel ever operates under vacuum conditions — common with distillation columns, for example — the temperature limit is lower, so the user might specify another fluid, such as DC704. Unfortunately, DC704, while safe from vaporization at higher temperatures, suffers from very high viscosity as temperatures decrease. Higher viscosity means very slow response. [1]

In a cold climate, if the vessel were tall, with a long capillary connecting the upper seal (which measures blanket pressure) to the transmitter, its oil could cool significantly by the time it reached the transmitter. With DC704, the oil could freeze and stop responding entirely at 20°C; even at slightly higher temperatures, response would still be very slow.

If the lower seal (which measures liquid head plus blanket pressure) were directly connected to the transmitter without a capillary — which provides the best performance to changing process level — its oil would remain hot, with low viscosity and fast response. As a result, in a cold climate, the high and low measurements could become desynchronized. When this happens, changes in blanket pressure would immediately affect the lower seal, but only affect the high seal after some lag time.

Since 1 psi equals 27.7 in. of water column, a relatively small change of ±1 psi in blanket pressure would cause a swing of up to ±27.7 in. in the measured level reading, until the top sensor measuring blanket pressure "catches up."

1. DC200 and DC704 are silicone oils manufactured by Dow Corning, and are commonly used by many manufacturers of remote diaphragm seals.

FIGURE 6. When carrying out pressure-based liquid level in a closed tank, the difference between the top and bottom tap is proportional to liquid level

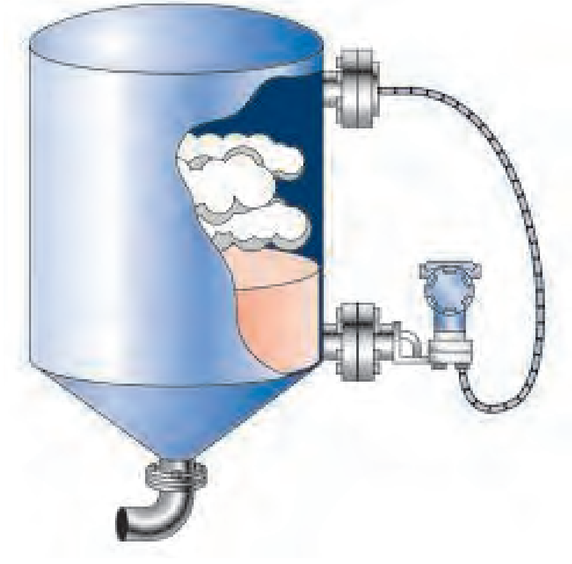


TABLE 1. COMMON FILL FLUIDS			
Silicone fill fluid	Temperature range, °C	Temperature range, °F	Viscosity at 25°C, cps
DC200	-45 ↔ 205	-49 ↔ 400	9.5
Syltherm XLT	-73 ↔ 149	-100 ↔ 300	0.85
DC704	20 ↔ 350	68 ↔ 662	175
* All of these oils are from Dow Corning.			

Unlike water, silicone oil does not expand when it freezes. This helps to avoid physical damage to the system and allows full recovery when ambient temperatures rise in the spring. Unfortunately, since no components fail, the user may not become aware of these problems. The only symptom will be that the level measurement will be stable in the summer, and unstable in the winter. To prevent this, users in cold climates will usually heat trace their important capillaries. While effective, heat tracing is very expensive to procure, install, operate and maintain, and the weight and bulk of the heat tracing further complicates repair in case of failure.

Electronic solutions

In theory, a better solution would be to install separate high- and low-pressure transmitters, and subtract the signals in the control system to obtain the level measurement. Since the two transmitters are connected electrically instead of hydraulically, capillaries — and their attendant cost, reliability and response time problems — are eliminated. Unfortunately, while this approach can work well with a digital bus such as Foundation fieldbus, it is not as effective if the user is using a more common HART or 4–20-mA connection. Not only must the user double the transmitters, field wiring and distributed control system (DCS) inputs, but relatively small errors in the transmitters and analog inputs can lead to relatively large errors in the measurement.

To understand why this happens, consider the case of a vessel operating with a maximum pressure of 200 psig, and a maximum level of 200 in. of water. In a traditional capillary system, the user would probably select a single dP transmitter with a range of 250 in. H_2O. (The line pressure is not relevant since only the difference is being measured.) Each error of ±0.1% — in the transmitter, in the analog input calibration, or in the math block of the DCS — would cause an error of ±0.25 in. H_2O in the level measurement. This is relatively trivial in most process applications.

When using separate transmitters, the user must select two transmitters, each with a range of at least 200 psig.

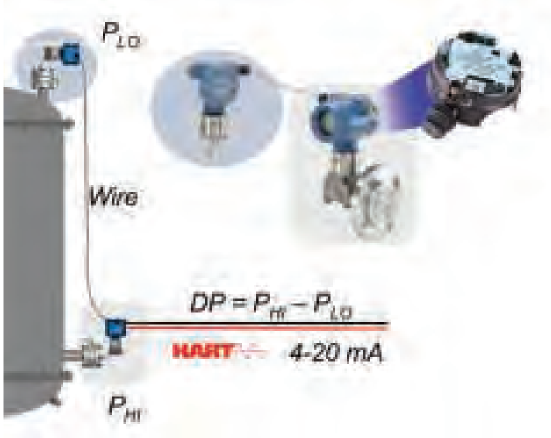


FIGURE 7. When today's electronic remote sensors are used for level measurement, they eliminate capillaries and do not require extra field wiring

If the user selects transmitters with a range of, say, 300 psig, each ±0.1% error in the system would cause a non-trivial error of ±0.3 psig or ±8 in. in the level measurement. Since high vessel pressures result in large errors, users have traditionally been limited to using two-transmitter, all-electronic solutions with the lowest pressures, or when high accuracy is not needed.

New electronic remote sensors, shown in Figure 7, minimize these problems. Two high-accuracy sensors communicate digitally, and a single HART 4-–20-mA output provides the subtracted level. No additional wiring, DCS input or barriers are required, even in a hazardous environment. A user with a HART handheld communicator or HART DCS inputs can access both of the measurements independently, for process variable (level and blanket pressure) as well as setup and diagnostic information.

The new best practice of using electronic remote sensors provides better accuracy compared to the use of the tuned system or balanced system described above, at low or vacuum pressures. Electronic remote sensors provide comparable accuracy up to about 300 psig of vessel pressure. Response is much faster, and there are no synchronization problems. Other benefits include the following:

- *Easier installation, typically by a single technician*. Instead of a sealed system with two heavy flanges connected to a transmitter via long, inflexible capillaries, the user simply installs two pressure transmitters, and then connects them with standard electrical cable. The top transmitter that measures tank pressure does not require a flange at all — it can be use simple threaded connection, thereby lowering cost. In very hot vessels, the supplier should "thermally optimize" the design of the connection to ensure that the oil stays hot enough to respond quickly, yet cold enough to avoid boiling the sensor, under all ambient and process conditions
- *Reduced spare parts.* Instead of a complete spare system for each unique level system, the user would need only a spare transmitter for each range and connection type in the plant. This also allows the user to optimize each individual application without increasing spare parts
- *Easier maintenance and greater uptime*. Instead of removing and shipping the complete system to the supplier for repair and then reinstalling it, the user would simply replace any single failed component with a replacement unit

In remote, cold climates, these benefits would be magnified, and the user could significantly reduce lifecycle cost by eliminating the need for heated capillaries.

Summary of recommendations

New transmitter advanced diagnostics and wired and wireless digital protocols give users and equipment suppliers unprecedented access to device performance and failure modes in real applications. Access to such detailed insight over extended timeframes is teaching interested observers that traditional practices — even those proven through thousands of installations over decades — may not actually be the best practice in every application. Specific examples of improved practices that have been identified so far include the following:

- Users can eliminate heated enclosures, and heat only the sensing lines and manifold that connects the transmitter to the hot process, thereby reducing cost and system footprint. The sensor temperature can be used to diagnose failure of the heat tracing, thereby improving reliability
- Users can install steam flowmeters with the transmitters above the pipe, so that the configuration has no wet legs. This new approach is less expensive to install and operate compared to a traditional installation, and provides higher reliability with less maintenance
- Electronic remote sensors can provide superior performance at low to medium pressures, with no need for heated capillaries. They simplify installation and maintenance, reduce spare parts and improve uptime

Although these new practices should be considered for any environment, they should be of special interest to users installing a measurement outdoors in cold climate. ■

Edited by Suzanne Shelley

References

1. Menezes, M., Improve plant safety with advanced measurement diagnostics, *Chem. Eng.*, Oct. 2000.
2. Menezes, M., When your plus and minus doesn't add up," *Flow Control*, Jan. 2005, pp. 18–21.
3. Barhydt, P., and Menezes, M., Energy management best practices and software tools, *Energy Eng.*, April 2005, pp. 47–56.
4. Top Mount Installation for DP Flowmeters in Steam Service, Rosemount White Paper 00870-0200-4809.

Author

Mark Menezes manages Emerson's measurement business in Canada (1421 Samuelson Circle, Mississauga Ont., Canada L5N 7Z2; Phone: 416-459-5935; Email: Mark.Menezes@Emerson.com.). He holds a B.S.Ch.E. from the University of Toronto, and an MBA from York-Schulich University in Toronto. Menezes has 22 years of experience in industrial automation, specializing in control systems, loop controllers and flow measurement.

Better Chemistry By Design

Simulation software helps to create higher-performance, safer and more-economical CPI plants

David Jechura
SSOE Group

SIMULATION SOFTWARE IN THE CPI

Simulation software works well in the CPI for the following activities:

- Test the ranges of distillation and calculate values to maximize production
- Repurpose equipment as processing goals change
- Establish optimum order and efficiency of raw material processing
- Set up a work and material flow that makes sense

At one time, the design of distillation columns and other major components for the chemical process industries (CPI) required engineers to make one-at-a-time calculations in order to project what-if scenarios covering the processes, equipment, raw materials and capital necessary for renovation or construction. If an engineer was fortunate, he or she might have had access to central computer facilities that would shorten the time to make these calculations to provide decision-making support. Otherwise, it was a slow, manual process that made it difficult to cover all bases. In fact, some bases were never touched.

Today, modern simulation software running on a desktop computer makes it possible to automate these scenarios' creation. Simulation software works well with straightforward chemical processes, as well as processes that require intermediate feedstock mixes, equipment and piping sizing, optimum inventories, raw materials costs and applications analysis, and even comprehensive safety designs.

Process equipment sizing

With distillation column design, simulation software can help maintain expensive components within the overall project's budget limits. The software enables the engineer to work with the program features to ensure that a distillation column will be no taller than the process requires. The simulation itself tests the ranges of distillate that different feedstocks will produce, and calculates values that will enable the plant to maximize production.

In a real world example, simulation helped design a distillation column that maximized the value of various products being distilled out of a stream of liquid natural gas. By adjusting the software program to simulate the culling of propane, butane and ethane more efficiently, the resulting design cut the column's cost by $2 million. This brought an over-budget project back in line.

A simulation program can also help to repurpose equipment as processing goals change. For instance, in one project a distillation unit that originated from a canceled project was located at a used equipment vendor. Although not an optimal solution to the process' needs, performance simulation showed that with modification, the unit could produce the required fractionation. The combined purchase and modification costs came in under what was budgeted for a new unit. Additionally, starting with the base unit as already constructed shortened the construction schedule, which improved cash flow for the project.

Inventory and material flows

Simulation software can also help to develop production routines, such as establishing the optimum order in which each raw material should be processed to produce the timeliest result. An efficient routine, in turn, influences raw material purchases so that they will be efficiently incorporated into the process, while keeping inventory costs low.

An even more complex task for simulation software sets the routine for producing and then using intermediate raw materials. Software can incorporate details, such as the length of time that various materials must age before they reach a specification acceptable to the process.

For example, water-based paint is an emulsion normally produced in batches due to the ever-changing formula differences between batches. Each batch might require as many as ten raw materials, plus half a dozen

DESIGNING FOR SAFETY, MATERIALS MANAGEMENT AND COST SAVINGS

Simulation software can aid in a number of tasks including the following:

- Tune production planning to optimize raw material costs, inventories, usage rates and projected sales
- Simulate the usage of a chemical to maximize worker safety and minimize inventory costs
- Project scenarios for changes in costs of materials and labor, usage rates, material transport and vessel transfer

intermediate materials, that must be formulated, produced and stored ahead of time. Keeping track of these intermediate materials can be complex. One key ingredient in paint is a grind of solids that must be held in suspension before completing the formulation. Selection of the equipment to produce the intermediate — starting with a cleaned system to avoid inter-batch contamination, proper emulsion preparation, and cleaning of the equipment prior to the next intermediate — can all be improved with the use of material-flow simulation.

As a rule, simulation can help a processor minimize the amount of work involved with controlling inventories and the flow of materials. This keeps complex material flows from overwhelming the process and causing errors. It also ensures that the plant will not produce products that have no orders or even prospects of orders. Also, work-process minimization makes it possible for the plant to operate on an efficient just-in-time basis. Ultimately, the goal is to complete a product formulation, transfer it into a shipping container, and then send it on its way, leaving as little finished product in inventory as possible.

Simulation software can map out a number of scenarios to streamline inventory control and material costs. It can accept inputs for product orders, raw material inventories, in-process mix, and the timing required to formulate and return intermediate materials. In all, simulation software helps to set up a work and material flow that makes sense.

Managing raw material costs

Simulation can also be used to tune production planning to optimize raw material costs, inventories, usage rates and projected sales — all with the goal of ensuring that neither raw materials nor finished products sit in inventory longer than necessary.

To consider raw material costs, it is important for the engineer to understand usage rates. While volume pricing is an important means to control costs, another consideration is how much material will be used and stored. That's because the inventory cost of stored material can offset any savings from volume purchasing.

Consider, for example, the way auto assembly plants use and inventory brake fluid. A hydroscopic material cannot be inventoried and stored in the same way as other chemical ingredients can. Some manufacturers bring the material in 250-gal totes, which cost a couple cents more per gallon than 55-gal drums. On the other hand, material in 55-gal drums is difficult to protect from the air during use. Still other manufacturers prefer bulk storage tanks that hold thousands of gallons of brake fluid, for two reasons. First, it is the easiest way to limit contact with air even though it raises inventory costs. Second, it can make sense as a strategy for materials that are difficult to resupply.

A material's total supply cost, however, includes not just the material's purchase price and capital cost to store and supply onsite, but also non-valued-added costs. Relocation of drums or totes from delivery point to storage location to usage point may be small compared to capital costs for a bulk system during the first year of operation. However, the return-on-investment curves may cross at a point in the future. This may be surprising if an accurate evaluation of all factors — raw material supply (including materials not received by drum or tote, such as in pails or by bulk tanker trucks), return shipping costs, disposal costs and so on — is available.

Designing for safety

Chemical processes often employ or create hazardous materials during processing. Engineers must take both worker and community safety into account when designing a CPI plant. Safety considerations often mirror material-cost-management considerations. For example, sulfuric acid is both extremely corrosive and hydroscopic. Safety, as well as prudent cost management, suggests avoiding 55-gal drums to minimize chemical handling and to eliminate the disposal costs of used drums. An alternative is to use 250-gal totes, which cost more to buy and also create inventory costs, along with a tote-return cost to the supplier. Bulk deliveries become a third option to consider, with employee safety considerations and reduced material costs offset by increased capital investment and material inventory costs.

Small versus large quantities isn't necessarily the issue. Depending upon utilization, examination of bulk storage requirements is needed. Bulk storage could be utilized regardless of whether it's for frequent, infrequent or quantity-usage limits. The goal is to reduce chemical handling, especially for chemicals that are hazardous.

Drum use requires a dedicated drum-storage area. Someone needs to go get the drum, transport it to where it will be used, open it and then use a siphon tube or drum pump to extract the material. Drum use makes material handling more frequent and increases the potential for worker exposure (more risk). Tote use means less handling; and piping directly from the tote minimizes exposure risk as only attaching and detaching the pipe is needed. Where chemicals are hazardous due to instability, however, smaller containers may be the best option to reduce quantities onsite.

Simulation software analyzes costs of materials and transport, cleaning of drums and disposal. Use of a drum or tote may initially be more cost-effective, but if production rates increase, a bulk storage system may pay for itself. Total cost includes costs of materials, usage rates and labor.

There is risk with all methods of chemical retrieval and transfer — from point of delivery to end point of application in the process. Simulation helps evaluate risk factors for all methods of delivery, storage and retrieval in conjunction with cost. The goal is to simulate to find out which storage option is the most safe and least costly for the plant's use of that raw material.

Plant designers can minimize employee exposure with proper storage and appropriate transfer equipment, and by connecting to permanently mounted piping. These precautions minimize operator exposure and safety risks. By simulating the usage of the chemical in question (such as sulfuric acid), engineers can determine the best selection for maximizing worker safety and minimizing cost. They can also project scenarios that take into account changes in cost of materials, usage rates and labor costs, especially for non-valued-added steps such as material transport and vessel transfer. Without such simulation-generated data, decisions are made based upon "rules of thumb", past practices or intuitive responses.

Simulation software

A number of simulation software applications are available on the market. A quick Internet search reveals dozens of packages, each with its own set of features and benefits. The examples provided here are based upon chemical-process and material-flow simulators. Selection of a simulation package can be difficult, as each package has attributes that make it better for one process than another, and each undergoes feature enhancements with each version upgrade. Simulation software applications provide many opportunities to test a range of operational and safety boundaries. They also help to ensure that equipment specifications, raw materials inventory, and safety considerations will enable processing as required, yet at the most economical rates. That's how companies can create better chemistry by design. ■

Edited by Dorothy Lozowski

Author

Dave Jechura, is a senior chemical engineer at SSOE Group (1001 Madison Avenue Toledo, Ohio 43604; Email: Dave.Jechura@SSOE.com; Phone: 419-255-3830; Website: www.ssoe.com/chemical), an international engineering, procurement and construction management firm. With over 30 years of experience, Jechura specializes in chemical process engineering and industrial wastewater treatment. He is a professional engineer registered in the states of Ohio and Mississippi, and holds a B.S.Ch.E. from the University of Toledo.

Focus on Physical Properties To Improve Processes

Girish Malhotra, PE
EPCOT International

Exploiting the physical properties of chemicals can offer pathways to more simplified and elegant processes

Music is nature's gift to humans. Irrespective of nationality, we all like to hum melodies, tap rhythms and sway to pleasing tunes. Even children just learning to stand enjoy wiggling to good music. In all cultures, the notes that comprise musical scales are used in varying sequences and different combinations to compose music. These note can be thought of as the the physical properties of music. Just as composers use notes to create music, designers of chemical processes use scientific and engineering principles to assemble processes. And just as creating the most enjoyable music takes time, skill, hard work and imagination, creating elegant, cost-effective chemical processes requires exploiting the physical properties of chemicals (the musical "notes" of chemicals) in imaginative ways to craft excellent chemical manufacturing and formulation processes.

Whether an architect envisioning a building, an automotive engineer building cars or a metallurgist producing metal ingots, all use the principles of science and engineering, along with the physical characteristics of the materials and their own creativity and imagination to create a product via a process that is sustainable, cost-competitive and has the desired quality for the price. Similar factors are at play when simplifying and improving existing chemical processes.

KEY PROPERTIES REVIEW

The following list represents several of the critical physical properties that should be examined in process design and process optimization:

1. Physical state of a material at room temperature, along with its melting, boiling or freezing point
2. Solubility
3. Density
4. Viscosity
5. Specific heat
6. Heat of formation
7. Azeotropic behavior

In addition to those listed above, other physical properties may have to be considered for specific processes and applications, but those above are the most commonly used in process development, scaleup and process design. Molecular weight is also important, but is excluded from the list because every developer has to know the formula and molecular weight of every chemical they deal with.

Although chemists and chemical engineers are familiar with the properties mentioned in the list, it is worth discussing the value of each individually, as well as how each interacts with others and how they can be exploited in process development, scaleup and commercialization of products.

Physical state

A chemical's physical state at room temperature, its melting, boiling or freezing point, along with solubility, tells process developers a great deal about how the product can be handled during process development and in a commercial operation. It is advisable to handle every chemical with respect, even if the product literature suggests low or no toxicity. Chemical quantities used in the laboratory are small, so handling them in a safe manner is generally easier. However, the quantities required for scale-up experiments and commercial-scale operations are higher and different methods are used to handle and feed materials. Care needs to be exercised for each chemical.

Solid chemicals, when used in a scale-up or commercial operation, will require proper equipment to feed at the desired rate while controlling dust emissions. Additional precautions might be necessary when handling toxic materials. Another way to handle solid materials can be by dissolving or slurrying them in appropriate solvent, preferably the one that is being used in the process. When slurries are used in a process, it is important that the slurry be uniform. If feed to the reactor or the formulation vessel is not uniform, the product quality would vary for a continuous process and could result in potential financial loss. Variable feed rate can influence batch-process product quality also. Each situation has to be considered on an individual basis.

Since we do not handle molten materials in the laboratory, we do not consider melt addition on a larger scale. This can be due to our lack of experience in handling molten materials or lack of availability of bulk molten material. Melt feed addition might be economical for high volume or selective products as molten liquid metering systems are commercially available. We should consider melt use as it can reduce solvent need, which in turn can improve process productivity and sustainability. Lower product cost and higher profits are additional incentives.

When a gas is needed for a reaction, we end up bubbling the gas using a weight-loss system or, in the case of ammonia, using its solution. This works well for the laboratory, but on a commercial scale, the large volume of water required to dissolve ammonia takes up reactor volume. This can lower productivity significantly. Weight-loss systems work well for batch operations, but are not very efficient for continuous processes. If the volume is justified, liquefied gas addition is safer because, in its liquid state, it can be metered more effectively. Gas would be evaporated and mixed in the reaction mass.

Solubility

Solubility is not an exotic property but is an important and valuable property. Mutual solubility or the lack thereof, can be very useful in reactive chemical processing and formulations. If the reactants and reaction product dissolve in the same solvent, the reaction rate can improve through improved mass transfer. Solubility of materials in the solvents used in the formulated products improves mixing and results in a uniform product. Solubility characteristics of chemicals are also critical for product crystallization, purification and separation of products.

Generally, higher solubility is considered to be more valuable, but low solubility can also be useful, especially for separating chemicals. In reactive processes, low solubility can be effectively used to separate phases and reaction products to improve process yield. Creative use of solubility in reaction systems to improve conversion will be discussed more later.

Density

Density is defined as mass per unit volume, and shows mass relative to other chemicals. In a thoroughly mixed system, density might not have value, but it is one of the unique properties that can be effectively used for separation of two immiscible liquids. I think of density as mother nature's gift — imagine the challenge involved with separating petroleum and water if their densities were same. Density differences can be effectively used for product separation, and also for creating a mix that is beneficial in the reaction and formulation process.

Viscosity

The importance of viscosity is different in chemical reactions versus formulated products. By itself, viscosity may not be considered a very important property, but engineers must be aware of it, especially when the chemicals in the process mixtures are in liquid form. Viscosity is important while feeding, mixing and pumping liquids. It is best to reduce the viscosity to its lowest levels to facilitate addition, pumping and mixing. This can be accomplished either by dissolving in suitable solvents, or by heating the liquids, although the stability of the liquid has to be carefully considered. Preferred solvents should be the ones that are being used in the process. In certain formulated products, viscosity control is necessary for product performance and their applications.

Specific heat

Specific heat of a chemical is an important property and is of value in chemical reactions. For chemical reactions, it is important to control the heat of reaction, and specific heat determines how much heat needs to be removed. Specific heat values impact capital investment because it affects the size of the heat-transfer equipment required.

Heat of formation

Process reactions are either endothermic or exothermic. In general, most reactive processes are exothermic. How we control the heat of reaction can significantly impact the rate of reaction as well as the size of the equipment necessary. In addition, it is critical to control the heat of reaction, as a runaway reaction can rapidly raise the process temperature and result in explosions and other hazardous situations. Effective control of the heat of formation can reduce the reaction residence time, which in turn, reduces the size of the equipment (that is, investment). Heat of formation is also influenced and controlled by the method and sequence used for raw material addition.

Azeotropic behavior

To many chemists or chemical engineers, the azeotropic behavior of chemicals might appear to be of limited value — it does not have much value in formulations. However, the azeotropic behavior of chemicals can be used very creatively in manipulating reaction processes. Imagine a reaction process where the liquid mix has an azeotrope and the chemicals are immiscible. Combination of these two properties can be very effectively used not only to control a reaction exotherm but also used to improve yield.

EXAMPLES

Physical properties are valuable tools for the process creator and manipulator, and he or she can take advantage of them when creating and simplifying a process. Exploiting several different physical properties in a process is an exhilarating challenge with moments of success and failure. However, failures should be viewed as learning experiences that will help in future applications.

When developing processes, engineers should look to incorporate anything and everything they can imagine. Imagination and creativity can lead to unconventional ways of exploiting unique chemical properties and their interactions to arrive at excellent processes. In the end, how the simplified process is executed in a commercial scenario matters a great deal. This is very similar to creation of an excellent musical composition. Some of the examples of how physical properties can be manipulated for process simplification are included here:

Use of molten raw materials

Traditional approach: A primary raw material "A" is solid at room temperature. Its melting point is about 65°C. It reacts with chemical "B", a liquid, in presence of a solid catalyst. The reaction is carried out at about 75°C. The resulting product "C" is a liquid at room temperature. The product-solvent mix is reacted further. Traditionally, "A" would be dissolved in a solvent and added to the reactor. Catalyst would be added using appropriate methods. Concentration of "A" in the solvent is about 25% to have a soluble solution.

Alternate approach: Since the melting point of the raw material "A" is low and to achieve a reasonable reaction rate requires the reaction mass to be heated to a temperature higher than the melting point of "A," it may be efficient and productive to feed the raw material "A" as a melt. Melt addition raises the temperature of the reaction mass faster than heating the reaction mass from room temperature. This will reduce the cycle time of the batch process. Reaction temperature can be controlled using conventional process-control strategies.

RELATIONSHIP AMONG PROPERTIES

Those working in the chemical process industries (CPI) are likely familiar with physical properties such as melting point, boiling point, density, specific heat, density and others. However, using physical properties to create great chemical processes depends on their mutual relationships, and to the nuances of the manufacturing process. Reaction chemistries produce new molecules, and when different molecules are blended, formulated products are produced. Some physical properties are common to reaction chemistries and formulated products, while others are not. How these properties are used in a process depends upon our understanding of their value and relationship with other properties. Just as each process has its own individual requirements, each physical property is unique. The uniqueness of the physical properties of one chemical relative to other chemicals in the process offers engineers the opportunity to manipulate them to create an optimal process. ❑

If the process is continuous, maintaining the reaction temperature at the desired temperature can control the reaction rate. Because the solvent is replaced with a melt, the process productivity improves considerably. Since product "C" is a liquid at room temperature, using a melt also raises process productivity. Reduced solvent use also lowers the solvent recovery load and improves process sustainability.

To be viable, the alternate method has some built-in caveats, including that the raw material "A" has to be available in melt form, and the production volume has to be large enough to warrant the melt material handling investment.

There are numerous cases where molten raw materials can be used with very tight stoichiometric control. Each situation has to be evaluated. The resulting product can be purified using different unit operations and crystallized to produce products with the desired quality. Such processes are environmentally more sustainable, productive and highly profitable compared to solvent-based processes.

Use of phase separation

Case A: In some reactions, a byproduct, such as water, must be removed. If the solvent is insoluble in water, and if their densities are sufficiently different, then the solubility and density differences can be used to separate the two and the solvent can be recycled back to the process.

In processes where water forms an azeotrope with the solvent, water is evaporated out with the solvent and the mix is condensed. Use of chilled water in the overhead condenser can not only improve the condensation of the azeotropic mix, but since the solvent temperature will be lower compared to that of condensation using cooling-tower water, the reaction rate can be improved. This will lower the batch cycle time and improve profitability.

Case B: Phase separation can be effectively used to enhance process yield. In the following reaction, intermediates "C" and "D" are produced. Intermediate "C" is soluble in water and "D" is soluble in an organic solvent. In the subsequent reaction, these two intermediates are reacted to produce product "E." However, intermediate "D" hydrolyzes to produce an unwanted product if left in contact with water, and process yield is significantly lowered.

A + B —> C + D —> E

To preserve the yield, it is best to separate the two phases and mix them just before the production of "E" begins.

U.S. patent no. 7,078,524 discusses a chemical reaction where two isomers are produced. One is a desired pharmaceutical product and the other cannot be converted to a saleable product. However, the overall process yield is improved if the undesired isomer is isolated and recycled after separation. The process suggested in the patent can be significantly simplified through creative solvent selection. Were the described process to be commercialized as indicated in the patent, it would be cumbersome and would extend the batch cycle time significantly.

However, through proper solvent selection, the "undesired" isomer can be recycled in situ, the process could be not only simplified, but process yield would be improved. This is an example of how human creativity, along with the ability to finesse physical characteristics, could generate a better process — a possible "Eureka" moment.

For any reactive chemical process, solvent selection is extremely important, especially where phase separation is involved. Greater difference in densities facilitates and accelerates phase separation. Recognize that solution density increases as more solid is dissolved in a solvent. If the densities of the solutions to be separated approach each other, separation can become a challenge, and will take longer. Thus it is important to choose solvents such that there is a noticeable density difference under the process conditions. This difference can hasten the separation, lowering the processing time. From a manufacturing standpoint reduced process time through a faster separation is important.

Capitalizing on exotherm

Due to equipment capability limitations during process development in the laboratory, the exotherm is controlled either by lowering the reaction temperature with ice or chilled water, or by slowing the raw-material addition rate. When such processes are scaled-up, the same practice continues. These methods work, but they extend the reaction time and reduce the process productivity.

It is well known that raising the reaction temperature speeds the reaction rate and can improve yield. A reaction exotherm can be very effectively controlled by the efficient use of heat exchangers. Commercial technologies exist for doing this. What variables can be manipulated (such as, feed method, flow, flowrate, temperature control, and so on) and how they are controlled, will improve profits through the development of a simpler and more sustainable process.

Controlling exotherms effectively, and as soon as they happen, using heat exchangers can not only improve the process yield, but makes the process safer and prevents formation of color bodies that can occur due to localized heat generation. Inline heat exchangers in a pump-around system represent one of the methods. Other methods are situation dependent.

Creating excellent processes

Engineers are routinely educated about the physical and chemical properties of common reactants, solvents and products. However, they generally are not taught how to creatively exploit them to develop processes that are simple, sustainable and economical. Finding methodology to finesse these properties into simplified processes comes from a firm understanding of the properties, and from previous experience. Chemical properties must be integrated with the correct unit operations and proper stoichiometry control to produce a quality product. Such processes will be more robust, economical and will require minimal in-process testing of intermediates. Products will have consistent and repeatable quality, and therefore, lower cost. Incomplete understanding and poor manipulation of the physical properties of the chemicals in a process and their interactions can lead to quality issues. It would be like composing a musical piece where the notes are poorly placed and required fine tuning each time the composition is performed.

Working with creative people who are "masters in manipulation" of chemical properties helps a great deal. Additional examples and methods to those discussed in this article can be found in [*1*].

Establishing processes that yield the desired quality and that require minimal (or no) testing of process intermediates should be the goal of chemists and engineers involved with both chemicals and pharmaceuticals. Most existing chemical processes can be simplified and improved as part of a "continuous improvement" exercise by fine tuning, using design of experiments and other similar tools. However, changes to processes and products requiring regulatory approval (such as pharmaceuticals) pose a cost and time challenge in this area, since process adjustments to a product that has been approved would require re-approval, and that can be an expensive undertaking.

A key challenge for chemists and process engineers in both the chemical and pharmaceutical arenas is to gain a comprehensive understanding of the nuances of the physical properties of the chemicals they work with, and to think carefully — from the earliest stages of process design and development — about how to leverage those properties to create a simple process. ■

Edited by Scott Jenkins

References

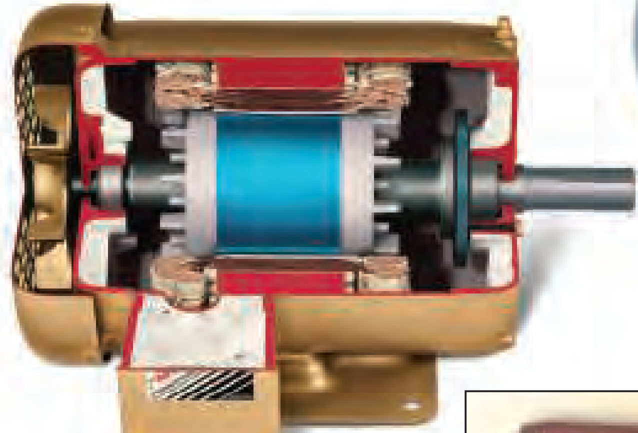
1. Malhotra, G. "Chemical Process Simplification: Improving Productivity and Sustainability," John Wiley & Sons, Hoboken, N.J., 2011.

Author

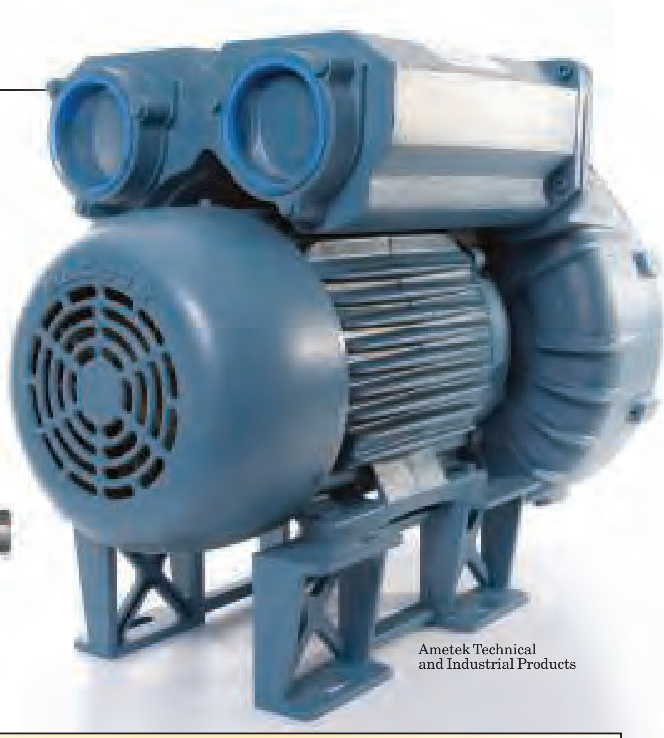
Girish Malhotra is president and founder of EPCOT International (29150 Bryce Road, Pepper Pike, OH 44124; Email: girish@epcotint.com; Phone: 216-292-0626). He has more than 43 years of industrial experience in pharmaceuticals, specialty, custom and fine chemicals, coatings, resins and polymers, additives in manufacturing, process and technology development and business development. Malhotra enhances profitability by simplifying technology and manufacturing practices using engineering and science principles. Malhotra focuses on process technology development; process simplification and quality improvement; lowering manufacturing costs; process improvements; and waste reduction. He has an M.S.Ch.E. from Clarkson University and a B.S.Ch.E from H. B. Technological University, India. Malhotra is a Member of AIChE and is a licensed professional engineer in the states of Illinois and Ohio.

FOCUS ON

Motors & Drives



Baldor Electric



Ametek Technical and Industrial Products

Omega Engineering

More motors added to this product line

This company has added 98 new ratings to its Super-E motors with Internal AEGIS Bearing Protection Ring (photo). The additional ratings expand the existing four-pole line of TEFC & ODP designs through 100 hp, and add a generous offering of two- and six-pole models as well. Also, 575-V TEFC motors were added, 1–50 hp, as well as TEFC & ODP close-coupled pump motors. While most shaft-ground applications use a shaft ground on the outside of the motor, the Super-E has the grounding ring factory installed internally on the motor. This internal design minimizes exposure to the outside elements and keeps the grounding ring from being damaged by external forces, says the manufacturer. Applications include heating, ventilation and air conditioning (HVAC) blower and fan motors, pump motors and other general-purpose applications using an adjustable-speed drive. — *Baldor Electric Co., Fort Smith, Ariz.*
www.baldor.com

Precise speed control for small motors with this device

The OMDC-MD Series (photo) is a compact, programmable speed control with digital closed-loop feedback and LED display for d.c. motors rated to 2 hp. It features adjustable minimum and maximum speeds, adjustable acceleration and deceleration, and display options include decimal point positions and intensity. The pulse input capacity for speed feedback is 50,000 pulses per minute (833 Hz). Non-volatile memory in the device provides programmable power-on initial settings and allows all custom settings to be stored for future use. — *Omega Engineering, Inc., Stamford, Conn.*
www.omega.com

The motors in these blowers are explosion proof

Rotron EN and CP regenerative blowers incorporating explosion-proof a.c. motors (photo) provide ideal solutions for a wide range of environmental remediation and chemical processing applications. These motors are UL and CSA approved for Class 1 Group D explosive-gas atmospheres to promote safe operation in potentially hazardous locations. Typical applications include spot sourcing, vent header off-gassing, landfill gas recovery and scrubbing, to name a few. The explosion-proof motors can accommodate international voltage and frequency requirements, and can deliver the power necessary to satisfy the most demanding applications, says the company. — *Ametek Technical and Industrial Products, Kent, Ohio*
www.ametektechnicalproducts.com

These brushless motors are very efficient

In January, this company introduced its next generation design of 3- and 5-hp PremiumPlus+ motors (photo, p. 56). Gen2.0 brushless permanent-magnet motors driven by variable frequency drives (VFDs), boast motor-

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

Novatorque

Force Control Industries

Siemens Industry

only rated point efficiencies of 93 and 92% for the 3- and 5-hp versions, respectively — far exceeding the levels achieved with induction motors, says the manufacturer. In addition to higher efficiencies, the PremiumPlus+ motors also maintain their high efficiency over a much wider speed range. These motors are packaged in standard NEMA frame sizes and mounting dimensions for easy substitution, and are compatible with readily available VFDs from most leading manufacturers. — *Novatorque, Inc., Sunnyvale, Calif.*
www.novatorque.com

Motion control for when rapid speed changes are required
Posidyne clutch/brakes (photo) feature oil-shear technology that allows rapid and precise stopping, starting, reversing, speed change and positioning — all without adjustment and virtually no maintenance, says the manufacturer. These motion-control devices are suited for applications with frequent start/stop cycles, and allow higher cycle rates (as high as 300 cycles per minute) to increase production rates with lower downtime. The unit dissipates heat through the housing by flowing fluids from the friction surface to the housing. Additional heat can be dissipated by adding an integral fan or a water-cooling system, or even by withdrawing the fluid out of the unit for additional heat exchanger cooling and filtration. The controller is totally enclosed, making it impervious to dust, chips, chemicals, coolants, caustic wash-down, weather and more. — *Force Control Industries, Inc., Fairfield, Ohio*
www.forcecontrol.com

These motors operate in hazardous zones
Suitable for pumps, compressors, fans, extruders and mixers in the chemical and petrochemical industries, the Loher Chemstar Ex nA II motor (photo) is designed to fulfill the requirements for use in hazardous Zone 2 applications. For example, an extremely high-quality paint finish and galvanized fan cowl protect against aggressive atmospheres. Anti-condensation heating is often no longer required — even for high levels of air humidity. When required, the motors can be equipped with corrosion-resistant stainless-steel screws and bolts. Shaft seals rated to IP66 protect against water and dust, and the protection extends up to IP67. The enclosure is manufactured out of rugged, gray cast iron, and is therefore extremely resistant to corrosion. It also dampens vibration and has a high strength, says the manufacturer. — *Siemens Industry, Inc., Norwood, Ohio*
www.usa.siemens.com/motors

Control machinery via single network with this drive
The new Allen-Bradley PowerFlex 755 AC Drive with Integrated Motion provides users with the simplicity of using a single EtherNet/IP network for complete machine control, thereby eliminating the need for a dedicated motion network. The ability to support variable frequency drives, servo drives, I/O, smart actuators and other EtherNet/IP-connected devices on a common network helps increase design flexibility, improve system performance and reduce engineering costs, says the manufacturer. The PowerFlex 755 AC drive and the Kinetix 6500 servo drive can reside on the same standard network, helping to simplify machine design, operation and maintenance. Both drives provide high-performance, closed- and open-loop drive control using the Common Industrial Protocol (CIP) Motion technology on EtherNet/IP. Users can also configure the drives using the same Rockwell Software RS Logix 5000 software. — *Rockwell Automation, Inc., Milwaukee, Wisc.*
www.ra.rockwell.com ■

Gerald Ondrey

CHEMICAL ENGINEERING

Gulf Coast

special advertising section

A Box 4 U
Aggreko
Bryan Research & Engineering
Cashco
Chemstations
EPCON Software
EPI Engineering
Flexitallic
HTRI
Mustang Engineering
Solutia Therminol
Tuthill Vacuum and Blower Systems
Zeeco

Access Intelligence

A powerful simulation resource for refiners

Bryan Research & Engineering introduces the latest addition to its simulation suite: ProMax Refinery Reactor Suite

For over 35 years, **Bryan Research & Engineering Inc.** (BR&E) has been committed to providing the energy industry with process simulation software that accurately and efficiently predicts the performance of gas processing, refining and petrochemical processes. Today, BR&E's ProMax simulator is used by engineers around the world to design and optimize processing facilities. Totally integrated with Microsoft Visio, Excel, and Word, ProMax is a comprehensive tool that offers incomparable flexibility.

The current version of ProMax contains a suite for modeling equilibrium, conversion, Gibbs minimization, and user-defined reaction sets. In addition to these features, BR&E is excited to introduce its newest simulation resource, ProMax Refinery Reactor Suite, which is a series of catalytic reactor models based on the concept of single event kinetics. This tool will allow the refiner to model reactors with little to no kinetic rate-based data. ProMax Refinery Reactor Suite accounts for differences in catalyst performance by providing the user with a calibration toolbox to tune single event kinetic parameters to predict plant performance. The first release of the Reactor Suite will include catalytic reforming, with future releases covering hydrotreating, hydrocracking, and fluidized-bed catalytic cracking (FCC).

ProMax is also widely known for its ability to model many aspects of a refinery. For instance, ProMax may be used to:

- model atmospheric and vacuum towers;
- model main fractionators, including FCC and coker;
- characterize crude oils;
- model gas and liquid sweetening;
- model sulfur recovery;
- study refinery changes on sour treating systems;
- simulate caustic treaters; and
- investigate preheat exchange and fouling.

A ProMax license includes much more than just software. Bryan Research & Engineering is committed to providing unrivaled customer support. BR&E offers free training sessions around the world, provides timely customer support from a staff of knowledgeable and experienced engineers, and sets up free initial plant models for operating companies.

ProMax's advanced technology, including over 2,500 pure components and 50 thermodynamic package combinations, along with BR&E's exceptional client services unite to make ProMax the "must have" simulation resource.

www.bre.com

Gasket manufacturer celebrates centennial

Global sealing gasket manufacturer Flexitallic has been serving the chemical process industries since 1912

2012 marks the 100th anniversary for leading industrial gasket sealing company **Flexitallic**. Since 1912, when the first spiral-wound gasket was invented, Flexitallic has developed and manufactured innovative and sustainable gasket devices to companies in the U.S. and around the world.

"All of us at Flexitallic celebrate this momentous year and our position as a leader in engineering, manufacturing and distribution of industrial sealing solutions," says Jerry Lastovica, President of Flexitallic. "We have evolved substantially over time by continuing to meet the needs of our customers and the rapidly changing industries that we serve." Flexitallic operates in process industries including oil and gas, petrochemical, chemical, pharmaceutical and power generation as well as serving original equipment manufacturers.

"The constant development of new products and capabilities has been the true foundation of our growth and success," says Keith Miller, Vice President of Marketing & Engineering for Flexitallic. "Revolutionary product materials such as Thermiculite and Sigma are just a couple of examples of the high-quality products that Flexitallic has developed and that are being used globally."

In celebration of continued innovation and to kick off its second century of success, Flexitallic is bringing Change to the sealing industry. Change is a new metal-wound heat exchanger gasket that delivers a more dynamic seal than anything on the market today. "We are excited to launch Change," adds Miller. "It is a product that was developed by listening to our customers and their chronic problems with double jacketed (DJ) gaskets in heat exchangers.

"Whether it is a new product or a legacy solution, our commitment to our customers remains the same… and that is to design and build products that are the benchmark of quality, safety, reliability, and longevity," adds Lastovica. "For the future, we look forward to continuing to pave the way as a leader in sealing devices and solutions."

flexitallic.com

These blast-resistant buildings are tested for real

A Box 4 U supplies blast-resistant buildings that have been tested in real explosions – unlike those of some other manufacturers, points out Dr Ali Sari, PE

Tested at 10 psi: a blast-resistant building from A Box 4 U

When my team investigated the Texas City, Texas, refinery disaster in 2005, I immediately noticed two things: one, where wood-frame office trailers had stood, only splinters remained; and two, a number of shipping containers in the blast zone were still standing.

Around the same time, ConocoPhillips approached Kansas-based company **A Box 4 U** to ask if they could build a more rugged office to protect personnel in blast zones. A Box 4 U contacted me, and we set out to create a blast resistant building based on the shipping container form factor.

There were other companies selling blast resistant buildings, so we researched their products, only to find that none had actually been blast tested. I was amazed to learn that some petrochemical plants were buying them based on interior amenities like attractive lighting fixtures and even glass mirrors in the restrooms, which could injure or kill personnel in a blast. This is still true of many blast-resistant buildings.

We worked through the engineering process, adding reinforcements to the basic shipping container model, and ultimately created what has evolved into a custom design that can be either portable or permanent, plain or elegant.

Then we did something unprecedented in the field of blast-resistant buildings: we blast tested the product (rated at 10 psi using a high explosive charge at a standoff distance of 100 feet). We needed to be confident that our building could actually save lives. It can. Everything inside our building was unharmed: the lights, furniture, computers and test dummies. The blast test videos on our website speak for themselves in terms of the product's ability to survive close-proximity explosions.

Hopefully there will never be an opportunity to find out how they perform in a real disaster, but if I'm ever close enough to witness an explosion at a refinery or chemical plant, I know where I want to be. **www.abox4u.net**

50 years of leadership in heat transfer

HTRI this year celebrates half a century of helping companies in the chemical process industries effectively use heat transfer technology

Heat Transfer Research, Inc. (HTRI) is a leading global provider of process heat transfer and heat exchanger technology, research, and software. Founded in 1962, this industrial research and development consortium serves the engineering needs of over 1200 corporate member sites in 57 countries. In 2012, HTRI proudly celebrates 50 years in business.

HTRI's proprietary research is currently conducted on seven rigs at the organization's state-of-the-art Research & Technology Center. These industrially relevant studies are augmented by the use of computational fluid dynamics (CFD) and quantitative flow visualization. HTRI uses the proprietary data from these efforts to develop methods and software for the thermal design and analysis of heat exchangers and fired heaters.

HTRI ***Xchanger Suite***®, the most advanced software for the design, rating, and simulation of heat exchangers, brings HTRI's rigorous research to end users in an integrated graphical environment. It delivers accurate design calculations for:

- shell-and-tube heat exchangers;
- jacketed pipe and hairpin heat exchangers;
- plate-and-frame heat exchangers;
- plate-fin heat exchangers (coming in ***Xchanger Suite***® Version 7);
- spiral plate heat exchangers;
- fired heaters;
- air coolers and economizers;
- tube layout and vibration analysis.

Additionally, HTRI provides technical support to all members and offers training, consulting, and contract services to both members and non-members.

HTRI's dedication to excellence assures customers of a distinct competitive advantage and a high level of operating confidence in equipment designed with HTRI technology. **www.htri.net**

Optimization is key to operational efficiency

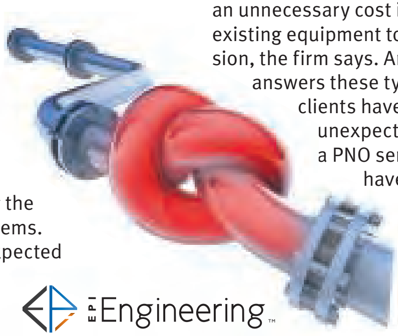
Houston-based engineering firm sets the standard for efficiency studies to reduce overall energy and water consumption at refineries and chemical processing plants

Many refiners and chemical processors realize there are hidden energy and water savings within their facilities – but just don't know how to capture them. **EPI Engineering**, a Houston-based engineering firm, leads the way in finding these hidden savings through a range of efficiency studies that have been proven in industry all across the Gulf.

The way EPI is able to achieve such a high rate of success is due to the patented technology it uses in the majority of the studies, and the strategic partnerships EPI has formed over the years. EPI has reduced the majority of its clients' energy and/or water consumption figures with little or no capital requirements, and describes the approach as a "no-brainer".

The most popular service is EPI's Pipeline Network Optimization (PNO) Study based on the firm's expertise in fluid flow. With a PNO study, every pipeline network in a facility will be looked at in detail and optimized to reduce energy consumption and waste while increasing the overall safety of the operation. EPI aims to accomplish these goals by optimizing what already exists, compared to other engineering firms which may recommend costly capital additions that are not needed to solve the problem. To further optimize the overall operation of the facility's pipeline network hydraulic systems, EPI also studies how each system works in harmony with the others.

Using these techniques, EPI reduced the overall energy and water consumption at a local petrochemical processing facility that resulted in an implemented water and energy savings of $12 million annually, just by optimizing the existing hydraulic systems. The best part: an unexpected $10 million capital cost avoidance was also realized from EPI's work. EPI also helped increase one of its client's throughputs by optimizing their cooling water systems which resulted in greater production rates and reduced water consumption.



Steam, condensate and boiler feed water studies, along with cooling water system studies, usually give the highest returns on investment, but other studies are also critical especially in times of expansion. Adding to existing systems is an unnecessary cost if there is a way to use existing equipment to support an expansion, the firm says. An EPI study always answers these types of questions. EPI clients have come to expect the unexpected when conducting a PNO service because they have seen how EPI always finds significant, hidden savings that require little or no capital expenditures to capture.

epiengineering.com

Delivering results for chemicals and polymers

Mustang provides highly experienced process engineers and project managers for all types of process projects, including automation and control

Mustang has wide-ranging experience on chemical and polymer projects, with a project management team whose members have worked together for more than 30 years. Similarly, Mustang's process engineers average more than 20 years on these types of process industry projects. Behind the scenes, the company boasts superior support teams and the latest 3D modeling techniques, including laser scanning, to streamline projects and reduce costs.

Mustang has completed more than 11,000 engineering projects worldwide

Mustang can manage its client's projects from conception through to operations. With its proven processes and focus on safety, it executes projects that come in with predictable results – on budget, on time and with flawless startup. Mustang personnel have experience in most of the licensed petrochemical, chemical and polymer processes used today and can assist clients with the introduction of "first of a kind" or licensed technologies. Mustang offers comprehensive technical and economic studies, technology evaluation, experimental program design, pilot plant programs, and acquisition of physical and chemical property data.

Mustang's Automation and Control group adds still another dimension to Mustang's total project capabilities on behalf of its clients. An experienced team with extensive process knowledge provides a vendor-independent approach with cost-effective and workable solutions for complex IT, automation and control projects. Front-end definition is a forte of the team, combined with innovative tools and methodologies that allow Mustang to be a full service provider of automation integration services, including advanced process control and abnormal condition management.

Mustang supports its projects with extensive front-end planning, established procedures and proven best practices. The company uses its own stage gate process (Stage COACH) and a proprietary project management tool (PACESETTER) to ensure that projects are successful from start to finish.

Founded in 1987, Mustang has more than 4,000 employees with offices around the globe and has completed over 11,000 projects for more than 350 clients.

www.mustangeng.com

The expert source for rental energy solutions

Aggreko supplies rental equipment and services for temporary process cooling, climate control, power generation, and compressed air

Cooling towers and generators are among the equipment available

Aggreko's proven experience and innovation have made it the premier resource for rental energy solutions for the petrochemical and refining industries. Drawing on vast industry-specific knowledge, the company develops custom solutions to meet the challenges of turnarounds, shutdowns and general maintenance, including process, operational and environmental constraints.

Aggreko Process Services (APS) consists of an experienced process engineering team. It can design and install process enhancement solutions within a matter of weeks, rather than the months required for a typical capital project. This enables customers to capture short-run market opportunities. APS specifically targets process limitations caused by high ambient temperatures and fouled or under-performing equipment.

To address the demands for emergency or supplemental cooling at refineries, factories or other plants, Aggreko Cooling Tower Services (ACTS) was created. It provides 24-hour availability of the largest fleet of modular cooling towers in the industry, and enables operations to keep running smoothly during emergencies or maximize production while reducing the risks inherent in process cooling. Additional benefits of ACTS include:

- maximize production during hot summer months or peak demand times;
- maintain production while repairing or maintaining existing cooling tower;
- reduce costly downtime after disaster strikes; and
- meet or exceed customers' own environmental and safety standards.

Whether providing rapid emergency response to equipment failures or vessel cooling services to increase production, Aggreko is committed to delivering the highest performance standards 24/7/365. Aggreko keeps production and profitability flowing while delivering valuable time and cost savings, thanks to its experience, skill and specialized equipment.

www.aggreko.com/northamerica

Pipe flow analysis software continues to evolve

Industry-leading pipe flow analysis software Engineer's Aide SiNET from EPCON Software improves simulation convergence speeds by 100 times

Since its introduction to industry over 20 years ago, the pipe flow analysis software solution Engineer's Aide SiNET from **EPCON Software** has established itself as a leader in fluid flow simulation. A vital tool used by many process manufacturers and engineering firms around the world, Engineer's Aide SiNET gives engineers the ability to quickly and easily size and design over 20 types of equipment including pipes, pumps, control valves, heat exchangers, compressors, pressure vessels, tanks, fans and blowers.

In addition to equipment sizing and design tools, Engineer's Aide SiNET also provides the industry's leading fluid flow simulation solution; but it just got better with the release of version 8.4. SiNET's powerful, patented graphical user interface combined with EPCON's newly developed computational engines provide unmatched performance with improved model convergence speeds of up to 100 times faster. Models that once took minutes to converge now only takes seconds.

With Engineer's Aide SiNET, simulating and analyzing large liquid or gas piping networks for steam, condensate, nitrogen, hydrogen, cooling water, fire water, or compressed air is a breeze

SiNET's newly developed computational engines now also support unlimited piping and equipment in simulation models where previous versions only allowed up to 2000 model components. And when it comes to physical properties EPCON offers only the best by including the latest version of the AIChE DIPPR database for no additional cost. This physical properties database has been developed by leading industry experts over the past 30+ years. This is why unlike other pipe flow analysis software products, Engineer's Aide SiNET provides simulation support for both liquid and gas flow systems.

EPCON plans to redevelop its patented graphical user interface still further. The ninth version of Engineer's Aide SiNET will allow dynamic simulation of any type of liquid or gas piping system for quick identification of pressure drops and other flow deficiencies. Free upgrade is offered for those who purchase SiNET 8.4 before the official version 9 release.

EPCON Software, who also developed other industry leading software products such as the API Technical Data Book and the GPA Data Bank, plans to continue the evolution of its software products to meet the always changing demand of industry through feedback from its customer base.

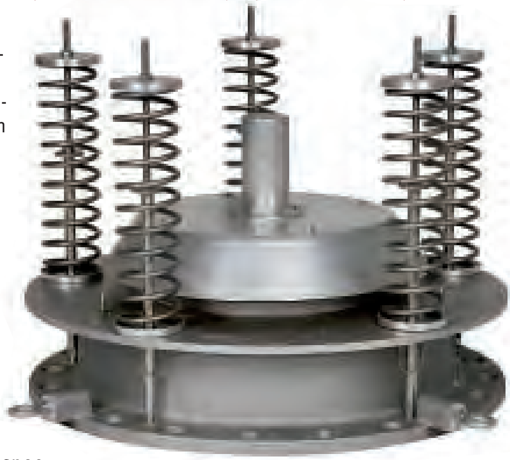
www.epcon.com

A versatile range of emergency relief vent valves

These new manway pressure and pressure/vacuum relief vents go well beyond the performance of normal pressure relief systems, says manufacturer Valve Concepts

The new VCI 8900 Series from **Valve Concepts, Inc.** (VCI) provides the versatility that comes with innovative design and modular construction. Available in both top-guided (spring-loaded) and hinged (weight-loaded) configurations, 8900 Series relief vents feature a one-piece flange base with an integrated bolting pad to accommodate the hinged design. The modular design allows the valves to be converted from a pressure/vacuum vent to a pressure-only vent or vice versa.

"The design also permits the pressure pallet assembly to be easily removed for unobstructed access to the tank for cleaning, inspection or repairs," says Aaron Brantley, VCI product engineer. "Plus, the flange base incorporates a set of integrated lifting lugs for easier removal or installation."



Modular design makes the VCI 8900 a versatile pressure/vacuum relief valve

Unlike competitive emergency pressure relief vents that use an O-ring for sealing, 8900 Series units utilize a flat diaphragm, which forms around the seat to provide a tighter seal and improved reliability. "The pressure pallet assembly provides an effective vapor-tight seal when the tank is not under emergency conditions," Brantley continues, "and after the excess pressure is relieved, the pallet assembly will reseat to again provide a vapor-tight seal."

Relief pressure on the hinged Model 8930 pressure relief vent and Model 8940 pressure/vacuum relief vent can be adjusted to <0.5 psig by adding or removing lid weights and counter-balance weights in any combination. The top guided Model 8910 pressure relief vent and Model 8920 pressure/vacuum relief vents can be adjusted from 0.5 to 15 psig by simply tightening or releasing spring pressure. All models are available with 20-inch or 24-inch ASME and API flanged bases, with other designs on request.

VCI, a division of Cashco, Inc., is headquartered in Ellsworth, Kan. Cashco manufactures a broad line of throttling rotary and linear control valves, pressure reducing regulators and back pressure regulators. **www.cashco.com**

Heat transfer fluids for the oil and gas industry

Therminol heat transfer fluids from Solutia are widely used in refining, gas processing, oil and gas pipeline operations, and reprocessing used lube oils

Therminol heat transfer fluids from **Solutia** are commonly used in offshore and onshore oil and gas processing, fractionation, refining, transportation, and recycling operations. Therminol 55, Therminol 59, Therminol 62, Therminol 66 and Therminol VP1 have successfully demonstrated low-cost, reliable, and safe performance in these applications for decades. Therminol fluids are selected because they provide lower capital and operating costs, and better temperature control, than other heat transfer options.

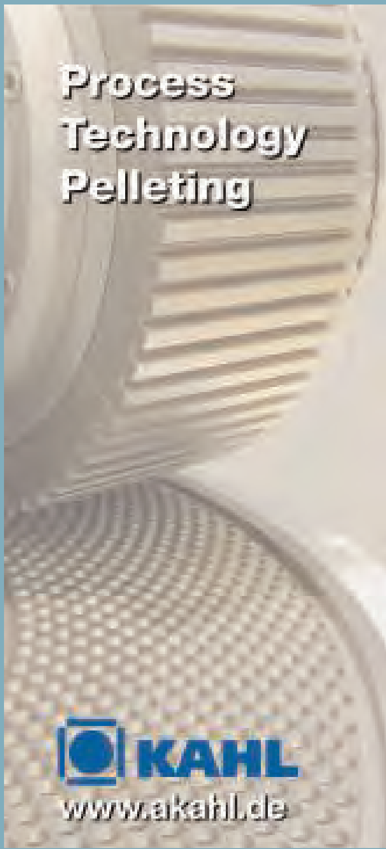
In gas processing and fractionation, Therminol fluids are frequently used to heat gases for regenerating solid desiccants (such as molecular sieve) in gas dehydration beds; to reboil liquid desiccants (such as glycols) used for gas dehydration; to regenerate liquid solvents (such as amines) used for gas sweetening; to heat gas stabilization and NGL fractionation reboilers; and for other gas processing operations.

In oil processing and refining, Therminol fluids are often used to enhance oil/gas/water/sediment/salt separation and for other processing and refining operations such as low-sulfur gasoline production, solvent extraction, and sulfur recovery.

Therminol heat transfer fluids have applications in transportation too. Pumping stations along oil and gas pipelines often require heating to control the viscosity of oil streams, and to prevent condensation of components from gas streams. Therminol heat transfer fluids have proven capable of meeting these requirements in virtually any environment.

And the reprocessing of used lubricating oils involves operations at very high temperatures and high vacuum, for which Therminol heat transfer fluids are ideal. A variety of Therminol fluids are available with low vapor pressure, high thermal stability, and good heat transfer performance, supporting process needs at virtually any temperature. **www.therminol.com**

Circle 202 on p. 77 or go to adlinks.ce.com/40266-202



Circle 201 on p. 77 or go to adlinks.ce.com/40266-201

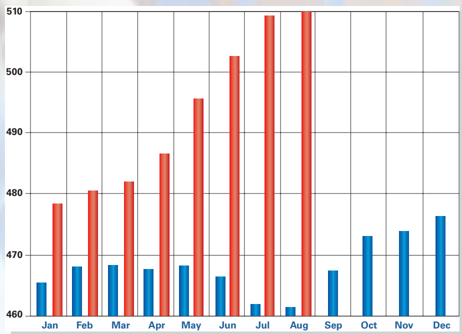
Circle 203 on p. 77 or go to adlinks.ce.com/40266-203

Get *Chemical Engineering*'s plant cost index to improve plant cost estimates… and delivered in advance of the print edition!

For more than 37 years, chemical process industries professionals- engineers, manager and technicians, have used *Chemical Engineering's* Plant Cost Index to adjust process plant construction costs from one period to another.

This database includes all annual archives (1947 to present) and monthly data archives (1970 to present). Instead of waiting more than two weeks for the print or online version of *Chemical Engineering* to arrive, subscribers can access new data as soon as it's calculated.

	Sep '06 Prelim.	Aug '06 Final	Sep '05 Final
CE Index	513.1	510.0	467.2
Equipment	606.5	602.3	541.2
Heat Exchanges and Tanks	565.1	560.9	509.2
Process Machinery	559.6	556.2	521.7
Pipe, valves and fittings	734.7	731.7	620.8
Process Instruments	441.4	437.2	379.5
Pumps and Compressions	788.9	788.3	756.3
Electrical equipment	418.9	414.2	374.6
Structural supports	643.7	637.7	579.3
Construction Labor	314.7	312.9	309.1
Buildings	476.9	475.2	444.7
Engineering Supervision	350.7	351.9	346.9



Resources included with *Chemical Engineering*'s Plant Cost Index:

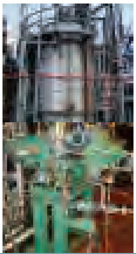
- Electronic notification of monthly updates as soon as they are available
- All annual data archives (1947 to present)
- Monthly data archives (1970 to present)
- Option to download in Excel format

17817

Subscribe today at www.che.com/pci

NEW & USED EQUIPMENT

EQUIPNET www.EquipNet.com/chemical :: 781.821.3482 :: Sales@EquipNet.com



Chemical Processing Equipment from Merck

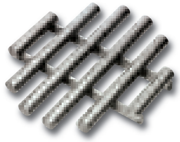
- 236018 • Alloy Fab 5000 Gallon 316L Stainless Steel Reactor
- 235923 • Wiped Film Evaporator System
- 235909 • Westfalia Separator
- 235912 • Ross 42N Double Ribbon Blender in 316L Stainless Steel
- 235977 • Hull Tray Dryer with SIHI Vacuum Skid
- 236029 • Tolan 1500 Gallon 316L Stainless Steel Reactor

Circle 242 on p. 77 or go to adlinks.che.com/40266-242

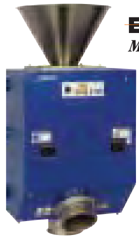
Remove Tramp Metals

ProGrade Magnets
Low Cost • High Power

Plates from $248



Grates from $85



EZ Tec 9100
Metal Separator

- Detects & Rejects:
  - Aluminum - Steel
  - Brass/Copper - Stainless

ERIEZ 70 Years

call 888-300-3743
visit www.eriez.com

Circle 243 on p. 77 or go to adlinks.che.com/40266-243

WABASH SELLS & RENTS

Boilers
20,000 - 400,000 #/Hr.
Diesel & Turbine Generators
50 - 25,000 KW
Gears & Turbines
25 - 4000 HP

We stock large inventories of:
Air Pre-Heaters • Economizers • Deaerators
Pumps • Motors • Fuel Oil Heating and Pump Sets
Valves • Tubes • Controls • Compressors
Pulverizers • Rental Boilers & Generators

24/7 Fast Emergency Service
800-704-2002
Phone: 847-541-5600 Fax: 847-541-1279
www.wabashpower.com

wabash POWER EQUIPMENT CO.
444 Carpenter Ave., Wheeling, IL 60090

Circle 246 on p. 77 or go to adlinks.che.com/40266-246

BOILERS

Boilers (various styles & sizes)
Boiler Parts & Accessories
Burner Management
Chillers
Combustion Controls
Construction Services
Deaerators
Design & Build
Diesel Generators
Economizers
Engineering
Fuel Systems
Pumps
Water Treatment

Rent Lease Sell

Mobile Boilers
(10HP - 250,000PPH)

Rental Diesel Generators
(125KW - 2200KW)

EMERGENCY SERVICE 24HR

Chillers
(Water Cooled: 75-1000 tons
Air Cooled: 75-400 tons)

Please contact us to inquire on our extensive line of Industrial Power Plant Equipment available from stock

INDECK
847.541.8300 / 800.446.3325
info@indeck-power.com
www.indeck.com

Circle 244 on p. 77 or go to adlinks.che.com/40266-244

HEAT EXCHANGERS

FOR GASES & LIQUIDS!

Talk Directly with
Blower Cooling Ve

XCHANGER INDUSTRIAL HEAT EXCHANGERS
(952) 933-2559 info@xchanger.com

Circle 247 on p. 77 or go to adlinks.che.com/40266-247

SOFTWARE

www.ae-sim.com
Process Simulators
Material Balance - Process Control
Power Plant Steam Cycles
Free Demo Downloads

Circle 241 on p. 77 or go to adlinks.che.com/40266-241

ADVERTISE IN THE CLASSIFIED

Contact Diane Hammes
Tel: 713-444-9939
Fax: 512-213-4855
Email:
dhammes@accessintel.com

STATIC/ MOTIONLESS MIXERS

Designs for turbulent or laminar flow

- Most delivered from stock
- Low prices

Call Ross today!
1-866-797-2660
Toll Free
www.staticmixers.com
ROSS

Circle 245 on p. 77 or go to adlinks.che.com/40266-245

Advertisers' Index

* International Edition

Classified Index April 2012

Send Advertisements and Box replies to: **Diane Hammes**
Chemical Engineering, 11000 Richmond Ave, Houston, TX 77042
E-mail: dhammes@che.com Tel: 713-343-1885

See bottom of next page for advertising sales representatives' contact information

CHEMICAL ENGINEERING New Product Information

April 2012

JustFAXit! or go to www.che.com/adlinks

Fill out the form and circle or write in the number(s) below, cut it out, and fax it to 800-571-7730.

Go on the Web and fill out the online reader service card.

Name ______________________ Title ______________________

Company ______________________

Address ______________________

City ______________ State/Province ______________ Zip/Postal Code ______________

Country\ ______________ Telephone ______________ Fax ______________

Email | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

FREE PRODUCT INFO
(please answer all the questions)

YOUR INDUSTRY
- 01 Food & Beverages
- 02 Wood, Pulp & Paper
- 03 Inorganic Chemicals
- 04 Plastics, Synthetic Resins
- 05 Drugs & Cosmetics
- 06 Soaps & Detergents
- 07 Paints & Allied Products
- 08 Organic Chemicals
- 09 Agricultural Chemicals
- 10 Petroleum Refining, Coal Products
- 11 Rubber & Misc. Plastics
- 12 Stone, Clay, Glass, Ceramics
- 13 Metallurgical & Metal Products
- 14 Engineering, Design & Construction Firms
- 15 Engineering/Environmental Services
- 16 Equipment Manufacturer
- 17 Energy incl. Co-generation
- 18 Other__________

JOB FUNCTION
- 20 Corporate Management
- 21 Plant Operations incl. Maintenance
- 22 Engineering
- 23 Research & Development
- 24 Safety & Environmental
- 26 Other__________

EMPLOYEE SIZE
- 28 Less than 10 Employees
- 29 10 to 49 Employees
- 30 50 to 99 Employees
- 31 100 to 249 Employees
- 32 250 to 499 Employees
- 33 500 to 999 Employees
- 34 1,000 or more Employees

YOU RECOMMEND, SPECIFY, PURCHASE
(please circle all that apply)
- 40 Drying Equipment
- 41 Filtration/Separation Equipment
- 42 Heat Transfer/Energy Conservation Equipment
- 43 Instrumentation & Control Systems
- 44 Mixing, Blending Equipment
- 45 Motors, Motor Controls
- 46 Piping, Tubing, Fittings
- 47 Pollution Control Equipment & Systems
- 48 Pumps
- 49 Safety Equipment & Services
- 50 Size Reduction & Agglomeration Equipment
- 51 Solids Handling Equipment
- 52 Tanks, Vessels, Reactors
- 53 Valves
- 54 Engineering Computers/Software/Peripherals
- 55 Water Treatment Chemicals & Equipment
- 56 Hazardous Waste Management Systems
- 57 Chemicals & Raw Materials
- 58 Materials of Construction
- 59 Compressors

1	16	31	46	61	76	91	106	121	136	151	166	181	196	211	226	241	256	271	286	301	316	331	346	361	376	391	406	421	436	451	466	481	496	511	526	541	556	571	586
2	17	32	47	62	77	92	107	122	137	152	167	182	197	212	227	242	257	272	287	302	317	332	347	362	377	392	407	422	437	452	467	482	497	512	527	542	557	572	587
3	18	33	48	63	78	93	108	123	138	153	168	183	198	213	228	243	258	273	288	303	318	333	348	363	378	393	408	423	438	453	468	483	498	513	528	543	558	573	588
4	19	34	49	64	79	94	109	124	139	154	169	184	199	214	229	244	259	274	289	304	319	334	349	364	379	394	409	424	439	454	469	484	499	514	529	544	559	574	589
5	20	35	50	65	80	95	110	125	140	155	170	185	200	215	230	245	260	275	290	305	320	335	350	365	380	395	410	425	440	455	470	485	500	515	530	545	560	575	590
6	21	36	51	66	81	96	111	126	141	156	171	186	201	216	231	246	261	276	291	306	321	336	351	366	381	396	411	426	441	456	471	486	501	516	531	546	561	576	591
7	22	37	52	67	82	97	112	127	142	157	172	187	202	217	232	247	262	277	292	307	322	337	352	367	382	397	412	427	442	457	472	487	502	517	532	547	562	577	592
8	23	38	53	68	83	98	113	128	143	158	173	188	203	218	233	248	263	278	293	308	323	338	353	368	383	398	413	428	443	458	473	488	503	518	533	548	563	578	593
9	24	39	54	69	84	99	114	129	144	159	174	189	204	219	234	249	264	279	294	309	324	339	354	369	384	399	414	429	444	459	474	489	504	519	534	549	564	579	594
10	25	40	55	70	85	100	115	130	145	160	175	190	205	220	235	250	265	280	295	310	325	340	355	370	385	400	415	430	445	460	475	490	505	520	535	550	565	580	595
11	26	41	56	71	86	101	116	131	146	161	176	191	206	221	236	251	266	281	296	311	326	341	356	371	386	401	416	431	446	461	476	491	506	521	536	551	566	581	596
12	27	42	57	72	87	102	117	132	147	162	177	192	207	222	237	252	267	282	297	312	327	342	357	372	387	402	417	432	447	462	477	492	507	522	537	552	567	582	597
13	28	43	58	73	88	103	118	133	148	163	178	193	208	223	238	253	268	283	298	313	328	343	358	373	388	403	418	433	448	463	478	493	508	523	538	553	568	583	598
14	29	44	59	74	89	104	119	134	149	164	179	194	209	224	239	254	269	284	299	314	329	344	359	374	389	404	419	434	449	464	479	494	509	524	539	554	569	584	599
15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390	405	420	435	450	465	480	495	510	525	540	555	570	585	600

If number(s) do not appear above, please write them here and circle: ______________

Fax this page back to 800-571-7730

ADVERTISING SALES REPRESENTATIVES

North America

Eric Freer, **District Sales Manager**
Chemical Engineering
11000 Richmond Ave, Suite 690, Houston, TX 77042
Tel: 713-343-1904 *E-mail:* efreer@che.com
Alabama, Alaska, Canada, Connecticut, Delaware, Florida, Hawaii, Idaho, Kentucky, Maine, Maryland, Massachusetts, Michigan, Mississippi, Montana, Nebraska, New Hampshire, New Jersey, New York, North & South Carolina, North & South Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, Tennessee, Utah, Vermont, Virginia, Washington, D.C., West Virginia, Wyoming, Latin America

Jason Bullock,
District Sales Manager
Chemical Engineering
8325 Broadway, Ste. 202/PMB 261
Pearland, TX 77581
Tel: 281-485-4077; Fax: 281-485-1285
E-mail: jbullock@che.com;
Arkansas, Arizona, California, Colorado, Georgia, Kansas, Louisiana, Missouri, New Mexico, Nevada, Oklahoma, Texas, Washington

Dan Gentile
District Sales Manager
Tel: 512-918-8075
E-mail: dgentile@che.com
Indiana, Illinois, Iowa, Minnesota, Wisconsin

Diane Hammes
Inside Sales Manager
Chemical Engineering;
11000 Richmond Ave, Suite 690, Houston, TX 77042
Tel: 713-444-9939
E-mail: dhammes@che.com
Product Showcase, Literature Reviews, Classified Display Advertising

International

Petra Trautes
Chemical Engineering
Zeilweg 44
D-60439 Frankfurt am Main
Germany
Phone: +49-69-58604760
Fax: +49-69-5700-2484
Email: ptrautes@che.com
Austria, Czech Republic, Benelux, Eastern Europe, Germany, Scandinavia, Switzerland, United Kingdom

Dipali Dhar
Chemical Engineering
88 Pine Street, 5th floor, New York, NY 10005
Tel: 718-263-1162
E-mail: ddhar@accessintel.com
India

Katshuhiro Ishii
Chemical Engineering
Ace Media Service Inc., 12-6, 4-chome
Nishiiko, Adachi-ku, Tokyo 121, Japan
Tel: 81-3-5691-3335; Fax: 81-3-5691-3336
E-mail: amskatsu@dream.com
Japan

Ferruccio Silvera
Chemical Engineering
Silvera Pubblicita
Viale Monza, 24 Milano 20127, Italy
Tel: 39-02-284-6716;
Fax: 39-02-289-3849
E-mail: ferruccio@silvera.it/www.silvera.it
Andorra, France, Gibraltar, Greece, Israel, Italy, Portugal, Spain

Rudy Teng
Sales Represntative
Chemical Engineering;
Room 1102 #20 Aly 199 Baiyang Road
Pudong Shanghai 201204
China
Tel: +86 21 50592439
Fax: +86 21 50592442
MP: +86 13818181202
E-mail: rudy.teng@gmail.com
Asia-Pacific, Hong Kong, People's Republic of China, Taiwan

BUSINESS NEWS

PLANT WATCH

Wacker invests €40 million to expand polymer site in China

March 5, 2012 — Wacker Chemie AG (Munich, Germany; www.wacker.com) is expanding its polymer activities by investing around €40 million to build two new production facilities at its Nanjing site. Wacker is expanding the site's existing facilities for vinyl acetate-ethylene copolymer (VAE) dispersions by adding a new reactor with an annual capacity of 60,000 metric tons (m.t.). This measure will double Nanjing's VAE dispersion capacity to approximately 120,000 m.t./yr. The new reactor is scheduled to come on stream in mid-2013. Wacker is also building a new plant to produce polyvinyl acetate (PVAc) solid resins with a capacity of 20,000 m.t./yr. This plant is due for completion in early 2013.

WorleyParsons is awarded contract to build plants in China for Evonik

March 1, 2012 — Evonik Industries AG (Essen, Germany; www.evonik.com) has awarded WorleyParsons Ltd. (North Sydney, Australia; www.worleyparsons.com) a contract for the detailed engineering, procurement support and construction management for plants that will produce isophorone and isophorone diamine. The plants will be located in Shanghai, and will have a total capacity of 50,000 ton/yr. The production is scheduled to start in the 1st Q of 2014.

Jacobs selected for Solvay's specialty-polymers project in China

February 28, 2012 — Jacobs Engineering Group Inc. (Pasadena, Calif.; www.jacobs.com) has been awarded a contract from Solvay S.A. (Brussels, Belgium; www.solvay.com) for a specialty-polymers production plant to be built at Solvay's industrial site in Changshu, which is located in the province of Jiangsu, China. Solvay is investing approximately $160 million in this plant, which is scheduled to become operational in the 1st Q of 2014 and is expected to significantly boost Solvay's global production capacity for specialty polymers.

Lanxess to invest €40 million at Newcastle site in South Africa

February 23, 2012 — Lanxess AG (Leverkusen, Germany; www.lanxess.com) is investing €40 million to build a CO_2 concentration unit at its South African site in Newcastle. The modern plant at this site mainly produces sodium dichromate, which is further processed into chrome tanning materials for the global leather industry. The production technology requires a permanent supply of highly concentrated CO_2. Construction of the new unit will start in the 1st Q of 2012, and commissioning of the unit is planned for the 2nd half of 2013.

MERGERS AND ACQUISITIONS

Lanxess makes third acquisition in U.S. within six months

March 14, 2012 — Rhein Chemie (Mannheim, Germany; www.rheinchemie.com), a wholly owned subsidiary of Lanxess, has acquired Tire Curing Bladders LLC (TCB; Little Rock, Ark.), a leading manufacturer of bladders for the tire industry. TCB is a privately owned company that achieved sales of $21 million in 2011. Financial details were not disclosed. The transaction is expected to close with immediate effect.

Outotec strengthens its process control technologies by acquiring Numcore

March 12, 2012 — Outotec Oyj (Espoo, Finland; www.outotec.com) is acquiring all shares in Numcore Ltd. (Kuopio, Finland; www.numcore.fi) — a startup company that develops process control solutions based on 3D imaging. The parties have not disclosed the acquisition price.

Evonik plans to sell it its global colorants business

March 6, 2012 — Evonik Industries AG has entered into an agreement to sell its global colorants business to the U.S.-based private investment firm, Arsenal Capital Partners. Financial terms were not disclosed. The transaction is expected close in April 2012, following the approval of Evonik's supervisory board and the relevant regulatory authorities.

Air Products to acquire DuPont's stake in DA NanoMaterials

March 1, 2012 — Air Products (Lehigh Valley, Pa.; www.airproducts.com) has entered into a definitive agreement to acquire all of DuPont's (Wilmington, Del.; www.dupont.com) interest in DuPont Air Products NanoMaterials LLC (DA NanoMaterials; Tempe, Ariz.; www.nanoslurry.com), the two companies' 50-50 joint venture (JV) serving the global semiconductor and wafer polishing industries. Terms of the agreement were not disclosed.

BASF strengthens its lithium-ion battery portfolio via an acquisition from Merck

February 21, 2012 — BASF SE (Ludwigshafen, Germany; www.basf.com) will acquire the electrolytes business for high-performance batteries from Merck KGaA (Darmstadt, Germany; www.merckgroup.com). The acquisition comprises the technologies and products for enhancing battery performance that Merck has developed, patented and brought to market. The companies have agreed not to disclose financial details of the transaction.

DuPont and Yingli Green Energy enter $100-million strategic agreement

February 16, 2012 — DuPont (Wilmington, Del.; www.dupont.com) and Yingli Energy Co. (Yingli China; Baoding, China; www.yinglisolar.com) have signed a $100-million strategic agreement for photovoltaic materials aimed at accelerating the adoption of solar energy in order to help reduce dependence on fossil fuels. Yingli China is a wholly owned subsidiary of Yingli Green Energy Holding Company Ltd. (Yingli), a solar energy company and a vertically integrated photovoltaic manufacturer.

BASF acquires Ovonic Battery Co., a leader in NiMH battery technology ...

February 14, 2012 – BASF SE has acquired Ovonic Battery Co., a wholly owned subsidiary of Energy Conversion Devices Inc. Based in Rochester Hills, Mich., Ovonic is a global leader in nickel-metalhydride (NiMH) battery technology, including the production of cathode active materials (CAMs) for this battery type. The company also has a battery materials-research facility in Troy, Mich. Ovonic is the inventor of the NiMH technology as it is used today. As part of BASF, Ovonic will be managed under BASF's new global business unit "Battery Materials," which was launched on Jan. 1, 2012, to integrate the company's current and future battery-materials-related activities within a single operating unit managed by its Catalysts div., which is based in Iselin, N.J.

... and invests $50 million to acquire equity ownership position in Sion Power

January 12, 2012 — BASF Corp. (Iselin, N.J.; www.basf.com) has invested $50 million to acquire an equity ownership position in privately held Sion Power (Tucson, Ariz.; www.sionpower.com), a leader in the development of lithium-sulfur (Li-S) batteries. This equity partnership expands upon an existing JV agreement that BASF Future Business GmbH (www.basf-fb.de) established with Sion Power in 2009 to accelerate the commercialization of Sion's proprietary Li-S battery technology. ■

Dorothy Lozowski

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

April 2012; VOL. 119; NO. 4

Chemical Engineering copyright @ 2012 (ISSN 0009-2460) is published monthly, with an additional issue in October, by Access Intelligence, LLC, 4 Choke Cherry Road, 2nd Floor, Rockville, MD, 20850. Chemical Engineering Executive, Editorial, Advertising and Publication Offices: 88 Pine Street, 5th Floor, New York, NY 10005; Phone: 212-621-4674, Fax: 212-621-4694. Subscription rates: $149.97 U.S. and U.S. possessions, $166.97 Canada, and $269 International. $20.00 Back issue & Single copy sales. Periodicals postage paid at Rockville, MD and additional mailing offices. Postmaster: Send address changes to Chemical Engineering, Fulfillment Manager, P.O. Box 3588, Northbrook, IL 60065-3588. Phone: 847-564-9290, Fax: 847-564-9453, email: clientservices@che.com. Change of address, two to eight week notice requested. For information regarding article reprints, please contact Wright's Media, 1-877-652-5295, sales@wrightsmedia.com. Contents may not be reproduced in any form without written permission. Canada Post 40612608. Return undeliverable Canadian Addresses to: PitneyBowes, P.O. BOX 25542, LONDON, ON N6C 6B2

FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

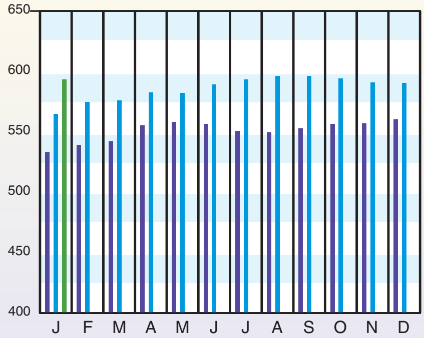
2009 — 2010 — 2011 — 2012

DOWNLOAD THE *CEPCI* TWO WEEKS SOONER AT WWW.CHE.COM/PCI

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Jan.'12 Prelim.	Dec.'11 Final	Jan.'11 Final
***CE* Index**	593.1	590.1	564.8
Equipment	724.5	718.7	681.9
Heat exchangers & tanks	683.1	681.6	635.8
Process machinery	675.7	670.9	643.7
Pipe, valves & fittings	924.9	902.1	859.2
Process instruments	427.0	428.0	431.1
Pumps & compressors	911.6	910.1	876.5
Electrical equipment	511.6	511.5	495.2
Structural supports & misc	768.9	762.4	707.4
Construction labor	327.0	331.4	326.6
Buildings	520.6	519.1	505.5
Engineering & supervision	329.0	329.6	334.8

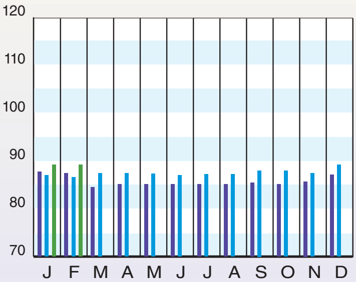
Annual Index:
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7



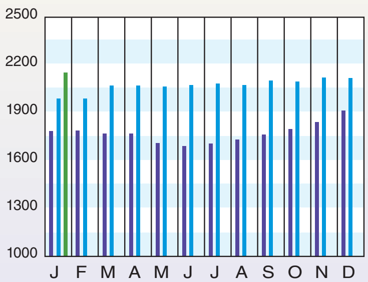
CURRENT BUSINESS INDICATORS

	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2007 = 100)	Feb.'12	=	89.2	Jan.'12	=	89.2	Dec.'11	=	89.2	Feb.'11	=	86.6
CPI value of output, $ billions	Jan.'12	=	2,151.5	Dec.'11	=	2,119.8	Nov.'11	=	2,121.0	Jan.'11	=	1,989.2
CPI operating rate, %	Feb.'12	=	77.2	Jan.'12	=	77.2	Dec.'11	=	77.1	Feb.'11	=	74.7
Producer prices, industrial chemicals (1982 = 100)	Feb.'12	=	318.1	Jan.'12	=	303.9	Dec.'11	=	309.6	Feb.'11	=	311.5
Industrial Production in Manufacturing (2007=100)	Feb.'12	=	94.0	Jan.'12	=	93.8	Dec.'11	=	92.8	Feb.'11	=	89.5
Hourly earnings index, chemical & allied products (1992 = 100)	Feb.'12	=	156.0	Jan.'12	=	158.8	Dec.'11	=	158.5	Feb.'11	=	154.0
Productivity index, chemicals & allied products (1992 = 100)	Feb.'12	=	108.7	Jan.'12	=	109.3	Dec.'11	=	110.5	Feb.'11	=	112.3

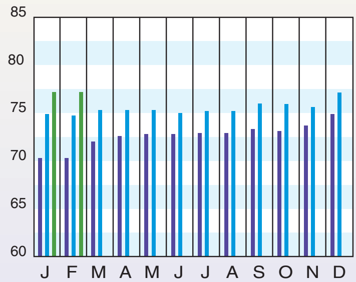
CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



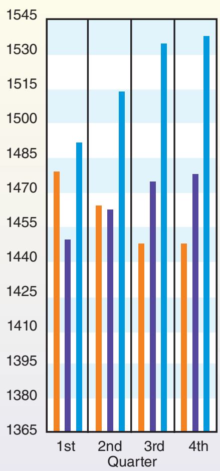
Current Business Indicators provided by IHS Global Insight, Inc., Lexington, Mass.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	4th Q 2011	3rd Q 2011	2nd Q 2011	1st Q 2011	4th Q 2010
M & S INDEX	1,536.5	1,533.3	1,512.5	1,490.2	1,476.7
Process industries, average	1,597.7	1,592.5	1,569.0	1,549.8	1,537.0
Cement	1,596.7	1,589.3	1,568.0	1,546.6	1,532.5
Chemicals	1,565.0	1,559.8	1,537.4	1,519.8	1,507.3
Clay products	1,583.6	1,579.2	1,557.5	1,534.9	1,521.4
Glass	1,495.7	1,491.1	1,469.2	1,447.2	1,432.7
Paint	1,613.6	1,608.7	1,584.1	1,560.7	1,545.8
Paper	1,507.6	1,502.4	1,480.7	1,459.4	1,447.6
Petroleum products	1,704.9	1,698.7	1,672.0	1,652.5	1,640.4
Rubber	1,644.2	1,641.4	1,617.4	1,596.2	1,581.5
Related industries					
Electrical power	1,515.0	1,517.6	1,494.9	1,461.2	1,434.9
Mining, milling	1,659.6	1,648.6	1,623.5	1,599.7	1,579.4
Refrigeration	1,889.4	1,884.4	1,856.4	1,827.8	1,809.3
Steam power	1,574.3	1,572.2	1,546.5	1,523.0	1,506.4

Annual Index:

2003 = 1,123.6	2004 = 1,178.5	2005 = 1,244.5	2006 = 1,302.3
2007 = 1,373.3	2008 = 1,449.3	2009 = 1,468.6	2010 = 1,457.4



CURRENT TRENDS

Capital equipment prices, as reflected in the *CE* Plant Cost Index (CEPCI), increased 0.5% from December to January. This month's issue presents the annual 2011 CEPCI, 585.7, which is an 6.3% increase from 2010 and an 11.4% increase from 2009. It also is the first annual number to surpass the previous peak of 2008.

Visit www.che.com/pci for more information and other tips on capital cost trends and methodology. ■