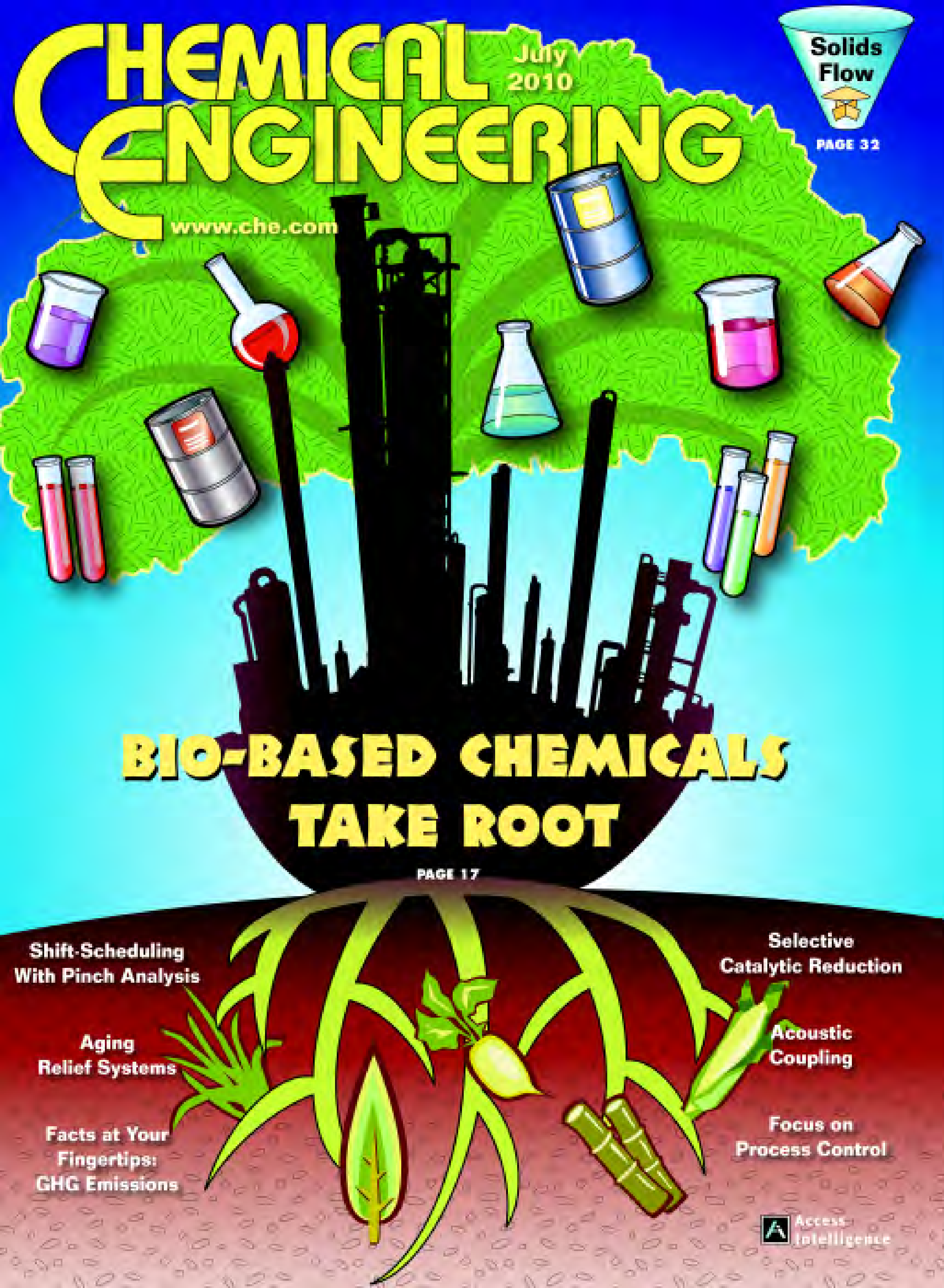

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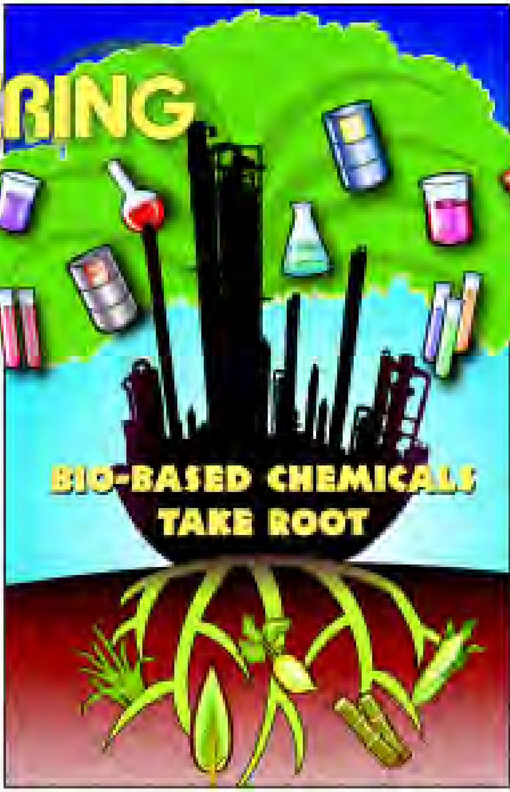

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Editor's Page

Time for new views on China

When it first became a player in the global chemical process industries (CPI), China was framed purely as an opportunity for reducing the costs to produce goods that are consumed elsewhere. More recently, the picture has broadened to include a burgeoning demand for products to be consumed within China by its own increasingly prosperous population. For CPI stakeholders in developed nations, the positive spin on any consequential plant migration is to say that developed nations can continue to thrive by supplying technological innovation and know-how that China does not yet have access to itself. All along, however, anxiety has been brewing about the sustainability of the current path.

Some of the more-obvious red flags are environmental ones that reflect China's much weaker standards than those of the developed world. "The tremendous increase of industrial activities is causing surface water pollution, and scarcity of water is a serious issue in some regions," said Sven-Uwe Geißen, of the Technical University of Berlin, at last month's AchemAsia, the 8th International Exhibition-Congress on Chemical Engineering and Biotechnology, which is organized every three years by Dechema e.V. (Frankfurt am Main, Germany) and the Chemical Industry and Engineering Society of China (CIESC; Beijing). In 2008, of the 409 sections being monitored in the seven key river systems, 20.8% were below grade V, the lowest grade in the Chinese National Standard for Water Quality. Grade V water cannot be used, not even for irrigation*. Turning to air quality, the situation is not any better.

Meanwhile, the labor force in China is increasingly aware of the disparity in wages and seems empowered to changing the situation. Last month, for instance, workers at the Honda Lock (Guangdong) Co. plant in southeastern China went on strike, requesting nearly double their wages, according to an article in the *Wall Street Journal*. And similar incidents are taking place all over China on a weekly, if not daily, basis. If workers are this zealous about wages on the heels of a recession, the significant wage advantage cannot last for long.

Given these and other looming effects of the status quo, everyone would be better off in the longterm if multinational companies would put more focus on servicing China's environmental challenges and less on the cost advantages of doing business there. According to Matthew Sullivan, director of business development and communications at U.S.-Pacific Rim International, Inc. (Baltimore, Md.; www.us-pacific-rim.com), there are many business opportunities in this vein for both equipment providers and CPI companies with strong environmental track records.

It would be naïve to suggest that foreign companies would simply turn a blind eye to the traditional opportunities that exist in servicing China's growing economy. But, the developed world must not relax its standards for short-term gain, and must start putting more attention back into producing innovative products on its own turf as opposed to just services.

In the end, experience, proficiency in foreign languages and the associated accessibility of technical literature and best practices are really the only things holding China back from being able to accomplish all of its goals alone. It is only a matter of time before China's Universities employ mandatory English study, in line with what Russia and many other nations do. And when the time comes, we had better be holding onto something more substantial than the carrot of expertise that no longer hangs above their heads. ■

Rebekkah Marshall

* More, in-depth articles on the technological needs in China can be found in the online version of this article at www.che.com.

Nicholas P. Chopey Scholarship

Striving to continually advance the chemical engineering profession has been a goal of this magazine since its founding more than 108 years ago. To help cultivate new talent, *CE* established the annual Chopey Scholarship for Chemical Engineering Excellence in memory of Nicholas (Nick) P. Chopey, our former Editor In Chief. Nick carried many torches at *CE,* including those for the Kirkpatrick and Personal Achievement Award competitions that are held in alternating years.

We are happy to announce that the winner of this year's Chopey Scholarsip is Elizabeth Mahoney, a chemical engineering student at the University of Kansas. Ms. Mahoney is a member of Theta Tau, Engineering Ambassadors, and a recipient of an Undergraduate Research Award.

About the award: The scholarship is a one-time award for current third-year students who are enrolled in a full-time undergraduate course of study in chemical engineering at one of the following four-year colleges or universities, which include Mr. Chopey's alma mater and those of the current senior-editorial staff:

- University of Virginia
- University of Kansas
- SUNY Buffalo
- Columbia University

The program utilizes standard Scholarship America recipient-selection procedures including the consideration of past academic performance and future potential, leadership and participation in school and community activities, work experience, and statement of career and educational aspirations and goals. Applications are accepted between January 1 and April 1 of each scholarship year. Guidelines are distributed directly to the chemical engineering department of the qualified schools.

2011 donations: Donations are accepted year round. *CE* will match all donations up to $10,000 that are received between June 1, 2010 and June 1, 2011 for the 2011 award.

Postscripts, corrections

June, Who's Who, p. 25: The photos labeled Scoffin and Funchess are incorrectly placed. The labels should be interchanged. The corrected photos are included in the online version of this story at www.che.com.

April, Focus on Flow Measurement: Convert local flow signals for long distance transmission, p. 71: The photo referenced in this story actually corresponds to a different product from GF Piping Systems. The correct photo is included in the online version of this story at www.che.com. ■

Computational Techniques for Multi-Phase Flows. By Guan H. Yeoh and Jiyuan Tu. Butterworth-Heinemann. 30 Corporate Drive, Burlington, MA 01803. Web: elsevierdirect.com. 2009. 664 pages. $130.00.

Reviewed by Simon Lo
CD-adapco, Didcot, U.K.

This guide effectively covers many complex topics associated with computational fluid dynamics (CFD), multiphase flow turbulence, numerical methods and multiphase flows. Packed with information, the book would serve as a good reference for engineers and research students using CFD to solve multiphase flow problems — a concept known as computational multiphase fluid dynamics (CMFD). The book's three sections address: fundamentals, modeling of various types of multiphase flows and advanced multiphase flows. Useful features include equations that are written out in full and repeated as necessary, eliminating the need to flip between pages, and the series of author comments and observations. They add information and details from the authors' experiences.

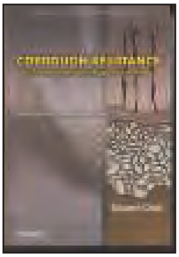
The second chapter is especially important, as it takes the reader through the derivation of the governing transport equations for multiphase flows written in the form of a mixture or separate phases. The transport equations are those related to the conservation laws of mass, momentum and energy. This chapter also covers the complex topic of turbulent multiphase flows.

Chapter three discusses numerical methods for the various types of multiphase flows. Topics covered include: computational meshes (structured, body-fitted and unstructured); derivation of finite-difference and finite-volume equations; discretization schemes; solution algorithms, such as SIMPLE for single phase flow and IPSA for multiphase flows; the Euler-Lagrange approach for particle flows; interface tracking, volume of fluid (VOF), level-set methods for free surface flows; and boundary conditions.

Chapters four to nine follow a set structure, with a detailed description of the relevant theory and equations followed by work examples. The examples are particularly effective in demonstrating that the theories and methods shown in the book can give good results, as well as sharing with the readers the authors' experience in applying the theories and methods to solve real problems.

Chapter six — on gas-liquid flows, such as bubbly flows — deserves special recommendation. The depth of coverage reflects the authors' extensive experience and interest in this area. The chapter provides all required theory, models and equations for modeling bubbly flows and sub-cooled, boiling flows. The complex topics of modeling bubble-size distribution using various population-balance methods, and wall-boiling mechanisms, are explained clearly. This chapter will be particularly useful to engineers in the nuclear power industry.

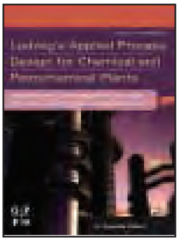
Chapter seven describes the VOF method for modeling free-surface flows, while the final three chapters consider more advanced topics associated with multiphase flows. These include freezing and solidification, extension of modeling methods to three-phase flows, and future trends in modeling turbulent multiphase flows using direct numerical simulation (DNS) and large-eddy simulation (LES), methods that currently are largely in the academic sector.



Corrosion Resistance of Aluminum and Magnesium Alloys. By Edward Ghali. Jon Wiley and Sons Inc., 111 River St., Hoboken, NJ 07030. Web: wiley.com. 2010. 719 pages. $149.95.

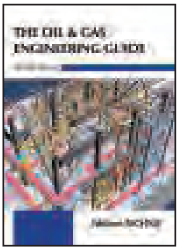
Formulating Adhesives and Sealants. By Bodo Müller and Walter Rath. Vincentz Publishing, Plathnerstrasse 4c, 30175 Hannover, Germany. Web: vincentz.de. 2010. 288 pages. $236.00.

Handbook of Physical Vapor Deposition (PVD) Processing. By Donald Mattox. William Andrew Inc., 13 Eaton Ave., Norwich, NY 13815. Web: elsevierdirect.com. 2010. 792 pages. $249.00.

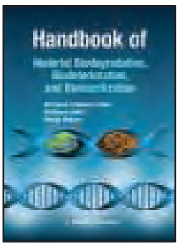


Ludwig's Applied Process Design for Chemical and Petrochemical Plants, 4th ed.: Distillation, packed towers, petroleum fractionation, gas processing and dehydration. By A. Kayode Coker. Gulf Professional Publishing, c/o Elsevier, Linacre House, Jordan Hill, Oxford OX2 8DP U.K. Web: elsevierdirect.com. 2010. 1,008 pages. $210.00.

Manual 1, Significance of Tests for Petroleum Products. By ASTM International. ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA, Web: astm.org. 2010. 350 pages. $117.00.



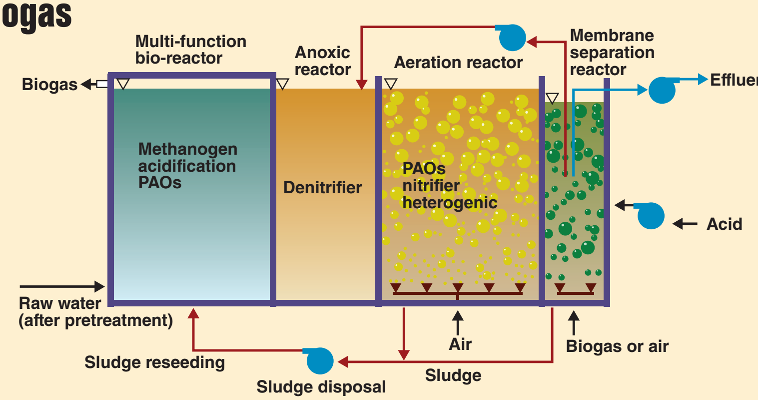
The Oil & Gas Engineering Guide. By Hervé Baron. Editions Technip, 25 rue Ginoux, 75015 Paris. Web: editionstechnip.com. 2010. 208 pages. $66.00.



Handbook of Material Biodegradation, Biodeterioration and Biostabilization. By Michalina Falkiewicz-Dulik, Katarzyna Janda and George Wypych. ChemTec Publishing, 38 Earswick Drive, Toronto M1E 1C6 Ontario. Web: chemtec.org. 2010. 368 pages. $265.00. ■

Scott Jenkins

This compact wastewater-treatment system reduces sludge volumes and recovers biogas



The Industrial Technology Research Institute of Taiwan (ITRI, www.itri.org.tw) is conducting a 10-m^3/d pilot-plant project to test the performance of its A2O membrane system for municipal wastewater treatment. The project, which is nearing completion, has already supplied important data, including capital cost, running cost and amount of waste sludge produced. ITRI is conducting negotiations with the largest environmental engineering company of Taiwan to market the patented A2O system.

Kuan-Foo Chang, a researcher at the Advanced Water Treatment Laboratory at ITRI's Energy and Environmental Research Labs (EEL), says A2O offers several advantages over conventional systems, including smaller operating space and costs, and 70% reduction in the amount of sludge produced. It also produces methane, which can be used for power generation. The effluent is suitable for industrial reuse.

In the A2O system (diagram), pretreated influent enters the system's multifunction bioreactor. Unlike traditional secondary treatment, which uses aerobic microorganisms, the A2O system uses anaerobic processing. This eliminates the need for a grid tub and sludge tank, and also reduces the amount of sludge produced.

After the bioreactor, the water enters the anoxic reactor for denitrification. It then enters the membrane bioreactor for final processing.

The system can eliminate nitrates and phosphates. In general, ITRI claims, chemical-oxygen-demand (COD) removal efficiency can reach 95%. The effluent is therefore clean enough for reuse. The system also generates and captures methane, because the methanogen (microorganisms that produce methane in their metabolism) and phosphorus-accumulating organisms (PAOs) can coexist in the multifunction bioreactor. Thus, methane is produced at the same time that phosphorus is removed.

For every kilogram of COD removed about 0.35 m^3 of methane is generated, which can be used to generate power. ITRI says that, based on Taiwan's current wastewater volumes, about 8.4-million m^3/yr of methane could be produced, which could generate about 25 million kWh.

A hydrogen generator featuring longer-lasting electrodes

This Fall, Vantec Co. (Tochigi Prefecture, Japan; www.vantec-jp.com) plans to commercialize a water electrolyzer that incorporates electrodes with a ten-year lifetime — nearly twice that of conventional technology, says the manufacturer. The long-lasting electrodes are expected to reduce the cost of splitting water into hydrogen and oxygen by about a third compared to conventional electrolyzers.

Today's electrolyzers typically use nickel-coated, stainless-steel electrodes, which are prone to localized corrosion at the crystal grains of the surface, thereby limiting their service life to 4–5 years. To mimimize this problem, Vantec, in collaboration with Utsunomiya University, has developed an amorphous, phosphorus-nickel alloy that is said to be 10,000 times more resistant to alkali corrosion than stainless steel. The alloy can be homogeneously electroplated onto stainless steel to produce the corrosion-resistant electrodes.

A prototype of Vantec's new H_2 generator, tradenamed Hydro^3 (hydro-cube), consists of 120 electrolysis cells and a H_2 purifier and is capable of producing 10 Nm^3/h of H_2 with 99.999% purity. The system is expected to reduce H_2-production costs by 30%, to about ¥200/Nm^3 of H_2 ($2.20/Nm^3).

Torrefaction of biomass

Last month, the Energy Research Center of the Netherlands (ECN; Petten; www.ecn.nl) and Vattenfall AB (Stockholm, Sweden; www.vattenfall.com) established a partnership to scale up ECN's BO_2 technology — a process for upgrading biomass into a high-grade solid fuel. Vattenfall will support ECN to further develop the technology, including testing the process on a large scale and prepare a technical design of the specifications for a demonstration plant.

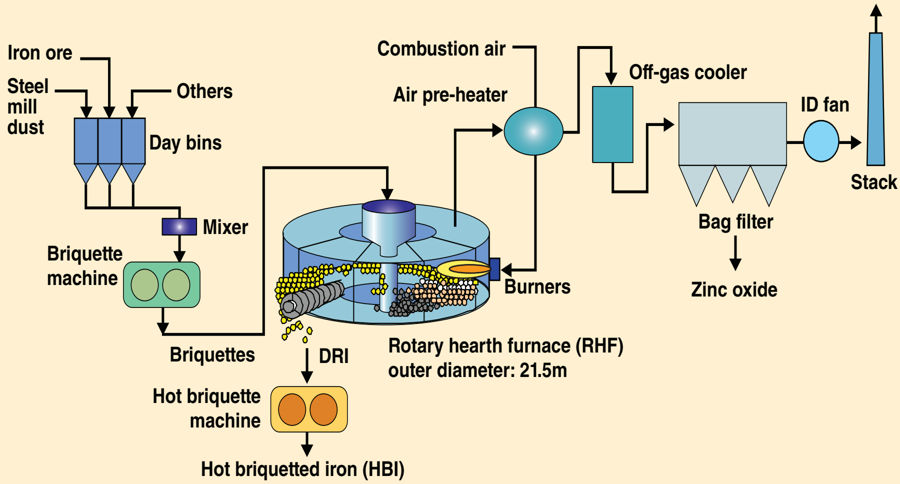
The BO_2 process combines a patented torrification technology with pelletizing or briquetting to convert biomass (wood cuttings and agricultural waste) into an easily transported, solid fuel that retains 90% of the biomass' energy content. Torrification involves heating biomass in an O_2-free atmosphere to 200–300°C (similar to roasting coffee beans), which transforms the material into a form that can be ground and stored. ECN has demonstrated BO_2 in a 50-kg/h pilot plant, achieving more than 100 h of continuous operation.

Fast pyrolysis

Ensyn Technologies Inc. (Ottawa, Ont., Canada; www.ensyn.

(Continues on p. 12)

Note: For more information, circle the 3-digit number on p. 58, or use the website designation.



Japanese JV to recycle steel-mill dust

Nippon Steel Corp. (Tokyo; www.nsc.co.jp) and Kobe Steel, Ltd. (Kobe, Japan; www.kobelco.com) plan to begin construction of a plant to recycle steel-mill dust — a byproduct from the steelmaking process — into direct reduced iron (DRI). The two companies will use steel-mill dust and iron-ore fines from their steel mills as raw materials to recycle the iron from the waste materials into DRI and recover zinc. For this purpose, a joint-venture (JV) company, Nittetsu Shinko Metal Refine Co., has been established within Nippon Steel's Hirohata Works (Himeji, Hyogo Prefecture, Japan). The JV will construct a direct reduction plant utilizing Kobe Steel's Fastmet Process. When it starts up in October 2011, the ¥10-billion ($110-million) investment will process approximately 220,000 metric tons (m.t.) per year of steel-mill dust to produce 150,000 m.t./yr of DRI.

In Fastmet (diagram), steel-mill dust and pulverized coal (as reductant) are heated to more than 1,300°C in a doughnut-shaped rotary-hearth furnace (RHF) and, within 6–12 min, the iron oxide in the dust is reduced into DRI, which is then formed into hot briquetted iron (HBI). At the same time, the zinc in the dust is vaporized, cooled and recovered by a bag filter. The Fastmet Process was first commercialized in 2000, and this new unit will raise the number of RHFs currently in operation at the Hirohata Works to four.

Nippon Steel and Kobe Steel say that the joint business will be a counter measure for the decreasing quality and higher prices of raw materials. Also, the firms will be able to promote steel-dust recycling and get closer to zero emissions in the local region.

A new catalyst for the direct hydrogenolysis of glycerin into PDO

Professor Keiichi Tomishige and colleagues at Tohoku University (Sendai City, Japan; www.che.tohoku.ac.jp/~erec/) have developed a high-performance catalyst for synthesizing 1,3-propanediol (PDO) — a raw material for highly functional poly(trimethyleneteraphthalate) (PPT) fibers — from glycerin as starting material. The catalyst — developed under a project supported by the New Energy and Industrial Technology Development Organization (NEDO, Kawasaki City, www.nedo.go.jp) — is expected to offer a commercial outlet for glycerin, a byproduct of biodiesel production.

The new catalyst consists of fine (2-nm-dia.) iridium particles supported on silica, with the surface of the Ir partially covered with clusters of rhenium oxide. In laboratory trials, an aqueous solution of glycerin reacts with hydrogen over the catalyst at 120°C and 80 atm pressure to produce PDO with 67% selectivity in a single pass. A PDO yield of 38% is achieved for a glycerin conversion of 81%, which is "remarkably" higher than the 27% yield achieved by conventional catalysts, according to the researchers. The catalyst can easily be recovered and reused, without degradation, and turnover numbers of more than 500 have been observed.

(Continued from p. 11)

com) and Tolko Industries Ltd. (Vernon, B.C., www.tolko.com) have formed a partnership to build what is claimed to be the world's largest commercial fast-pyrolysis plant in High Level, Alberta, Canada. The partnership, High North BioResources Ltd., will build and operate a plant capable of processing 400 metric tons (m.t.) of dry biomass per day into 850,000 L/yr of pyrolysis oil, which will be used as fuel to make electricity and heat for Tolko's sawmill at High Level. The facility will also be capable of producing a renewable resin ingredient that can be used for making wood-panel products.

Improving ceramics

Researchers from N.C. State University (Raleigh; ww.ncsu-edu) have discovered that the application of a small electric field (13.9 V/cm) during the manufacturing of ceramics enables materials with increased strength to be produced at lower temperatures. Application of a 60-Hz a.c. field eliminated the porosity of sintered ceramic powders at 1,250°C, compared to 1,500°C needed without the field. The field also reduced the grain size of the ceramic by 63%, creating grains with 134-nm dia. versus 360-nm dia. grain sizes produced by conventional sintering. Smaller grain size leads to stronger ceramics. The researchers demonstrated the effect of the electric field using zirconia (3Y-TZP) powder. Processing improvements were also observed using a d.c. field, but they were less dramatic.

Abrasion resistance

Energy Composites Corp. (Wisconsin Rapids, Wisc.; www.energycompositescorp.com) has developed a polymer-ceramic-composite coating, XLCR, that improves the abrasion, chemical and temperature resistance of tanks. XLCR-lined tanks exhibit the abrasion resistance similar to 2205 Duplex stainless steel, making the coating suitable for applications in the paper-and-pulp, power-generation, mining and other industries. The latest

(Continues on p. 14)

Novel gasifier uses liquid copper as the heat source

Liquid copper is employed to gasify wastes in a process being developed by Ze-gen (Boston, Mass.; www.ze-gen.com) and will be tested in a small commercial plant in an industrial park in Attleboro, Mass. Scheduled for completion late next year, the plant will convert 150 ton/d of ground wood waste into synthesis gas (syngas). The gas will generate 7 MW_{th} of energy for use by the park, either as electricity or steam.

Ze-gen's gasifier is a refractory-lined vessel that contains a bath of liquid copper. Waste material is fed into the top of the vessel and falls onto the copper, where it is instantaneously gasified at 2,000–2,500°F. Air or oxygen is also injected into the gasifier. The resultant syngas is 1:1 H_2:CO, plus some carbon dioxide, says David Robertson, vice-president of technology. Impurities in the gas are removed by conventional fluegas treatment, while solid residue from the waste accumulates as slag, which is removed periodically. The process is exothermic, so external heating (by natural gas or electricity) is needed only for startup.

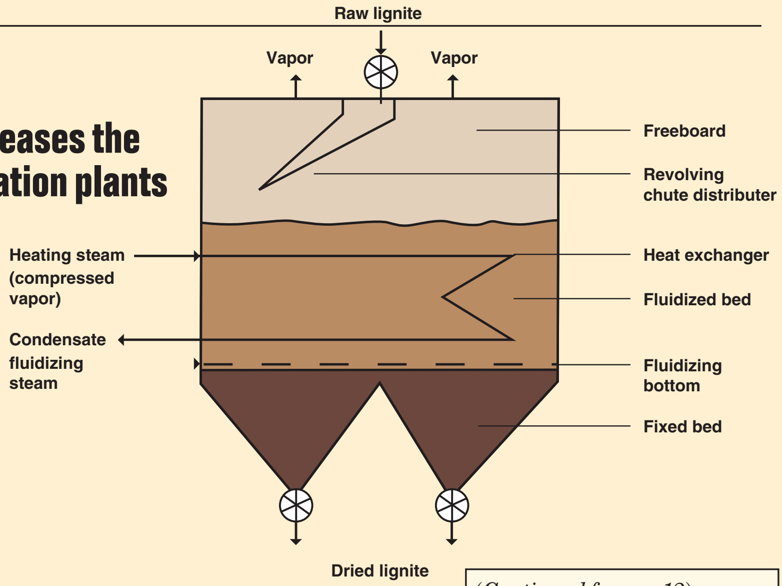
Liquid copper is used for the bath because it maintains a steady temperature and a constant concentration of O_2, says Robertson. Another advantage of the process is its flexibility — the feed may be biomass, construction demolition debris, and railroad ties or telephone poles, which now have to be landfilled because of their creosote content. Ze-Gen has tested the process in a 5-ton/d pilot plant, and 90% of the feed was railroad ties.

The Attleboro facility will use air or enriched air, but future plants may use O_2 to obtain a higher-grade syngas for liquid fuels. Robertson says the economics of the process will be demonstrated at the Attleboro plant, which is expected at least to break even financially, and that future, larger plants will be profitable.

Lignite drying-and-refining system formally dedicated

Last month, Great River Energy (Maple Grove, Minn.; www.greatriverenergy.com) dedicated its patented DryFining coal enhancement system at its power-generating plant, Coal Creek Station, N.D. The system, developed by Great River Energy, uses waste heat to reduce the moisture level of low-rank coal, such as lignite, from 38.5% to 29%, which boosts heating value of the coal from 6,250 Btu/lb to 7,100 Btu/lb. As a result, the overall efficiency of the plant increases by 2–4%, says the company.

(*Continues on p. 16*)



This lignite-drying process increases the efficiency of power and gasification plants

Last month, RWE Power (Cologne, Germany; www.rwe.com) and Linde-KCA-Dresden GmbH (www.linde-kca.com), a subsidiary of The Linde Group (Munich, Germany; www.linde.com), signed a framework agreement on the use of RWE's *WTA* technology — a German acronym for fluidized-bed (FB) drying with internal waste-heat utilization. The agreement makes Linde-KCA-Dresden a provider and supplier of *WTA*.

The *WTA* technology (diagram) is based on a stationary FB with low expansion. Coal is fed to the dryer through a star feeder, and a specially developed system at the upper section of the dryer distributes the coal onto the FB surface. The coal is dried by steam via an internal heat exchanger integrated in the center of the dryer. Dried coal is then discharged from the bottom via star feeders.

Unlike conventional lignite drying, which uses hot (900–1,000°C) fluegas that is recirculated from a steam-generator furnace, *WTA* drying takes place at only 110°C. As a result, the efficiency of future lignite-fired power stations can be increased by 10% to over 47%. In a 1,000-MW power plant, this will reduce CO_2 by up to 1-million ton/yr with the same amount of power being generated. Moreover, *WTA* drying can be applied for the gasification of lignite into synthesis gas (syngas), which can be used for producing fuels or chemicals. *WTA* technology lowers the moisture content of raw lignite from over 55% to 12%.

Since February 2009, RWE Power has been operating a €50-million demonstration prototype plant at Niederaußem, Germany. The prototype processes 210 ton/h of raw coal and generates 110 ton/h of dry lignite. This is equivalent to up to 30% of the entire coal requirements of the BoA unit in Niederaußem, currently the most efficient (over 43%), says RWE Power.

Molybdenum-oxo catalyst offers cheap route to H_2 from water

A novel catalyst designed by scientists at the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley, Calif.; www.lbl.gov) and the University of California at Berkeley (www.berkeley.edu) has shown the ability to catalyze the electrolysis of water into hydrogen and oxygen, and is 70 times cheaper than platinum ($2,000/oz.), which has also been used to catalyze the reaction.

In a recent paper in *Nature*, the research team reports that the catalyst does not require organic acids or other additives, and can operate in neutral water, as well as in the most abundant H_2 source on earth, seawater. An inexpensive and efficient water-splitting catalyst could expand hydrogen's role as a clean energy alternative in the future. Lead author Hemamala Karunadasa explains that the new proton reduction catalyst is based on a molybdenum-oxygen complex, and can generate hydrogen gas at the rate of 2.4 moles H_2 per mole catalyst per second. These values represent lower bounds, the authors say, and "are significantly higher than any other reported metal catalyst for electrochemical hydrogen production from neutral water."

The catalyst has a pseudo-octahedral geometry, where the pentadentate ligand 2,6-bis(1,1-bis(2-pyridyl)ethyl) pyridine (PY5Me2) surrounds a molybdenum atom.

The authors speculate that applications using the metal complex they developed would arrange the molecules in a single layer on an electrode surface. They calculate that the number of molybdenum catalyst molecules needed to cover the area of a naturally occurring hydrogenase enzyme would generate 140 to 300 hydrogen molecules per second, while offering far superior stability.

(*Continued from p. 12*)

order — for five, 28,327-gal, bone-maceration tanks — will be completed before the end of 3rdQ 2010. For this application, conventional tanks normally require replacement shortly after their one-year warranty. Five or more tank replacements should be avoided over the next ten years with the XLCR-lined tanks, says the firm.

CO_2-based polymers

Researchers from Bayer MaterialScience (www.bayer-materialscience.com), Bayer Technology Services (both Leverkusen; www.bayertech-nology.com), RWE Power (Cologne; www.rwe.com) and RWTH Aachen University (www.rwth-aachen.de) have received more than 4.5-million from the German Federal Ministry of Education and Research (BMBF; Bonn) for a three-year project to develop a process to produce polyether polycarbonate polyols (PPPs) using CO_2 as feedstock. A kilogram-scale pilot plant will be constructed at Chempark Leverkusen, which will produce PPPs that will then be processed into polyurethanes. Key to the process is a new catalyst.

CO_2 used for the project will come from RWE Power's Lignite-fired power plant in Niederaußem, Germany. The CO_2 is captured from the power plant's fluegas, by a gas scrubber, then liquefied for transportation to Leverkusen. ❑

Circle 4 on p. 58 or go to adlinks.che.com/29252-04

Produce polymer nanofibers at greater yield and control

New technology for fabricating nanoscale polymer threads boosts yields and improves control compared to conventional methods for producing nanoscale fibers by using a technique analogous to that for making cotton candy.

The technology, known as rotary jet spinning (RJS), was developed by engineers at Harvard University (Cambridge, Mass.; www.harvard.edu) and is described in a recent paper in the journal *Nano Letters*.

In RJS, a high-speed rotating nozzle is attached to the shaft of a controllable motor. Rotation propels the polymer solution through a nozzle capillary, and the outward centrifugal force stretches the extruded polymer. Simultaneously, the polymer solvent evaporates, solidifying the material into threads of around 100-nm dia. The extruded fibers then deposit on a circular collector. Nanofiber production output for RJS is "many times greater" than conventional techniques for making nanofibers, such as electrospinning, says Harvard bioengineer Kit Parker, who heads the group where the method was developed.

Lead author Mohammad Reza Badrossamy says the RJS system has formed fibers from a variety of synthetic and natural polymers, including polylactic acid in chloroform, gelatin in mild acetic acid and polyethylene oxide in water.

By changing nozzle rotation speed and solvent volatility, the researchers can control the fiber thickness and morphology. Nanofibers could have a wide variety of applications, including textiles, air filters, bio-scaffolds and others, say the scientists.

LIGNITE DRYING-AND-REFINING SYSTEM

(*Continued from p. 13*)

In addition, the refining component of DryFining segregates the lignite stream and removes the higher density compounds that contain higher levels of sulfur and mercury. As a result, emissions are also reduced, namely, SO_2 and Hg by more than 40%, NOx by more than 20% and CO_2 by 4%.

The process has been developed through a number of DOE grants, starting in 2003, which culminated in the startup of a commercial system (four units, each processing 135 ton/h of coal) at Coal Creek Station, which started up last December. The DryFining system will be licensed through a partnership with WorleyParsons (Sydney, Australia; www.worleyparsons.com). ■

BIO-BASED CHEMICALS GET REAL

FIGURE 1. While several bio-based chemicals are poised for commercialization, some are already here, like bio-based propanediol from this DuPont Tate & Lyle plant in Tennessee

Biochemicals are poised for rapid growth. Can they compete with petroleum-based products?

With bio-based chemical production growing, and several newer companies ready to enter commercial production, indications are that biologically derived chemicals will be an increasing force in the petrochemicals market. But bio-based chemical producers must confront the bottom-line requirements of product performance and cost, rather than riding their products' environmental benefits.

Susan Sun, director of the Center for Biobased Polymers by Design at Kansas State University (Manhattan, Kan.; www.k-state.edu), says the single biggest challenge to the burgeoning biofuels and bio-based chemicals industries is achieving lower-cost manufacture of products that equal the performance of petroleum-derived chemicals, or delivering performance benefits at similar cost.

"Without government policies or subsidies, environmental benefits of bio-based chemicals are not enough to make them commercially viable," agrees David Bressler, University of Alberta (Edmonton, Alta.; www.ualberta.com) professor and director of the Biorefining Conversions Network.

As startup biochemicals producer ZeaChem's (Lakewood, Colo.; www.zeachem.com) CEO Jim Imbler puts it, "Green credentials will probably win the ties" — with all else equal, customers opt for sustainably produced products, but Imbler says without competitive cost and performance, products won't sell.

A wide range of companies — some established, many new — are hard at work making sure their products offer performance benefits or cost savings over petroleum-derived chemicals. To do that, many have adopted a "business-first" attitude in which the requirements of cost-competitiveness and improved performance are the primary motivators from the earliest stages of development.

Chemicals will drive biofuels

Although biofuels development has received more attention and government support in recent years, there is growing recognition that biologically derived chemicals will advance more quickly than biofuels because value-added chemicals command higher profit margins than biofuels.

Sam McConnell, senior vice president at Myriant Technologies (Quincy, Mass.; www.myriant.com), a company commercializing bio-based succinic acid, sees an increasing focus on bio-based chemicals over biofuels, because a host of biochemicals "are technically and economically viable today," whereas second-generation biofuels are still reaching for cost-competitiveness with fossil fuels. One major reason for the shift toward biochemicals is that while "process costs for fuels and chemicals are similar, chemicals sell for much higher prices," points out McConnell.

The addition of higher-value products to a plant's production portfolio is a key piece of the business model at Elevance Renewable Sciences Inc. (Bolingbrook, Ill.; www.elevance.com). The company is looking for partners who can install its catalyst technology (see below) in an effort to generate a new and more profitable product stream for a plant. "It's tough to make a profit producing fuels alone," says Elevance CEO Andy Shafer. "One of the things we're working to do is help companies make a minor capital investment and use our biorefinery technology to provide an upgraded product mix."

A diversified product mix is a central concept behind the movement toward establishing biorefineries, a term for which a clear and accepted definition has yet to solidify, but one that indicates an integrated processing system that produces fuels, power and chemicals from a range of biomass feedstocks.

Bruce Erickson, a vice president at the Biotechnology Industry Organization (BIO; Washington, D.C.; www.bio.org) says when produced together, "biochemicals can make it economical for biofuels plants to operate."

Biorefineries take the stage

Elevance and ZeaChem are joined by LS9 Inc. (South San Francisco, Calif.; www.ls9.com) and others in pursuing a biorefinery model. Each is taking a different approach to commercialization, but all have focused on economics from the earliest stages.

In early June, ZeaChem broke ground on a 250,000-gal/yr biorefinery in Boardman, Oregon that will use a hybrid fermentation-based system to produce acetic acid, ethyl acetate and ethanol from a variety of cellulosic feedstocks. "Our organism is feedstock-agnostic," says ZeaChem's Imbler. Nevertheless, about 80% of ZeaChem's raw biomass will come from the hybrid poplar tree, which offers many advantages, including fast growth, high yields and relatively low input requirements. The first ZeaChem product will be ethyl acetate, which requires "half the energy of ethanol, but sells for twice the price," says Imbler. For its process, ZeaChem has consciously chosen previously known microbes and fermentation equipment to reduce risk, and started out with an economics model to ensure that its operation would be cost-competitive. "We started out thinking business first," Imbler says, adding that to maximize the changes of commercial success, "economics should drive the science, not the other way around."

Meanwhile, the firm LS9 Inc. has developed a one-step fermentation process that depends on genetically engineered bacteria to generate biodiesel and other transport fuels, as well as chemicals from five- and six-carbon sugars in sugarcane syrup. Since 2009, the company has generated biodiesel fuel at a 1,000-L/batch pilot facility at its headquarters. LS9 spokesperson Jon Ballesteros points out that the product meets fuel standards set by ASTM International and is registered with the U.S. Environmental Protection Agency. The company recently acquired a former bioprocessing facility at a bargain price in Florida, where they are assembling a demonstration-scale plant that will produce 50,000 – 100,000 gal/yr of biodiesel starting at the end of 2010. The process reduces greenhouse gas emissions by 85% compared to petroleum-based diesel, Ballesteros says. While biodiesel is the initial focus, LS9 is adopting a biorefinery model, and producing chemicals, such as surfactants and transportation fuel replacements beyond biodiesel as well.

In contrast to LS9, Elevance's focus is squarely on specialty chemicals from renewable sources, although it can make biofuels as well. Its biorefinery process depends on olefin metathesis catalysts exclusively licensed from Materia Inc., a company set up to commercialize the catalysts, which were developed by Nobel Prize-winning California Institute of Technology (Pasadena, Calif.; www.caltech.com) chemist Robert Grubbs. The powerful synthetic technique redistributes olefin substrates, yielding a net exchange of the substituents on two double bonds. Elevance uses the catalysts to synthesize performance chemicals, such as waxes, antimicrobial compounds, lubricants and fuel additives from plant oils such as palm or soybean oil. Elevance shares the ideals of Zeachem in that it is focused on reducing technical risk by employing well-understood equipment and technology, only coupled in a unique manner. The process is feedstock-agnostic and designed for lower pressures and temperatures.

Currently, Elevance is looking to work with partners to install its technology for contract manufacturing at existing sites. Also, Elevance's Shafer says the company is in advanced talks with a partner to form a joint venture for constructing a biorefinery that uses metathesis chemistry to produce specialty chemicals from bio-oils.

Gevo Development LLC (Englewood, Colo.; www.gevo.com) is another company with a variation on the biorefinery model. Gevo has developed a fermentation-based route to non-petroleum isobutene, a key raw material for synthetic butyl rubber. Gevo will use a range of sugars and starches and, later, cellulose, as feedstock. It will produce a range of products, including isobutanol, propene and distillers' dried grains with solubles (DDGS) for animal feeds, in addition to the isobutene. The world's largest rubber producer, Lanxess AG (Leverkusen, Germany; www.lanxess.com) invested $10 million in Gevo in May 2010.

Elsewhere, Chempolis Oy (Oulu, Finland; www.chempolis.com) began operating a biorefinery in May based on non-food, cellulosic feedstocks from agricultural waste. The initial product will be bioethanol, but the company says its conversion platform will enable production of multiple chemicals.

Bio-based succinic acid

Developing a biological route to the 1,4 diacid compound succinic acid has received much attention in recent years. A number of studies, including an influential 2004 report from the U.S. Department of Energy (DOE; Washington, D.C.; www.energy.gov) have identified succinic acid as among the top building block chemicals — in terms of technical feasibility, size of market and interest to the chemical industry — that could be derived from biomass. Succinic acid is used in a wide variety of applications including plastics, fibers, polyesters and pigments. Industrially, succinic acid has been made through the catalytic hydrogenation of maleic acid or its anhydride. Since both are derived from benzene or butane, succinic acid costs have been relatively high and linked to fossil fuel feedstocks.

ZeaChem

FIGURE 2. Many bio-chemicals are produced in fermenters, like this one at ZeaChem, but some companies are pursuing catalytic methods

Myriant Technologies' bio-based succinic-acid project is among the leaders in the area. The company intends to operate as a nascent biorefinery, producing a single product from one feedstock initially, but eventually expanding to produce other chemical building blocks in the future.

Myriant piloted its fermentation process last year, using a genetically engineered *E. coli* strain, and recently was selected to receive up to $50 million from the DOE to help construct a manufacturing facility for bio-based succinic acid in Louisiana. Currently, the 30-million-lb/yr facility is in the final design stage, and full-scale construction is set to begin in September 2010. "We already have contracts or commitments for the initial 30 million pounds," says Myriant's McConnell. Following the start of commercial production in the second half of 2011, the company expects to expand the facility to produce 150 million lb/yr.

Myriant's bio-based succinic acid will utilize both local sorghum and carbon dioxide as feedstocks, but McConnell says the company expects to utilize cellulosic biomass in the future, and to produce additional products, including fumaric acid.

A commercial biosuccinic acid plant has actually been operating since December 2009. The 2,000-metric-ton/yr facility is operated by Bioamber (www.bio-amber.com), a joint venture (JV) between DNP Green Technology (Montreal, Quebec; www.dnpgreen.com) and the French firm ARD (Pomacle, France; www.a-r-d.fr). Bioamber has developed a proprietary fermentation process to

NatureWorks

FIGURE 3. Polylactic acid (PLA) pellets manufactured by NatureWorks LLC are among the bio-based chemicals currently on the market

produce succinic acid using glucose from wheat. The company says the cost of its succinic acid is lower than butane-derived succinic acid, while the purity is higher. The process also consumes significant quantities of CO_2.

Established products

While the bio-based chemical field is full of processes in the pilot stage or just entering commercial production, several companies already market biologically derived chemicals. One example is NatureWorks LLC (Minnetonka, Minn.; www.natureworksllc.com), a subsidiary of Cargill Inc. (Minneapolis, Minn.; www.cargill.com). NatureWorks makes polylactic acid (PLA), marketed as Ingeo, to compete with petroleum-based polyethylene terephthalate (PET), polypropylene (PP) and polystyrene (PS) primarily in packaging and food serviceware, and also in the durable plastics and fibers markets. NatureWorks won this magazine's Kirkpatrick award for commercializing PLA in 2003.

Peer-reviewed studies initiated by NatureWorks suggest CO_2 emissions from production of Ingeo, at around 1.3 kg CO_2 equivalent per kilogram polymer, are significantly lower than that of other widely used petroleum-based polymers, such as PET (3.4 kg CO_2/kg polymer), PP (1.9), PS (3.4), low-density polyethylene (2.1) and nylon (9.1).

Another company with a viable bio-based chemical product on the market is the JV DuPont Tate & Lyle BioProducts (Loudon, Tenn.; www.duponttateandlyle.com). With a fermentation-based process, the JV manufactures 1,3-propanediol (PDO) from corn sugar for both industrial and personal care product markets. The company's Tennessee facility currently produces 100 million lb/yr of Bio-PDO, and is working on adding another fermenter unit, which will boost capacity by 35%. DuPont Tate & Lyle president Steve Mirshak says his company anticipates "strong growth in sales of Bio-PDO over the next five to ten years." The expanded capacity should be in use around mid-2011, he adds. DuPont Tate & Lyle found that, compared to petroleum-derived PDO and propylene glycol, its Bio-PDO process emits 56% less greenhouse gases and uses 40% less energy.

Bio-PDO serves as the monomer for Dupont's (Wilmington, Del.; www.dupont.com) family of polyether diols (polyols), marketed as Cerenol, and is a key ingredient of the company's Sorona (a copolymer of Bio-PDO and petroleum-derived terephthalic acid). Cerenol, a 2009 *Chemical Engineering* Kirkpatrick award finalist (See *CE* Dec. 2009, p. 20), is part of Dupont's effort to offer renewably sourced products.

Meanwhile, through another JV, Metabolix Inc. (Cambridge, Mass.; www.metabolix.com) and Archer Daniels Midland Co. (Decatur, Ill.; www.adm.com) manufacture a family of bioplastics from plant-derived sugars, and Dow Chemical Co. (Midland, Mich.; www.dow.com) has introduced a line of bio-based plasticizers for use in wire insulation. Metabolix has a portfolio of intellectual property in metabolic pathway engineering and a platform technology that will be used for other bio-based chemicals and fuels.

Bio-based products now on the market mostly depend on sugar feedstocks derived from food crops, such as corn or sugarcane. Intense activity across the bio-based chemical industry is focused on technologies to enable the use of lignocellulosic biomass as feedstock, such as agricultural waste or energy crops. It is likely that case-by-case details of bio-based chemicals and fuels projects will demand a multitude of feedstocks for the foreseeable future.

Bio-based specialties

During the continuing emergence of the bio-based chemical industry, most activity has surrounded biofuels, and more recently synthesizing bio-based chemical building blocks. But several companies are commercializing new bio-based specialty chemicals. For example, Isobionics (Geleen, the Netherlands; www.isobionics.com), and Allylix (San Diego, Calif.; www.allylix.com), are using a bio-based fermentation approach to produce low-cost terpenoid compounds for use as flavorings and fragrances, as well as in other agricultural and specialty chemical applications. Terpenes are a diverse class of hydrocarbons based on the five-carbon isoprene unit. Plant terpenes have wide use as flavors and aromas, but are usually present only in minute quantities in plants, making isolation difficult and prices high.

Allylix has begun marketing the grapefruit flavor nootkatone, a sesquiterpene with a currently limited market due to the inefficiency of isolating quantities from the fruit rind. The company engineers metabolic pathways in yeast to coax the organism to produce sesquiterpene at very high purities. In the future, Allylix will use its platform to generate a range of terpenoid molecules for a variety of applications.

Meanwhile, Isobionics just announced commercial-scale production of bio-based valencene, a citrus flavor found in oranges that is closely related to nootkatone. The company says its product has shown consistent quality and purity and has been used in samples tested by potential customers. Isobionics' process efficiency is orders of magnitude greater than that of the conventional process for isolating valencene from oranges.

The path forward

Looking past the rush of commercialization over the next few years, development activity in biologically derived chemicals and fuels should increase further. It is likely that much attention will be lavished on metabolic pathway engineering as a method to get microbes to produce valuable chemicals. Companies such as Metabolix and others are working on projects driven by genetically engineered metabolism. The industrial enzyme producer Genencor, a division of the food ingredient maker Danisco A/S (Copenhagen, Denmark; www.danisco.com), has developed an *E. coli* strain to ferment isoprene, the monomer of natural rubber, as well as a process to harvest the substance from the gas phase to achieve cost-effective purity. Genencor teamed with the tire maker Goodyear to produce a concept bio-isoprene automobile tire, which was unveiled earlier this year.

Genomatica (San Diego, Calif.; www.genomatica.com) has focused its microbial metabolic engineering technology on an *E. coli* strain capable of producing 1,4-butanediol (BDO) from a wide variety of sugars. Genomatica executive vice president Dennis McGrew says the company expects its process to be cost-advantaged relative to existing chemical processes. Genomatica has produced kilogram-quantities of its BDO, and is scaling up through contract manufacturing to produce 3,000-kg quantities in 2012.

Another area in the bio-based chemicals likely to see significant activity is the development of methods to enable production of bio-based chemicals without the need for fermentation. An example comes from Haldor Topsøe A/S (Lyngby, Denmark; www.topsoe.com), which recently announced a research-stage process for converting carbohydrates from biomass into lactic acid using a catalyst, rather than fermentation.

Virent Energy Systems Inc. (Madison, Wisc.; www.virent.com) has also been developing a catalytic (non-microbe) route to biofuels and biochemicals. Known as Bioforming, the process is assembled around a proprietary aqueous-phase reforming (APR) method, which is coupled to conventional catalytic processing technology.

Startup Segetis Inc. (Golden Valley, Minn.; www.segetis.com) offers another example of a non-fermentation-based process. The company opened a demonstration facility last year capable of producing 250,000 lb/yr of one of its main products, levulinic ketal. As Segetis scales up, the company is taking advantage of operations knowledge in the chemical industry, since its core ketal technology is based on a thermochemical route, rather than on a fermentation pathway. Segetis is pursuing commercial-scale production of levulinic ketal as a toll manufacturer by early-2011, and eventually will be able to produce "tens of millions of pounds a year," says Segetis business vice president Snehal Desai. Segetis intends its levulinic ketal to be an alternative to petroleum-based plasticizers, polyols and solvents.

Engineered microbes for industrial production of fuels and chemicals will continue to be a focus of the biotechnology industry, but work has already begun on moving a step beyond that — custom-designed, synthetic organisms. Researchers at the J. Craig Venter Institute (Rockville, Md.; www.jcvi.org) have been working for several years toward that goal, and recently announced their latest advance. In a paper published in a recent edition of *Science*, the team describes the successful transplantation of a fully synthetic genome into a recipient bacterial cell to produce a new self-replicating cell that is controlled exclusively by the artificially synthesized genome. ■

Scott Jenkins

Newsfront

SCR: NEW AND IMPROVED

Already proven and reliable, selective-catalytic-reduction technology gets an overhaul to make it more efficient for NOx reduction

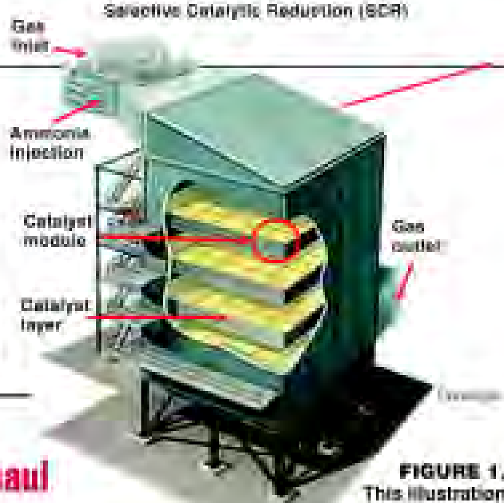


FIGURE 1. This illustration demonstrates the typical SCR process

As environmental awareness receives renewed focus in the government, the public and industry, it appears that higher standards will be applied to processors to achieve even higher oxides-of-nitrogen (NOx) removal than in the past. And since selective catalytic reduction (SCR) has been proven to be one of the most efficient systems for NOx removal from high output sources, such as coal-fired power plants and generators used for back up power, it makes sense that the chemical process industries (CPI) are using this same technology to reduce harmful emissions from their plants.

The beauty of SCR is that it is an already proven technology, making it a reliable and trusted choice for processing facilities that need to reduce NOx emissions. And, since SCR has existed and been in mainstream use for more than 15 years, system and catalyst providers have been tweaking their technologies to make them even more efficient.

"New developments of SCR catalyst and in the design of the systems themselves make it possible to reach NOx conversions of about 95% without ammonia slip," says Peter Lindenhoff, general manager of SCR/De-NOx Catalyst and Technology with Haldor Topsøe (Lyngby, Denmark). "This means it is now possible to install SCRs on the highest NOx producing units in the plant and avoid doing NOx control on smaller units while still meeting the overall NOx reduction of the plant. A few large SCRs are more cost efficient than doing NOx control via methods such as ultra-low NOx burners on all units."

Not only is the technology proven and improved, but it is also possible to easily retrofit SCR to existing facilities. SCRs have successfully been installed on practically all types of furnaces, according to the experts. And, the continued design improvements mean it's also possible to reduce the pressure drop that used to be associated with SCR, making it possible for processors to keep and use most of the existing equipment in their facility. The catch in a retrofit, however, is the process temperature and its effect on the catalyst. Some catalysts perform better within a specific temperature range, says Dale Purdy, sales and marketing manager with Turner EnviroLogic (Deerfield Beach, Fla.). "Performance will drop off dramatically if the process temperature is too high or too low. We see it best between 400 and 800°F, so in an existing facility or process that generates that temperatures it's a perfect fit."

However, if the temperature is above or below this sweet spot, steps can be taken to boost catalyst performance. "We have used assist heaters to raise the temperature of the waste stream to get it within the right range. If the process is too hot, we can bring cooler air or outside air into the waste stream to get it to a more favorable operating temperature," explains Purdy. "It takes some extra planning, but it is possible to do a retrofit and get the operating temperatures to a place where the catalyst will operate best."

Reducing ammonia slip

Whether it's a new application or a retrofit, reducing or eliminating ammonia slip is a big deal for SCR, as Lindenhoff indicated above, so providers are working on different methodologies to achieve this improvement. "Ammonia slip is a critical problem for SCR users because ammonia slip is a very evident issue due to its odor. Often putting out ammonia can be worse than NOx emissions," says Ben Velazquez, engineering manager with Ducon (Farmingdale, N.Y.).

Ammonia slip — where expensive unreacted ammonia is exhausted to the stack — occurs when too much ammonia is injected. In some regions of the U.S., the amount of ammonia slip is also part of a plant's operating permit restrictions.

To avoid the problem, Ducon is using heavily engineered calculations to determine the proper amount of ammonia to be injected into a system. The company uses instrumentation to track flow, pressure, temperature and other inputs that vary within a system. These inputs are monitored and factored in to achieve a more accurate ammonia calculation. "If you don't use the right amount of ammonia in relation to the amount of catalyst you need

NOX REDUCERS

BASF Catalysts	www.basf.com
Coologix	www.coologix.com
CRI Catalyst	www.cricatalyst.com
Ducon	www.ducon.com
Entropy Technology and Environmental Consultants	www.etecinc.net
Haldor Topsøe	www.topsoe.com
Hamworthy Peabody Combustion	www.peabodyengineering.com
Nationwide Environmental	www.nationwideboiler.com
Seiler	www.seiler.co.at
Turner Envirologic	www.tenviro.com
Zeeco	www.zeeco.com

ALTERNATIVES TO SCR

While SCR is known to provide the best De-NOx rates, the case can sometimes be made for other technologies, such as ultra-low NOx burners, in some fired-heater, general refinery and petrochemical applications. "From a burner technology perspective, ultra-low NOx burners achieve the lowest NOx emissions available in the market for these types of applications," says Darton Zink, president and CEO with Zeeco, Inc. (Broken Arrow, Okla.).

Some units of this kind offer a simple design that enhances the level of internal fluegas recirculation and fuel dilution that takes place in the combustion reaction of a process burner, says Zink. "This is an improvement over earlier generations because the technology is able to recirculate higher quantities of furnace gases or fluegas while at the same time increasing safety and stability of the combustion taking place within the burner."

Zeeco

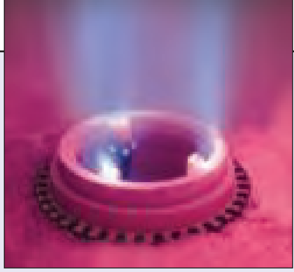


FIGURE 2. GLSF Free-Jet Burner, a next generation ultra-low emissions round-flame burner, offers a design that uses the free-jet method of mixing the fuel gas ejected from the gas tips with the surrounding inert products of combustion to dramatically lower thermal NOx production

Zeeco's GLSF Free-Jet Burner, a next generation ultra-low emissions, round-flame burner, offers a design that uses the free-jet method of mixing the fuel gas ejected from the gas tips with the surrounding inert products of combustion to dramatically lower thermal NOx production. The predicted NOx emission range for natural draft is 6 ppmv to 20 ppmv, while the predicted NOx emissions range for 600°F preheated air is 10 ppmv to 25 ppmv.

Hamworthy Peabody Combustion (Shelton, Conn.) is also introducing a new ultra-low NOx burner that operates on a different principle. Called the ECOjet, this model provides ultra-low emissions with little or no flue gas re-circulation. Ignition is achieved using a reliable, self-cleaning and low-maintenance ignitor. The art burst mode of ignition with flashing indicator allows the operator to observe the ignitor condition during operation. This also eliminates the need for an ignitor fuel train. The ECOjet offers ultra-low NOx of less than 10 ppm.

One of the benefits of choosing an ultra-low NOx burner is that it doesn't require add-on abatement technology. "With a retrofit, ultra-low NOx burners operate the same way as usual from the owner's perspective," says Zink. "There's no additional apparatus or device and the burner functions largely in the same manner as a conventional burner is operated. In that way it's a like-for-like replacement, but from the emissions standpoint, ultra-low NOx burners are significantly improved."

"In many cases, if the application is suitable, the use of the most recent-generation ultra-low NOx burners can do away with the need for an SCR," says Zinc.

However, that doesn't mean that the two can't co-exist. Often processors look at NOx removal as a case of either a low NOx burner or an SCR, but the two can be used in tandem to minimize costs and maximize operating flexibility.

"The benefit here would be that not as much NOx would be going through the SCR," says Randy Sadler, director of marketing and sales with CoaLogix (Charlotte, N.C.). "That means the SCR doesn't have to work as hard, and they won't have to inject as much NH_3 into the system or use as much catalyst."

It is possible that these savings would provide financial benefits despite the purchase of two pieces of equipment, according to the experts. And, the generation of less NOx right off the bat helps processors meet or beat emission limits with less hassle.

Such was the case when Nationwide Environmental's (Freemont, Calif.) CataStak SCR system was retrofitted to a 700-hp, natural-gas fired firetube boiler, equipped with a low NOx burner (with fluegas recirculation) at a California manufacturing facility. The SCR was guaranteed to operate at less than 5 ppm. However, the unit exceeded this guarantee and was recently certified to operate with less than 0.5 ppm NOx, which is less than the minimum reportable detection limit of the testing method used. Average CO emissions were reported at 13.3 ppm, and average ammonia slip was reported at only 0.3 ppm, operating between a stack temperature range of 330 and 366°F (low to high fire).

Another SCR alternative is on the horizon in the form of a hybrid technology being introduced by Entropy Technology and Environmental Consultants (ETEC; Houston). According to the company's Website, this hybrid NOx-control technology matches NOx control from SCR, but for a fraction of the cost. The technology combines Induced Fluegas Recirculation (IFGR) and Combustion Modification (C-Mods) to create a hybrid approach that achieves De-NOx levels similar to that of SCR, says ETEC.

The company claims that when compared to competing NOx control technologies like SCR, the hybrid approach is expected to result in cost savings of \$10 to \$20 million, depending on the size of the unit. ❑

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for NOx concentration, then you end up with excess or unreacted ammonia, so getting the amount right the first time goes a long way toward avoiding slip," he says. The company also monitors the output of the SCR, so if there is an ammonia slip, it can make necessary adjustments in the formula.

The folks at Turner EnviroLogic offer an ammonia-vaporization system that uses waste heat from the process itself to vaporize the ammonia in conjunction with a distinct method of ammonia distribution. "We use a self-balancing ammonia-injection grid instead of a series of valves and regulators that typically need to be worked by the 'Wizard of Oz' behind the curtain pulling all sorts of cranks and levers to keep things moving along," says Purdy.

He says the company's inherent self-balancing design provides an equal flow of ammonia across the catalyst with minimal effort. The combination of these two features helps reduce ammonia slip because if ammonia is properly distributed across the catalyst, there's a much better chance of reducing the amount of unused ammonia. "You don't have to flood the system with ammonia to make it work," he explains.

Catalyst providers, too, are working to reduce ammonia slip. Randy Sadler, director of marketing and sales with CoaLogix (Charlotte, N.C.) says his employer is working on a multi-pollutant reduction system that could possibly remove NOx, SOx, PM, mercury and ammonia slip via catalyst. "We've been working with different technology leaders to use their products in conjunction with our regenerated SCR catalysts and sell them as a complete system to remove a variety of pollutants for the end user."

He says the company is a few months away from a technology that would reduce ammonia slip via a catalyst. Sadler further says the technology would likely feature banks of regenerated SCR catalyst and, at the tail end, a thin strip of "what we'll call 'ammonia catalyst'" that would clean up the excess ammonia emitted from the SCR. "It doesn't take much to clean up ammonia at the tail end."

Topsøe's Lindenhoff agrees that this technology is probable for the future of SCR. "Fifteen years ago we developed the DNO catalyst, a combined NOx and CO removal catalyst. With the development of lower limits for ammonia slip, it looks like the units in the future will have a DNO catalyst downstream from the SCR to reduce the NH_3 slip together with CO and VOC removal," he says.

Newsfront

FIGURE 3. The ECOjet ultra-low NOx burner provides ultra-low emissions with little or no fluegas re-circulation

Moving SCR to the end of the pipe may help reduce NH_3 slip in more ways than one, according to Brad Morello, technical services manager with CRI Catalyst (Houston). "Success in reducing NH_3 slip is more favorable when designing an SCR system at lower temperatures. One of the reasons for lower slip at lower temperatures relates to the enhanced adsorption capability of SCR catalyst in general."

And the temperatures are typically lower at "end of pipe" installations since lower temperatures are found farthest away from the heat source and nearer to the exhaust stack. Plus, in many situations, closer to the stack yields more space and residence time available for NH_3 mixing, thus increasing the possibility for a homogeneous mixture of NOx and ammonia to be established at the SCR catalyst inlet. This is also key in the effort to minimize ammonia slip. As a bonus benefit, this location may also be preferred for low-to-no N_2O formation. Like CO_2, N_2O is considered a greenhouse gas. In the near future, suppressing the formation of N_2O will likely be a secondary goal to NOx reduction, says Morello. It is believed that at a sufficient temperature window, N_2O formation occurs from the partial oxidation of ammonia in the presence of certain metallic compounds commonly present in and around an SCR system. In the chemical process of SCR, ammonia is often injected as a reducing agent. At certain conditions and at lower temperatures, minimal-to-no N_2O formation has been demonstrated. Therefore, the lower temperatures at the end of pipe may be preferred for low-to-no N_2O formation, as well as reduced ammonia slip. ■

Joy LePree

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Conservation economics: Carbon pricing impacts

Reduction of greenhouse gas (GHG) emissions continues to be a major issue in national and international public policy, as well as a major focus for companies in the chemical process industries (CPI). Many countries are considering systems that place a price on GHG emissions though a carbon cap-and-trade system, for example.

In an environment where GHG emissions have a given price, certain energy conservation measures that may have provided a small or negligible internal rate of return (IRR) based on fuel savings alone will be much more attractive economically as GHG emissions prices increase.

Returns from efficiency projects

Example calculations that illustrate the impact of GHG emissions prices on the economics of energy efficiency projects are those for calculating the IRRs of several energy-efficiency projects at a hypothetical 150,000-bbl/d petroleum refinery with a range of GHG prices ($0 to $100/metric ton (m.t.) CO_2 equivalent). In general, results demonstrate that incorporating the cost of GHG emissions into project economics can improve the attractiveness of previously marginal energy projects.

IRRs for the following projects are shown at GHG price levels from $0 to 100/m.t. in Figure 1:

- Revamp crude-preheat exchanger train to increase the crude-heater inlet temperature
- Replace the vacuum tower steam ejectors with a liquid ring compressor (LRVP)
- Utilize diesel hydrodesulfurization (HDS) unit hot feed for additional steam generation
- Recover power from fluid catalytic cracking (FCC)-regenerator hot fluegas.

If these four projects were combined, they would result in a 9.5% reduction in GHG emissions for the hypothetical refinery.

Example: Air pre-heat

An example of an energy efficiency improvement project to consider is using combustion air preheat for fired heaters. For this study, it was assumed that a heater without this feature would have an overall thermal efficiency of 82%. The addition of air preheat will increase the heater efficiency to approximately 92%. IRRs for the project at various GHG emissions prices are shown in Figure 2.

Heaters with an absorbed duty of just over 150 million Btu/h would achieve a 20% IRR with GHG emissions valued at $15/m.t. and natural gas priced at $5.50/million Btu. If natural gas is priced at $6.50/million Btu, the 20% IRR can be achieved with an absorbed duty of 100 million Btu/h.

Considerations

- Care must be taken to evaluate all energy usage; not only in the process unit of interest, but also changes in net energy usage in the entire facility
- A thorough review is needed to ensure that all appropriate costs are included
- A facility-wide audit is recommended to identify all potential energy conservation opportunities
- An energy-saving project not evaluated here, but worth further study is improved heat exchanger duties with welded plate exchangers, twisted tubes, tube inserts and/or helical baffles

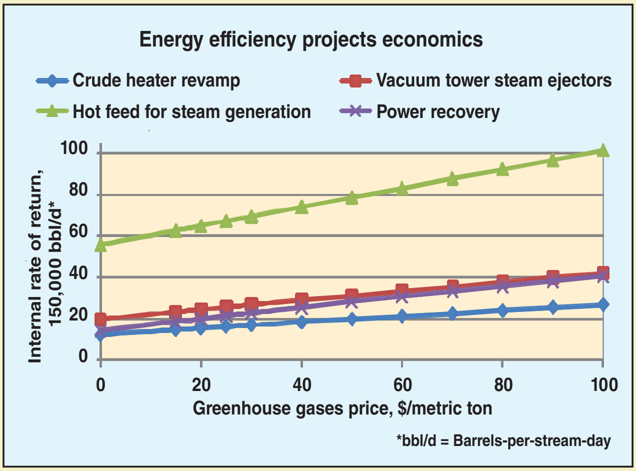


FIGURE 1. Various energy efficiency projects with cost of GHG emissions included.

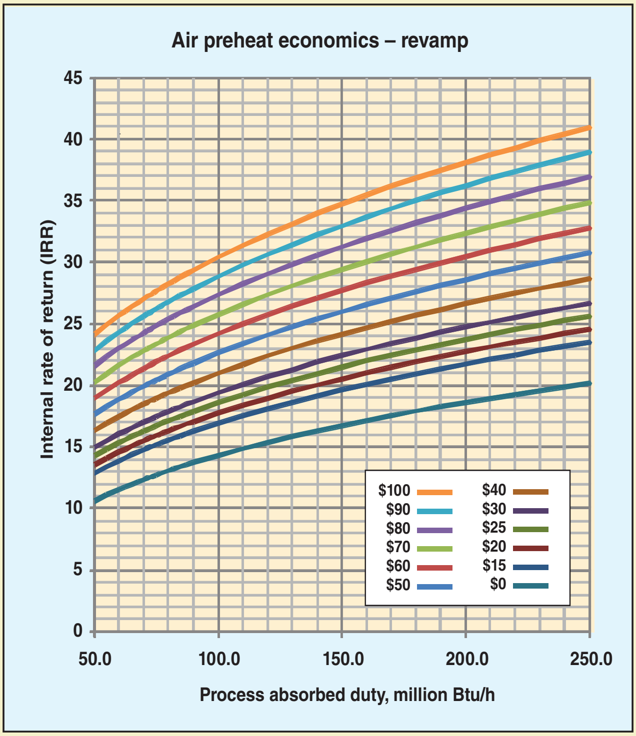


FIGURE 2. Revamp heater air preheat economics with GHG emissions cost included.

Reference

1. U.S. Energy Information Administration (EIA). Emissions of Greenhouse Gases in the United States 2008, , U.S. Department of Energy, December 2009.

Note: Material for this "Facts at Your Fingertips" was supplied by I.M. Glasgow, S. Polcar, E. Davis, T. Nguyen, J. Price, C. Stuecheli and R.E. Palmer at Mustang Engineering LP, Houston.

Seeking out difficult situations

In 1952, 37 companies established Fractionation Research, Inc. (FRI). Most of those original members are now gone or absorbed by other companies. Nevertheless, their goal was to study distillation in columns having diameters and heights that were similar to industrial columns. The columns of the world were getting larger and more numerous and were too often being designed using bench-top apparatuses and rules of thumb. If it were not for that early initiative, what we know today about practical operation of distillation columns would probably be very different.

The original test columns were located on a C.F. Braun property in Alhambra, California. After about 35 years of very successful operation, the columns were moved to the Oklahoma State University (OSU) campus, which is where they still reside. History has shown that Oklahoma weather is not as friendly to turnarounds and operations as was California, but at least the unit was not moved to Fort Saskatchewan.

The FRI technicians and operators are a very sturdy lot and often remind me of a line from the cult-classic movie "Repo Man" that goes something like this, "Most people spend their entire lives trying to keep out of difficult situations; repo men spend their lives getting into difficult situations." The FRI operators are the repo men of the distillation world. For them, steady state is a brief luxury. After steady state data are collected, the operators change several set points and then spend the next hour or two settling the test column down.

During a typical two-week data collection, the FRI operators flood the column five times. Those flood points are often dramatic, with liquid in the overhead system and a lost bottoms level. Once a flood point has been identified, the operators start all over, collecting steady state data at loadings like 20, 40, 60, 80, 90, 95 and 98% of flood. At 98% of flood, pressure drops are high, tower efficiency is low and true steadiness is usually elusive. There is little free time for coffee table chats in the FRI control room. Compare this to a typical control room where some operators silently pray that a level alarm will go off during their shifts — and give them something to do. FRI's repo men spend their shifts getting *into* difficult situations.

FRI operators do more than just control the test columns. They collect fluid samples from the columns using "bombs" at high pressures and vials at low pressures. They run the gas chromatograph. Every one or two months, they shut the unit down, steam it out and then air it out in anticipation of a revamp. Trays, random packings and structured packing all take regular turns in the columns. Most of the revamp work is effected using removable heads at the tops of the two test columns. FRI operators are lowered into the columns using chairs and safety lines and winches. Random packings are removed and installed using buckets. Structured packings are removed and installed using thick gloves. Tray installations require that tabs be welded to the inside of the shell, with removable expansion rings being used above the tabs.

None of this work is easy, especially during Oklahoma winds storms, yet the operators' biggest complaint is the singing of the other operators. With that, FRI salutes operators everywhere. ■

Mike Resetarits
resetarits@fri.org

WHO'S WHO


Speake


Hale


Foose


Reda


Speed

Graham Speake joins **Yokogawa Corp. of America** (Newnan, Ga.) as principal systems architect for the company's IA Global Strategic Marketing Center in Dallas.

Clark Hale joins **Brooks Instrument** (Hatfield, Pa.) as president and chief operating officer.

Satya Sachdeva becomes vice-president of business intelligence and information management services for IT service provider **Sogeti USA** (Dayton, Ohio).

Harvel Plastics (Easton, Pa.), manufacturer of PVC and CPVC industrial piping and duct systems, has appointed *Patrick Foose* as president and general manager.

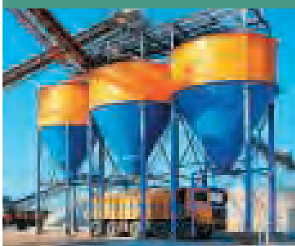
David M.J. Foo becomes director of business development for the chemical business of logistics company **DHL Global Forwarding** (Singapore) in the South Asia Pacific region.

The role of chairman of the board, president and CEO at **GE Hitachi Nuclear** (Wilmington, N.C.) is being split into two roles, with *Jack Fuller* remaining as chairman, and *Caroline Reda* becoming president and CEO.

Dover Corp.'s **Pump Solutions Group** (Chicago, Ill.) names *Greg Aschman* vice-president and chief financial officer.

Thaddeus Speed is the new technical director of the Global Energetic Materials testing and analytics div. at **Chilworth Global** (Schaumburg, Ill.) ■

Suzanne Shelley



JULY New Products

Georg Fischer Piping Systems

New diaphragm valve delivers twice the flow

Launched in April, this new generation of diaphragm valves (photo) is said to have a number of decisive advantages in handling and safety, but also in regard to efficiency. The flow in these valves is, on average, double that of conventional diaphragm valves, says the manufacturer. The central plastic thread, which is used instead of the normal four metal screws, guarantees a corrosion-resistant connection. The more homogeneous thermal expansion behavior achieved by this central plastic thread also eliminates the need for retightening. Leak tightness is provided for operating pressures of up to 16 bar. — *Georg Fischer Piping Systems, Schaffhausen, Switzerland*
www.piping.georgfischer.com

Camlab

Measure turbidity in the field with this portable instrument

The portable TB200 white-light turbidity meter (photo) is designed to quickly provide reliable onsite testing of water samples. The unit uses a white light source and a 90-deg infrared detection technique to meet specifications of EPA Standard 180.1. The instrument is capable of performing 600 tests without a battery charge. Calibration of the turbidity meter is simple, and the device comes with four turbidity standards. Autoranging is a feature that allows the instrument to automatically select the correct turbidity range for a given sample. — *Camlab Ltd., Cambridge, U.K.*
www.camlab.co.uk

Emerson Process Management

This valve family now has an expanded outlet version

The Fisher Vee-Ball family has been extended to include the V150E expanded outlet version (photo). The valve features a transitional flow contour that increases in flow area from inlet to outlet. The V150E is designed for installation directly to a medium-consistency pump-discharge flange, and the expanded outlet will accommodate larger diameter transfer lines. The valve is available in sizes down to DN 80x100 (NPS 3x4) and up to DN 250x300 (NPS 10x12), and mates with ASME Class 150 or PN 10/16 raised-face flanges. — *Emerson Process Management, Baar, Switzerland*
www.emersonprocess.com/fisher

BETE

Nozzles for keeping ethylene plants cool

An example of this firm's development of customized spraying solutions is a recent application involving oil quenching in the production of ethylene. Ethylene feedstock is mixed with steam and heated to around 1,500°F in the pyrolysis furnace. Downstream of the furnace, the process stream must be cooled. This is accomplished by injecting oil into the process stream to reduce the temperature. The solution is a MaxiPass series of nozzles (photo), which are designed for hydrocarbon feed applications, provide good drop size and are available in a wide range of materials, including the 316L stainless steel selected for this application. — *BETE Ltd., Lewes, U.K.*
www.beteuk.com

Note: For more information, circle the 3-digit number on p. 58, or use the website designation.

New Products


Edwards


Nikkiso-KSB


VEGA


Krüss

Profibus communication is one feature of this positioner

The Series 3730 electro-pneumatic control-valve positioner with Profibus-PA (photo; p. 28I-1) provides high-quality air output capacity combined with optimum functionality and ease of operation. The 3730 is one of a range of positioners from this firm, all of which are based on a common model platform. The Type 3720-2 and all higher versions come with the fully integrated Expert valve diagnostics that supply the required information for predictive maintenance. Alarms are indicated via the fault indication output and displayed as error codes. — *Samson Controls Ltd., London, U.K.*
www.samsoncontrols.co.uk

Reduce footprint with these exhaust-treatment systems

The Zenith range of integrated exhaust management systems (photo) has been expanded to include a new offering incorporating the iXH harsh process vacuum pump and the Alas family of gas-abatement solutions. This expansion of the Zenith range offers semiconductor manufacturers a highly efficient, low cost-of-ownership solution to the increasing vacuum and abatement demands of advanced semiconductor processing at the 60-nm and smaller design rules, says the manufacturer. A Zenith exhaust management solution can reduce system footprints by up to 70% and can reduce utility hookups by over 60%, says the firm. — *Edwards, Crawley, U.K.*
www.edwardsvacuum.com

Pumps designed to last a long time in harsh environments

This firm has launched a new pump-type series (photo) for use in the chemical and petrochemical industries. The pumps meet the requirements of API 685 Standards, and the series comprises 27 sizes designed for a minimum of 20 years of operation in a petroleum refinery under heavy-duty conditions and at pressures of at least 40 bar. The casings with their centerline pump feet and the flameproof motor housings are provided with a corrosion allowance of 3 mm. Throttle rings on the front and rear shrouds of the impeller and balancing holes, together with a hydraulic-pressure balancing chamber, ensure that the axial forces are absorbed. The new series generates a maximum flowrate of 350 m^3/h and a maximum discharge head of 200 m. — *Nikkiso-KSB GmbH, Bruchköbel, Germany*
www.nikkiso-ksb.com

Simplified level measurement of bulk solids

New hardware and extended software algorithms make the sensors of the Vegapuls 60 radar instrument series (photo) even more powerful, says the manufacturer. Application parameters describe the measurement task of the sensor, thereby enabling simple and optimal adaption to the application. The user only has to select the type of medium to be measured, the vessel geometry and mounting situation, and the measurement range. The software then operates to ensure the level is precisely measured. Setup and commissioning is simple to perform, and standardized diagnostics are included. — *VEGA Grieshaber KG, Schiltach, Germany*
www.vega.com

This analyzer provides a top view of surface properties

The TVA100 Top View Analyzer (photo) measures the contact angle of liquids using the image of light spots that are mirrored by the curved surface of the drop. Contact angles in the lower range (down to 1.5 deg), which in the past has been difficult to approach, can be measured with precision by this technique. The view from above makes wetting inhomogeneities immediately visible. Surface energy measurements can be carried out thanks to the insensitive precision dosing unit with a wide range of liquids. — *Krüss GmbH, Hamburg, Germany*
www.kruss.de

This valve isolates pressure gages for venting

The new compact gage valve (photo)

Circle 26 on p. 58 or go to adlinks.che.com/29252-26

New Products

is designed with a smaller footprint than conventional assemblies for quick, convenient access for the isolation and venting of pressure gages. Tube-fitting end connections reduce valve installation time and cost, and provide robust tube grip and vibration resistance. An integral purge valve eliminates a threaded connection, reducing potential leak points. The valve's 316 stainless-steel construction offers durability and corrosion resistance. — *Swagelok Co., Solon, Ohio*
www.swagelok.com


The Dolomite Centre


Hans Turck


BS&B Pressure Safety Management

More certification for this buckling-pin relief valve

The BPRV Buckling Pin Relief Valve (photo) may be certified according to the 2009 addendum of ASME Section III, Div. 1, bearing both the UD stamp and NB mark. Since 2004, the BPRV valves have been available with ASME UD stamp based on certification according to ASME Code Case 2091-3. This latest addendum welcomes pin-actuated devices to full code status. The patented BPRV is based upon the offset shaft butterfly valve concept. The offset of the shaft results in a turning moment being generated about the valve shaft when a pressure differential is applied across the device. A Buckling Pin mounted externally to the process normally resists the moment. By calibrating the pin, the BPRV provides accurate pressure relief. — *BS&B Pressure Safety Management LLC, Tulsa, Okla.*
www.bsbipd.com

A tight connector for multiple tubes of microfluidic systems

The Mitos Inline Connector System (photo) provides a single, fast and reliable multi-way connection for microfluidic tubing. Available in three sizes (4-, 8- and 12-way), the connector operates over a wide temperature range (–15 to 250°C) and handles pressures up to 10 bar. Low dead volume reduces the risk of cross-contamination between fluid samples. The system is compatible with a variety of polymeric tubes, including PTFE, FEP and PEEK. — *The Dolomite Centre Ltd., Royston, U.K.*
www.dolomite-microfluidics.com

Monitor and control many I/O functions — without wires

In May, this firm and Banner Engineering introduced a scalable wireless network that can monitor and control I/O functions or provide serial communication at up to 56 locations. The new SureCross DX80 product line (photo) replaces costly wiring in a wide range of industrial, agricultural, power generation, water supply and waste disposal applications. Discrete, serial and analog devices that can be controlled by the network include ultrasonic and photoelectric sensors, pumps, counters, thermocouple and RTD temperature sensors. The remote nodes gather data and transmit control commands between sensors and other devices and a central Gateway, which maps inputs from the remote nodes and interfaces with a PLC or HMI via RS-485 Modbus or EtherNet/IP. — *Hans Turck GmbH & Co. KG, Mülheim an der Ruhr, Germany*
www.turck.com

Remove or insert these flowmeters without flow interruption

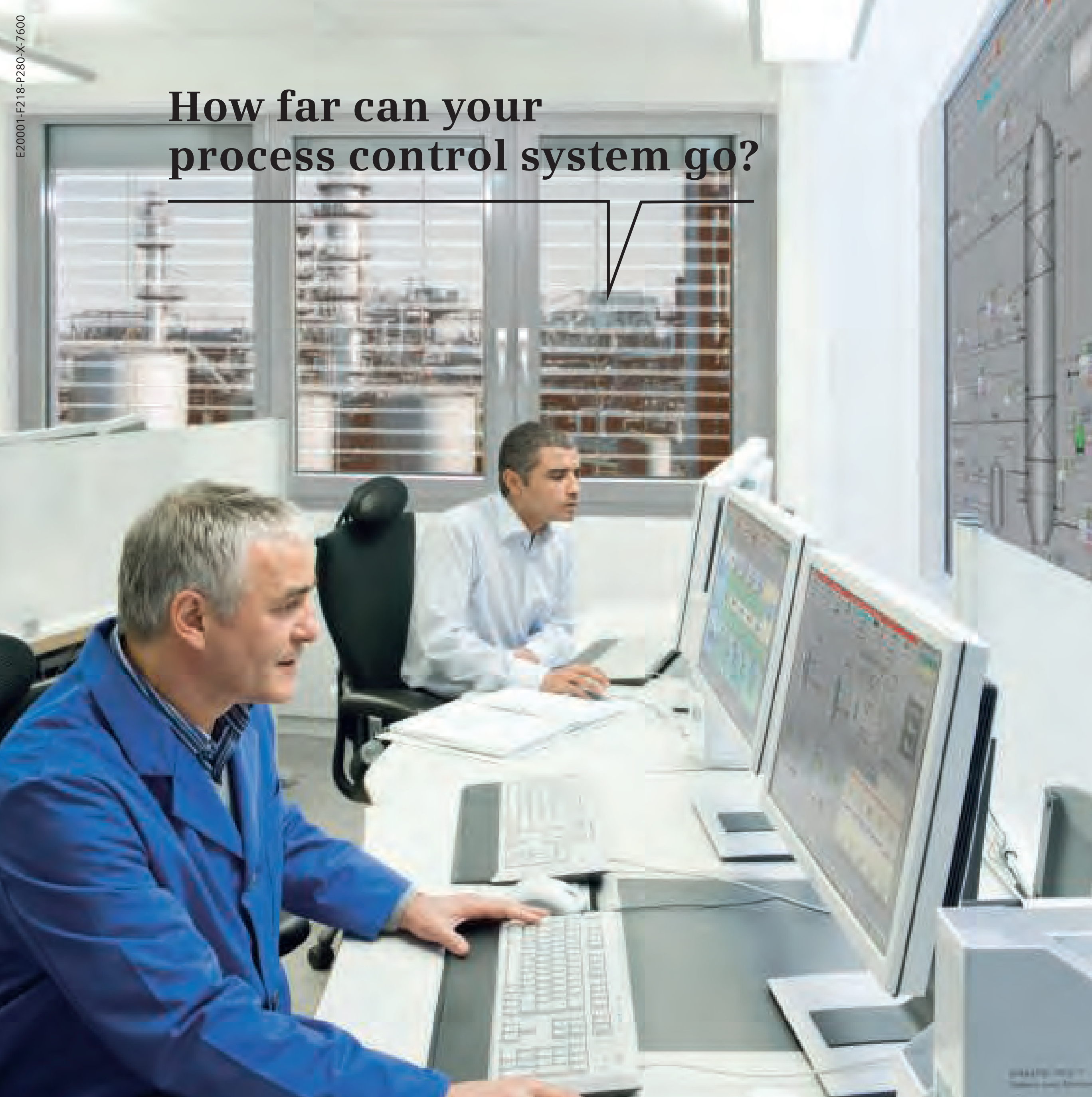
This firm now offers a new range of insertion flowmeters for applications where installation and removal from the pipeline without interruption to flow is more important than extreme accuracy. The Series 5000 turbine flowmeters (photo, p. 28I-6) are simple to install and remove, and are particularly suitable for large pipelines (4-in. dia. and upwards) where the cost of inline meters can be prohibitive. The flowmeters can be fitted with different, interchangeable rotor assemblies and are available with a wide range of electronic signal conditioning and readout devices. When used in conjunction with a ball valve, the metering head retracts fully into the housing, so it can be removed without interrupting flow. — *Filton Process Control Engineering, Haywards Heath, U.K.*
www.filton.com

An all-in-one dispersion laboratory

The Dispersion Analyzer LUMiSizer (photo, p. 28I-6) is said to be a complete dispersion laboratory in a single instrument. The LUMiSizer simultaneously determines the demixing of 12 different dispersions at original concentration, based on a patented STEP Technology. Due to acceleration of demixing in the LUMiSizer up to a factor of 2,300, information about colloidal stability, surfactant influence, particle size, agglomeration and flocculation of dispersions is obtained in a short time. The variation of the centrifugal force — comparable to a falling sphere viscometer — also provides first information about the rheological behavior of the dispersion. — *L.U.M. GmbH, Berlin, Germany*
www.lum-gmbh.com

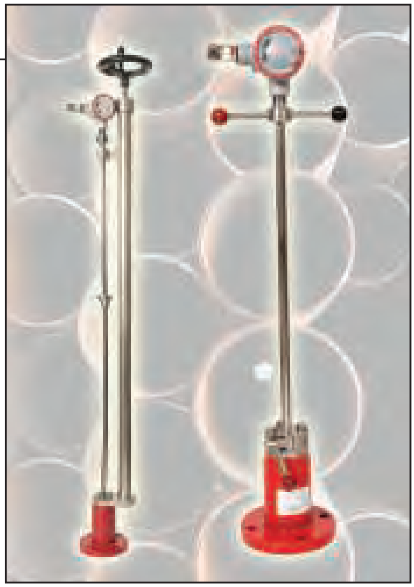
Aluminum-ring-type valve that's certified for gas applications

The new gas valve RD-G is a DVGW- (German Technical and Scientific Association for Gas and Water) certified control device without zero-cutoff, according to EC gas appliance directive 2009/142/EC, DIN 3394-1 and DIN


E20001-F218-P280-X-7600
How far can your
process control system go?

EN 13611. The valve is available with an electric or pneumatic actuator, and a swing-through version and a model with stop-bar sealing are also available, both with a nominal diameter of up to DN 150. — *ARIS Antriebe und Steuerungen GmbH, Troisdorf, Germany*
www.stellantriebe.de

L.U.M.



ilton Process Control Engineering

Three new, efficient progressive cavity pumps
Three new progressive cavity pumps are now available from this manufacturer: the Series C is designed for demanding duties in the pulp and paper, mining and minerals, and chemical industries; the Series D is designed for dosing applications; and the Series E is a compact solution targeting environmental and wastewater applications. The new pumps feature a number of innovations, including the precise Evenwall 3D technology with two-lobe rotor geometry, which offers a more rigid and tighter pumping unit compared to conventional progressive cavity pumps. This makes it possible to reduce the friction between the rotor and stator, which allows for a much lower starting torque and "significantly higher" efficiency, says the firm. A patented shaft design enables its mechanical seal to be quickly replaced without dismantling the entire pump or its drive shaft and coupling. — *Larox Flowsys Oy, Lappeenranta, Finland*
www.larox.fi

More modular mixer-mounting options now available
The Nettco i-Series Portable and Fixed Mount Mixers handle a wide variety of mixing and mounting requirements using a modular assembly design. Multiple mounting configurations, including clamp-style, open-tank or sealed designs can be quickly converted from one mounting arrangement to another in less than two minutes. The latest offering includes: the Bung Adapter, for mixing in drums by fitting securely into the opening of the lid; the Sanitary Flange Mechanical Seal Assembly, which clamps to sanitary tank flanges; the Sanitary Flange Lip Seal, which also clamps to sanitary tank flanges; the Angle Riser, for open tank units for off-center positioning of the mixer; and the Air Motor Option, for operation wherever compressed air is required or available. — *SPX Flow Technology, Rochester, N.Y.*
www.spxft.com

Reduce VOC emissions with this packing-free pump
The new Hydra-Cell T80 Series pumps are packing-free and designed to replace packed plunger pumps in oil and gas applications. Featuring a seal-less diaphragm design, the T80 Series pumps eliminate emissions of volatile organic compounds (VOCs), cleanup and disposal costs of packed-pump leakage, the need for external lubrication and maintenance and plunger wear problems associated with packing. The pumps can run dry without damage, will operate with a closed or blocked suction line and can pump abrasive fluids. The first model of the series, the T8045, has a flowrate capacity of 1,543 bbl/d (45 gal/min) at pressures of 3,000 psi. — *Wanner Engineering, Inc., Minneapolis, Minn.*
www.wanner.com

This holder allows rupture discs to be torqued after installation
The TQ+ is the latest addition to this firm's line of pretorqueable rupture disc holders. The holder allows rupture discs to be installed and then torqued to recommended static load levels, properly clamping to the rupture disc within the assembly. The TQ+ was designed with the ability to be installed in multiple international flange rating configurations, including ANSI, JIS, DIN and ISO. The holders can also be removed, inspected and re-installed during routine maintenance and plant turnarounds. Standard, stocked sizes range from 1 to 60 in. (DN25–DN150). — *Fike, Blue Springs, Mo.*
www.fike.com

A new name for a range of control valves
A comprehensive range of control valves, now known as iCV (intelligent control valves), was introduced in May. The iCVs are fully suited to both general and demanding applications, especially in hydrocarbon processing plants. The offerings consist of eccentric rotary-plug valves, V-port segment valves, Neles RotaryGlobe valves, high-performance eccentric disc valves and top-entry rotary control valves. The iCV rotary control valves eliminate the gland-packing leakages associated with rising stem globe valves. The company's non-leakage, live-loaded valve packing prevents loss of raw materials and also effectively eliminates the need for gland packing maintenance and associated costs. — *Metso Automation Oy, Helsinki, Finland*
www.metso.com/icv

Problem-free pumping of heat-transfer fluids
Etanorm SYT is the latest generation of single-stage volute casing pumps, which were developed for applications in modern heat-transfer systems and hot-water circulation. Besides hot water, the pumps handle mineral-oil-

SIS-Tech

Siemens Industry Sector

based thermal fluids and synthetic thermal oils at temperatures up to 350°C. The pumps' stable rib design and reinforced bearings make them resistant to external forces. A new vent design enables the gases to be removed during operation, and users can select between carbon (standard) or silicon-carbide plain bearings. — *KSB AG, Frankenthal, Germany*
www.ksb.com

Launch of an automated overfill protection system

The Automated Overfill Protection System (AOPS; photo) is a safety-instrumented system that can prevent dangerous overfill conditions in terminals, tank farms and process vessels. The AOPS incorporates a non-programmable Logic Solver (suitable up to SIL 3) that receives signals from switches or transmitters, determines if an abnormal process condition is present, and provides outputs to close isolation valves, shutdown transfer pumps or open dispersion valves. The system operates independently of the plant's process control system with the capability to communicate to the control system via hardwire, Modbus, Ethernet or wireless communications. — *SIS-Tech, Houston, Tex.*
www.sis-tech.com

Process control for cement and related industries

This firm's Industry Automation Div. has equipped Version 7.1 of its Cemat process control system (photo) with multiple new functions. An enhanced signaling and diagnostics concept is designed to reduce plant downtime as well as operating and maintenance costs, thus increasing plant availability and productivity. For example, Alarm Control is a freely-configurable signaling system integrated into the operator system for effective message display and processing. Interrupts can be individually filtered, or they can be exported for better analysis of critical plant states. Other new functions include the listing of by-passed process signals and the display of corresponding groups and routes for all process objects and object-granular alarm acknowledgement. — *Siemens Industry Sector, Nuremberg, Germany*
www.siemens.com/cemat ■

Gerald Ondrey

MTL Instruments

FOCUS ON

Process Control

Pepperl+Fuchs

Monitors with maximum viewing, even in sunlight

The latest addition to this firm's family of industrial liquid-crystal display (LCD) monitor solutions, these 15-in. transflective modules (photo) are specifically designed to deliver the high viewability needed in applications with direct sunlight, while also being robust for harsh outdoor environments. Made of 100% industrial-grade components that deliver the highest mean time between failure, at over 550,000 h, these monitors are available as general purpose displays or as a UL-listed Class 1/Div 2 device. They can also be equipped with the firm's EPS purge system for Class 1/Div. 1 hazardous environmental monitoring. — *Pepperl + Fuchs, Inc., Twinsburg, Ohio*

www.pepperl-fuchs.com

The first Coriolis mass flowmeter for EtherNet/IP network

The Promass 83 Coriolis Mass Flowmeter integrates with the Rockwell Automation Integrated Architecture, expanding the flow of realtime information. The EtherNet/IP-enabled Promass 83 is designed to offer process system designers greater freedom and choice in their selection of components and architectures. Rockwell Automation complements this hardware development with the software tools for RSLogix 5000 and FactoryTalk View integration as part of a PlantPAx system. — *Endress+Hauser, Inc., Greenwood, Ind.*

www.us.endress.com

A new range of Fieldbus Barrier wiring hubs

Launched in May, this new range of Fieldbus Barrier wiring hubs are said to establish a new benchmark for connecting intrinsically safe field instruments to Foundation Fieldbus networks in hazardous areas. The 9370-FB Fieldbus Barrier (photo) retains the major benefits of the High Energy Trunk techniques, while removing the drawbacks associated with existing Fieldbus Barrier implementations, says the manufacturer. The 9370-FB Series is modular in construction, comprised of fixed carrier assembly and pluggable components. These are assembled to form complete, self-contained enclosure systems in either stainless steel or carbon-loaded GRP, and sized according to the application. — *MTL Instruments, a div. of Cooper Crouse-Hinds, Luton, U.K.*

www.mtl-inst.com

This platform speeds system commissioning, and lots more

Launched last December, the S-Series platform with I/O on Demand and Electronic Marshalling is the latest in the company's DeltaV digital automation system (photo, p. 30). The new release includes many major enhancements to all the systems' I/O processing, operator displays, asset management, batch capability and system security. These combined capabilities are said to reduce user project complexity, eliminate needless work and speed system commissioning. With I/O on Demand, users

Note: For more information, circle the 3-digit number on p. 58, or use the website designation.

Focus

Emerson Process Management

decide what type of I/O they want — Wireless, Foundation Fieldbus, HART, AI, AO, DI, DO, DP T/C or RTD. They decide when they want the I/O, whether for late project changes, during startup, during operation or temporary installations; and where they want the I/O, whether in a rack room, remote locations, hazardous areas, safety systems or harsh environments. Further advantages are realized with Electronic Marshalling, a powerful new technology that streamlines design and installation for users. — *Emerson Process Management, Austin, Tex.*
www.emersonprocess.com

Version 5.1 of System 800xA offers new enhancements
System 800xA Extended Automation 5.1 includes enhancements to help users improve performance, usability and operator effectiveness with a substantially reduced system print. Based on Windows 7/2008 Server, System 800xA 5.1 includes many new features, including advanced alarm management capabilities; a new Point of Control feature, which allows an operator in a different area of a facility to request permission to control a plant area or unit from the currently responsible operator; engineering improvements, such as simplified bulk data handling when engineering Foundation Fieldbus projects; and more. This latest version of System 800xA uses virtualization to reduce the physical number of PCs required for installation by as much as 75%, says the firm. — *ABB Automation, Houston, Tex.*
www.abb.com ■

Gerald Ondrey

Stop wasting profits and energy on plant air.

Your cost-effective solution for tight budgets and even tighter places

A MiniVac™ pneumatic conveyor eliminates the need for expensive plant air or a separate compressor to convey material. Instead, it uses a highly efficient, integral regenerative blower. You'll spend less on energy as you move fragile product, granules, powder and pigment to where you need it. With its side-door filter access (no tools needed) you easily can get inside the MiniVac, even if it's installed up against the ceiling. Ready to tighten your operation budget? Let's talk.

Move up to 10,000 lbs/hr.

Access filter easily. Internal filter eliminates need for separate dust collector.

Discharge material through dump gate, rotary valve or slide gate.

Maintain filter efficiency with reverse-pulse filter cleaning system.

Save money and energy. Integral regenerative blower requires no plant air or separate compressor to convey material.

Improve your plant environment.

You need to minimize the environmental impact of processing chemical ingredients at your facility. So we've engineered a full range of innovative equipment and systems to help you succeed:

- Perform batch, intermittent and continuous operations.
- Convey free- and non-free-flowing bulk materials.
- Improve labor/energy efficiencies.
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Using Inserts to Address Solids Flow Problems

It might seem counter intuitive at first, but inserting an obstacle in the flow path often results in improved flow characteristics

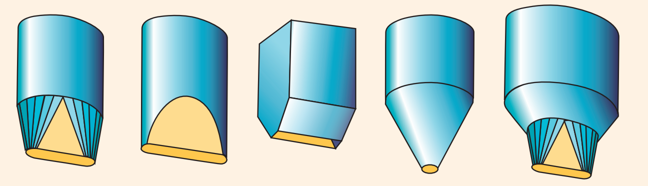

FIGURE 1. Shown here are five of the most commonly used hopper geometries for bulk solids. Conventional shapes include cone, pyramid (convergence from four directions) and V-shaped-wedge (convergence from two parallel planes) forms

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Storage of bulk materials in hoppers, bins and silos is ubiquitous in the chemical process industries (CPI), and so are the challenges that go along with it. Flow stoppage (bridging or arching), variability in mixture composition (de-mixing or segregation), erratic flow, uncontrolled flow (flooding), discharge-rate limitations and structural failures are not uncommon. While the impact of vessel geometry is relatively well-publicized in this context, the benefits that inserts offer — both to new and existing units — are not.

Developed in the 1960s, Andrew Jenike's powder test procedure and design methodology, which is based primarily on a steep cone and smooth wall, continue to provide scientifically determined solutions for securing reliable flow [*1*]. It is not always feasible, however, to design and install storage units with this geometry because of space constraints, cost or the need to retrofit an existing facility for a new application. And then there are materials with variable flow properties that create a moving target.

The suggestion that flow can be improved by inserting an obstacle in the flow path, or by using a wall surface with higher resistance to slip, might seem counter-intuitive at first. Closer investigation reveals, however, that overall flow regimes are formed by how the individual particles in bulk solids respond to the local forces at contact points. These forces determine whether a particle will move or not, in what direction and whether or not it remains intact. Inserts address flow on this local level.

BACKGROUND

The term insert embraces any static fitting on the inside of a bulk storage container, including liners and modifications that alter the internal space of a vessel. From the first step of deciding whether an insert would be helpful in a given application, it is critical to have an understanding of the patterns of flow regimes, stress systems and the behavior characteristics of loose solids. The performance of inserts depends on the hopper geometry, feeder type (or discharge control), and ambient and operating conditions. Therefore, design and selection of inserts requires an overall systems approach and must be based on the measured values of relevant bulk-material properties.

This short review is meant to increase the reader's awareness of the varied benefits inserts can provide and to provide an overview of the types, purpose, principles and attributes. Detailed design guidelines and calculation procedures for inserts are beyond the scope of this article. It must be emphasized that inserts are not a magic cure-all for grossly deficient designs. Selection and detailed design require special expertise, and therefore remain mostly in the domain of specialists.

In fact, most insert concepts and designs have been developed and introduced by equipment vendors, rather than arising from fundamental research. Patents, registered designs and trademarks protect the intellectual property of some units and operating details of proprietary techniques are not in the public domain. The scope of technical publications on this subject is also limited, so the information and the design data on applications are somewhat restricted. Much work still needs to be done in developing a systematic selection criterion and in calculating stresses on inserts during filling and flow conditions.

ENSURING GRAVITY FLOW

Gravity flow occurs when the bulk material is deformed to the shape of the flow channel by stresses generated from the loss of potential energy of the system. Energy is lost in the form of friction, either by sliding on the container walls or by the internal friction when the flow channel boundary is within a bed of static product. The material will not flow unless the stresses generated in the flow chan-

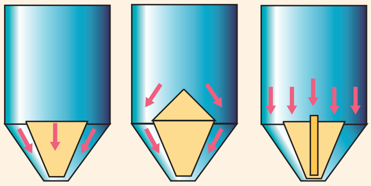

FIGURE 2a.
Cone-in-cone insert with variations

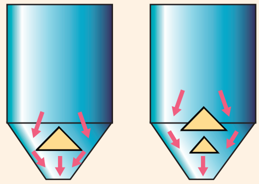

FIGURE 2b.
Inverted cone designs

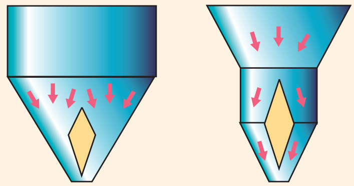

FIGURE 2c.
Bullet type inserts

FIGURE 2. These three sets of illustrations provide detail for the cone-in-cone, inverted cone and bullet inserts

TABLE 1. SUMMARY OF VARIOUS BIN INSERTS

Objective	Method	Type
Prevent arching	Reduce bulk strength	Tube insert
	Mass flow outlet region	Expanded flow
	Convert to annulus	Inverted cone, bullet type
	Divert impact compaction	Inlet disperser
	Break arch	Vibrating 'reed'
	Increase vertical wall friction	Liners, wall fittings
	Reduce converging wall friction	Liners and coatings
Prevent 'ratholes'	Convert to mass flow	Cone-in-cone
	Cut hoop strength	Tube insert
Prevent 'dead' storage	Convert to mass flow	Cone-in-cone, inverted cone
Reduce segregation	Create flow gradients	Cone-in-cone
	Mutiple point extraction	Tributary type
	Disperse in-feed	Inlet inverted cone
Prevent flushing	Accelerate de-aeration	Whirling rods
	Avoid short residence time	Cone-in-cones
Increase discharge rate	Increase effective outlet area	Inverted cone
	Accelerate radial flow	Vertical screw
Reduce dis-charge dust	Focus output stream	Inverted cone
Reduce attrition	Prevent flow stream impact	Inlet disperser
Prevent 'caking'	Disrupt particle contacts	Mass flow plus bulk flow disturbance
Reduce feeder loads	Reduce outlet pressures	Cross inverted 'V's
	Provide flow expansion relief	Longitudinal inverted 'V's

TOP REASONS FOR INSTALLATION INSERTS

Inlet region
- Reduce segregation
- Reduce particle attrition
- Reduce ullage
- Reduce inertial compaction by inflow Minimize dust generation

Outlet region
- Promote and sustain gravity flow
- Secure flow through smaller outlets
- Increase flowrates
- Improve consistency (of, say, density)
- Secure mass flow with less steep wall inclinations
- Expand the flow channel
- Improve the extraction pattern
- Reduce overpressures on feeders
- Save headroom, secure more capacity
- Counter segregation
- Blend the contents on discharge
- Improve counter-current gas flow
- Secure total self-clearing
- Prevent blockages by lumps
- Prevent 'flushing' and 'slurping'
- Reduce dust generation

Inside space
- Accelerate de-aeration
- Reduce compaction pressures
- Alter the flow pattern
- Counter 'caking' tendencies

nel due to gravity are greater than the local yield strength of the bulk material. There is often a large source of potential energy within a stored mass, but, all too often it exists in the wrong place, ultimately compacting the underlying bulk to a stronger condition rather than deforming the bulk to initiate and maintain the flow.

There are three basic ways to improve the potential for gravity flow [*2*, *3*]:

1. Minimize the development of strength in the bulk material
2. Modify the flow channel to generate adequate stresses that will deform the bulk
3. Apply external forces on bulk material to assist gravity flow

The first stage of the hopper design process is to determine the form of flow regime appropriate to the physical nature of the bulk material and circumstances of the application. Hopper constructions most often follow the simple, conventional shapes of a cone, pyramid (convergence from four directions) or V-shaped wedge form (convergence from two parallel planes). A hopper of simple shape often meets the requirements of the flow channel, however, alternate designs may present a more economic alternative or offer benefits (Figure 1). Ideally, inserts should be routinely considered alongside conventional and novel hopper shapes to optimize the form of a bulk storage facility. Ancillary flow-aid techniques should also be included within this comprehensive approach.

Bin inserts are fitted for many functional reasons, so appreciation of purpose plays a big part in proper selection (see box, Reasons for Installation Inserts; and Table 1). Some insert designs are simple and easy to implement, while others require professional expertise to select and design. In all cases, care is required to ensure that adverse consequences, whether performance or safety related, are avoided. Obstructions to flow can suffer far greater loads than their size may suggest. Therefore, the structural integrity of installations must be verified. Small storage containers present special difficulties because the characteristics of bulk materials do not scale down, but structural integrity is generally less sensitive for small containers.

Minimize strength development

The strength of particulate solids is dependent upon many physical properties of the constituent particles. However, in contrast to 'solid' solids, bulk particulates do not have a unique strength value, but exhibit a variable condition that depends, among other things, on how close the particles are packed together and the confining forces acting on the system. Bulk density is a basic measure of particle packing.

Energy during so-called bed flow, which takes place in a parallel flow channel (cylindrical section), is absorbed by wall friction and compaction

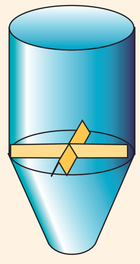

FIGURE 3a.
Inverted V beam

FIGURE 3a. V-cross inserts help reduce the compaction forces applied by incoming material

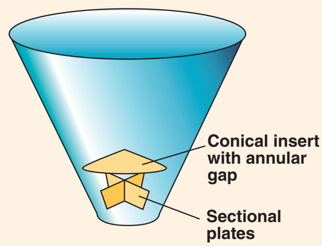

FIGURE 3b.
Conical insert

FIGURE 3b. With any inserts that offer multiple flow paths, it is prudent to fit vertical crossed ribs above the outlet to promote flow from all sections and prevent the development of preferential flow channels

CRITICAL ISSUES FOR DESIGN AND APPLICATION

- Selection of type and geometry of insert depends on hopper shape and application
- Calculation of load (stresses) on the insert and subsequent design of supports remains a challenging problem
- Sensitivity of performance to dimensional tolerance of the insert and material properties must be understood
- Inserts by their very nature are in the flow path of bulk material. The consequences of plugging and recovery from plugged state due to upset conditions must be considered. ❑

of the bulk. Over one-hundred years ago, Janssen's research showed that the vertical load (stress) transmitted through a vertical bed reaches a limiting value at a depth dependent on wall friction and the hopper cross section. Underlying material carries no further increase in compacting pressure since wall friction supports additional bed depth. An optimum wall surface will have high friction on the parallel walls by liners or wall protrusions and low friction on the converging walls.

Alternatively, to increase the boundary drag in flow regions of large cross section, without obstructing bulk movement, vertical ribs or cross plates can be employed. Impact of the fill stream onto previously deposited bed of material can cause compaction. An insert to slow, diffuse or deflect the flow path, to prevent the impact load on the sensitive flow region immediately above the outlet point, will reduce forces that compact the material.

A more radical approach is to fit a cross of inverted V-beam (or V-cross) inserts at the transition point between the parallel and converging sections. When compared to the inverted cone (Figure 2b), V-cross inserts (Figure 3a) have the advantage of possessing high beam strength to carry the superimposed load. Provided the remaining flow areas are larger than the critical arching dimension and flow takes place over the whole area, V-cross inserts usefully reduce overpressures.

With any inserts that offer multiple flow paths, it is prudent to fit vertical crossed ribs above the outlet to enforce flow from all sections and prevent the development of preferential flow channels (see Figure 3b).

Another method of reducing compacting pressures due to material level in the bin or silo is to install conical inserts or slip resisting fittings at various elevations along the vertical wall (Figure 4). This design results in transference of vertical stresses from the material to the silo wall.

Soft, elastic or fibrous materials, such as cork and rubber granules, strands of plastic used for carpets, machine chippings and detergent powders, tend to be sensitive to compacting pressures. One method that has been used successfully for cork granules employs layers of coarse grids with such openness and spacing that the contents exert only a trivial pressure on the layer below, but the granules dribble through each grid (Figure 5).

To prevent undue compaction forces arising in large hoppers storing pressure sensitive granules, arrays of inverted V-shaped plates can be suspended from the roof of a silo or hopper by chains. If the development of preferential flow channels is likely, arrays of inverted V-shaped tents can used instead. In both cases, the flexibility of suspension avoids the formation of stable supports around a flow channel, as the insert will tend to move toward a region of differentially reduced pressure, as from a static bed to a live flow channel, thereby favoring flow to develop in the previously static region. Clearly, the supports need to be appropriately designed to account for loads on the insert during filling and flow.

Modify the flow channel

Planar versus conical flow. The stress needed to deform a given solid also depends on the form of flow channel. Planar flow has various advantages over a conical flow. Flow in conical flow channels, termed 'radial flow', causes circumferential strain ($\pi/2 \times$ the radial strain). Material in a V-shaped hopper deforms less by comparison, so it will flow down less-steep walls and through smaller outlets.

A stable 'rathole' can form in a circular flow channel by virtue of the hoop strength of the material. On the other hand, a V-shaped hopper with a fully live outlet cannot sustain a rathole, provided the slot length exceeds three times its width, and the flow takes place along the full length of the slot. A circular hole has to be twice the width of a V-hopper slot for an arch to collapse and enable gravity flow. The performance of a feeder on a slot outlet is crucial to efficient hopper operation.

By modifying the flow channel, an insert can make the shape of convergence more favorable for flow. An inverted cone (Figure 2b) alters the flow channel from a radial flow form to a type of annular V-shaped hopper that has a greater deforming capacity. Johanson describes the correct placement of inverted cones in his classic paper [*4*]. The bullet type insert (Figure 2c) forms a two-stage flow channel of this form. The upper section has a diverging cone. The lower converging part provides a boundary for an annular, V form of flow channel that reduces the rate of convergence of the bulk.

A pyramid-shaped hopper of non-mass-flow construction is also prone to forming a rathole. Fitting the hopper with a mass flow section from the outlet to a dimension greater than the critical rathole size improves flow potential and avoids rathole prospects. Extending this flow channel by walls with steeper slope provides total discharge and secures maximum storage capacity.

A 'cone-in-cone' construction (Figure 2a) creates two flow channels. The central portion is a conventional mass-flow cone with steep walls. The outer region forms an annular, V-shaped flow channel, in which the material deforms

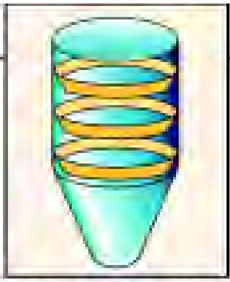

FIGURE 4. Another option for reducing compacting pressures is to install slip resisting fittings at various elevations along the vertical wall

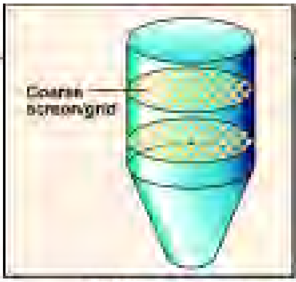

FIGURE 5. Layers of coarse grids can reduce compacting pressures on soft, elastic or fibrous materials, while letting the material flow through

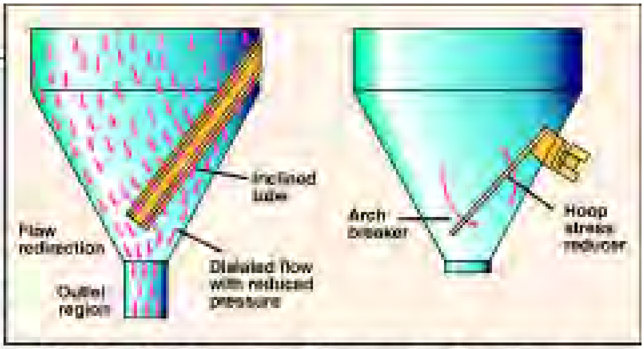

FIGURE 6. A tube insert (a, left) is one option for solving the problem of ratholing. This principle has been extended (b, right) with members stimulating flow from outer regions of a conical chamber

easier than in a cone. The contents of the outer annulus slip on the wall and deform for flow against a much shallower outer wall inclination than would be the case for the original cone. A limitation is that the two separate flow channels each require an outlet size greater than the critical arching span. Since the width of each outer channel (as an elongated slot) is half the diameter required for a cone, the total outlet diameter for the system has to be twice that of a normal cone.

An inverted cone fitted above the outlet opposes central extraction (Figure 2b). These inserts may be used to increase the rate of discharge, expand the flow path or induce mass flow.

The stability of the annular strain acting in a conical flow can be undermined by preferentially extracting a segment of this circular region. The tube insert design, which is attributed to Lyn Bates, creates a skewed form of an annular, V-shaped flow channel in which central discharge is obstructed and a sheltered channel of preferential extraction destroys the continuity of the peripheral body of material (Figure 6). The shielded region fails more readily in flow and preferentially draws material from under the eccentrically extended insert.

The essential feature of tube inserts is that they weaken the circumferential stress field in a conical hopper by redirecting the extraction of material from peripheral regions of the cross section. Obstructing flow in the center favors flow down from the shielded section under the insert, which allows the remaining cross section to converge in a skewed manner like the closing of an incomplete ring. Devoid of circular continuity, the residual horseshoe shape of material bends inwards, failing in tension on the periphery, and flows to the region of reduced pressure under the insert. This principle has been extended with multiple members stimulating flow from outer regions of a conical chamber.

COMMON REASONS FOR LACK OF PERFORMANCE

- Inadequate definition of problem
- Material flow properties not properly measured
- Variable material or operating conditions
- Wrong selection of insert or poor design
- Lack of attention to detail in design or manufacture
- Task just too difficult. Bin redesign would have been more appropriate

Overcoming friction. A common method employed to develop mass flow in marginal cases is to fit wall liners with lower wall friction than the original walls. Shedder plates at the hip, providing a smooth transition from the vertical to the converging wall, enhance slip by the equivalent of 2–3 deg. of extra hopper-wall steepness.

Reducing dynamic overpressures. Many failures in shallow bottom silos can be attributed to difficulty in predicting dynamic overpressures during funnel flow. Dynamic overpressures occur at the location of effective transition where the switch occurs from cylindrical to arched stress field. By inserting a tube, which is open at both ends and has discharge ports at the bottom, the silo is effectively divided into two halves (Figure 7). The overpressure on the wall can be significantly reduced with the use of such anti-dynamic tube inserts. The diameter and height of the tube depends on the material flow properties [6].

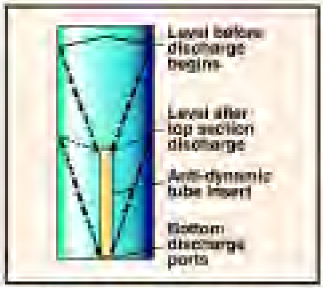

FIGURE 7. This tube effectively divides the silo in two halves, reducing overpressure

Promoting material dilation. A situation that gives rise to extremely high shear resistance is the initiation of shear failure of a firm granular product in confined conditions. While the structure of such a bed will reorder and pack down relatively easily under applied vibration, it offers strong resistance to any reduction in volume. For example, granular sugar or salt in a storage hopper will settle to a structural packing array whereby the grains overlap. To form a shear plane these particles must either separate or fracture. For the crystals to move apart in a confined bed, the remaining bed must compact, to which a granular structure offers exceptionally strong resistance, as it can only compacted by way of granule fracture or re-ordering of the packing to closer particle proximity.

Inverted V inserts placed over a feeder screw in a hopper outlet provide a continuous void and allow the bed to expand with little resistance. Once flow commences, the product in motion dilates to ease continuation of the feeding process.

Preventing caking. Caking is a time-, environment- and pressure-related process. Inserts can reduce contact pressures, as described above and influence the time that a bulk material stays in a static structural condition. A disturbance to particle packing will disrupt incipient crystal bridge formations and embryonic sintering and fusions that would hold together the bulk as a firm agglomerated mass or as clusters. Mass flow prevents stored regions remaining static for an indeterminate time, but will not upset

DO'S AND DON'TS

Do:
- Determine full nature of the problem
- Establish all operating conditions
- Clearly define performance requirements
- Measure flow properties (typical and offset conditions)
- Check structural integrity of the silo/bin and make sure that inserts support do not cause structural failures
- Honor intellectual property rights and pay appropriate royalties

Don't:
- Act in undue haste in selecting appropriate insert concept
- Compromise design based on cost and space constraints
- Ignore human factor
- Expect miracles!!

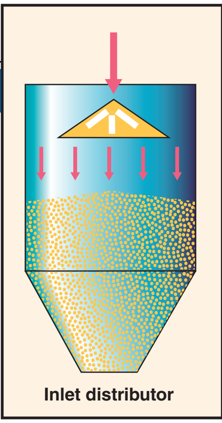

FIGURE 8. Segregation can be countered in non-mass-flow hoppers by diffusing the fill distribution

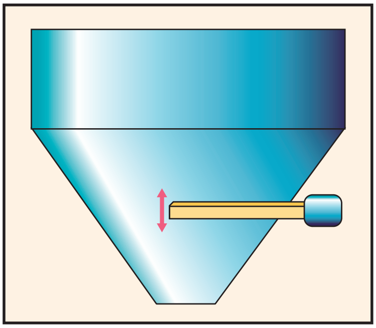

FIGURE 9. Vibrated inserts of this type have the triple effect of shielding the outlet from overpressures, redirecting the flow channel to a more efficient pattern for deformation and oscillating at the tip to break arches

the product in a parallel body section of a mass flow hopper until it travels to reach the converging section.

A design with converging/diverging wall profile can be used to distort such beds. Intermittent flow obstructions can cause regular cross section deformations that dislocate particle orientations during flow, an event that negates the growth of caking bonds within the mass. This process is caused to repeat at more frequent intervals and be more effective at preventing caking if the stored contents are recycled through the hopper, even if intermittently or at a very low rate.

Reducing segregation effects. Segregation can be countered in non-mass-flow hoppers by diffusing the fill distribution (Figure 8), extracting material from multiple regions of storage, or both, thereby diluting the effect of any local concentration of fractions. A feed stream with a horizontal component, as from a belt conveyor, aggravates segregation. If the stream is funneled to a feed tube that impinges on a shallow inverted cone, it will spill uniformly at a large diameter, giving a more homogeneous ridge fill. Care must be given to avoid circumferential bias. Also note that product in the sensitive flow region above the outlet can be compacted by the impact of a concentrated feed stream. Diverting the flow or spreading it over a wide area by an insert will avoid or reduce this effect.

Apply external forces

Vibration is often used in association with inserts to stimulate flow. Fitting a vibrator only to the outside wall of a hopper can have adverse, as well as beneficial effects because the energy input is not usually directed to the location of greatest need for flow. More effective is a flat bar extended inwards from a wall-mounted vibrator, tuned to resonate at the natural frequency of the applied vibration, can transmit vibration to sensitive flow regions. Vibrated inserts of this type (Figure 9) have the triple effect of shielding the outlet from overpressures, redirecting the flow channel to a more efficient pattern for deformation and oscillating at the tip to break arches.

Flushing, flooding or slurping are synonymous terms associated with excessive dilation (aeration) of the bulk material. A rotary vibrator on a frame with hanging rods that vibrate at a natural frequency will accelerate the de-aeration process. The rods resonate and whirl, to form vertical holes through the bed to generate 'volcanoes' of spurting powder and air on the surface by air escaping from lower regions. The technique may be combined with limited air injection to sustain an easy-flow state of the bulk material. The air content progressively decays as the state of the bulk material approaches, and retains, a non-fluidized, stable flow condition. A surface with a negative inclination acts also as an inverted sedimentation plate for rising gas. Solids fall away from the outer wall of a cone-in-cone insert; the underside of bullet type inserts are commonly used to provide uniform gas percolation in gas contact-bed processing. The radial arms, inner periphery of the insert and a negative step in the outer casing, employed as areas shielded from the flow path, allow an unobstructed entry for the gas.

For more on discharging techniques see Ref. 2 and 3.

INSERT SELECTION

Various aspects need to be considered while selecting an appropriate insert for a given application.

Application objective. What are the performance objectives of the insert installation? Optimal insert design is meant to balance the relative importance of these objectives (see box, p. 33).

Retrofit design versus new hopper. Retrofit situation might limit the choices due to space constraints, structural integrity of the vessel, ability to install the insert in the field and support design.

Complexity of fabrication and total cost. The complexity of design and total installed cost must be balanced with other alternatives available to solve the flow problem.

Static inserts versus externally activated inserts. Static inserts are preferred since they are cheaper to maintain and operate. However, per-

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formance differentiation for cohesive, sticky and rubbery materials might justify externally activated inserts.

Cleanability and product variability. Inserts can create cross-contamination problems for a multi-product facility. It is important to understand the potential of plugging and material accumulation during unsteady state operation, startup and production that is off specification. Acceptable time and effort required to clean the internals is a critical factor in selection.

Effect on feeder. What desirable and undesirable effect does the insert have on the feed system?

Patents. Many concepts and ideas are patented. Appropriate royalties must be paid to the inventor (for a list of innovative patents, see the online version of this article at www.che.com).

Commercial design. If a commercial design of the insert is available, it can be implemented much faster than designing one from the first principles.

Summary

We have presented a brief overview of an extensive but largely under-developed technology of bin inserts. Application of fundamental concepts of powder mechanics and good engineering practices, driven by ingenuity, are key to future innovations in this field. ■

Edited by Rebekkah Marshall

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Aging Relief Systems — Are they Working Properly?

Common problems, cures and tips to make sure your pressure relief valves operate properly when needed

Sebastiano Giardinella
Inelectra S.A.C.A.

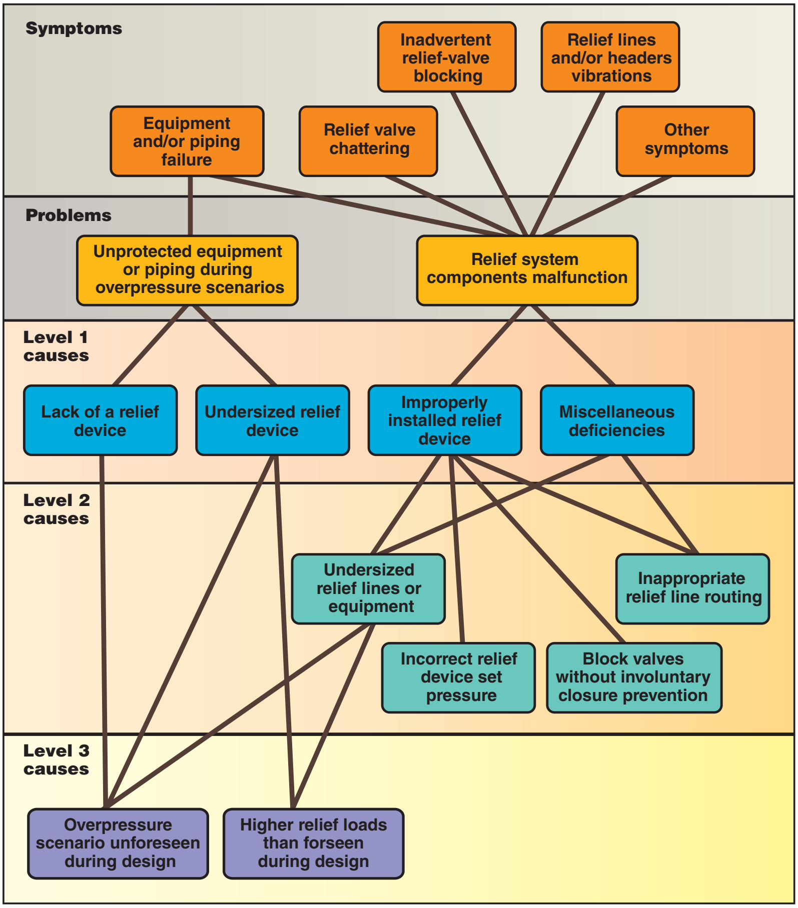

FIGURE 1. A problem tree for relief system shows causes, problems and symptoms

Relief systems are the last line of defense for chemical process facilities. Verifying their capability to safeguard equipment integrity becomes important as process plants age, increase their capacities to adjust to new market requirements, undergo revamps or face new environmental regulations.

In the past, approximately 30% of the chemical process industries' (CPI) losses could be attributed, at least in part, to deficient relief systems [*1*]. Furthermore, in an audit performed by an independent firm at more than 250 operating units in the U.S., it was determined that more than 40% of the pieces of equipment had at least one relief-system-related deficiency [*2*]. These indicators underscore the importance of checking the plant relief systems.

This article presents the most common types of relief system problems with their possible solutions and offers basic guidelines to maintain problem-free relief systems.

COMMON PROBLEMS IN EXISTING RELIEF SYSTEMS

Problems and their causes

Relief system problems or deficiencies can be identified, with respect to the U.S. Occupational Safety and Health Admin. (OSHA) regulation 29 CFR 1910.119, as items that do not comply with "recognized and generally accepted good engineering practices" [*3*] in relief systems design. The recognized and generally accepted good engineering practices are criteria endorsed by widely acknowledged institutes or organizations, such as the Design Institute for Emergency Relief Systems (DIERS) or the American Petroleum Institute (API). For instance, in the petroleum refining industry, the accepted good engineering practices are collected in API Standards 520 and 521.

The most common relief system deficiencies can be classified into one of three types [*2*]:

1. No relief device present on equipment with one or more potential overpressure scenarios
2. Undersized relief device present on equipment with one or more potential overpressure scenarios
3. Improperly installed pressure relief device

The first type of deficiency refers to the lack of any relief device on a piece of equipment that is subject to potential overpressure. The second type

TABLE 1. RELIEF-SYSTEM PROBLEM IDENTIFICATION DURING OVERPRESSURE-SCENARIO MODELING

Relief System	Deficiency	Identified When:
Undersized relief device	Insufficient relief-device area	Calculated relief-device area > installed relief device area
Improperly installed relief device	Excessive relief-valve inlet-line pressure drop	Friction pressure drop in pressure-relief-device inlet line > allowable friction losses (typically 3% of the set pressure)
	Excessive relief valve backpressure	Relief valve backpressure > allowable backpressure (typically 10% for conventional valves, or 50% for balanced bellows valves considering backpressure capacity-reduction factor)
	Incorrect relief-valve set pressure	Pressure in protected vessel or line > Maximum allowable accumulated pressure (typically 10, 16 or 21% of the MAWP for pressurized vessels with single relief valves for non-fire scenario, multiple relief valves for non-fire scenario, and relief valves for fire-scenario), AND pressure at PSV inlet < PSV set pressure
Miscellaneous	Excessive line velocity	Line Mach number > allowable Mach number (typically 0.7)
	Insufficient knockout drum liquid separation	Effectively separated droplet size at maximum relief load > allowable droplet size (typically 300–600 μm)
	Excessive flare radiation	Calculated radiation level at a specific point > allowable radiation level (typically 1,500 Btu/h-ft^2 where presence of personnel with adequate clothing is expected for 2–3 min during emergency operations, or 500 Btu/h-ft^2, where continuous presence of personnel is expected, both including sun radiation)

refers to an installed relief device with insufficient capacity to handle the required relief load. The third type encompasses relief devices with incorrect set pressures, possibility of involuntary blocking or hydraulic problems. In addition to these problems, other less frequent ones can be cataloged as miscellaneous deficiencies. A relief-system problem tree is shown in Figure 1.

In a previous statistical analysis of 272 process units in the U.S., it was observed that [*2*]:

- 15.1% of the facilities lacked relief devices on equipment with one or more potential overpressure scenarios
- 8.6% of the relief devices were undersized
- 22% of the relief devices were improperly installed

Identifying potential problems

There are work methodologies that allow identifying potential problems in relief systems. OSHA regulation 29 CFR 1910.119 is based on safety audits that use techniques such as process hazard analyses performed at regular intervals. The work methodology established by this regulation to identify safety hazards comprises two basic steps [*3*]:

1. Process safety data gathering, which includes the following:

- Process chemical safety data
- Process technology data
- Process equipment data [materials of construction (MOCs), piping and instrumentation diagrams (P&IDs), design standards and codes, design and basis of design of the relief systems, among others]. As part of these data, "the employer shall document that equipment complies with recognized and generally accepted good engineering practices" [*3*]

2. Process hazards analysis, which may include: What-if, hazard and operability (HAZOP) study, failure mode and effects analysis (FMEA), fault-tree analysis or equivalent methodologies.

In order to document that the plant equipment complies with recognized and generally accepted good engineering practices, the plant management must validate that the facilities are protected against potential overpressure scenarios, in accordance with accepted codes and standards, such as API standards 520 and 521. An effective relief-system-validation study comprises the following steps:

1. Plant documents and drawings gathering. The first step involves obtaining and classifying the existing plant documents and drawings: process flow diagrams (PFDs), mass and energy balances, product compositions, equipment and instrument datasheets, P&IDs, relief device datasheets, relief loads summaries, relief line isometrics, one-line diagrams, unit plot plan, and so on.

2. Plant survey. The second step consists of inspecting the installed relief devices to verify that they are free of mechanical problems, to update and fill-out missing data in the plant documents and to verify consistency between the documents and drawings and the actual as-built plant. During plant surveys, other typical indications of relief system problems are the presence of pockets, leaks or freezing in relief lines and headers.

3. Overpressure scenario identification. In this step, the P&IDs are examined in order to identify credible overpressure scenarios for each piece of equipment.

4. Overpressure scenario modeling. The fourth step is to model each credible overpressure scenario. Each model is developed in accordance with the chosen reference standard (for instance, API 520 and 521). The following calculations are typically performed during this step:

- Required relief load for each overpressure scenario
- Required relief-device orifice area for each overpressure scenario
- Relief line's hydraulics
- Knockout drum (KOD) liquid-separation verification
- Flare or vent radiation, dispersion and noise level calculations

The overpressure scenario modeling can be done in different ways, be it by hand calculations, spreadsheets or by the use of steady-state or dynamic relief-system simulation software. The results of the models are analyzed to identify potential problems. Table 1 summarizes the possible relief system problems and the ways to identify them on the calculation results.

Available solutions

There are various solutions for each type of relief system problem. The available solutions can be classified as: (a) modification of existing relief system components, (b) replacement of existing relief system components, (c) installation of new relief system components, or (d) increasing the reli-

TABLE 2. CONDITIONS THAT INCREASE THE PROBABILITY AND IMPACT OF RELIEF SYSTEM FAILURE

Conditions that increase the probability of relief system failure	Conditions that increase the impact of relief system failure
The plant has over 20 years of service	The plant handles toxic, hazardous or flammable fluids
The plant currently handles different products to those it was originally designed for	The plant handles gases
The plant operates at a different load or at different conditions to those it was originally designed for	The plant operates at high pressures
There have been contingencies that have required the replacement of equipment or lines in the past	The plant operates at high temperatures
Rotating equipment (pumps, compressors) has been modified (for instance, new impellers) or replaced	The plant has furnaces, or equipment that adds considerable heat input to the fluids
The relief valves have not been checked or validated in the last ten years	The plant has high-volume equipment (such as columns, furnaces)
Modifications have been made to existing relief valve lines (that is, they have been rerouted)	The plant has exothermic reactors, or chemicals that could react exothermically in storage
A complete and up-to-date relief valve inventory is not available	The plant has large relief valves (8T10), or the relief header has a large diameter
The relief load summary has not been updated in the last ten years	The plant has a high number of operations personnel
A relief header backpressure profile is not available, or the existing model has not been updated in the last ten years	The plant is located near populated areas

ability of the emergency shutdown systems.

The modification of existing relief-system components includes changes made to installed components, without requiring their replacement. Some examples of this type of solution include the following:

1. Recalibrating the pressure relief valve by readjusting the set pressure (solution to incorrect set pressure) or the blowdown (solution to inlet-line friction losses between 3% and 6% of the set pressure)
2. Adding locks to relief lines' block valves (to prevent involuntary valve closure)

The replacement of existing relief system components involves substituting inadequate relief system elements for newer, appropriate ones. Some examples of this solution are the following:

1. Replacing the installed pressure relief valve, either for one with a larger orifice area (solution to undersized relief device) or for one of a different type (solution to excessive backpressure)
2. Replacing relief line sections to solve hydraulic problems, such as: excessive relief-valve inlet-line friction losses, excessive backpressure, excessive fluid velocity, pockets, among others

The installation of new relief system components involves the addition of relief system elements that were not included in the original design, such as the following:

1. New pressure relief valves, either on equipment lacking overpressure protection, or as supplementary valves on equipment with undersized relief valves
2. New headers, knockout drums or flares, when the revised relief loads exceed the existing relief system capacity, or when relief system segregation (that is, acid flare/sweet flare, high-pressure/low-pressure flare) is required

Increasing the reliability of the emergency shutdown systems is typically done via implementation of high integrity protection systems (HIPS), in which redundant instrumentation and emergency shutdown valves are installed in order to cutoff the overpressure sources during a contingency. The main advantage of this type of solution is that it can significantly reduce the required relief loads, hence posing an economical alternative to the installation of new relief headers, knockout drums or flares.

EXAMPLES OF PROBLEMS IN AGING SYSTEMS

What follows are examples of some typical relief-system problems that can be found in aging process facilities and the recommended remedy.

Deficiency No. 1

The first type of deficiency is when no relief device is present on equipment with one or more potential overpressure scenarios.

Case 1. New overpressure scenario after pump replacement. In a process unit, a centrifugal pump was replaced for another one with a higher head, without considering the downstream system's maximum-available working pressure (MAWP). Since the downstream system was designed at the previous pump's shutoff pressure, the installation of a higher shutoff pressure pump created a new blocked outlet scenario. Therefore, the installation of a new pressure safety valve (PSV) was recommended.

Deficiency No. 2

This type of deficiency involves undersized relief devices that are present on equipment with one or more potential overpressure scenarios.

Case 2: Insufficient orifice area after changes in the stream composition. In a petroleum refinery, a desalter that was originally designed to process heavy crude oil was protected against a potential blocked outlet by a relief valve on the crude outlet. When the refinery started processing lighter crude, simulations showed partial vaporization in the relief valve. The vapor reduced the PSV capacity until it was insufficient to handle the required relief load. In this case, the recommendation was to replace the original PSV for one with a larger orifice and appropriate relief lines.

Deficiency No. 3

The third type of deficiency involves improperly installed pressure relief devices.

Case 3: Excessive backpressure due to discharge line modifications. An existing vacuum-distillation column's PSV outlet lines were rerouted from the atmosphere to an existing flare header due to new environmental regulations. The installed PSVs were a conventional type, so with the new outlet-line routing, the backpressure exceeded the allowable limit. A recommendation

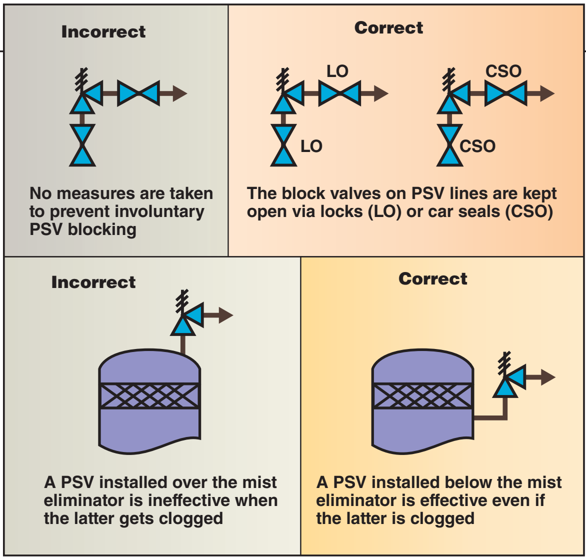

FIGURE 2. The risk of blocking in a pressure safety valve (PSV) can sometimes be readily identified on P&IDs

FIGURE 3. Non-free-draining lines in installed relief lines, such as shown in these two constructions, may cause accumulation of liquids that can hamper relief valve performance

was made to replace the existing PSVs for balanced bellows PSVs.

Case 4: Incorrect PSV set pressure due to static pressure differential. A liquid-full vessel's relief valve was set to the vessel's MAWP; however, the relief valve was installed several feet above the equipment's top-tangent line. The static pressure differential was such that the pressure inside the vessel exceeded the maximum-allowable accumulated pressure before the PSV would open. The problem was solved by modifying the existing PSV, recalibrating it to the vessel MAWP minus the static pressure differential.

Case 5: Incorrect PSV set pressure due to higher operating temperature. The temperature of a stream was increased with the addition of new heat exchangers, and no attention was paid to the set pressure of the thermal relief valve in the line. By increasing the temperature, the pipe MAWP was reduced. The PSV set pressure was lowered to the new MAWP at the new working temperature plus a design margin.

Case 6: Risk of blocking the relief valve. A relief valve can be blocked for various reasons. Some of the most common include the lack of locked-open (LO) or car-seal-open (CSO) indications in the PSV inlet- and outlet-line block valves, and installing the PSV above the mist eliminator on a separator. Both deficiencies can be readily identified on P&IDs (Figure 2).

Case 7: Pockets. Relief lines going to closed systems should be self-draining. It is not uncommon during construction that, due to space limitations, a non-ideal line arrangement is installed, creating pockets on relief lines that may cause liquid accumulation and hamper relief valve performance (Figure 3).

Deficiency No. 4

The fourth category of deficiencies is a miscellaneous grouping.

Case 8: Problems in an existing flare network due to additional discharges. The additional discharges of various distillation-column relief valves were rerouted to an existing flare network because of new environmental regulations. The additional discharges exceeded the system capacity, and the entire flare network and emergency shutdown system had to be redesigned by selecting the optimum tie-in locations for the discharges, and by implementing HIPS in order to reduce the required relief loads.

Case 9: Sweet and sour flare mixing. When revamping a section of a process unit's relief headers, some acid discharges were temporarily routed to the sweet flare header in order to maintain operations. Soon afterwards, the header backpressure started to increase and scaling was detected upon inspection. The acid gases could also generate corrosion, as the sweet flare header material was inadequate to handle them.

Case 10: High- and low-pressure flare mixing. The discharges of low pressure PSVs located on drums were routed to the closest flare header, which was a high pressure header. Since the design case for relief of the drums was only for a fire, additional discharges were not considered by the designer. However, the power failure also affected these drums. When this case was evaluated, the backpressure was too high for the installed PSVs, so they had to be replaced by piloted valves.

MAINTAINING PROBLEM-FREE RELIEF SYSTEMS

Some practical guidelines are offered below to help the plant management to assess, identify and troubleshoot relief system problems.

Tip No. 1: Assess the risk

Some factors tend to increase the probability and impact of a relief system failure. Table 2 qualitatively shows some of them. If several of the conditions shown on Table 2 apply, then the plant management should consider planning a detailed study, such as a quantitative risk analysis (QRA), or a relief-system validation study.

Tip No. 2: Maintaining up-to-date relief-valve information

The plant management should maintain accurate, up-to-date relief-valve data for maintenance and future reference. The following documents are of particular interest: (a) relief valve inventory, (b) relief loads summary and (c) relief header backpressure profile.

Relief valve inventory. The relief valve inventory is a list that contains basic information and status for each relief valve, which should include the following:

- Valve tag

TABLE 3. RELIEF SYSTEM VALIDATION STUDY TYPICAL EXECUTION PHASES AND DELIVERABLES		
Phase	**Deliverable**	**Deliverable description**
Survey and data gathering	Updated relief device inventory	A list containing up-to-date, accurate data for each relief device located in the plant. The minimum data to be included on the list are as shown in Tip No. 1, and they should be obtained by combining relief-valve manufacturer documentation with onsite inspections
	Updated P&IDs	P&IDs showing the existing installed relief-device information: connection diameters, orifice letter, set pressure, inlet- and outlet-line diameters and block valves
	List of pockets	A document identifying pockets on relief lines, with the appropriate photographs
Existing relief system modeling	Updated relief loads summary	A list containing the required relief loads for each applicable overpressure scenario of each relief device, the required orifice area and the relieving fluid properties, based on actual process information
	Updated relief-network backpressure profile	A document showing a general arrangement of the relief headers and subheaders, along with updated backpressure profiles for the major plant contingencies
	Updated relief device calculations	A document containing the calculations for each relief device under actual operating conditions
	List of relief system deficiencies	A document listing all of the deficiencies found in the existing relief system, categorized by type
Relief system troubleshooting	Conceptual engineering	A document defining the modifications required to solve the relief system deficiencies

- Process unit and area
- Location
- Discharge location
- Connection sizes
- Connection rating
- Orifice letter
- Manufacturer
- Model
- Type (conversion, ball, pilot)
- Set pressure
- Allowable overpressure
- Design case
- Installation date
- Last inspection date
- Last calculation date

Relief loads summary. The relief loads summary contains all the overpressure scenarios and relief loads for each relief device at the plant. The data in this document can be used to identify the critical overpressure scenarios in the plant.

Relief-header backpressure profile. A backpressure profile of the entire relief network is valuable when evaluating the critical contingencies in the system, as it can be used to identify relief valves operating above their backpressure limits.

Tip No. 3: Planning and executing a relief system study

The execution of a typical, relief-system validation study comprises three phases: (a) survey and information gathering, (b) existing relief system modeling and (c) relief system troubleshooting. The typical deliverables for each phase are described in Table 3. If the plant management has specific document formats, it should provide them as part of the deliverable description.

The study may require a number of resources that are not readily available in the plant. If the plant management has available resources but lacks specialized software licenses, then it can assign some of the tasks to inner resources, for example, survey and data gathering. Tasks requiring expertise or software packages above the plant's capabilities, such as complex distillation column, reactor system or dynamic simulations, should be outsourced.

A consulting firm should be selected based on its experience in similar projects, technological capabilities (specialized software licenses) and a reasonable cost estimate. In order for the consulting firm to deliver an accurate estimate, the plant management should provide the scope definition along with sufficient information to identify each relief device within the scope of the project, its location and the possible overpressure scenarios. These data are available in the relief loads summary and relief device inventory.

One person should be assigned on the plant management side to manage the project, along with administrative personnel, and at least one in charge of technical issues; the latter should be available to provide technical information and verify the validity of the consulting firm's calculations. The typical information that the consulting firm will request in order to complete the study includes: relief device inventory, relief loads summary, relief device datasheets, mass and energy balances, PFDs, P&IDs, equipment datasheets and relief line isometrics for each evaluated process unit/area. The consulting firm may also request process simulations, if available.

Tip No. 4: When modeling, go from simple to complex

Replacing a relief valve or header section generates labor, materials, installation and loss of production costs that can only be justified when the results of an accurate model identify the need for it. However, developing an accurate model for every relief device in the plant can be impractical and costly, especially if only a small number of relief devices require replacement at the end.

A practical compromise is to verify each system starting from a simple model with conservative assumptions, and developing a more accurate model for those items that do not comply with the required parameters under such assumptions. This approach minimizes the time and effort dedicated to items, and concentrates on those items that could present problems.

For instance, for a blocked outlet downstream of a centrifugal pump and control valve system, the simplest model is to assume a relief load equal to the pump's rated capacity. If the relief-valve orifice area is insufficient under the previous assumption, the next step would be to read the required relief load from the pump curve with the control valve's rated discharge coefficient and the valve's downstream pressure equal to the relief pressure, ignoring piping friction losses. If the orifice area still seems insufficient, then a rigorous hydraulic calculation of the entire circuit should be performed to determine the required relief load.

Tip No. 5: Evaluate various solutions to problems

As was mentioned earlier, there are multiple solutions that are possible for a single relief system problem, and the plant management would naturally wish to implement the quickest, most practical and least costly one. For instance, when a relief valve's inlet losses are between 3 and 6% of the set pressure, the valve blowdown can be adjusted instead of replacing the entire valve inlet line.

Tip No. 6: What to do after validation and troubleshooting

A routine revalidation of the relief system's correct operation not only bring that security to the plant management over the integrity of its facilities, but also to third parties, such as occupational safety organizations and insurance companies. The cost of a relief valve study may very well be paid with a reduction in the plant insurance premium. Furthermore, the image of a company that worries over the safety of its employees and the environment constitutes an important intangible benefit. ■

Edited by Gerald Ondrey

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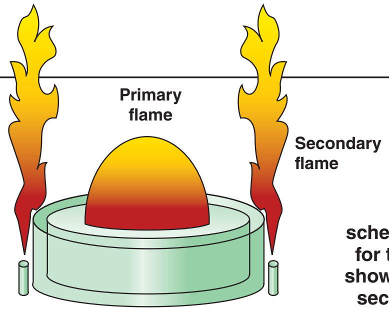

FIGURE 1. A schematic diagram for the test burner shows primary and secondary flames

Controlling Acoustic Coupling

Furnace pulsation is a problem caused by the coupling between heat release from a burner and acoustic waves of the hosting heater. Enhancing natural damping of the heater is a practical and attractive solution

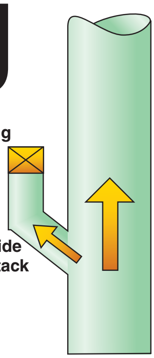

FIGURE 2. The inducing device is attached to the side of the heater stack

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Acoustic coupling in industrial furnaces is an issue that appears to have become more prevalent as designs increase the volumetric heat density of furnaces, and burner technology is required to meet more-stringent emission requirements. The problems associated with acoustic coupling appear in the form of either large oscillations in the heater pressure or tonal and high-level emitted noise. Although the burner is often blamed for these occurrences, the coupling depends on both heater acoustic characteristics and burner dynamic characteristics. The acoustic coupling is a form of burner-heater interaction. This article shows that acoustic coupling in industrial heaters can be mitigated by enhancing the natural damping of the heater.

An experimental study on how one can enhance heater damping is presented. The approach depends on restricting the flow of fluegases while they exit a smaller side stack using an inducing device to enhance natural damping and hence mitigate acoustic coupling in heaters. The use of this technique is proven to be independent of burner type, in other words, burner combustion dynamics. So, details of the burner combustion dynamics do not have to be known for configuring and designing the device. The approach sheds some light on the conditions under which the tested burner engages in acoustic coupling.

Acoustic coupling

Furnace pulsation is a problem that is encountered in combustion systems due to a rare coupling between heat release from the burner and acoustic waves of the hosting heater or enclosure. The problem appears in a form of a large oscillation in the heater pressure or draft.

The two sides of acoustic coupling. Although the blame for this disturbance is usually laid on the burner, the coupling depends on both heater acoustic characteristics and burner dynamic characteristics. In this acoustic coupling, oscillation frequency is normally determined mostly by acoustic characteristics of the hosting heater [*1–3*]. However, the strength of the oscillations strongly depends on the heat-release rate from the burner. The acoustic coupling is a unique cause for combustion system instability and is much different from intrinsic, burner flame instability. The latter is an inherent flame-stabilization problem because of either poor mixing, exceeding the flammability limits, lack of low velocity regions, or quenching by a strong shear-flow or excessive-flow gas recirculation. Also, when instability occurs as a result of coupling, it is common practice to see a burner pulsing in one heater and not pulsing in another heater with different resonance frequency.

While the acoustic side of the coupling is fairly well understood [*4–7*], the dynamic characteristics of a burner are still a challenge [*8, 9*]. Acoustic coupling in industrial heaters may lead to a wide variety of problems, which range from performance deterioration to burner or heater structural damage. When the acoustic pulsation is strong, it may lead to structural damage of the process tubes or refractory lining. Examples of performance deterioration are the occurrence of flashback in premix burners or an increase in NOx emissions. In spite of the fact that acoustic coupling is a system problem, the common practice is to modify the burner design until the acoustic coupling disappears. However, in many situations that solution comes with some sacrifice in the burner performance.

Mitigating the problem. Acoustic coupling can be mitigated through passive or active means of control. The active control of combustion acoustic instability is now common in gas turbine applications, [*3, 9, 10*]. The passive means include modification of either the burner or the heater characteristics. Since the prediction of burner dynamics is extremely difficult without dynamic characterization (experimental), burner modification is usually done on a trial-and-error basis. However, heater modification, which

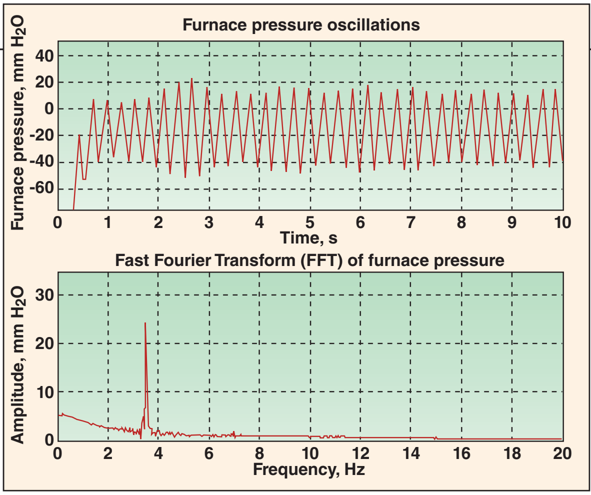

FIGURE 3. Furnace pressure under unstable conditions at 100% of burner capacity on a relatively cold day and 5% excess O_2

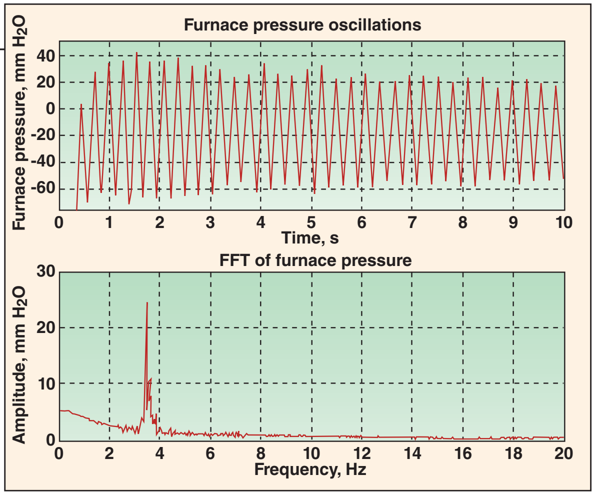

FIGURE 4. Furnace pressure under unstable conditions at 83% of burner capacity on a relatively warm day and 8% excess O_2

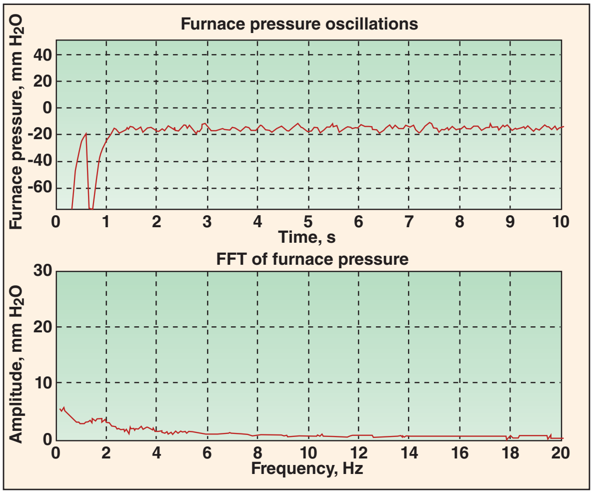

FIGURE 5. Furnace pressure under stabilized condition at 100% of burner capacity on a relatively cold day and 2% excess O_2

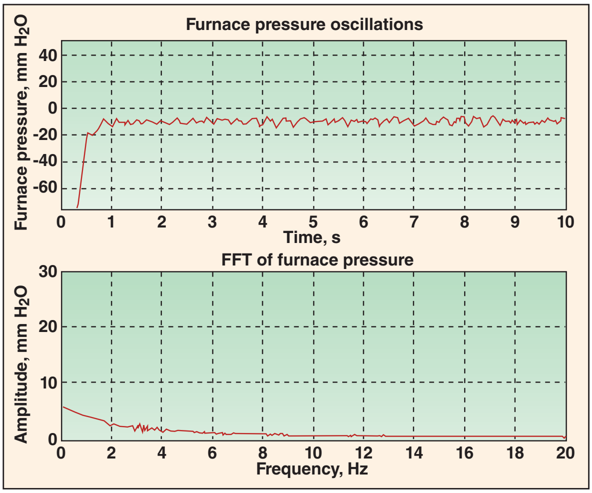

FIGURE 6. Furnace pressure under stabilized condition at 83% of burner capacity on a relatively cold day and 5% dry excess O_2

can be approached systematically, is categorized into two techniques. In the first technique, the heater modification leads mainly to a shift in resonance frequency of the heater. Examples of this technique are changing the physical dimensions of some parts of the heater and using reactive devices [*11*]. The second technique of heater modification is to enhance the natural damping of the heater.

An experimental study

The impact of enhancing the natural damping of the heater on acoustic coupling has been investigated experimentally. The work described in this section studies enhancing the natural damping of the heater through restricting the fluegases while they exit a side stack, and hence, controlling the acoustic coupling. Enhancing the natural damping of the heater is an attractive solution and comes with little penalty. The implementation of a flow-restricting-based damping-enhancement technique in an experimental furnace and the experimental results obtained are presented in detail. Results show that the technique not only suppresses acoustic coupling, but also allows an instability map of the burner-heater system to be generated. Also, the map of the resulting oscillation suppression can be constructed.

Apparatus. An experimental, natural-draft heater accommodating an industrial-scale single burner was used in this study. A closed water cycle removes heat from the heater. The combustion air is delivered to the heater by the natural draft created by the stack. The excited resonance mode of the heater is governed by dimensions of both the heater box and the stack [*11*].

Figure 1 depicts a low NOx burner used in the experimental work. This type of burner operates as a natural-draft, staged-fuel combustion system.

An inducing device — a powerful steam sparger — was installed on the side of the heater stack (Figure 2). This device has the capability of forcing the flow of fluegases through a relatively narrow side stack. The acoustic waves are known to encounter high losses when they propagate through a passage with high mean velocity [*7*]. The inlet of the side stack needs to be located upstream of the main stack damper and downstream from the fluegases sampling tube.

Experiment. Pulsations due to acoustic coupling depend on several parameters, including fuel composition, firing rate, burner design, and so on. Pulsations show a strong dependence on ambient temperature. The burner

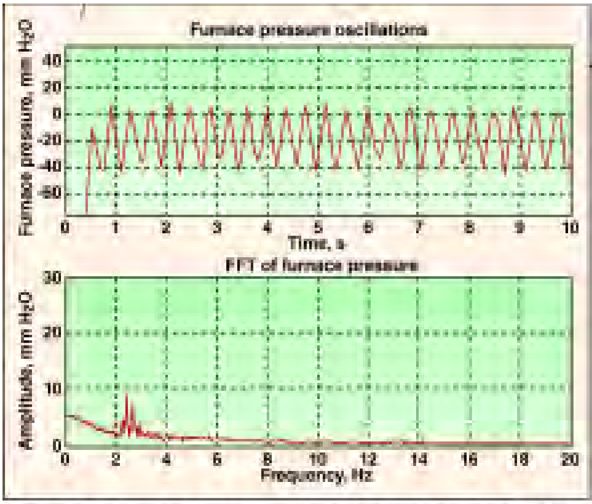

FIGURE 7. Furnace pressure under stabilized condition at 83% of burner capacity on a relatively hot day and 6% excess O_2

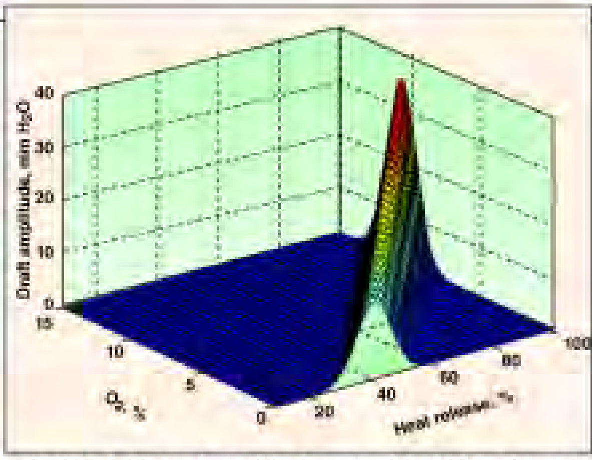

FIGURE 8. The surface of the burner pulsing driving force at an ambient temperature of 70°F is shown

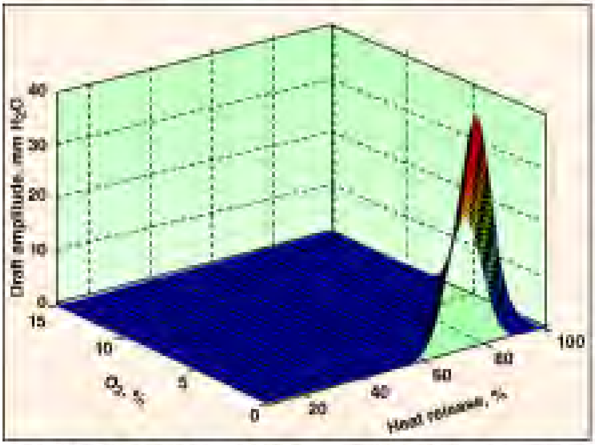

FIGURE 9. The surface of the burner-pulsing drive force at an ambient temperature of 40°F is shown here

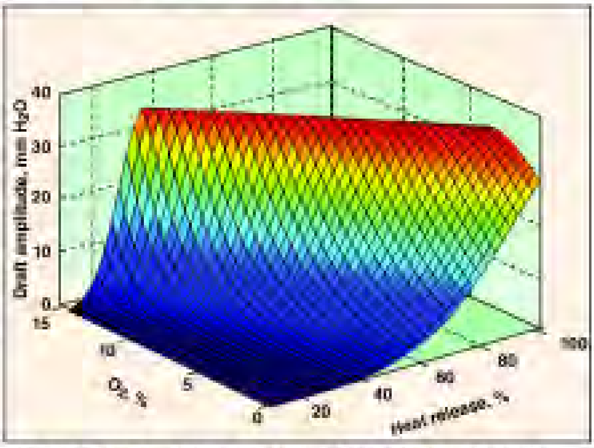

FIGURE 10. The damping ability of the side stack is not a function of the ambient temperature

was tested under several loading and atmospheric conditions. Samples for the pressure oscillations when acoustic coupling occurred are shown in Figures 3 and 4. It was found that at maximum heat release, the amplitude can reach a value of 25 mm H_2O on a relatively cold day, and about 50 mm H_2O on a relatively hot day.

To test the effectiveness of the side stack, a portion of the fluegas was shifted to the side stack with a partially closed main stack. Under these conditions, high amplitude oscillations essentially disappeared, and the burner was stable even at reduced O_2 levels. Figures 5 and 6 show some samples for the furnace pressure when the side stack and the inducing device were in operation. On some hot days, the side stack was not able to stabilize the pressure oscillation at low O_2 levels (Figure 7). From these tests, it seems that the damping ability of the side stack and the pulsing power of the burner are varying with operating conditions as well as ambient temperature.

A plethora of data was collected during the test, both under nonpulsing and pulsing furnace conditions. The data for the unassisted heater were used to build a mathematical model for the furnace status (pulsing or nonpulsing) as a function of operating conditions. Examining these data, one

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finds that the pulse amplitude (heater draft amplitude) depends on heat release rate, excess O_2 and ambient temperature. A mathematical model with unknown constants was built and a least square method (LSM) was used to fit the unknown constants. Figures 8 and 9 show the pulse amplitude of the driving force of the burner as a function of the heat release and excess O_2 at different ambient temperatures. One can see that the pulse peak shifts to lower excess O_2 as the ambient temperature decreases. This shows clearly why it was difficult to find a pulsing state on a cold day.

A curve characterizing the damping ability of the side stack must be similar to those in Figures 8 and 9. The damping ability of the side stack can only be determined as it mitigates oscillations at a certain amplitude. Whether higher amplitude oscillations can be mitigated by the additional damping of the side stack, can only be determined by its effectiveness in the presence of oscillations of higher magnitude. Maximum amplitudes obtained in the experiments were on the order of 40 mm H_2O. In cases when a pulsing condition with certain amplitude could be dampened with the side stack, one can conclude that the side stack has a damping ability of that amplitude or larger.

A mathematical model for the damping ability of the side stack was built using LSM to fit the pulse peak points of the experiment. Figure 10 shows the surface or envelope of the damping ability of the side stack as a function of heat release rate and excess O_2. It is worth noting that the damping ability, unlike the driving force, is not a function of the ambient temperature.

Conclusions. Based on the experimental and analytical work, we conclude that:

1. Acoustic coupling in process burners is strongly dependent on ambient conditions.
2. Enhancing natural damping of the heater is a practical and attractive solution for acoustic coupling.
3. Enhancing the natural damping does not require any knowledge of burner dynamics. ■

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Optimize Shift Scheduling Using Pinch Analysis

This technique, already proven in countless heat-integration and waste-minimization operations, can also be applied to human resources management

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Pinch analysis emerged as a systematic design tool during the energy crisis of the late 1970s, particularly for the optimization of heat-exchanger networks and other heat-recovery systems [*1*]. Since then, ongoing breakthroughs in the use of pinch analysis have helped to establish mass- and property-integration techniques to assist with waste-minimization efforts [*2, 3*]. More recently, pinch analysis has been applied to other types of resource-conservation applications [*4–14*], as well.

Besides the three traditional areas of heat, mass and property integration, pinch technology is also being used in a variety of non-conventional areas, to assist with and improve financial management [*15*], supply-chain management [*16–18*], so-called "emergy analysis"* [*19*], carbon-constrained energy-sector planning [*20–21*] and short-term scheduling of batch processes [*22*]. In all cases, the common underlying principle is that pinch analysis uses information about stream quantities in conjunction with data about the quality of those individual streams to optimize the overall process. Depending on the application, stream quality may be defined by such key process variables as temperature, concentration, "emergy," time of occurrence, material properties and so on.

In a new extension discussed here, a recently developed pinch analysis technique for short-term, batch-process scheduling [*22*] has been applied to the short-term scheduling of workers, in order to address a common challenge that impacts optimum human-resources management. The problem arises when a company or facility is trying to maximize the use of company employees by minimizing both idle time and periods of excess workload. The latter may require measures such as overtime, hiring temporary personnel or outsourcing the work — any of which will incur extra costs. Since this situation is analagous with other well-established resource-conservation problems where pinch analysis can play a vital role, using the same principles, pinch analysis techniques can thus be used to improve human-resources allocation.

In the examples discussed here, the common graphical composite curves used in pinch analysis are particularly helpful to identify allocation bottlenecks and provide insights on possible scheduling adjustments or task reassignments that would allow deadlines to be met in the most time- and cost-efficient manner. One of the main benefits of the pinch approach is its intuitive, visual appeal, which allows users to arrive at a clearer understanding of the problem at hand — insight that often is not possible using other optimization approaches. Two different cases are analyzed here: Planning for a single worker, and scheduling an entire team.

Planning for a single worker

Suppose we have a project that consists of four tasks to be completed by an engineer in a consulting company within a span of three weeks with these assumptions:

- Tasks 1, 2, 3 and 4 must be completed by June 9th, 14th, 18th and 25th, respectively
- Tasks 1 and 2 will take four days each to complete
- Tasks 3 and 4 will need six and three days, respectively
- The engineer cannot start working on the project until June 7th

Our task is to identify if the engineer will be able to deliver the given tasks on time, and if not, to determine how the work bottleneck can be addressed.

Figure 1 shows a new variant of the recently developed time-composite curves (comprising both source-composite curves, shown in red, and sink-composite curves, shown in blue) for short-term scheduling [22], which will now be used for human-resource planning. In these composite curves, task duration is shown on the horizontal axis, and actual calendar days are plotted on the vertical axis.

As shown, the worker is treated as a "source" of man-hours in the pinch diagram, as he/she possesses the capacity to do work. Hence, the available working days of the engineer are plotted as the source-composite curve on the right, starting from the beginning (June 7th) until the end of the project, which is the deadline of the last task (June 25th). Because each day is counted as a working day, the source-composite curve takes the shape of a staircase. Note that weekends are also plotted, but because no work is done during these days, they appear as vertical discontinuities in the curve.

The horizontal distance of the source-composite curve represents the time availability for the engineer (the number of days), from the beginning until the end of the project. In this case, the time availability is counted as 15 days (June 7th to June 25th, minus the two non-working weekends).

On the other hand, individual tasks required to complete a given project

* "Emergy" is the term used for solar energy embodied in a product, which has been accumulated as a result of energy and material inputs into the process chain or lifecycle.

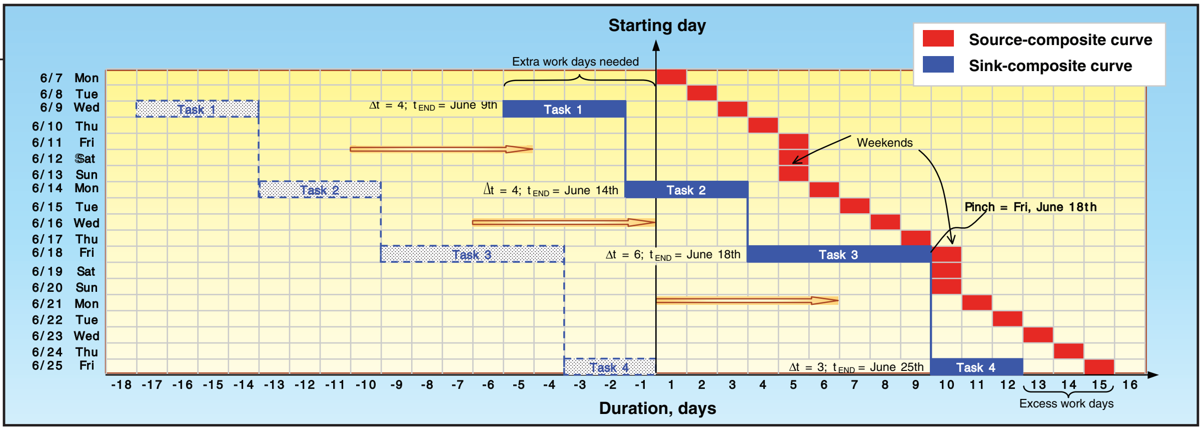

FIGURE 1. Time-composite curves for Case 1 (planning for a single worker), shows "demands" or tasks in blue and "sources" or available workdays in red. The horizontal axis denotes duration in days, while the vertical axis indicates the calendar date. Shifting the sink- and source-composite curves until they touch determines the minimum outsourced manpower required before the time pinch, and indicates excess manpower after the time pinch

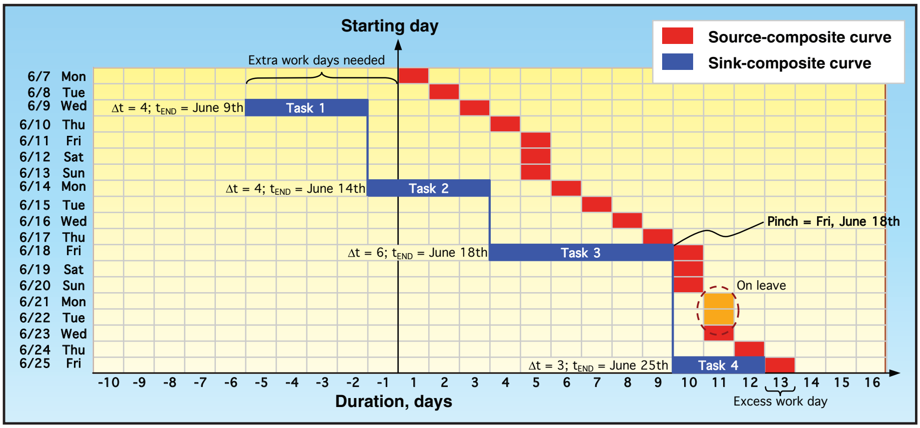

FIGURE 2. The time-composite curves can be used to plan for scheduling personal leave for individual workers at the most advantageous time. In this case, scheduling the leave after the pinch point allows the project to proceed on schedule

are treated as man-hour "sinks" or "demands," as they require work inputs for their completion. Hence, each task of the project is plotted as a sink-composite curve, with specific deadlines adjacent to each other and the horizontal span representing the duration needed to complete each task. Initially, the sink-composite curve is plotted to the left of the start date, during the targeting stage of the project.

In the example discussed here (scheduling the single worker), Task 1 is plotted on the deadline on June 9th, with a horizontal span of four days. Task 2 is next plotted adjacent to Task 1 on June 14th, and so on. Hence, the total length of the sink-composite curve indicates the total duration required to complete the entire project — in this case, 17 working days are required to complete all four tasks.

The time-composite curves are conceptually similar to the water source and demand composite plots of Dhole et al. [*5*]. One interesting point to be noted here is that tasks are plotted on the sink-composite curve as flat horizontal lines culminating at the project deadline, while the source-composite curve takes a step for each day. The reason for having the flat lines in the sink-composite curve is that, only the end deadlines are of concern during the targeting stage, and no assumption is made as to which particular days the tasks will be worked on.

Note also that our problem only specifies the deadline and duration of each task, and that in general it may be possible for some slack to be present in the sink-composite curve. In other words, it is possible that there are days for which no tasks are scheduled. These slack days represent opportunities for rescheduling and task integration, as will be discussed later.

To determine if the individual engineer will be able to complete the assigned tasks, the sink-composite curve is moved horizontally to the right until it touches the source-composite curve (Figure 1). With the pinch approach, only horizontal shifting is permitted for both curves, as the curves represent time duration for either time sources or sinks. Vertical shifting is not permitted for this case, as the vertical axis represents the deadline for the completion of the specific task, unless the deadline may be moved (discussed later).

The pinch day is hence identified as the overall time bottleneck that will impact the completion of the tasks at hand. As shown in Figure 1, the two composite curves touch at the pinch point on the day of June 18th. The overshoot of the sink-composite curve, shown at the beginning of the project start date, indicates the extra work days that are needed to complete the given tasks. In this scenario, the engineer will have to start working on the project 5 days earlier than the planned start day (June 7th). If this is not possible (for instance, due to other work commitments), then outsourced manpower will be needed to fulfill the given tasks.

On the other hand, Figure 1 shows that three excess workdays are found at the end of the project. At this end, it is interesting to note that the extra and excess work days in this problem correspond to the minimum hot and cold utilities in a heat-integration application [*1*], or the fresh resource and waste discharge streams in a resource-conservation network [*4–14*].

There may be some confusion be-

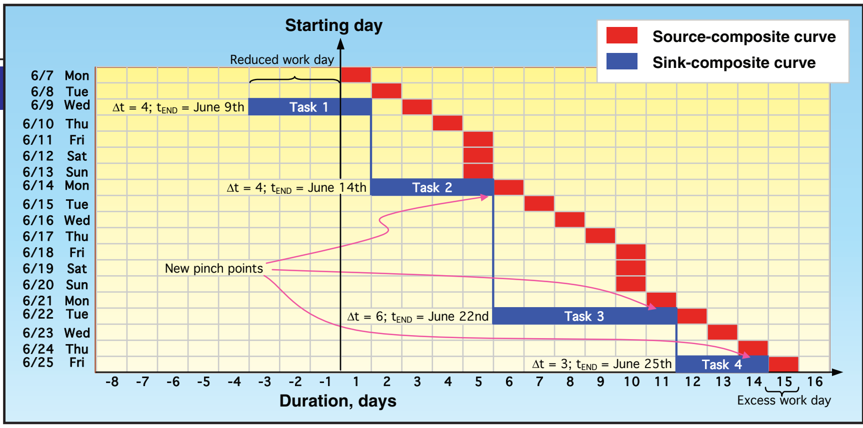

FIGURE 3. The time-composite curves can also be used to visualize the impact of changes in production schedule. Here the deadline of Task 3 is postponed to June 22nd. This results in simultaneous reduction of extra and excess work days

TABLE 1. TASK DATA FOR CASE 2

Engineer 1			Engineer 2		
Task	t_{END}	Δt, days	Task	t_{END}	Δt, days
1	May 5th, 2010	4	5	May 7th, 2010	5
2	May 10th, 2010	4	6	May 13th, 2010	5
3	May 17th, 2010	3	7	May 20th, 2010	7
4	May 24th, 2010	3	8	May 26th, 2010	3

tween the time-composite curves and Gantt charts (the most commonly used graphical aids to assist with scheduling). However, the time-composite curves possess two extra features: First, the composite curves separate dates and activity durations into two perpendicular axes. This provides better visualization and allows for easy adjustment. (By comparison, these two aspects are plotted along the same axis in a Gantt chart.)

Second, the pinch diagram plots the resources and activities separately, so that they can be manipulated independently. Two scenarios are further analyzed to illustrate the usage of the time-composite curves.

When should a leave of absence be taken? Scenario 1 presents the case where the engineer is planning to take a leave of absence. Since there are three excess work days in the region below the pinch, the engineer may take a maximum of three days off once the pinch day of the project (in this case, June 18th) has passed. On the other hand, no leave can be taken before the pinch day, that is, in the region above the pinch, since this region has a deficit of manpower.

Figure 2 shows such a case, where the engineer takes two days off on June 21st and 22nd, resulting in the leftward shift of the source-composite curve (the portion after the pinch), and a reduction in excess work days from three to one (see the x-axis).

What if we can postpone a particular task deadline? Scenario 2 presents another case where Task 3 has a flexible deadline that can be rescheduled to the following week (June 22nd). As shown in Figure 3, the sink-composite curve is shifted further to the right, resulting in three new pinch days. The advantage of this shift is the simultaneous reduction of extra and excess work days, to three and one days, respectively.

Outsourced manpower needs?

From Figure 1, it can be seen that five days of outsourced manpower is needed to fulfill the given tasks if the engineer does not start the project at a much earlier time. However, the outsourced manpower is not necessary at the beginning of the project, so its deployment may be delayed until it is actually needed.

However, the exact day when the outsourced manpower is needed cannot be seen directly in the time-composite curves. This calls for the use of the time-grand-composite curve, which was used extensively for appropriate utility selection in heat integration [*1*]. The construction of the time-grand-composite curve is shown in Figure 4, where the horizontal distance between the source and sink-composite curves is plotted on the exact day throughout the whole project on the time-grand-composite curve.

Each shaded area in the time-grand-composite curve represents a time pocket (see the right-most image in figure 4), where the required time slot is supplied by the available time of the engineer. The open area above the pinch day (June 18th) represents the total outsourced manpower needed to fulfill the given tasks; the area below the pinch day represents the available excess work days. Even though Figure 1 shows that 5 days of outsourced manpower is needed to fulfill the given tasks, Figure 4 shows that not all outsourced manpower is needed at the same time. Specifically, it is only needed on June 8th, 9th, 14th, 17th and 18th. Armed with this insight, project managers gain flexibility in deploying outsourced manpower.

Scheduling team activities

Scenarios presented in the previous section focus on the planning of single worker in completing multiple tasks. Frequently, a team is necessary for completing multiple tasks in bigger projects. This scenario will now be analyzed. Table 1 shows the data for Case 2, where two engineers are working as a team in a project that consists of eight tasks (four tasks per engineer). The main objective is to maximize the available time for both engineers before any outsourced manpower is sought, assuming both start the work on May 3rd.

Their time-composite curves can be plotted in the same manner as previously described. Doing so reveals that Engineer 1 actually experiences an earlier pinch day (May 10th) as compared to Engineer 2 (May 20th), as shown in Figure 5. In other words, Engineer 1 has excess work days much earlier than Engineer 2. Hence it is possible to utilize the excess work days of Engineer 1 to assist Engineer 2 (assuming that both engineers share the same skills).

This is similar to integrating resource surpluses below the pinch

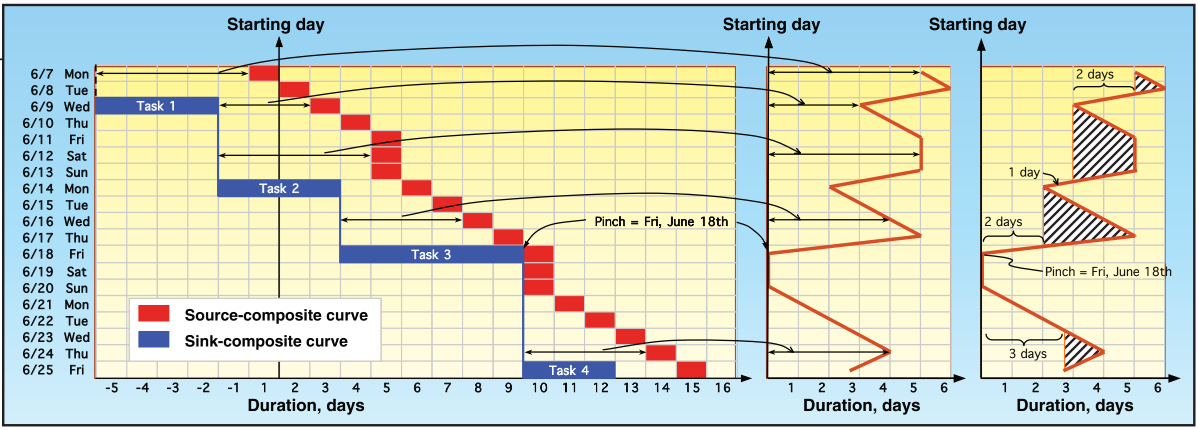

FIGURE 4. The time-grand-composite curve is plotted to graphically illustrate the horizontal gaps between source- and sink-composite curves

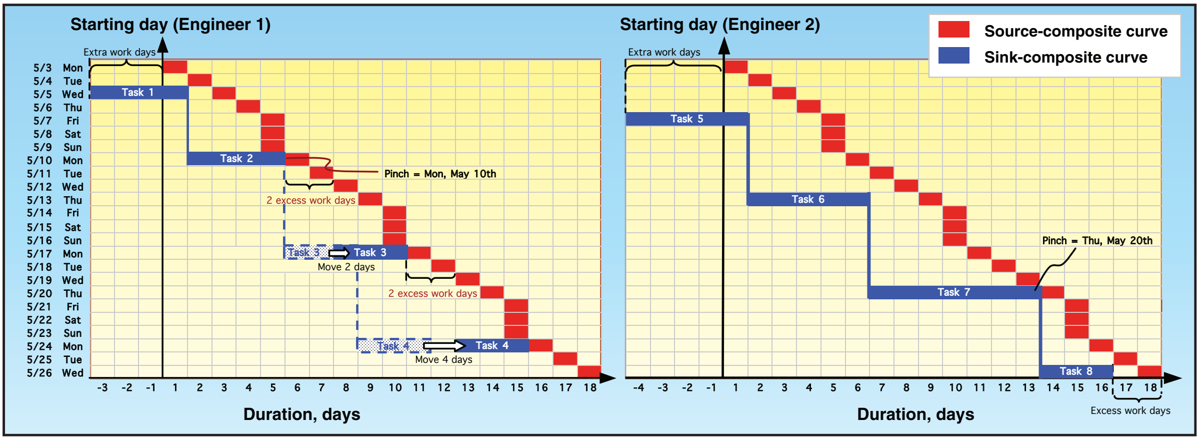

FIGURE 5. When plotting the composite curves for two individual engineers separately, but side by side, it becomes readily apparent that Engineer 1 has an earlier pinch day, so he may be available to assist Engineer 2 after this date

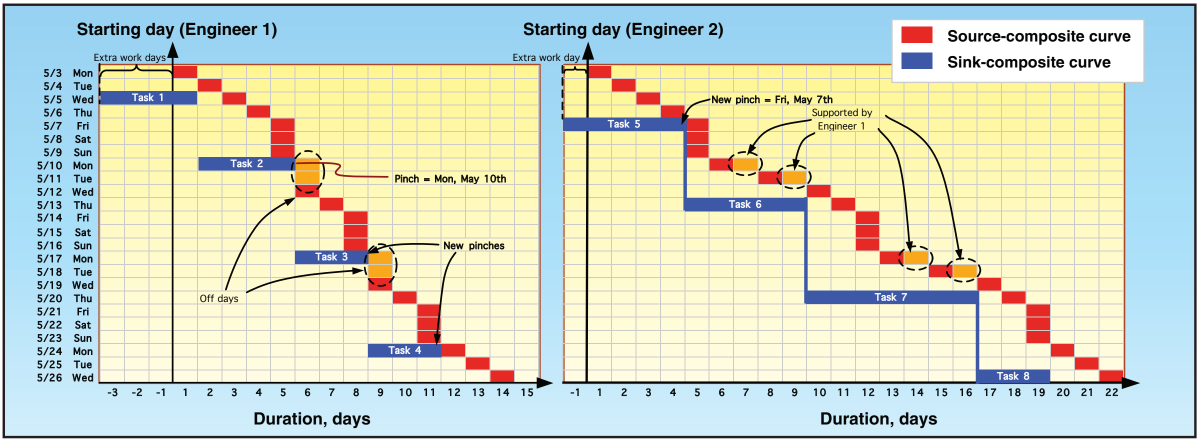

FIGURE 6. Task integration between 2 engineers can be accomplished by removing excess workdays from the source-composite curve of Engineer 1 and transferring them to the source-composite curve of Engineer 2. Note how this generates a new (and earlier) pinch point for Engineer 2

point (such as waste heat, wastewater and so on), the region above the pinch is experiencing a resource deficit. We then disconnect the sink-composite curve of Engineer 1, and shift the available tasks below the pinch as far to the right as possible. As a result, Engineer 1 has two excess work days upon the completion of Tasks 2 (May 10th, 11th) and 3 (May 17th and 18th), respectively. These excess work days may be utilized to assist Engineer 2 in completing Tasks 6 and 7.

One could logically expect that the availability of four excess work days of Engineer 1 will completely remove the four extra work days needed by Engineer 2. However, this is not the case. As shown in Figure 6, a new pinch day forms for Engineer 2 on May 7th, which creates a new bottleneck for this case. Thus, this pinch analysis reveals that Engineer 1 will only need to contribute three of the excess workdays to Engineer 2. For this case, any three of the four excess days that Engineer 1 can contribute will help Engineer 2 meet his/her workload requirements with just one extra work day leftover.

This procedure is also possible using the time-grand-composite curves. Task integration between the two engineers is possible as long as the relative timing of activities will allow for this. As shown in Figure 7, Engineer 1 has seven excess workdays after the pinch day of May 10th (Figure 6 was used to generate Figure 7, using the methodology described for Figure 4).

However, only four of these excess workdays are before the pinch day of Engineer 2 (May 20th) — that is May 10th, 11th, 17th and 18th. On the other hand, Engineer 2 requires four outsourced workdays before the pinch day of May 20th. However, help provided by Engineer 1 can only cover those tasks after May 10th (the pinch day of Engineer 1). This means that the task on May 7t cannot be covered by Engineer 1. In other words, Engineer 1 will still have four excess workdays after helping Engineer 2 (including those in May 24th – 26th).

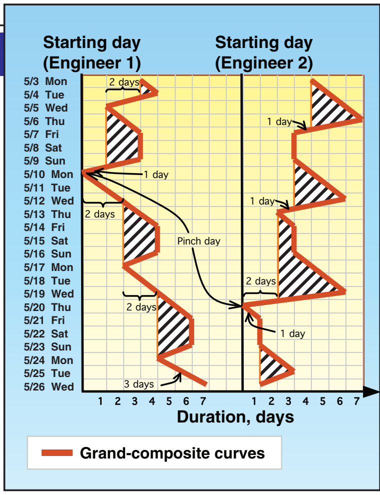

FIGURE 7. To gain additional insight, the time-grand-composite curves can also be used to visualize task integration between the two engineers

Final thoughts

The graphical pinch analysis approach to human resource management presented here is similar to many previous pinch analysis applications, and was demonstrated for cases that involve the planning of the tasks of a single worker, as well as personnel working in a team. The graphical technique provides the same intuitive appeal and insights common to pinch analysis techniques for heat, mass and property integration, and its visual nature facilitates planning and allows for easy communication of results to human-resource planning personnel. In addition, this method is easy to use, and can be implemented using ordinary spreadsheet software such as Excel or Lotus 123. ■

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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

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BUSINESS NEWS

PLANT WATCH

U.A.E. to become home of world's largest CSP plant

June 10, 2010 — Masdar (Abu Dhabi; www.masdar.ae) has appointed the bidding consortium of Total (Paris, France; www.total.com) and Abengoa Solar (Seville, Spain; www.abengoasolar.com) to own, build and operate Shams 1, said to be the world's largest concentrated solar power (CSP) plant, and the first of its kind in the Middle East. The joint venture between Masdar (60%), Total (20%) and Abengoa Solar (20%) will develop, build, operate and maintain the plant, which will be located in Madinat Zayed in the United Arab Emirates (U.A.E.). Construction is slated to begin during 3rdQ 2010 and is expected to take about two years.

KBR is awarded a contract for the Araromi Refinery Project in Nigeria

June 2, 2010 — KBR Inc. (Houston; www.kbr.com) has been awarded a contract by FPR Inc. (Houston) to provide design and early engineering services for the development of the Araromi Refinery Project in Nigeria. The low-complexity 160,000-bbl/d greenfield refinery will produce motor gasoline, automotive gas oil, kerosene and jet fuel. The project will be developed in phases, with an ultimate capacity of 320,000 bbl/d with a full petrochemical complex.

Aker Solutions named in contract for first Russian chlorine-dioxide plant

June 1, 2010 — Aker Solutions (www.akersolutions.com) has signed a contract with Ilim Group to supply an integrated chlorine-dioxide plant for Ilim's pulp mill project in Bratsk, Russia. The 15-metric ton (m.t.) per day integrated chlorine-dioxide plant is scheduled for commissioning in 2012, and will complement Ilim's $700 million project to build a new, modern 720,000 m.t./yr pulp line at Ilim Group's existing Bratsk Mill. The plant will utilize Aker Solutions' proprietary integrated chlorine-dioxide process technology.

Dow Corning invests in innovation and solar energy

June 1, 2010 — The Dow Corning Corp. (Midland, Mich.; www.dowcorning.com) has announced that it will invest up to $13 million to expand its European capabilities to innovate with silicon-based materials and technologies. The investment in a Solar Energy Exploration / Development Center (SEED) includes two new buildings that will complement the company's Business & Technology Center in Seneffe, Belgium. Construction is expected to begin later in 2010.

Cellulosic biofuel to be demonstrated in China

May 31, 2010 — Novozymes A/S (Bagsvaerd, Denmark: www.novozymes.com), Cofco Ltd. (www.cofco.com/en) and Sinopec Corp. (both Beijing, China; english.sinopec.com) have signed a memorandum of understanding covering the next steps toward commercialization of cellulosic biofuel in China. As part of the agreement, Cofco and Sinopec will build a cellulosic ethanol demonstration plant for which Novozymes will supply enzymes. The new plant comes online in the 3rd Q of 2011 and will produce 3-million gal/yr of bioethanol made from corn stover.

Borouge signs an agreement to build second compounding plant in China

May 28, 2010 — Borouge, a joint venture between the Abu Dhabi National Oil Company (ADNOC; Abu Dhabi; www.adnoc.com) and Borealis (Vienna, Austria; www.borealisgroup.com) has announced its intention to build a manufacturing plant to produce up to 105,000 m.t./yr of compounded polypropylene resins. Construction is expected to be completed by mid-2012.

Instant-coffee plant to be delivered by GEA Niro in Laos

May 26, 2010 — GEA Niro (Soeborg, Denmark; www.niro.com) has recently won a contract with Dao Heuang Group in Laos for the delivery of a complete instant-coffee processing line. When in full production the processing line will produce 3,000 ton/yr of instant coffee and is scheduled to start operation in November 2011. The plant will be constructed in Pakse and will be one of the country's largest food-processing plants.

MERGERS AND ACQUISITIONS

Wacker acquires silicon production site in Norway

June 7, 2010 — Wacker Chemie AG (Munich, Germany; www.wacker.com) is acquiring the Norwegian Fesil Group's silicon-metal production site in Holla and will take over all of Fesil's production facilities in Holla. The transaction requires approval of Wacker's supervisory board and Fesil's board of directors as well as clearance by the antitrust authorities. Closing of the transaction is expected before the end of the 3rd Q 2010.

Evonik acquires Ravindra Heraeus catalyst business

June 7, 2010 — Evonik Industries AG (Essen, Germany; www.evonik.com) has acquired the precious-metal-powder catalysts business of Ravindra Heraeus Pvt. Ltd. (Udaipur, Rajasthan, India). All know-how, technology, and business relationships with catalyst customers will pass from Ravindra Heraeus to Evonik, while the production equipment will remain with Ravindra Heraeus. Both partners have also concluded longterm agreements concerning contract manufacturing and precious metal recycling. Ravindra Heraeus is a joint venture between the precious metal and technology company Heraeus (Hanau, Germany) and the family enterprise Ravindra Choksi (India). Each partner holds a 50% stake in the joint venture.

GE and Ramky enter into agreements for industrial water treatment

June 7, 2010 — GE (Fairfield, Conn.; www.ge.com) and Ramky Enviro Engineers, an environment and waste management organization, have signed emergency water and industrial-wastewater treatment agreements designed to address India's industrial-wastewater treatment and recycling needs. Under the agreement, GE's ultra filtration (UF) and membrane bioreactor (MBR) technologies will be utilized by Ramky for wastewater treatment and recycling in India's industrial sector.

Total acquires interest in a developer of polysilicon production technology

June 7, 2010 — Total (Paris, France; www.total.com) has announced that its subsidiary, Total Gas & Power USA has acquired a 25.4% interest in the U.S.-startup company, AE Polysilicon Corp. (AEP), which has developed an advanced technology to produce polysilicon for photovoltaic panels (for more on polysilicon production, see *CE,* April 2010, pp. 21–26). The acquisition is being made through a reserved capital increase.

UPL to acquire fungicide from DuPont Crop Protection Business

June 2, 2010 — DuPont (Wilmington, Del.; www.dupont.com) has announced that it has divested its global non-mixture mancozeb fungicide business assets to United Phosphorus, Ltd. (UPL), including manufacturing and formulation production facilities in Barranquilla, Colombia. Financial terms of the agreement were not disclosed. ■

Dorothy Lozowski

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

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Economic Indicators

2010 2009 2008

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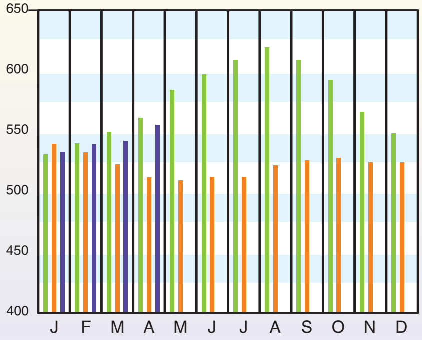
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Apr.'10 Prelim.	Mar.'10 Final	Apr.'09 Final
***CE* Index**	555.2	541.8	511.7
Equipment	666.0	645.5	600.4
Heat exchangers & tanks	622.6	592.5	534.2
Process machinery	625.4	614.0	584.9
Pipe, valves & fittings	829.5	801.7	752.5
Process instruments	426.7	421.0	390.1
Pumps & compressors	902.4	903.4	897.5
Electrical equipment	472.5	472.1	460.2
Structural supports & misc	688.7	665.6	609.0
Construction labor	326.8	328.2	326.5
Buildings	508.7	504.3	487.9
Engineering & supervision	341.4	341.8	348.5

Annual Index:
2002 = 395.6
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9

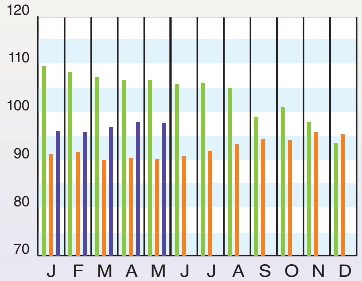
Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics



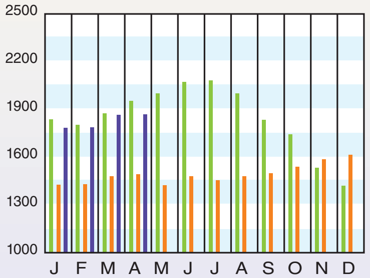
CURRENT BUSINESS INDICATORS

	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2000 = 100)	May.'10	=	97.7	Apr.'10	=	97.9	Mar.'10	=	96.8	May.'09	=	90.1
CPI value of output, $ billions	Apr.'10	=	1,870.4	Mar.'10	=	1,866.7	Feb.'10	=	1,789.6	Apr.'09	=	1,492.4
CPI operating rate, %	May.'10	=	73.0	Apr.'10	=	72.9	Mar.'10	=	72.1	May.'09	=	65.8
Producer prices, industrial chemicals (1982 = 100)	May.'10	=	272.8	Apr.'10	=	274.0	Mar.'10	=	273.3	May.'09	=	223.4
Industrial Production in Manufacturing (2002=100)*	May.'10	=	102.3	Apr.'10	=	101.4	Mar.'10	=	100.5	May.'09	=	94.8
Hourly earnings index, chemical & allied products (1992 = 100)	May.'10	=	153.9	Apr.'10	=	151.4	Mar.'10	=	150.0	May.'09	=	147.4
Productivity index, chemicals & allied products (1992 = 100)	May.'10	=	136.0	Apr.'10	=	137.9	Mar.'10	=	137.3	May.'09	=	133.4

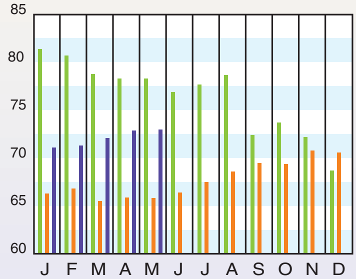
CPI OUTPUT INDEX (2000 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



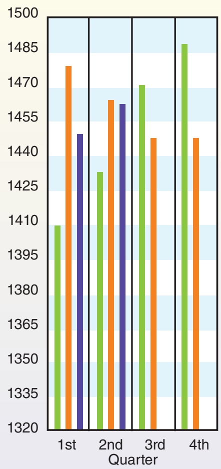
CPI OPERATING RATE (%)



MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	2nd Q 2010	1st Q 2010	4th Q 2009	3rd Q 2009	2nd Q 2009
M & S INDEX	1,461.3	1,448.3	1,446.5	1,446.4	1,462.9
Process industries, average	1,522.1	1,510.3	1,511.9	1,515.1	1,534.2
Cement	1,519.2	1,508.1	1,508.2	1,509.7	1,532.5
Chemicals	1,493.5	1,481.8	1,483.1	1,485.8	1,504.8
Clay products	1,505.6	1,496.0	1,494.3	1,495.8	1,512.9
Glass	1,416.4	1,403.0	1,400.1	1,400.4	1,420.1
Paint	1,527.6	1,515.1	1,514.1	1,515.1	1,535.9
Paper	1,430.1	1,416.4	1,415.8	1,416.3	1,435.6
Petroleum products	1,625.9	1,615.6	1,617.6	1,625.2	1,643.5
Rubber	1,564.2	1,551.0	1,560.5	1,560.7	1,581.1
Related industries					
Electrical power	1,414.0	1,389.6	1,377.3	1,370.8	1,394.7
Mining, milling	1,569.1	1,552.1	1,548.1	1,547.6	1,562.9
Refrigeration	1,786.9	1,772.2	1,769.5	1,767.3	1,789.0
Steam power	1,488.0	1,475.0	1,470.8	1,471.4	1,490.8

Annual Index:
2002 = 1,104.2 2004 = 1,178.5 2006 = 1,302.3 2008 = 1,449.3
2003 = 1,123.6 2005 = 1,244.5 2007 = 1,373.3 2009 = 1,468.6



CURRENT TRENDS

Capital equipment prices (as reflected in the April *CE* Plant Cost Index) continue to climb according to a typical mid-year trend, but the deficit between 2010 and 2008 prices has widened a bit.

Overall production in the chemical process industries fell by 0.9% in May, following a 0.4% gain in April, the American Chemistry Council (ACC; Arlington, Va.; www.americanchemistry.com) says. Among the five major segments of U.S. Federal Reserve Board data that ACC analyzes, production rose for agricultural chemicals and specialty chemicals, but was weak in consumer products, pharmaceuticals and basic chemicals.

Visit www.che.com/pci for more on capital cost trends. ■

Circle 23 on p. 58 or go to adlinks.che.com/29252-23