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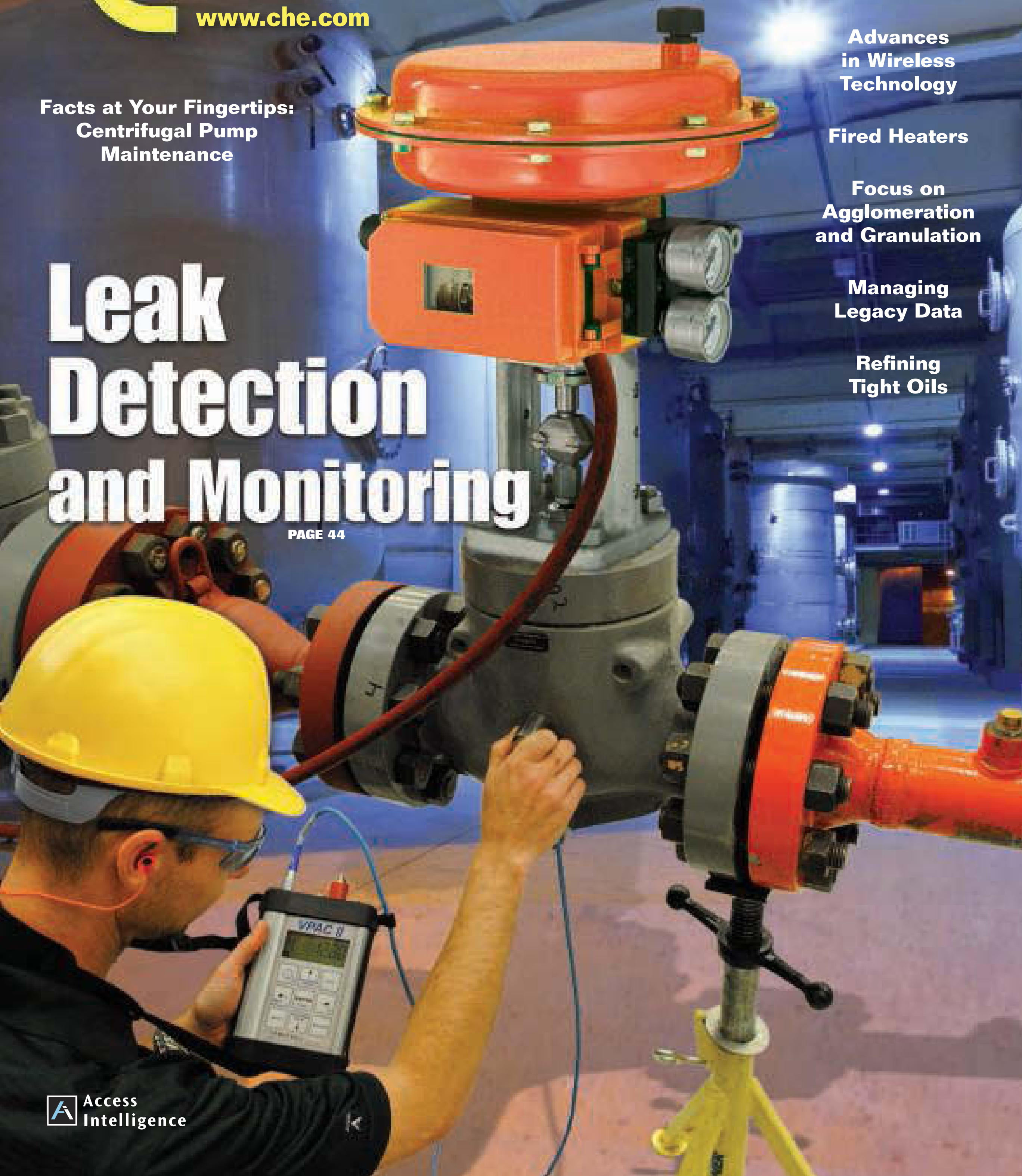

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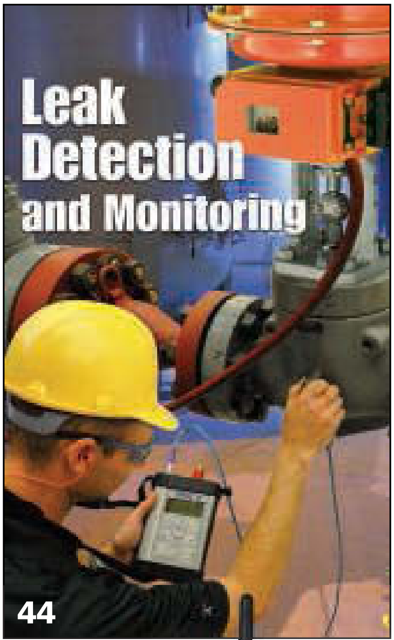

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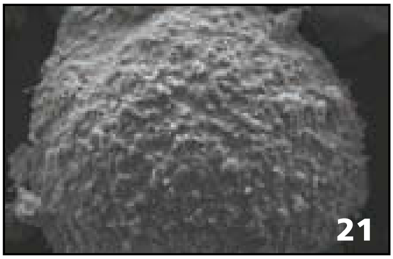
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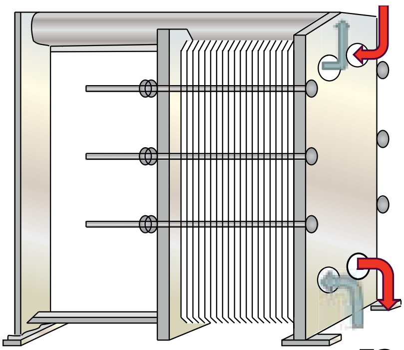
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BPA

Developing practical technologies

I remember a cartoon a colleague once showed me when I was a process development engineer working on process scaleup in a pilot plant. It showed a huge production-sized Erlenmeyer flask in a plant with several white-coated scientists standing around it scratching their heads. The caption read something like "Why we need chemical engineers." I also remember friends and acquaintances, who were not familiar with the chemical process industries, asking me what process scaleup was. Sometimes I simply described it as converting grams into pounds, and as translating the language of the chemist into that of the production engineer. While converting metric units was literally part of the job, the translation analogy encompasses the much broader scope of scaleup that is needed to transform a proven laboratory-scale process into a workable, economical and safe production-scale process.

In his keynote address at the AIChE Spring Meeting (New Orleans, La.; March 31) titled "Possible vs. Practical: Engineers Must Lead the Development of Practical Technologies," William Banholzer, chief technology officer for The Dow Chemical Company (retired), addressed the role of chemical engineers in worldwide developments. He spoke about a number of inventions that scientists have brought to the world and pointed out that engineering skills and judgment are what is needed to make inventions useful and practical. Engineers shine in making things practical.

Banholzer outlined three rules for the business component of technology. They are to make sure that what you pursue is: 1) what people want; 2) what people will pay for; and 3) what people can afford. And safety, he said, is essential for any business. Many scientific innovations are not economically feasible. This is where the engineering skills that encompass both technology and business come in. The "compass" of chemical engineering, as Banholzer described it, is needed for sustainable success.

And the areas where those chemical engineering skills are needed are plentiful. In her presentation at the AIChE Spring Meeting, Sharon Robinson, waste management systems and technology manager, Nuclear Science & Technology Div. of the Oak Ridge National Laboratory (Oak Ridge, Tenn.; www.ornl.gov) highlighted opportunities in chemical engineering that are being created by the shale gas boom in the U.S. She reported research needs that were identified during a workshop held at the Process Science and Technology Center at the University of Texas at Austin in 2013. The areas identified include: 1) hydraulic fracturing technology, particularly in the fluids used and in the treatment and recovery of water; 2) improvements in distillation, particularly complex column arrangements, such as divided-wall columns; 3) energy efficiency, particularly in distillation and waste heat utilization; 4) natural-gas-to-products technologies, such as direct methane routes to products, and improvements to make use of "stranded" natural gas; and 5) carbon dioxide technologies, such as carbon capture and sequestration technologies.

In addition to these areas related directly to the shale gas boom, which has received much attention in recent years, there are a myriad of new innovations and technology areas continuously under development worldwide where that "compass" of chemical engineering judgment that Banholzer referred to is needed. ■

Dorothy Lozowski, Editor in Chief

Letters

Fred Aftalion receives the Franklin-Lavoisier Prize

The Chemical Heritage Foundation (CHF) and the Fondation de la Maison de la Chimie (FMC) presented the Franklin-Lavoisier Prize to author Fred Aftalion in a dinner ceremony on April 3, 2014, at CHF in Philadelphia, Pa.

A graduate of the École Nationale Supérieure de Chimie de Paris, Fred Aftalion devoted his life's work to chemistry. He studied under Herman Mark at Brooklyn Polytechnic's Polymer Institute in 1946. His first job in the chemical industry was as an engineer with Hercules, with which he spent five years in the U.S. and Latin America. Returning to France in 1951, he joined Naphtachimie, where he set up the marketing networks of what was then a new petrochemicals company.

Called in by Laboratoire Roger Bellon in 1956 to take over the management of the Société Française d'Organo-Synthèse (SFOS), he turned it over the course of the next three decades into an efficient specialty chemicals enterprise. Aftalion also served as president of Société la Vermiculite et la Perlite, now an affiliate of Elf Aquitaine, and he became a board member of Rhône Poulenc Specialités Chimiques when SFOS was acquired by that company. He is currently a member of the Board of Directors of Total Chimie and of the Maison de la Chimie.

As an author, Fred Aftalion has recorded and enhanced our understanding of our chemical heritage, and has helped make known to the broader public the important impact of the chemical sciences and technologies. His book, "A History of the International Chemical Industry," is a seminal work of history and a unique publication, chronicling the rise of the chemical industry around the globe and the important human benefits that it has brought. The only book of its kind, "A History of the International Chemical Industry" has also advanced the sense of community among the various participants in the chemical endeavor.

Created in 2008, the Franklin-Lavoisier Prize is jointly awarded by the Fondation de la Maison de la Chimie in Paris and the Chemical Heritage Foundation. Named for Antoine-Laurent Lavoisier and Benjamin Franklin, two of the 18th century's greatest minds, this prize recognizes unusually meritorious efforts in the preservation or promotion of the entwined scientific heritage of France and the U.S.

The Chemical Heritage Foundation
Philadelphia, Pa.; www.chemheritage.org

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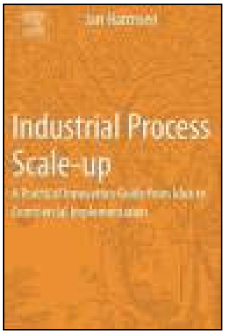


Industrial Process Scale-up: A Practical Innovation Guide from Idea to Commercial Implementation. By Jan Harmsen. Elsevier Inc., 225 Wyman St., Waltham, MA 02144. Web: elsevier.com. 2013. 112 pages. $64.95.

Reviewed by Jim Gregory, Senior Process Engineer, Fluor, Greenville, S.C.

Jan Harmsen has written a good book on process scaleup. The book guides the project engineer on how to approach and execute the scaleup opportunity. The emphasis is not on helping the process engineer who wants to, for example, calculate the optimum demonstration plant size for a particular application, and because of that, does not contain a great deal of engineering formulas.

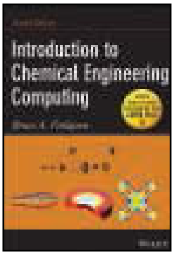
The book begins with the definition of terms and process industry characteristics. Chapters on ideation and research, development stage, demonstration stage, and commercial startup provide the reader with a broad view of the subject. The final chapters include numerous case studies that make the reader wish that more experts would take opportunities like this to share their knowledge.

At just over 100 pages, the book does not try to be a detailed treatment of the subject. Its brevity helps to make the book accessible to both people new to the topic and experienced engineers who want a refresher or a new perspective. The book would also be useful to managers who need to understand all the issues around scaleup for planning purposes.

One benefit that I got from this book is a greater appreciation of how important detailed consideration of materials of construction is for the mitigation of business risk. Since small, local differences in pH, dissolved oxygen, chloride concentration and others can have a significant impact on corrosion, materials used at small scale may not always be appropriate at larger scales. If an engineer does not size a pump correctly, then the plant may have to run at reduced speed until the problem can be fixed. But if unexpected corrosion takes place, the corrosion could ruin a piece of equipment that shuts the plant down for months.

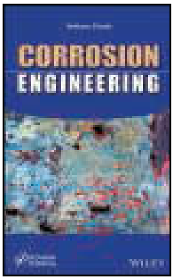
The book is marred slightly by some sentence repetition and occasional questionable grammar, but anyone interested in the subject would benefit from reading this book. Thanks should go to Harmsen for sharing the benefit of his experience.

Editor's note: If you are interested in reviewing a book for *Chemical Engineering*, contact senior editor Scott Jenkins (bookshelf@che.com).

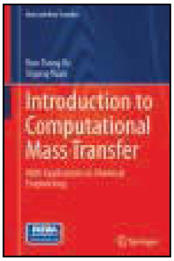


Introduction to Chemical Engineering Computing. 2nd ed. By Bruce Finlayson. John Wiley & Sons, 111 River Street, Hoboken, NJ 07030. Web: wiley.com. 2014. 402 pages. $59.95.

Separation of Molecules, Macromolecules and Particles: Principles, Phenomena and Processes. By Kamalesh K. Sirkar. Cambridge University Press, 32 Avenue of the Americas, New York, NY 10013. Web: cambridge.org. 2014. 909 pages. $120.00.

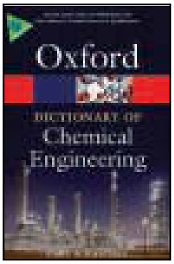


Corrosion Engineering. By Volkan Cicek. John Wiley & Sons, 111 River Street, Hoboken, NJ 07030. Web: wiley.com. 2014. 288 pages. $149.00.



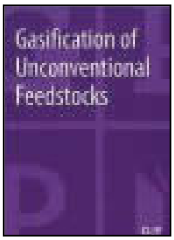
Introduction to Computational Mass Transfer with Applications to Chemical Engineering. By Kuo-Tsong Yu and Xigang Yuan. Springer, Publishing, 11 West 42nd Street, 15th Floor, New York, NY 10036. Web: springerpub.com. 2014. 340 pages. $179.00.

Project Recovery: Case Studies and Techniques to Avoid Project Failure. By Harold R. Kerzner. John Wiley & Sons, 111 River Street, Hoboken, NJ 07030. Web: wiley.com. 2014. 336 pages. $75.00.



A Dictionary of Chemical Engineering. By Carl Schaschke. Oxford University Press, 198 Madison Ave., New York, NY 10016. Web: oup.com. 2014. 448 pages. $21.95.

Chemical Reaction Engineering: Essentials, Exercises and Examples. By Martin Schmal. CRC Press, Taylor and Francis Group, 6000 Broken Sound Parkway NW, Boca Raton, FL 33487. Web: crcpress.com. 2014. 700 pages. $89.95.



Gasification of Unconventional Feedstocks. By James Speight. Gulf Professional Publishing (Elsevier) 225 Wyman St., Waltham, Mass. Web: elsevier.com. 2014. 162 pages. $49.95. ■

Scott Jenkins

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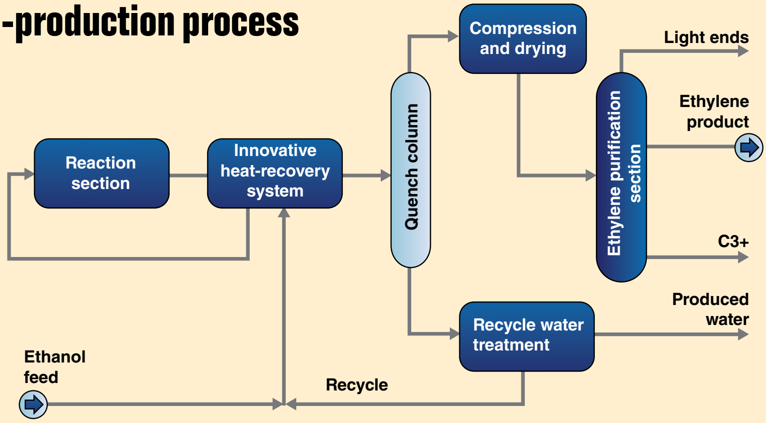
Edited by Gerald Ondrey

May 2014

The launch of a new bioethylene-production process



Last month, a new bioethanol-dehydration process was introduced by its developers Axens (www.axens.net), IFP Energies Nouvelles (IFPEN; both Rueil-Malmaison, France; www.ifpen.fr) and Total Refining & Chemicals (Brussels, Belgium; www.totalrefiningchemicals.com). Tradenamed Atol, the process is said to be the most profitable route for making polymer-grade bioethylene by dehydration of first- and second-generation renewable ethanol. The bioethylene produced can be integrated into existing downstream polymerization installations, such as polyethylene (PE), polystyrene (PS), polyethyleneteraphthalate (PET), polyvinylchloride (PVC) and acrylonitrile-butadiene-styrene (ABS) without need for modifications, says Axens.

Atol is the culmination of the three companies' partnership that started in 2011. Within this cooperation, Total developed a high-performance catalyst formulation at its research center in Feluy, Belgium, IFPEN improved catalyst performance within an innovative heat-recovery innovative process and Axens industrialized the catalyst formulation and finalized the process scheme with particular focus on energy efficiency. Total and IFPEN are the co-owners of the technology, and Axens is now in charge of commercializing Atol by providing all process licensing related services and catalyst manufacturing.

In Atol (flowsheet), ethanol is dehydrated in the vapor phase at a temperature of 400–500°C and moderate pressure. The use of a heat diluent enables operation of the exothermic reaction using only two fixed-bed, adiabatic reactors in series. The patented thermal integration allows a maximized heat recovery, and therefore mimimized utilities consumption, says Axens. The very high selectivity of the Atol ethanol-dehydration catalyst (ATO 201) leads to the recovery of polymer-grade bioethylene in a significantly simplified purification section. For instance, the caustic tower and ethane/ethylene splitter used in the conventional process are eliminated in the Atol process.

The catalyst has a high activity (space-time yield several times higher than published for conventional catalysts), and a high hydrothermal stability and tolerance to poisons, says the company. This allows the construction of high, single-train capacities (50,000–400,000 metric tons per year) in line with world-scale PE capacities, says Axens.

Biomass torrefaction plant undergoing expansion

A biomass torrefaction plant run by New Biomass Energy LLC (NBE; Quitman, Miss.; www.newbiomass.com) is currently undergoing an expansion that will increase its annual production capacity to 250,000 tons of torrefied wood product. The company expects the expansion to be completed by the end of 2014, says Alison Hunt, NBE's VP of development.

Torrefaction is the process of roasting wood or other biomass at high temperatures in an oxygen-deprived environment. The process removes moisture and volatile organic compounds (VOCs) from the material, Hunt explains, to create a product that is significantly more energy dense than raw wood or wood pellets. Torrefied wood is a carbon-neutral product and can be co-fired along with coal at high percentages, Hunt notes. It also generates less sulfur and ash than burning coal, she says.

NBE's proprietary roasting process can handle a variety of biomass feedstocks and can produce material in a wide range of energy densities, depending on the needs of the end user, Hunt says.

(*Continues on p. 12*)

Carbon nanofibers

Researchers at North Carolina State University (Raleigh, N.C.; www.ncsu.edu), in conjunction with the Oak Ridge National Laboratory (Oak Ridge, Tenn.; www.ornl.gov) have produced, via a plasma-enhanced vapor deposition process, vertically aligned carbon nanofibers using an acetone and ambient-air mixture. In conventional plasma-enhanced nanofabrication processes, H_2 or NH_3 is used to prevent carbon from settling on a catalytic surface, which can hinder the growth of the nanofibers. However, this research has demonstrated the feasibility of growing these nanofibers in ambient air, potentially decreasing the costs and risks associated with scaling up the process. Vertically aligned carbon nanofibers can be used in many applications, including scanning probe tips, electrochemical probes and gene-delivery arrays.

Bio-based acids

Last March, Johnson Matthey Davy Technologies Ltd. (JM Davy; London, U.K.; www.davyprotech.com) and Rennovia, Inc. (Menlo Park, Calif.; www.rennovia.com) began a collaboration to develop, dem-

(*Continues on p. 12*)

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

Renewable surfactant can replace solvents for cleaning

A nonionic surfactant that is derived from renewable chemicals can outperform common solvents in a range of applications, including industrial cleaning, adhesive removal, degreasing, paint and coating removal, and others. The molecule (N,N-dimethyl-9-decenamide), marketed as Steposol MET-10U, is the first result of a joint development agreement between Stepan Co. (Northfield, Ill.; www.stepan.com) and Elevance Renewable Sciences, Inc. (Woodridge, Ill.; www.elevance.com). The product was launched last month and is now available globally.

The starting material for the surfactant product is plant-based 9-decenoic ester, and is made using proprietary metathesis technology developed by Elevance. The renewable starting material is then modified on its hydrophilic end by Stepan to make the amide surfactant.

As a hard-surface cleaner, a 5% aqueous solution of Steposol MET-10U performs as well as full strength (100%) samples of high-VOC solvents, such as methylene chloride and N-methylpyrrolidone, and better than alternative "green" solvents like d-limonene, explains Robert Slone, vice president of surfactant product development at Stepan. For example, Steposol MET-10U's Kauri-Butanol value (a standardized measure of solvent power) is over 1,000, compared to 67 for limonene, notes Slone.

The joint development agreement between Elevance and Stepan began in 2010 and will continue, as the two companies plan to introduce additional products into other markets in the future, says Andy Corr, Elevance senior vice president for consumer and industrial ingredients.

New mass spec technique requires no sample preparation

A research group at Stevens Institute of Technology (Hoboken, N.J.; www.stevens.edu) has developed a new mass spectroscopy technique, called helium-plasma-ionization mass spectrometry (HePI-MS), that enables direct sampling of materials without the need for rigorous sample preparation, as is required for conventional mass-spectroscopy approaches.

"We can put any object into the outer chamber of the spectrometer and measure volatile species emanating from it" says Athula Attygalle, the leader of the Stevens team that invented the technique. Stevens has signed a license with an analytical instrument company to further develop and commercialize the technology.

To make the technique work, the Stevens team adapted a conventional electrospray ionization source to a helium plasma system in a way that creates a minute and stable plasma region to minimize consumption of helium. The HePI system generates both negatively and positively charged ions when exposed to vapors originating from organic or inorganic compounds.

Among the possible applications for the technique is the detection of explosives, especially less volatile inorganic compounds used in fertilizer-based explosive devices. Also, Attygalle says the technique could be used to detect counterfeit drugs, detect contaminants and as a quality control test.

Attygalle says the ultimate goal would be to miniaturize the device to allow portability for on-site uses.

BIOMASS TORREFACTION PLANT

(*Continued from p. 11*)

The higher energy density of torrefied wood pellets (similar to that of coal) allows significant logistical cost savings. Torrefied pellets are more economical to transport, are moisture-resistant and less likely to degrade than conventional wood pellets.

In addition to existing coal-fired power plants, torrefied wood pellets can also be used for heat generation in other industrial settings. Even before the current expansion, NBE's Mississippi plant is the largest wood torrefaction facility in North America, and the only one running commercial-scale reactors, adds Hunt. The plant will be operated by Solvay Biomass Energy, a recently created joint venture between New Biomass Energy and Solvay SA (Brussels, Belgium, www.solvay.com).

(*Continued from p. 11*)

onstrate and commercialize catalytic process technologies for the production of bio-based glucaric acid and adipic acid. Under the collaboration, Rennovia and JM Davy will work together to develop and demonstrate the processes based on Rennovia's technology for the catalytic aerobic oxidation of glucose to glucaric acid, as well as the catalytic hydrogenation of glucaric acid to adipic acid. The goal of the collaboration is to develop and jointly license a technology package enabling commercial production of these chemical products.

Both acids are currently derived from petroleum. Adipic acid is a multi-billion dollar global market, with major applications in nylon-6,6 fibers, engineering resins, polyester polyols for polyurethanes, and adipate ester plasticizers. Glucaric acid is an emerging platform chemical with wide applications in detergent, de-icing, cement and anti-corrosion markets.

Sustainable drugs

European scientists have elucidated the complete upstream segment of the terpenoid indole alkaloid biosynthesis pathway, paving the way for the biotechnological production of this important anticancer alkaloid used in chemotherapy. The milestone — published last month in *Nature Communications* — was achieved by the SmartCell project, a four-year FP7 framework project led by the Technical Research Center of Finland (VTT; Espoo; www.vtt.fi).

The terpenoid indole alkaloids, vinblastine and vincristine, are currently extracted — at high costs — from the Madagascar periwinkle plant (*Catharanthus roseus*). Typically, very low levels accumulate in plant tissues. The scientists reconstructed the complete pathway of twelve enzymes in tobacco plants, paving the way for cost-effective production of diverse therapeutic compounds. Moreover, cell culture technologies were developed, and the cultivation of the plant cells was scaled-up using bioreactors at VTT's pilot laboratory.

Covered lagoons treat wastewater and make biogas, too

The world's first installation of the so-called Cohral technology — deploying a covered lagoon for anaerobic wastewater treatment — was completed last March at Oakey Abattoir Pty Ltd. in the farming region of Darling Downs, in southern Queensland, Australia. The Cohral technology originates with Global Water Engineering Ltd. (Brugge, Belgium; www.globalwe.com), now operating from its office in Bangkok, Thailand. Global Water Engineering (GWE) is represented in Australia by CST Wastewater Solutions (Sydney; www.cstwastewater.com).

The lagoon uses concentrated anaerobic bacteria to digest 70% of the organic matter in wastewater. Covered anaerobic lagoons also providel the advantage of preventing the produced biogas (methane) from escaping into the atmosphere. The biogas is used to generate energy. Managing editor of CST Wastewater Solutions, Michael Bambridge, says open lagoon systems have been popular because they are simple, cheap and easy to operate. However, they have a poor ability to control algae and suspended solids and poor efficiency in removing pollutants. Covered lagoons are also useful where odor control is an important issue.

Cohral anaerobic lagoons consist of two zones, both of which are covered with an influent distribution system, which acts as a hydraulic mix-

(*Continues on p. 18*)

First in-situ refractive-index sensor for bioreactor monitoring

Process monitoring in biotechnology processes is critical to maximizing product yield and optimizing nutrient consumption. Startup company Stratophase Ltd. (Romsey, U.K.; www.stratophase.com) is now offering the first realtime, in-situ micro-optical sensor for monitoring and control of bioprocesses involving both microbes and mammalian cells.

Using specially configured optical structures that incorporate Bragg gratings, the sensor routes light around a semiconductor chip, and can directly measure the refractive index of the process media when immersed. The realtime measurement relates to the metabolic rate of the bioprocess, allowing continuous monitoring to observe the progress of the process or batch-to-batch variations.

"Refractive index can be used to measure a wide range of analytes

(*Continues on p. 16*)

Demonstration of a new CO_2-methanation process

The first phase of a study on the feasibility of producing methane from CO_2 has been completed by Hitachi Zosen Corp. (Tokyo; www.hitachizosen.co.jp) and Daiki Ataka Engineering Co. (Daiki Ataka) a subsidy of Hitachi Zosen, in collaboration with PTT Exploring and Production Public Co. (Thailand). The companies have been collaborating since 2012 to develop a methanation process to convert CO_2, which is generated during natural gas extraction, into CH_4. The process uses a nickel-based catalyst — developed by Daiki Ataka and Koji Hashimoto, professor emeritus of Tohoku University — and H_2 from electrolysis of water using renewable energy sources, such as wind or solar.

The tests have been performed on an integrated tubular-reactor system (5-m long tubes) with a production capacity of 1,000 Nm^3/h. When operated at the relatively low temperature of 200°C, the system achieved a H_2 conversion of 99.3% — claimed to be the highest in the world (90% conversion for existing high-performance methanation catalysts). The new catalyst contains no rare-earth metals, such as ruthenium, which is used in conventional methanation catalysts.

Over the next three years, the companies plan to scale up the process in Phase II. Earlier this year, Hitachi Zosen also announced the adoption of two additional projects, funded under Japan's Ministry of Economy, Trade and Industry: A 10-year project, "Development of Low-cost Hydrogen Production System Technology" and a five-year project, "Technology Development on Renewable Energy Storage and Transport."

IN SITU REFRACTIVE INDEX SENSOR

(*Continued from p. 14*)

common in industrial biotechnology and biopharmaceutical processes," says consultant George Barringer, of Stratophase. "The system, known as Ranger, can be used as a process monitor, a nutrient feeder or integrated into a process control system," he adds.

The sensor probe can be sterilized-in-place, and adjusts automatically for temperature-dependent changes in refractive index, Barringer says. A key advantage of the sensor system is that it requires minimal initial calibration and no recalibration. It can greatly reduce the time needed for design-of-experiment research in process development. The sensor is accompanied by software that renders raw optical data into usable parameters.

The first system was installed in the U.S. last year, and has been followed by another six installations. The market response has been positive, notes Barringer.

Circle 16 on p. 76 or go to adlinks.che.com/50976-16

A new class of polymers that utilize CO_2

A new plastic made from CO_2 and butadiene has been synthesized by Kyoko Nozaki and her research group at the University of Tokyo (Tokyo, Japan; www.chembio.t.u-tokyo.ac.jp/labs/nozaki). Although butadiene is already produced on a large scale for making synthetic rubber, it has previously been impossible to copolymerize CO_2 and butadiene in a single-step reaction, because the propagation step with CO_2 is highly endothermic.

To "make the impossible possible," the researchers avoided the thermodynamic and kinetic barriers by using a meta-stable lactone intermediate, 3-ethylidene-6-vinyltetrahydro-2H-pyran-2-one, which is formed by the palladium-catalyzed condensation of CO_2 and 1,3-butadiene. Subsequent free-radical polymerization of the lactone intermediate produces generated copolymers of high molecular weight with a CO_2 content of 33 mol% (29 wt.%). No poisonous gases are released upon ignition. The new polymer maintains its integrity at high temperature (maximum decomposition temperature of 340°C), making it suitable for melt molding, products such as housings, films and other general-purpose applications.

The process was also successfully applied for the one-pot terpolymerization of CO_2, butadiene and a second 1,3-diene. This copolymerization technique opens the door to a new class of polymeric materials that utilize CO_2 as a feedstock. (For more on CO_2 utilization, see *Chem. Eng.* July 2013, pp. 16–19.)

COVERED LAGOONS

(*Continued from p. 14*)

ing system. The first and largest zone receives most of the incoming wastewater. This is where the anaerobic digestion takes place. The second zone serves as a post-digestion and pre-settling zone where a partial clarification of the effluent wastewater takes place. Settled sludge collected here is pumped back to the lagoon's inlet. The remaining effluent flows by gravity toward complementary technology, such as GWE's SuperSep-CFS separation technology.

Each anaerobic lagoon is covered by a special floating membrane to retain the methane produced. A typical feature of the system is that it operates at zero biogas pressure. A membrane level measuring system controls the speed of a biogas extraction fan, bringing the gas at 20 mbar to go to the flare.

A copper catalyst with promise for utilizing CO_2 in organic synthesis

Scientists from the A*STAR (Agency for Science, Technology and Research) Institute for Chemical and Engineering Sciences (Singapore; www.a-star.edu.sg) have shown that a copper catalyst can incorporate CO_2 into organic molecules under mild conditions, opening the way to an inexpensive, nontoxic source of carbon for the synthesis of products such as plastics and pharmaceuticals.

Normally, a lot of energy is required to break up CO_2's strong chemical bonds. For example, the synthesis of salicylic acid requires subjecting CO_2 to a pressure of 100 atm and heating the reaction mixture to a temperature of up to 125°C.

The scientists used the commercially available catalyst, consisting of a copper atom attached to 1,3-bis-(2,6-diisopropylphenyl)imidazol-2-ylidene (empirical formula $C_{74}H_{84}N_4O_4Pd_2$). Lead scientist Duong Anh Hung says the materials commonly used in reactions involving carbon dioxide are high-energy materials containing metals such as lithium or magnesium, which are highly reactive and may break down the molecule during the reaction. Alternatively, less reactive starting materials containing tin tend to be highly toxic. Thus, the scientists looked at more environmentally benign materials, such as organoborons, he says. They looked at molecules featuring a carbon-carbon double bond close to a boron-containing group. According to the scientists, the copper catalyst works by knocking the boron group off the molecule and taking its place, allowing CO_2 to get in the right position to bond with the molecule. Duong says the products of the reaction contain a carbon-carbon double bond and a carboxylic acid group, which are highly versatile building blocks for organic synthesis.

The scientists obtained good yields at just 70°C and atmospheric pressure. However, the reaction requires large amounts of catalyst — about one catalyst molecule for every 10–20 molecules of the starting material — too high for industrial use. The scientists are now trying to exploit the high reactivity of the copper catalyst toward CO_2 to prepare other valuable organic compounds under mild conditions. ■

Heat recovery in Al production

In late March, a pilot plant for purifying the exhaust gases and recoving waste heat from an anode production process was opened at Alcoa Mosjøen Anode ANS (Mosjøen, Norway). The AHEX heat-exchanger technology used in the plant was developed over 10 years of collaboration between Alstom (Levallois-Perret, France; www.alstom.com) and Alcoa, with significant support from Enova Energiesysteme GmbH & Co.KG (Bunderhee, Germany). AHEX recovers the waste heat, which is used to make electricity that can be fed back to Alcoa's network and used for anode production. ❑

TIGHT-OIL TIGHTROPE FOR U.S. REFINERS

To take advantage of cost-advantaged crudes from shale formations, refiners must address a host of challenges associated with processing tight oils

Source: EIA

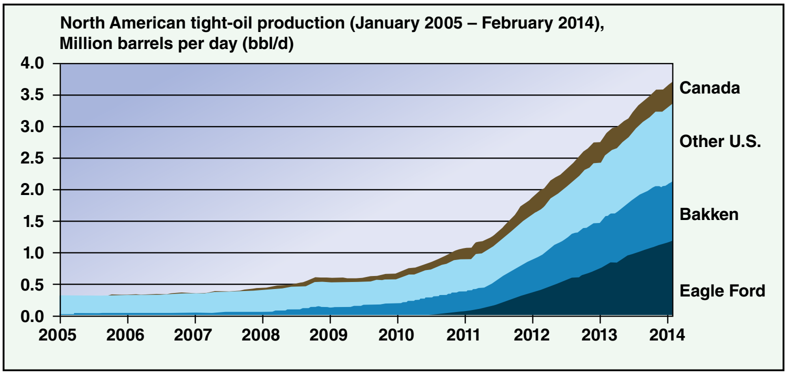


FIGURE 1. Tight-oil production has grown sharply in the U.S., with the majority coming from the Bakken and Eagle Ford formations

North American production of crude oil, driven by a rapid increase in output of "tight oil" from U.S. shale deposits like Bakken and Eagle Ford, is surging. In many, but not all areas, petroleum refiners are incorporating an increasing amount of this cost-advantaged feedstock into their crude-oil-processing slates to capitalize on its discounted price, which is partly a result of a lack of sufficient takeaway infrastructure and a ban on exporting crude oil from the U.S.

At the annual meeting of the American Fuels and Petrochemicals Manufacturers (AFPM; Washington, D.C.; www.afpm.org), held in March in Orlando, Fla., Sam Davis, an analyst with Wood MacKenzie (Edinburgh, U.K.; www.woodmac.com), said "We have seen a definite shift in behavior on the part of petroleum refiners that is driven by tight oil — the crude slate is changing to lighter and sweeter feedstocks."

U.S. Gulf Coast refiners are no longer processing imported light, low-sulfur crude oil; rather they are processing domestic light, sweet crudes, Davis said, and while East Coast refiners are still handling imported oil, an increasing amount of crude oil from the Bakken formation is making its way east.

While the discounted price of tight-oil crudes is attractive, the shift in crude slate presents petroleum refiners with a host of challenges. With a higher proportion of low-molecular-weight components, tight-oil crudes generate lower levels of vacuum gasoil (VGO) and heavy residual oils, which can result in diminished utilization levels in fluid catalytic cracking (FCC) and alkylation units. The underutilization of heavy-ends processing units parallels possible overstress situations in light-ends processing assets.

To increase utilization rates, refiners can blend heavier crudes with the lighter tight oils, resulting in what is called "barbell crude" (most material at the extreme ends of the boiling-point spectrum, but smaller amounts in the middle range). However, due to incompatibilities in the crude blends, thick emulsion layers can form and create processing challenges downstream.

Each refinery that handles tight oils operates in a unique situation that depends on its ability to access discounted domestic crude oils, and its processing capacities, among other factors.

Variable properties

Tight oils are defined as crude petroleum that is contained in low-permeability geologic formations, such as shale and sandstone. Tight-oil production in North America has increased from less than 500,000 bbl/d in 2008 to more than 3.5 million bbl/d in 2014 (Figure 1), according to estimates from the U.S. Energy Information Admin. (EIA; Washington, D.C.; www.eia.gov).

Tight oils have a number of properties that make them unique from conventional crude oils. And while it is possible to generalize about tight-oil properties, one significant hallmark is their variability of composition and quality, even within a single oilfield. Tight oils are light, with average API gravity (a measure of density) values higher than conventional crudes. They have low sulfur content and are highly paraffinic, with lower aromatics content. Typically, they have lower levels of contaminants, such as nickel and vanadium, but show high levels of other metals, such as iron, sodium, potassium and calcium.

"Tight oils can present a different slate of contaminants," says Fabian Florez, global marketing manager of refining catalysts at BASF's Catalysts Div. (Iselin, N.J.; www.catalysts.basf.com), "and they can change, often quickly, within the same oilfield." The way processing units are operated needs to be adjusted for tight oils, he adds. For example, maintaining heat balance in the FCC unit can be an issue.

Capital investments

Prior to the shale boom of the past five years, most capital investment in North American refineries was directed toward capacity for handling heavy, sour crude oils, at the expense of light crude oil. The influx of tight oils has required petroleum refiners to reverse course in the way they invest. Capital investments aimed at processing heavy crudes are becoming less common, and refineries are moving toward those that enhance the ability to process light crude oil, says Wood MacKenzie's Davis. A benefit of this shift, he notes, is that many of the investment projects for processing light, sweet crudes tend to be less capital-intensive than those for heavy crudes.

According to Wood MacKenzie analyses, average profit margins for refiners narrowed in 2013 compared to 2012, and average margins — while still healthy in general — are projected to narrow further in 2014, Davis says, placing more pressure on refiners to invest wisely.

"In refinery capital projects, we are seeing a paradigm shift toward debottlenecking investments and expanding CDUs [crude distillation units]," says Davis. "Capacity in CDUs is increasing, along with hydrocrackers to produce distillates to meet the growing global demand, especially in export markets," he explains. The first bottleneck is in the CDU, Davis says, and other bottlenecks can occur in light-ends processing units and naphtha hydrotreaters.

For refiners handling crudes with more condensate (generally API gravities over 45), such as those from the Eagle Ford formation, investments in condensate splitters are becoming more common to monetize the condensate streams, Davis says. Also, more future investment in hydrocrackers is anticipated, over FCC units, he continues, in order to meet the rising demand for diesel fuel and the declining demand for conventional gasoline. On the other hand, less incentive exists to invest in coker units, because margins there are not as attractive, Davis notes.

"Every crude is different, so it becomes even more important to know what you are buying as a refiner," Davis says. Tight-oil variability makes the crude assay critical. Assay values for tight oils can vary within a single field and the values' rates of change over time are much greater than was traditionally the case, Davis explains.

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Newsfront

Processing flexibility

Processing tight oils effectively and profitably has placed increasing importance on operational understanding, and on selecting catalysts with the correct characteristics to match crude properties. In FCC units, petroleum refiners are looking for catalysts to increase flexibility in their ability to opportunistically process a variety of feeds and maximize conversions from lower-value feedstocks to high-value products.

"Refiners have a need for flexibility," Florez says, "and BASF tries to be able to customize final products for the market. He adds, "BASF has developed various active components for refinery catalysts and we can change the amount of different active components in final catalyst products to match the needs of the available feedstock."

Grace Catalyst Technologies (Columbia, Md.; www.grace.com) also offers tailored catalyst properties for individual refinery situations. Grace has developed the broadest portfolio of catalysts, which is used to custom-make catalyst solutions for each customer, says Michael Federspiel, Grace's national sales leader for the Americas. "We can tune the different manufacturing inputs to tailor the catalyst properties to the characteristics of a particular feed and the equipment at a particular facility," he explains.

Grace's newest catalyst family, known as Achieve, is designed to allow users great flexibility while addressing the challenges of tight-oil processing. Achieve catalysts feature a high-diffusivity and tunable zeolite structure to maximize yield and performance when processing cost-advantaged feedstocks in the FCC unit.

"A much larger chunk of the catalyst market than ever before has to deal with blending of catalyst components and has to think about flexibility of catalyst surface area," Florez says.

When petroleum refiners optimize their operations for the available crude feedstock, an ancillary benefit is that the process of determining how to optimize forces

Johnson Matthey

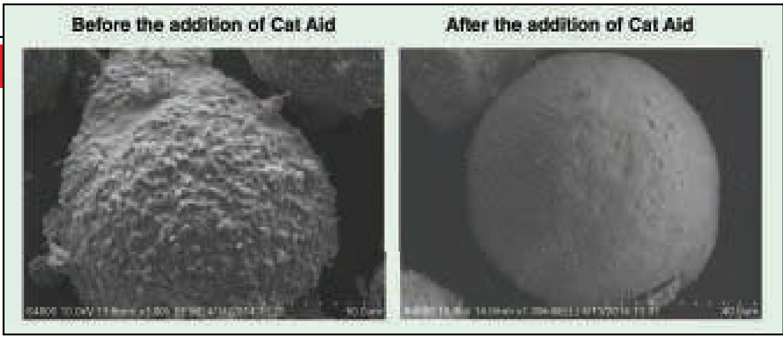


FIGURE 2. The surface of equilibrium catalyst particles shows nodules before a trial with Cat-Aid (left) and a smoother surface after treatment with Cat-Aid (right)

them to take a look at their entire operation. It allows them to identify areas for improvement that might not have otherwise been recognized, says Florez.

To support catalyst selection, Albemarle Corp. (Baton Rouge, La.; www.albemarle.com) has focused attention on the mechanics of diffusion for feed molecules to catalyst active sites. The company developed a laboratory method for measuring and comparing catalyst diffusional properties (called the Albemarle Accessibility Index; AAI). The AAI test is quantitative, and directly measures the dynamic diffusion of high-molecular-weight molecules into an FCC catalyst particle.

Technical services

Optimizing catalyst use and adjusting refinery-operating parameters has created an increased need for technical services that has been amplified by the continuing decline in experience level for the petroleum-refinery workforce as a whole.

"We don't necessarily see a specific need among the industry for a new catalyst product" that can address tight-oil processing challenges, explains BASF's Florez. "The existing slate of catalyst products can service the demands of end-users, but what we do see is a need for increased technical services for catalyst use — how best to use the products."

"There used to be 'cat lifers,' who spent their whole careers on a catalytic cracking unit," says Grace's Federspiel. Now, workers rotate to other units after a year or less.

Grace and BASF are among the catalyst providers that have sharpened their focus on customer service for catalyst products and expanded their service offerings. BASF has regionalized its technical experts and increased the size of staff serving the market. "We're also offering more customer technology seminars and training packages," Florez notes.

"We are doing more training, and weeklong workshops, because there is less experience overall at the refineries. We have the experience to know what will happen when catalyst types and operating parameters are changed," says Federspiel.

Iron contamination

A key challenge for tight-oil processing is the high levels of iron contamination commonly found in those oils. Iron can create significant problems when depositing on refining catalysts. While most tight oils are relatively low in the "normal" catalyst-poisoning metal contaminants Ni and V, Fe is often present at high concentrations, sometimes along with Ca, Na and K, which further exacerbate iron's adverse effects. In the FCC process, finely dispersed Fe-oxide particles lead to the formation of "glassy" nodules on the surface of a catalyst (Figure 2). Fe combines with silica, Ca, alkali metals and other contaminants to form low-melting-point eutectic mixtures that collapse the catalyst's pore structure. This inhibits feed-molecule diffusion into the catalyst particles and product diffusion out. In the FCC unit, Fe is a mobile poison, able to move from one catalyst particle to another.

FCC catalyst makers have offered strategies for combating the effects of Fe poisoning. One has been to engineer the catalyst matrix structure to mitigate the effects of the Fe. Because silica is a contributor in Fe/Ca poisoning, catalysts with high alumina content in their matrices and binders can help. Grace's Midas catalyst family is suited to processing Fe- and Ca-containing feeds, because it resists forming the low-melting phases that destroy pore structure.

Federspiel says Grace is working on the next generation of Midas catalyst, with the maximum matrix and improved metals tolerance. The company plans to offer it commercially next year.

Another iron-management strategy involves the use of additives. Johnson Matthey Process Technologies' (Chicago, Ill.; www.jmprotech.com) FCC additive, Cat-Aid, originally designed as a trap for vanadium, has also been found to be effective at trapping Fe in tight oils and reversing the effects of Fe poisoning.

"An Fe-poisoned catalyst has a distinctly nodulated surface, creating a dense barrier layer on the catalyst surface," says Johnson Matthey FCC R&D director Bart de Graaf.

Using Cat-Aid has allowed refiners to greatly reduce, or even eliminate, the use of flushing equilibrium catalyst (Ecat) they need to add, de Graaf says. Adding Ecat is a typical strategy for diluting the iron and dulling its effects, but Ecat quality is variable and can change the selectivities of the base catalyst. Johnson Matthey is currently developing a new, more potent, iron-trapping additive product that it plans to launch later this year. ■

Scott Jenkins

WIRELESS TECHNOLOGIES GET BETTER

Advances in wireless technology improve the performance and boost the benefits

Pepperl+Fuchs

FIGURE 1. As part of its WirelessHART family, Pepperl+Fuchs offers WirelessHART gateways with Network Manager, which determines the best primary and alternative paths between the single wireless sensors

In the past, words such as "unproven," "risky" and "expensive" may have come to mind when chemical processors considered wireless technology. However, today's wireless solutions address these previously perceived limitations. In fact, wireless solutions are quickly becoming a must-have technology in the chemical processing environment because they provide a relatively low-cost, simple and reliable way to help boost the bottom line and keep existing facilities competitive.

Here, experts debunk the most common concerns and explain how wireless products improve the process.

Enhanced wireless solutions

One of the biggest misunderstandings is that wireless installations will provide spotty coverage. This is simply not true, say the experts. "We now have WirelessHART and ISA 100 standards, which have pushed for the emergence of technologies that allow wireless signals to essentially 'hop' around obstructions in the facility," notes Steve Toteda, vice president and general manager with Eaton (Pleasanton, Calif.; www.eaton.com). He adds, "Using mesh technology, sensors can easily and seamlessly — in almost realtime — communicate back to the control system. Mesh technology means that if a sensor gets blocked, it can find and use a new path to move the information along. The performance of these systems is remarkable. In most cases, they perform as well as a wired system."

For instance, Pepperl+Fuchs (Twinsburg, Ohio; www.pepperl-fuchs.us) offers WirelessHART gateways with Network Manager that determines the best primary and alternative paths between the single wireless sensors (Figure 1). It also determines which sensor is allowed to send a message on a specific channel. Network wireless communication is organized and optimized to provide the best performance in terms of speed, throughput and energy consumption. The WirelessHART gateways provide the connection to the DCS or asset management systems with an Ethernet and RS485 interface, which can transfer data via HART or Modbus protocols.

"We offer unique features like a topology overview that allows users to take a map of the plant, import it and drag instruments around. The topology feature allows someone to see if the signal strength is good or determine why one signal may be slower than the others and correct it by looking at the connection path," explains Robert Schosker, product manager with Pepperl+Fuchs. "It goes a long way toward providing a better, clearer signal path in the facility."

Similarly, Emerson Process Management's (Austin, Tex.; www.emerson.com) Smart Wireless Gateway 1410 makes it easier for process industry users with remote operations to set up and run wireless networks (Figure 2). In the past, remote operations often had challenges with difficult installations, but the self-organized networks of this WirelessHART gateway connect with host systems and data applications automatically, which means there is no need to configure communication paths. This allows additional data points to be easily added to remote operations without the need to reconfigure the communication paths

Emerson Process Management

FIGURE 2. Emerson Process Management's Smart Wireless Gateway 1410 makes it easier for process industry users with remote operations to set up and run wireless networks

Eaton

FIGURE 3. Eaton's Elpro 450U-E licensed wireless Ethernet modem provides ultra-long-range connectivity in challenging wireless industrial applications

each time. The gateway delivers greater than 99.9% data reliability.

One of the other previous challenges, says Craig McIntyre, industry manager for chemicals with Endress+Hauser (E+H; Greenwood, Ind.; www.us.endress.com) was the lack of quality of and trust in measurement information. "As increased process reliability and control improvements were sought, the demand for more precise and trustworthy measurement information from the sensors has increased," he says.

To meet those needs, E+H has been working on advancements in instrument diagnostics and associated management systems. "For example, the company's FMD71 and FMD72 loop-powered, 4–20-mA HART electronic differential-pressure systems eliminate error from impulse tubing and provide additional sensor diagnostics that can be accessed through an FDT standards-based tool (like Fieldcare) and then integrated and managed in something like E+H's W@M Life Cycle Management environment asset management system," says McIntyre.

Diagnostic data from each instrument can be read by the automation system or by the asset management system. These data can be used to optimize calibration, to diagnose problems and to detect minor issues before they grow into substantial ones.

"Almost all instrument providers provide this kind of information in realtime, typically via fieldbuses such as Profibus PA, Foundation Fieldbus, or EtherNet/IP," says McIntyre. "Depending on the fieldbus, flowmeters can also provide diagnostic data directly to technicians in the field. Server-based flowmeters using EtherNet/IP, for example, let devices be polled by a condition-monitoring or automation system to determine if there are any diagnostic messages that need to be sent to maintenance personnel as an alert."

All this works together to boost the performance of the wireless system and the facility itself by reducing unplanned downtime, notes McIntyre.

FreeWave Technologies

FIGURE 4. WavePoint from FreeWave is a wireless networking platform that securely communicates industrial data over long distances to enable M2M, broadband and SCADA applications

Often, those considering wireless have concerns regarding performance issues, such as getting signals to travel long distances and whether equipment can perform in hazardous locations. Many newer solutions overcome these issues, as well.

For instance, Eaton's Elpro 450U-E licensed wireless Ethernet modem provides ultra-long-range connectivity in challenging wireless industrial applications (Figure 3). The modem is designed to integrate with Elpro wireless and wired networks to connect remote sensors, actuators and instrumentation to mission-critical monitoring and control-system programmable logic controllers, distributed control systems and supervisor control and data acquisition. It uses dynamic network optimization and intelligent routing to achieve high reliability, lower latency and deterministic power management. Additionally, the modem operates in extended temperature ranges to meet the demands of industrial environments and provides secure encryption.

Similarly, the WaveLine 10i from FreeWave Technologies (Boulder, Colo.; www.freewave.com) is a Class 1 Division 1 (C1D1) certified high-performance wireless I/O networking solution for use in industrial applications in hazardous environments. The C1D1 certification means users can achieve a safe operating environment for a variety of monitoring applications, including pressures, temperatures and liquid levels. In addition, WaveLine 10i eliminates the need for conduit and installation outside of the C1D1 area, offering easier, faster and less expensive installations.

Improved security

According to industry experts, it is only a perceived challenge that today's wireless technology is not secure. "The wireless systems used in industrial settings are actually far more secure than wired systems," says Eaton's Toteda. "The wireless signals are highly encrypted with encryption keys and codes that are considered military-grade. So while the signals are passing over the Ethernet, the high levels of encryption make it virtually impossible to intercept them. This is not always true of wired."

The key to ensuring security, says Glenn Longley, senior product manager for I/O and software with FreeWave, is to make sure the wireless solution offers the security level that is appropriate for the type of installation. For instance, FreeWave's latest product release, WavePoint, provides a fast, flexible and secure wireless machine-to-machine (M2M) platform (Figure 4). The wireless networking platform securely communicates industrial data over long distances to enable M2M, broadband and SCADA applications. The solution provides customers with a variety of network configuration options and support for up to four wireless OFDM (orthogonal frequency division multiplex) broadband modules per unit, operating in the 900 MHz, 2.4GHz and 5 GHz ISM and U-NII bands, and options for 3G and Wi-Fi operations. Since a single WavePoint platform enables multi-purpose communications and can operate in multiple frequencies, users can easily integrate it with existing local area networks, wide area networks and more, thus protecting their existing network infrastructure investments. It is also highly secure. The platform defends against unauthorized access using security protocols based on advanced encryption standards (AES).

Low cost

While most people realize that wireless devices and systems reduce the costs associated with laying cable to install wired solutions, many still believe there is a high cost associated with installing the infrastructure to support a wireless system. Many people assume the cost of wireless communication is more expensive because of the degree of electronics involved. However, today's wireless systems have benefited from years of innovation in the chips and electronics used within the devices. "Today a wireless system can be implemented in a cost-effective electronic package that leverages these advances," says Toteda. "Not only are the chips low cost, but they are so robust that you can build an engineered solution that performs well over long distances in extreme conditions."

What must be understood, says Toteda, "is that the first application is the one that pays the toll." He explains that in order to put a proper system together, it requires initial planning and a properly deployed infrastructure. "In many cases the initial installation requires the processor to add networking infrastructure to effectively move the signals to the control system, so it is not uncommon for first applications to incur some associated costs. However, once that first layer is there, the second, third and fourth applications are much more cost effective and less expensive when used to add new systems or expand existing systems."

Also helping to maximize costs are the WirelessHART and ISA100 standards, which require vendors of each respective technology to create devices that work on their respective platforms, regardless of which company manufactured them. (Note that ISA100 devices will only work with other ISA100 devices and WirelessHART devices will work only with WirelessHART devices, they will not work across platforms, with each other.) For example, says Peter Eleftherion, wireless field lead for Yokogawa (Sugarland, Tex.; www.yokogawa.com/us), most ISA100 vendors offer a host of different wireless devices such as temperature transmitters, level sensors, vibration sensors, and so on, that will work together, even if the temperature transmitter was made by Yokogawa and the level sensor was made by another ISA100 system vendor. "The fact that they are all ISA100-compliant means that end users can pick whatever device they'd like, so long as it is from the ISA100 family of vendors, and have it work with their other ISA100-compliant devices, seamlessly," says Eleftherion. "This means that you do not have to stick with one vendor, which helps keep costs down and choices up."

Yokogawa

FIGURE 5. Yokogawa recently developed a multi-protocol wireless adapter that enables wired field instruments to function as ISA100 wireless devices

To bring even more value to the table, Yokogawa recently developed a multi-protocol wireless adapter that enables wired field instruments to function as ISA100 wireless devices (Figure 5). When the multi-protocol wireless adaptor is mounted on a wired field instrument or analytical sensor, the instrument or sensor is able to function as an ISA100 wireless device. The first two models are intended for wired HART and RS485 Modbus communication to Sencom digital sensor as a first release, general Modbus to follow, both of which are widely used in plants. Yokogawa plans to release models that are compliant with other wired field communications standards, such as Foundation Fieldbus and Profibus.

"This ability to support not only ISA100 transmitters, but also wired Modbus and HART instruments, over multiple protocols, using the architecture that is already in place allows users to maximize their investments and reduce the cost of using wireless technology," says Charles Pate, product manager for transmitters with Yokogawa.

New frontiers

All of these improvements are coming together to make wireless solutions and networks a required technology for chemical processors who need to remain competitive with processors overseas who have had the luxury of building new plants with all new technology. "Chemical processors are feeling the business pressure to drive efficiency and productivity and are looking for performance-enhancing technologies that they can overlay in existing facilities without disrupting the plant or production," says Toteda. "And this is where wireless technology shines. The speed at which it can be implemented is remarkable. In addition, the technology can act like glue to allow new measurement applications and data to be pulled into existing control systems. And these new measurement applications are direct pathways to improving the reliability and safety of the plant and processes. They are taking measurements that have never been taken before, enabling increased safety, productivity improvements and quality enhancements to be made thanks to data that can now be collected and evaluated."

In addition, some of these new measurement applications extend beyond traditional process-control and safety systems to address business-critical applications, such as site safety, reliability and energy efficiency in the process industries, says Eric Milavickas, wireless, sales and marketing director with Emerson Process Management (Austin, Tex.; www.emersonprocess.com). Emerson refers to these applications as "pervasive sensing," which may include things like wireless ultrasonic and point gas-leak sensors, corrosion- and erosion-detection technology, vibration sensing of rotating equipment, steam trap monitoring, and surface temperature monitoring. New software applications and embedded sensor intelligence work together to interpret the data from these various sensors and convert them into actionable information, enabling prompt response to potential problems and better insight for improved decision-making.

"Prior to advanced wireless technology, the majority of these types of applications were either done manually or not done at all and the only time they were addressed was if there was a failure, which led to either lost energy, less-than-desirable reliability or, worse, a safety incident," explains Milavickas. "Wireless technology now allows business-critical measurements to be available to a broader array of process applications, improving the bottom line, along with the process itself." ■

Joy LePree

Eriez

FOCUS ON

Agglomeration And Granulation

Using PAT to monitor and control granulation
Granulation is an important operation used for tableting, but its control can be challenging. The Parsum inline particle-sizing probe (photo) is being used as a PAT (process analytical technology) instrument in granulation research being conducted at Ghent University in Belgium. The instrument is being used to continuously monitor the granulation process and to develop effective automated strategies for process control. PAT is playing a key role in achieving the pharmaceutical industry's goal of moving away from batch operation and on-off monitoring toward continuous, integrated processing and realtime release. The Parsum probe measures particle sizes over the range from 50 to 6,000 microns using spatial particle velocimetry. Available in a number of different probe lengths, it is designed for in-process use and can be installed directly into a line or process vessel for realtime monitoring. — *Malvern Instruments Ltd., Malvern, U.K.*
www.malvern.com

An attractive way to recover mixed plastics
The PolyMag Process (photo) delivers a low-cost, effective and automated solution to recover manufacturing scrap and waste. PolyMag renders plastic resin magnetic with an additive (high-concentration pellets) in a process similar to adding color concentrate. The additive makes the resin susceptible to the powerful magnetic field produced by the PolyMag Rare Earth Roll Separator. Scrap parts are run through a traditional granulator and the PolyMag Separator can then separate the mixed polymer regrind. The quantity of magnetic additive is extremely small, and does not affect the physical properties of the plastic, says the company. — *Eriez, Erie, Pa.*
www.eriez.com

Sandvik Process Systems

Steel-belt granulation with hygienic-application features
The Rotoform G4 (photo) builds on more than 30 years' process experience and introduces a number of features relevant to hygiene-critical applications, including easier cleaning, enhanced bearing seals and a lubrication-free drive-belt option. The core process combines the Rotoform drop depositor with a steel belt cooler to create a system that produces granules of highly uniform shape, stability and quality. Typical applications include the granulation of fatty alcohols, which are used in a broad range of pharmaceutical and cosmetics products. Cleaning of the drop depositor has been simplified due to the introduction of a pneumatically actuated lifting device and a new hood design, eliminating the need for operator intervention during shutdown. — *Sandvik Process Systems, Fellbach, Germany*
www.processsystems.sandvik.com

Discharging agglomerated products from bags
Discharging bulk bags containing material that has solidified, hardened, or agglomerated can cause serious operational bottlenecks.

Malvern Instruments

Material Transfer

Conditioning and emptying bulk bags can be dangerous if the proper equipment is not utilized. This new, patented system (photo) utilizes hydraulically actuated, twin heavy wall tubular-steel pivoting conditioning arms. Each conditioning arm features V-shaped tubular-steel breaker profiles that safely and efficiently return solidified materials to a free-flowing state. A rotary lift table positions the bulk bag for complete material conditioning on all sides of the bulk bag, as well as the top and bottom. The unit features an ultra compact footprint and machine guarding for operator safety. — *Material Transfer, Allegan, Mich.*
www.materialtransfer.com

A compact pelletizing plant that facilitates integration
Introduced in January, the Circular Pelletizing Technology (CPT)

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

GEA Pharma Systems

is a new generation of iron-ore agglomeration facility featuring a circular induration furnace as its core element. Based on the well-proven travelling-grate pelletizing process, the circular induration furnace greatly reduces the footprint of the pelletizing plant, says the company. Overall space requirements for the CPT are approximately half of those needed for a conventional plant. Costs for civil works, equipment and steel structure are reduced accordingly, and plant installation can be completed more quickly, the company says. The circular induration furnace also results in a more efficient utilization of installed equipment, because nearly twice the number of pallet cars are always inside of the furnace compared to straight-type induration furnaces of the same capacity, the company adds. — *Siemens Industry Sector, Metals Technology, Linz, Austria*
www.siemens.com/metals

This modular system has eight granulator sizes to pick from
On display at the Interphex 2014 exhibition (New York; March 18–29, 2014) was the PharmaConnect (photo), a system that allows a number of diverse process modules from this company to be docked to a single control module. The primary processes are based around the Aeromatic-Feeder PMA granulation technology. The modular format enables special modules to be used to match a user's requirements, such as non-standard capacities, different shapes and even different materials, such as glass. In addition to the control unit, all process modules are "plug-and-play," with a range of eight high-shear granulators (from 1 to 60 L), and two size ranges of Buck Systems IBC blenders. With the Lighthouse Probe, complete online monitoring is possible for controlling blend homogeneity and to monitor moisture content within the granule to evaluate the end-point of the granulation process. Designed for laboratory through pilot-plant scale, the PharmaConnect can process from 0.2 to 25 kg of product. — *GEA Pharma Systems Ltd., Eastleigh, U.K.*
www.gea-ps.com

Maximum fluidized-bed process flexibility in one unit
Fluidized-bed (FB) equipment can be used for spray granulation, agglomeration and coating. The process can be controlled and the prod-

uct quality optimized by changing various parameters, including the design of the processing chamber. Feasibility laboratory equipment typically offers a wide range of adjustments and evaluation of process parameters. However, normal production-scale equipment is usually designed for only one process and frequently for a very limited number of products. Last year, this company introduced its AGT System (photo), which is said to offer more flexibility in pilot and even production scale. The system can be used for FB spray granulation, FB agglomeration and FB coating. The company can now offer laboratory equipment designed to test all of these processes in a 1-kg scale batch, a 1 kg/h continuous process and in pilot scale. At the company's technology center in Weimar, Germany is the AGT PilotSystem, a round FB unit that can be equipped with a circular insert, enabling plug flow through the unit. The capacity of the AGT PilotSystem varies between 10 and 120 kg/batch or 5 to 100 kg/h continuously. — *Glatt Ingenieurtechnik GmbH, Weimar, Germany*
www.glatt-weimar.de


Glatt Ingenieurtechnik

A thermal fines agglomerator for powder coatings

Said to be the world's first thermal fines agglomerator, the HotCooler allows producers of powder coatings and toner to re-feed "unwanted" fine dust directly, quickly and easily as chips or flakes back into the production process, thereby significantly reducing the cost of materials, saving disposal costs and ensuring higher process reliability, says the manufacturer. The thermal fines agglomerator is nicknamed HotCooler because of the way it works. After the extrusion melting process, the cooling and solidification of the viscous mass, which is processed into flakes or chips, takes place. The chips are ground to obtain final product, and this produces fines (less than 30–50 µm). The HotCooler melts and agglomerates these fines in one, closed process step to form an amorphous, viscous mass, which is then cooled (in the same system) and returned to the grinding process. — *BBA Innova AG, Aarau, Switzerland*
www.bba-innova.com ■

Gerald Ondrey


Banner Engineering

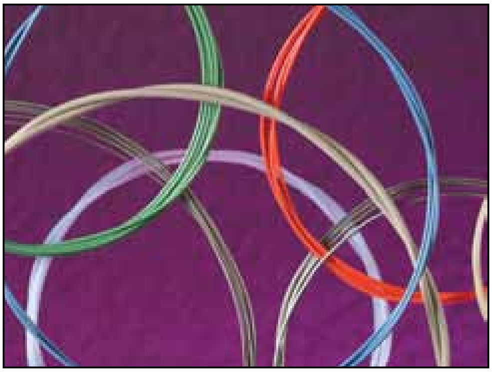
MAY New Products

Smart hazardous-area lights eliminate false ambient indication
The EZ-Light hazardous-area indicator lights (photo) are safe to use in every classified zone or area in both North America and Europe. Available in encapsulated and non-sparking models, these lights offer display flexibility with five different light colors: green, red, yellow, blue or white. To eliminate false indication from ambient light, the indicator appears grey when turned off. The EZ-Light product line can operate at temperatures ranging from –40 to 50°C. — *Banner Engineering, Minneapolis, Minn.*
www.bannerengineering.com

A supercritical fluid extractor for laboratory and pilot operations
The SFT-250 supercritical fluid extractor (photo) is designed for extractions in supercritical fluids in both laboratory and small-scale pilot applications. The unit is forged from 17-4-PH stainless steel, making it both durable and lightweight.The SFT-250 can extract very low levels of key components from raw materials and can also process larger amounts of bulk materials. Vessels can range in size from 100 to 5,000 mL, with operating pressures up to 10,000 psi. Operating temperatures from ambient to 200°C give flexibility in numerous supercritical applications. Pumping rates, pressures, temperature zones and safety interlocks are all controlled via a PID controller. — *Supercritical Fluid Technologies, Newark, Del.*
www.supercriticalfluids.com

Longterm corrosion protection with these inhibitor emitters
EcoSonic VpCI-105 emitters (photo) are designed to provide corrosion protection for metal components and parts enclosed in non-ventilated control boxes, cabinets or tool boxes up to 5 ft^3 in size. These non-toxic modules emit vapor-phase corrosion inhibitors (VpCIs), which form a monomolecular protective coating on all metal surfaces. The VpCI-105 has a breathable membrane through which the corrosion inhibitor is released, providing long-term (up to 24 months), continuous protection against corrosion, even in the presence of adverse conditions, including salt, moisture, airborne contaminants, H_2S, SO_2, NH_3 and other corrosive substances. These emitters do not interfere with electrical, optical or mechanical surface properties. Products are free of nitrites, halogens and phosphates and have very low volatile organic compound (VOC) content. No spraying, wiping or dipping is required. — *Cortec Corp., St. Paul, Minn.*
www.cortecvci.com


Supercritical Fluid Technologies


Valco Instruments

Cortec

Fused-silica, PEEK and polyimide nickel-clad tubing options
This company's new nickel-clad tubing (photo) is available in fused-silica (FS), polyetheretherketone (PEEK) or polyimide-coated FS versions. The FS tubing's thick nickel coating gives it a very high pressure rating. Nickel-clad FS tubing also allows the use of metal ferrules for improved leak-tight connections and permits resistive heating of columns and transfer lines. PEEK tubing allows direct connections using metal ferrules to produce enhanced pressure performance. Permitting use in pressures up to 40,000 psi, nickel-clad PEEK tubing is available with an outer diameter of 1/32 or 1/16 in. The nickel-clad polyimide-coated FS tubing is available in a thin-wall, low-mass version optimized for resistive heat applications. The nickel can be plated either directly over the fused silica polyimide layer or over the bare silica for temperature applications above 400°C. — *Valco Instruments Co. Inc., Houston*
www.vici.com

Use this static mixer with extreme viscosity ratios
The Kenics KMX-V static mixer (photo, p. 41) utilizes cross-stream mixing and flow splitting to achieve very rapid blending. Suitable for both laminar flow and applications with high or low viscosity or volume ratios, this mixer features very high mixing per unit length. Each

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

FilterSense

element is approximately one pipe diameter in length and consists of multiple intersecting blades, generating fluid layers as the mixture flows downstream. The KMX-V's proprietary "V"-shaped blades contribute to its liquid dispersion and gas-liquid contacting capabilities. The mixer is formatted for standard diameters up to 24 in. — *Chemineer Inc., Dayton, Ohio*
www.chemineer.com

This modular bagging system is enclosed for dust containment

The Encompass valve-bagging filling system consists of one or two valve bag fillers, an ultrasonic sealer and a robotic bag applicator, all of which are completely enclosed to contain dust within the assembly. This machine is suited for filling any powdery bulk material into valve bags for applications in the food and chemicals industries. The modular system is available with either air or impeller packers. Shipped as a single unit in an intermodal container, the Encompass system is designed for quick installation. Also, since no equipment is in contact with the floor, the interior layout of the machine lends itself to simple cleaning in the event of a spill. — *Stonepak, Salt Lake City, Utah*
www.stonepak.com

A single-filter vacuum receiver for dilute-phase conveying

This new vacuum receiver separates solids from air streams using filter media and gravity, and is suitable for applications in which materials contain small particles that are prone to dusting or when dust containment is a primary requirement. The unit features a flap-type dump valve for dilute-phase pneumatic conveying, which is actuated by a pneumatic cylinder via either manual contact closure or by programmable controls based on weight gain, elapsed time or other user-defined parameters. Constructed of stainless steel, the vacuum receiver features a clamp-together design that facilitates rapid, tool-free disassembly for filter cleaning and maintenance. The modular design permits the addition of cylinder segments for increased holding volume. Unlike conventional filter receivers that employ multiple small filter elements, this unit employs a single, large-diameter filter cartridge, facilitating rapid filter changes and automatic reverse pulse-jet cleaning of the filter element. — *Flexicon Corp., Bethlehem, Pa.*
www.flexicon.com

Also detect filter leaks with this loop-powered flow monitor

This loop-powered particulate-matter flow and emissions monitor (photo) also detects filter leaks

Chemineer

Flux-Geräte

in baghouses, cartridge dust collectors and cyclones. Simple two-wire installation and single-piece mounting, along with heavy-duty construction and charge-induction sensing with no optics enable low-maintenance operations, even in applications with challenging particulate types, such as flyash from coal and carbon black, and emissions from smelters, foundries, cement kilns and powder dryers. — *FilterSense Inc., Beverly, Mass.*
www.filtersense.com

These dryers use compression heat for dessicant regeneration

The XD+ range of desiccant dryers utilize the heat of compression from oil-free compressors to dry compressed air. They apply zero-purge cooling with two design variants to eliminate compressed-air consumption in the dessicant-regeneration process. The first variation produces a guaranteed dewpoint of –40°C. The second variation minimizes energy consumption and delivers dewpoint suppression due to extra heat elimination. Designed for capacities ranging from 550 to 3,600 L/s, these dryers feature valves and internal heaters constructed of stainless steel. — *Atlas Copco AB, Stockholm, Sweden*
www.atlascopco.com

Increase operational security with this key manager system

The new SmartKey+ key-management system provides additional security for managing safety interlock keys. The SmartKey+ protects against unauthorized or inadvertent operation of interlocked valves or process equipment, with the added ability to record movements of the keys required to operate mechanical interlocks in real time. The system encloses all keys in a cabinet. To access this key cabinet, users must identify themselves with a code for authorization. The user then selects the appropriate key from the panel and removes the key as the selected key position is unlocked. To return a key to the cabinet, the user scans the key with the integrated scanner and the corresponding key position is highlighted on the front display for re-insertion. Full transaction history is available, revealing details of key insertion and removal. Capable of managing more than 275 keys, the unit is designed to support a remote web interface. — *Smith Flow Control Ltd., Witham, U.K.*
www.smithflowcontrol.com

These pumps are outfitted with a brushless battery motor

The Combiflux line of pumps is now available with the new FBM-B 3100 brushless battery motor (photo). Especially suitable for transferring small volumes out of narrow openings and difficult-to-access containers, these sealless drum pumps feature stepless speed adjustment at capacities ranging from 12 to 60 L/min. The FMB-B motor provides mobility and independence from a main electrical power supply with its rechargeable lithium-ion battery, which can be fully recharged within 30 min, allowing for operations in areas where cables are problematic or the main power supply is unstable or unavailable. The brushless motor has no carbon brushes, resulting in a low-maintenance drive. — *Flux-Geräte GmbH, Maulbronn, Germany*
www.flux-pumpen.com ■

Mary Page Bailey

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Centrifugal Pump Maintenance

Optimal functioning of centrifugal pumps over time depends on sound maintenance practices. The following material represents tips and guidelines for routine preventive and protective maintenance for centrifugal pumps.

Monitoring

A basic maintenance routine for centrifugal pumps should include monitoring of the following items:

Bearing and lubricant condition. Monitor bearing temperatures, lubricant level and vibration. The lubricant should be clear with no signs of frothing. Changes in bearing temperature may indicate imminent failure.

Shaft seal condition. The mechanical seals should show no visible signs of leakage. Any packing should leak at a rate of no more than 40–60 drops per minute.

Overall pump vibration. Imminent bearing failure can be preceded by a change in bearing vibration. Unwanted vibration can also occur due to a change in pump alignment, the presence of cavitation or resonances between the pump, its foundation or the valving located in the suction and discharge lines.

Differential pressure. The difference between the pressure readings at the discharge and the suction of the pump will provide the total developed head pressure of the pump. A gradual decrease in the developed head pressure of the pump can indicate that the impeller clearance has widened, which requires adjustments to restore the pump's intended design performance: impeller clearance adjustment for pumps with semi-open impeller(s); or replacement of the wear ring(s) for pumps with closed impeller(s).

Maintenance

Quarterly, the following pump-maintenance actions should be taken:

- The oil should be changed after the first 200 hours of operation for a new pump, then after every three months or 2,000 operating hours, whichever occurs first
- Regrease bearings every three months or 2,000 operating hours, whichever comes first
- Check the pump's foundation and hold-down bolts for tightness
- Check the shaft alignment

A pump's performance should be checked and recorded in detail, at least annually. Performance benchmarks should be established during the early stages of a pump's operation, when the parts are new and the installation adjustments are correct. This benchmarking data should include the following:

- The pump's developed head pressure, as measured at the suction and discharge pressures, for three to five conditions should be obtained. Where possible and practical, a no-flow reading is a good reference and should be included
- Pump flowrate
- Motor amperage draw and voltage
- Vibration signature
- Bearing housing temperature

Maintenance and monitoring intervals should be shortened if the pump is used in severe-service conditions, such as with highly corrosive liquids or slurries.

When the annual assessment of a pump's performance is made, any changes in the benchmarks should be noted and used in determining the level of maintenance that may be required to get the pump back to operating at its best efficiency.


FIGURE 1. The oil level must be at the half-way point in the sight glass

Parts replacement

Whenever a pump's condition is being assessed, any worn parts should be replaced if they do not meet the following part-specific tolerance standards:

Bearing frame and foot. Visually inspect for cracks, roughness, rust or scale. Check machined surfaces for pitting or erosion.

Bearing frame. Inspect tapped connections for dirt. Clean and chase threads as necessary. Remove all loose or foreign material. Inspect lubrication passages to be sure that they are open.

Shaft and sleeve. Visually inspect for grooves or pitting. Check bearing fits and shaft runout, and replace the shaft and sleeve if worn or if the tolerances are greater than 0.002 in.

Casing. Visually inspect pump casing for signs of wear, corrosion or pitting. The casing should be replaced if wear exceeds 1/8-in. deep. Check gasket surfaces for signs of irregularities.

Impeller. Visually inspect the impeller for wear, erosion or corrosion damage. If the impeller vanes are worn more than 1/8-in. deep, or if they are bent, the impeller should be replaced.

Frame adapter. Visually inspect for cracks, warpage or corrosion damage and replace if any of these conditions are present.

Lubrication

Particular attention needs to be paid to bearing lubrication in order to maximize bearing life and, by extension, pump life. The following tips are related to pump lubrication:

- Use only non-foaming and non-detergent oils for pump-bearing lubrication
- The proper oil level is at the mid-point of the "bull's-eye" sight glass on the side of the bearing frame (Figure 1). Overlubrication can be just as damaging as underlubrication. Excess oil will cause a slightly higher horsepower draw and generate additional heat, which can in turn cause frothing of the oil
- Any cloudiness observed when checking the condition of the lubricating oil can be an indication that an overall water content of greater than 2,000 ppm is present. This is commonly due to condensation. If this is the case, the oil needs to be changed immediately
- If the pump is equipped with regreaseable bearings, never mix greases of differing consistencies or types
- Shields must be located toward the interior of the bearing frame. When regreasing, ensure that the bearing fittings are absolutely clean, because any contamination will decrease bearing life
- Overgreasing must also be avoided because this can cause localized high temperatures in the bearing races and create caked solids. After regreasing, the bearings may run at a slightly higher temperature for a period of one to two hours
- Instances where the operator of a chemical-processing facility may need to replace one or more parts on a malfunctioning pump should be treated as an opportunity to examine the pump's other parts for signs of fatigue, excessive wear and cracks (Figure 2)


FIGURE 2. Major components can be laid out for inspection

References

1. Brito, Edison, Making Pump Maintenance Mandatory, *Chem. Eng.*, October 2011, pp. 48–53.

Editor's note: This edition of "Facts at your Fingertips" is adapted from the article in Ref. [1].

Ethanol from the Direct Gasification of Biomass

By Intratec Solutions

Increasing global demand for energy and a drive to develop renewable energy sources have focused research and development attention on biomass (including wood, agricultural residues and municipal wastes) as a source of energy and products. Biomass can be converted into bioenergy via biochemical and thermochemical means. In biochemical routes, the biomass is converted into liquid or gaseous fuels by fermentation or anaerobic digestion. In thermochemical conversion, biomass is converted into gases via a number of methods, and the gases are then either used directly or synthesized into the desired chemicals. Thermochemical technologies include combustion, gasification and pyrolysis. This column describes a gasification process to produce ethanol.

The process

In the process of producing ethanol via direct gasification (Figure 1), biomass is converted into synthesis gas (syngas) by partial oxidation and the resulting stream of gases is partially burned to produce heat for the process and partially reacted to produce liquid alcohols. The process can be divided into the following areas: feedstock handling and gasification, gas cleanup and conditioning, alcohol synthesis and alcohol separation.

Feedstock handling and gasification. The biomass is dried with fluegas from the fuel combustor in the biomass drier. The dried biomass is fed into the oxygen-blown direct gasifier with steam and high-pressure oxygen from an air-separation unit.

In the presence of steam and oxygen at high temperature, biomass decomposes into syngas — a mixture of mostly H_2 and CO, with CH_4, CO_2, light hydrocarbons and water — and tar, ash and char. The combustion of a portion of the biomass supplies the heat for the endothermic reactions. A cyclone is used at the exit of the gasifier to remove residual solids from the syngas.

Gas cleanup and conditioning. Syngas from the gasifier is sent to the fluidized-bed tar reformer, where the hydrocarbons are converted to CO and H_2. The deactivated reforming catalyst is separated from the effluent syngas in a cyclone, regenerated and sent back to the tar reformer. The hot syngas is used for steam generation in heat exchangers and is then sent to the quench tower. The cooled gas from the quench is sent to the amine scrubber unit for the removal of CO_2 and H_2S. The CO_2 is vented to the atmosphere and H_2S is reduced to sulfur before disposal.

Alcohol synthesis. The treated gas is compressed and sent to the alcohol synthesis reactor, a fixed-bed system using a MoS_2-based catalyst. Carbon monoxide and H_2 combine through a series of reactions to form a mixture of alcohols, with ethanol being the main product. The reaction products are cooled so that the mixture of alcohols is condensed and separated from the unconverted syngas. The unconverted syngas is recycled to the tar reformer with a small purge.

Alcohol separation. The condensed stream from the alcohol synthesis reactor is vaporized and dehydrated by molecular sieves. The dehydrated alcohol mixture is fed to the higher alcohols column for separation of higher alcohols as a byproduct. The overhead from the column is then sent to the methanol column, where ethanol product is obtained. The column overhead, containing mainly methanol is recycled back to the alcohol synthesis reactor.

Economic performance

The capital expense of the process was estimated based on data from the second quarter of 2013 (Figure 2). The following assumptions were taken into consideration:

- A biomass processing unit producing 30 million gallons of ethanol per year erected on the U.S. Gulf Coast
- The process equipment is represented in the simplified flowsheet in Figure 1
- In the process, steam is generated through heat recovery from hot process streams. The power requirements for the process is generated in turbines driven by the steam produced
- Storage capacity equal to 30 days of operation for ethanol product

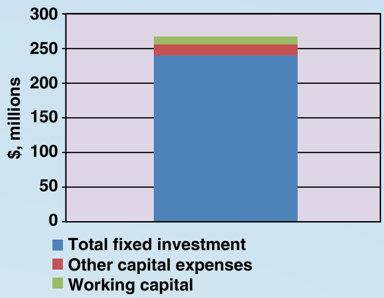


FIGURE 2. Capital expenditures to build a plant for ethanol

Ethanol production from biomass gasification is a promising technology that can use a wide range of low-cost feedstocks to produce liquid fuels. The main challenges for the technology are the development of mixed-alcohol catalysts, reforming and the high investment associated with the construction of a commercial plant. ■

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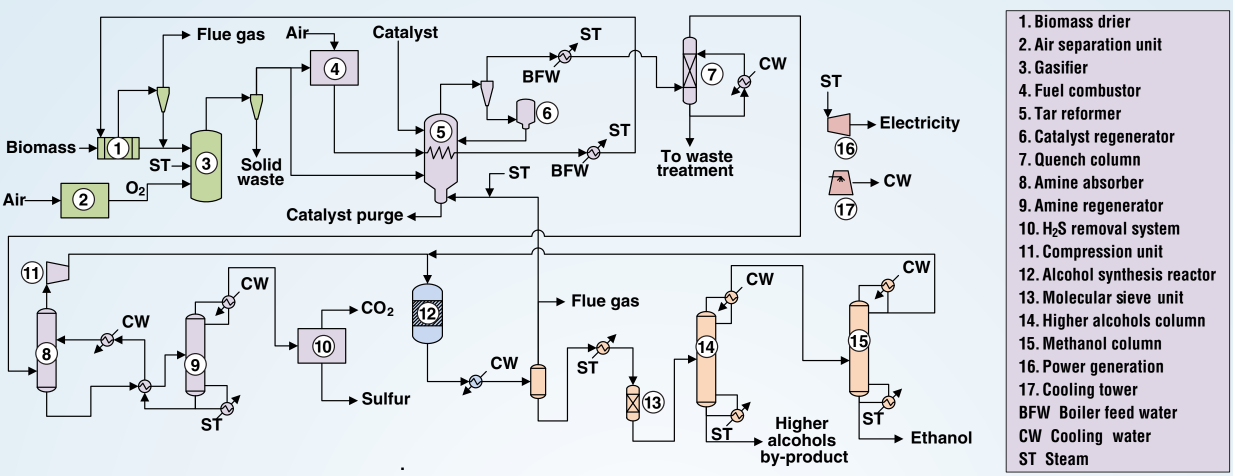


FIGURE 1. Ethanol production from direct gasification of biomass

Piping-System Leak Detection and Monitoring for the CPI

Eliminating the potential for leaks is an integral part of the design process that takes place at the very onset of facility design

W. M. (Bill) Huitt
W.M. Huitt Co.

Leaks in a chemical process industries (CPI) facility can run the gamut from creating a costly waste to prefacing a catastrophic failure.. They can be an annoyance, by creating pools of liquid on concrete that can become a possible slipping hazard and housekeeping problem, or a leak that can emit toxic vapors, causing various degrees of harm to personnel. In some cases a leak may be a simple housekeeping issue that goes into the books as a footnote indicating that a repair should be made when resources are available. In other cases it can become a violation of regulatory compliance with statutory consequences, not to mention a risk to personnel safety and the possible loss of capital assets.

Understanding the mechanisms by which leaks can occur and prioritizing piping systems to be checked at specific intervals based on a few simple factors is not only a pragmatic approach to the preventive maintenance of piping systems, but is part of a CPI's regulatory compliance. This includes compliance under both the U.S. Environmental Protection Agency (EPA) Clean Air Act (CAA; 40CFR Parts 50 to 52) and the Resource Conservation and Recovery Act (RCRA; 40CFR Parts 260 to 299). We will get into more detail with these regulations, as well as the leak detection and repair (LDAR) requirement within the above mentioned regulations, as we move through this discussion.

When discussing anything to do with government regulations, the terminology quickly turns into an "alphabet soup" of acronyms. The box on the right lists, for easy reference, the titles and acronyms that will be used in this discussion.

Leak mechanisms

Eliminating the potential for leaks is an integral part of the design process that takes place at the very onset of facility design. It is woven into the basic precept of the piping codes because it is such an elemental and essential component in the process of designing a safe and dependable piping system.

Piping systems, as referred to here, include pipe, valves and other inline components, as well as the equipment needed to hold, move and process chemicals. Why then, if we comply with codes and standards, and adhere to recommended industry practices, do we have to concern ourselves with leaks? Quite pointedly it is because much of what we do in design is theoretical, such as material selection for compatibility, and because in reality, in-process conditions and circumstances do not always perform as expected.

Whether due to human error or mechanical deficiencies, leaks are a mechanism by which a contained fluid finds a point of least resistance and, given time and circumstances, breaches its containment. What we look into, somewhat briefly, are two general means by which leaks can occur; namely corrosion and mechanical joint deficiencies.

Corrosion. Corrosion allowance (CA) is used as an applied factor in calculating, among other things, wall thickness in pipe and pressure vessels. The CA value assigned to a material is theoretical and predicated on four essential variables: material compatibility with the fluid, containment pressure, temperature of the fluid and velocity of the fluid. What the determination of a CA provides, given those variables, is a reasonable guess at a uniform rate of corrosion. And given that, an anticipated loss of material can be assumed over the theoretical lifecycle of a pipeline or vessel. It allows a reasonable amount of material to be added into the equation, along with mechanical allowances and a mill tolerance in performing wall thickness calculations. The problem is that be-

ACRONYMS

AVO	= Audio/visual/olfactory
CAA	= Clean Air Act
HAP	= Hazardous air pollutants
HON	= Hazardous organic NESHAP
LDAR	= Leak detection and repair
LUST	= Leaking underground storage tank
NEIC	= National Enforcement Investigations Center
NESHAP	= National Emission Standard for Hazardous Air Pollutants
NSPS	= New Source Performance Standards
RCRA	= Resource Conservation and Recovery Act
SOCMI	= Synthetic organic chemical manufacturing industry
TSDF	= Treatment, storage and disposal facilities
UST	= Underground storage tank
VOC	= Volatile organic compounds

TABLE 1. ELEMENTS OF A MODEL LDAR PROGRAM	
Written LDAR compliance	First attempt at repair
Training	Delay of repair compliance assurance
LDAR audits	Electronic monitoring and storage of data
Contractor accountability	QA/QC of LDAR data
Internal leak definitions	Calibration/calibration drift assessment
Less frequent monitoring	Records maintenance

yond the design, engineering, and construction phase of building a facility, the in-service reality of corrosion can be very different.

Corrosion, in the majority of cases, does not occur in a uniform manner. It will most frequently occur in localized areas in the form of pits, as erosion at high-impingement areas, as corrosion under insulation, at heat-affected zones (HAZ) where welding was improperly performed, causing a localized change to the mechanical or chemical properties of the material, and in many other instances in which unforeseen circumstances create the potential for corrosion and the opportunity for leaks in the pipe itself or in a vessel wall. Because of that incongruity, corrosion is an anomaly that, in reality, cannot wholly be predicted.

Corrosion-rate values found in various published resources on the topic of material compatibility are based on static testing in which a material coupon is typically set in a vile containing a corrosive chemical. This can be done at varying temperatures and in varying concentrations. After a period of time, the coupon is pulled and the rate of corrosion is assessed. That is a simplification of the process, but you get the point. When a material of construction (MOC) and a potentially corrosive chemical come together in operational conditions, the theoretical foundation upon which the material selection was based becomes an ongoing realtime assessment. This means that due diligence needs to be paid to examining areas of particular concern, depending on operating conditions, such as circumferential pipe welds for cracking, high-impingement areas for abnormal loss of wall thickness, hydrogen stress-corrosion cracking (HSCC), and others.

The LDAR program does not specify the need to check anything other than mechanical joints for potential leaks. Monitoring pipe and vessel walls, particularly at welds that come in contact with corrosive chemicals, is a safety consideration and practical economics. Performing cursory examinations for such points of corrosion where the potential exists should be made part of any quality assurance or quality control (QA/QC) and preventive maintenance program.

Mechanical joints and open-ended pipe. Mechanical joints can include such joining methods as flanges, unions, threaded joints, valve bonnets, stem seals and clamp assemblies. It can also include pump, compressor and agitator seals. Other potential points of transient emissions include open-ended piping, such as drains, vents, and the discharge pipe from a pressure-relief device. Any of these joints or interfaces can be considered potential leak points and require both monitoring and record-keeping documentation in compliance with the EPA's LDAR program.

Mechanical joints can leak due to improper assembly, insufficient or unequal load on all bolts, improperly selected gasket type, sufficient pressure or temperature swings that can cause bolts to exceed their elastic range (diminishing their compressive load on the joint), and an improperly performed "hot-bolting" procedure in which in-service bolts are replaced while the pipeline remains in service. "Hot bolting" is not a recommended procedure, but is nonetheless done on occasion.

Pump, compressor and agitator seals can develop leaks where shaft misalignment plays a part. If the shaft is not installed within recommended tolerances or if it becomes misaligned over time there is a good possibility the seal will begin to fail.

The LDAR program

Promulgated in 1970 and amended in 1977 and 1990, the Clean Air Act requires that manufacturers producing or handling VOCs develop and maintain an LDAR program in accordance with the requirements set forth under the Clean Air Act. This program monitors and documents leaks of VOCs in accordance with Method 21 — Determination of Volatile Organic Compound Leaks.

Table 1 provides a listing of key elements that should be contained in an LDAR program. Those elements are described as follows:

Written LDAR compliance. Compile a written procedure declaring and defining regulatory requirements that pertain to your specific facility. This should include recordkeeping certifications; monitoring and repair procedures; name, title, and work description of each personnel assignment on the LDAR team; required procedures for compiling test data; and a listing of all process units subject to federal, state and local LDAR regulations.

Training. Assigned members of the LDAR team should have some experience base that includes work performed in or around the types of piping systems they will be testing and monitoring under the LDAR program. Their training should include familiarization with Method 21 and also training as to the correct procedure for how to examine the various interface connections they will be testing. They should also receive training on the test instrument they will be using and how to enter the test data in the proper manner. All of this needs to be described in the procedure.

LDAR audits. An internal audit team should be established to ensure that the program is being carried out on a routine basis in an efficient and comprehensive manner in accordance with the written procedures. A third-party audit team is brought in every few years to confirm that internal audits are being carried out in the proper manner and that all equipment that should be included in the monitoring is listed as such. It also ensures that the tests are being carried out properly and that the test results are entered properly.

Contractor accountability. When selecting an outside contractor to perform internal LDAR audits for a facility or when bringing in an outside contractor to inspect the work of the internal audit team, it is recommended that the contract be written in a manner that places appropriate responsibility on that contractor. In doing so there should be penalties described and assessed as a result of insufficient performance or inaccurate documentation of prescribed testing and documentation procedures. Expectations should be well defined and any deviation from those prescribed norms by a third-party contractor should constitute a breach of contract. In all fairness, both parties must understand exactley what those expectations are.

Internal leak definitions. Internal leak definitions are the maximum parts per million, by volume (ppmv) limits acceptable for valves, connectors and seals, as defined by the CAA regulation governing a facility. For example, a facility may be required to set an internal leak-definition limit of 500 ppm for valves and connectors in light liquid or gas/vapor fluid service and 2,000 ppm internal leak definition for pumps in light liquid or gas/vapor fluid service. "Light liquid" is defined as a fluid whose vapor pressure is greater than 0.044 psia at 68°F.

Less frequent monitoring. Under some regulations it is allowed that a longer period between testing is acceptable if a facility has consistently demonstrated good performance (as defined in the applicable regulation). For example, if a facility has consistently demonstrated good performance under monthly testing, then the frequency of testing could be adjusted to a quarterly test frequency.

First attempt at repair. Upon detection of a leak, most rules will require that a first attempt be made to repair the leak within five days of detection; if unsuccessful, any follow-up attempts need to be finalized within 15 days. Should the repair remain unsuccessful within the 15-day time period, the leak must be placed on a "delay of repair" list and a notation must be made for repair or component replacement during the next shutdown of which the leaking component is a part.

Delay of repair compliance assurance. Placing a repair item on the "delay of repair" list gives assurances that the item justifiably belongs on the list, that a plan exists to repair the item, and that parts are on hand to rectify the problem. It is suggested that any item being listed in the "delay of repair" list automatically generate a work order to perform the repair.

Electronic monitoring and storage of data. Entering leak-test data into an electronic database system will help in retrieving such data and in utilizing them in ways that help provide reports highlighting areas of greater concern to areas of lesser concern. Such information can help direct attention and resources away from areas of least concern, while mobilizing resources to areas of greater concern. This enables a much more efficient use of information and resources.

QA/QC of LDAR data. A well written LDAR program will include a QA/QC procedure defining the process by which it is assured that Method 21 is being adhered to, and that testing is being carried out in the proper manner and includes the proper equipment and components. This also includes the maintenance of proper documentation.

Calibration/calibration-drift assessment. LDAR monitoring equipment should be calibrated in accordance with Method 21. Calibration-drift assessment of LDAR monitoring equipment should be made at the end of each monitoring work shift using approximately 500 ppm of calibration gas. If, after the initial calibration, drift assessment shows a negative drift of more than 10% from the previous calibration, all components that were tested since the last calibration with a reading greater than 100 ppm should be re-tested. Re-test all pumps that were tested since the last calibration having a reading of greater than 500 ppm.

Records maintenance. Internal electronic record-keeping and reporting is an essential component to a well-implemented LDAR program. It is an indication to the NEIC that every effort is being made to comply with the regulations pertinent to a facility. It provides ready access to the personnel associated with the program, the test data, leak repair reports and so on.

Testing for leaks

Results, when using a leak detection monitor, are only as accurate as its calibration and the manner in which it is used. Calibration is discussed in the next section, "Method 21." To use the monitor correctly, the auditor will need to place the nozzle or end of the probe as close as possible to the flange, threaded joint, or seal interface as follows:

- In the case of a flange joint test: 180 deg around perimeter of the flange joint at their interface
- In the case of a threaded joint test: 180 deg around perimeter of interface of the male/female fit-up
- If it is a coupling threaded at both ends, check both ends 180 deg around the perimeter
- If it is a threaded union, then check both ends and the body nut 180 deg around the perimeter
- In the case of a valve test:
  - 180 deg around perimeter of all end connections if anything other than welded
  - 180 deg around perimeter of body flange
  - 180 deg around perimeter of body/bonnet interface
  - 180 deg around perimeter of stem packing at stem

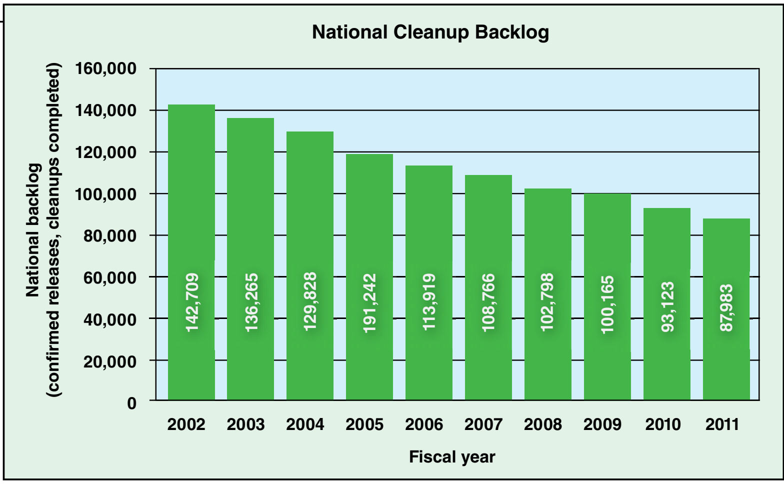


FIGURE 1. Progress is slowly being made to clean up leaking underground storage tanks under the RCRA program

- In the case of a rotating equipment shaft seal test: 180 deg around the perimeter of the interface of the seal and the shaft

Method 21

Method 21, under 40 CFR Part 60, Appendix A, provides rules with respect to how VOCs are monitored and measured at potential leak points in a facility. Those potential leak points include, but are not limited to: valves, flanges and other connections; pumps and compressors; pressure-relief devices; process drains; open-ended valves; pump and compressor seals; degassing vents; accumulator vessel vents; agitator seals and access door seals. It also describes the required calibration process in setting up the monitoring device. Essentially any monitoring device may be used as long as it meets the requirements set forth in Method 21.

Cylinder gases used for calibrating a monitoring device need to be certified to be within an accuracy of 2% of their stated mixtures. It is recommended that any certification of this type be filed in either digital form or at the very least as a hard copy. There should also be a specified shelf life of the contents of the cylinder. If the shelf life is exceeded, the contents must be either re-analyzed or replaced.

Method 21 goes on to define how to test flanges and other joints, as well as pump and compressor seals and various other joints and interfaces with the potential for leaks. There are two gases required for calibration. One is referred to as a "zero gas," defined as air with less than 10 ppmv (parts per million by volume) VOC. The other calibration gas, referred to as a "reference gas," uses a specified reference compound in an air mixture. The concentration of the reference compound must approximately equal the leak definition specified in the regulation. The leak definition, as mentioned above, is the threshold standard pertinent to the governing regulation.

Monitoring devices

A portable VOC-monitoring device will typically be equipped with a rigid or flexible probe. The end of probe is placed at the leak interface of a joint, such as a flange, threaded connection or coupling, or at the interface of a pump, compressor, or agitator seal where it interfaces with the shaft. With its integral pump, the device, when switched on, will draw in a continuous sample of gas from the leak-interface area into the monitoring device. The instrument's response or screening value is a relative measure of the sample's concentration level. The screening value is detected and displayed in parts per million by volume, or if the instrument is capable and the degree of accuracy needed, in parts per billion by volume (ppbv).

The detection devices operate on a variety of detection principles. The most common are ionization, infrared absorption and combustion. Ionization detectors operate by ionizing a sample and then measuring the charge (that is, number of ions) produced.

Two methods of ionization currently used are flame ionization and photoionization. The flame ionization detector (FID) theoretically measures the total carbon content of the organic vapor sampled. The photoionization detector (PID) uses ultraviolet light to ionize the organic vapors. With both detectors, the response will vary with the functional group in the organic compounds. PIDs have been used to detect equipment leaks in process units in SOCMI facilities, particularly for compounds such as formaldehyde, aldehydes and other oxygenated chemicals that typically do not provide a satisfactory response on a FID-type unit.

Operation of the non-dispersive infrared (NDIR) detector is based on the principle that light absorption characteristics vary depending on the type of gas. Because of this, NDIR detection can be subject to interference due in large measure to such constituents as water vapor and CO_2, which may absorb light at the same wavelength as the targeted compound. This type of detector is typically confined to the detection and measurement of single components. Because of that proclivity, good or bad, the wavelength at which a certain targeted compound absorbs infrared radiation, having a predetermined value, is preset for that specific wavelength through the use of optical filters. As an example, if the instrument was set to a wavelength of 3.4 micrometers, the device could detect and measure petroleum fractions, such as gasoline and naphtha.

The combustion-type analyzer is designed to measure either thermal conductivity of a gas or the heat produced as a result of combustion of the gas. Referred to as hot-wire detectors or catalytic oxidizers, combustion-type monitors are nonspecific for gas mixtures. If a gas is not readily combustible, similar in composition to formaldehyde and carbon tetrachloride, there may be a reduced response or no response at all.

Due to the variability in the sensitivity of the different monitoring devices, the screening value does not necessarily indicate the actual total concentration at the leak interface of the compound(s) being detected. The leak interface is the immediate vicinity of the joint being tested — the point at which the end of the probe is placed. Response factors (RFs), determined for each compound by testing or taken from reference sources, then correlate the actual concentration of a compound to that of the concentration detected by the monitoring device. As mentioned previously, the monitoring device must first be calibrated using a certified reference gas containing a known compound at a known concentration, such as that of methane and isobutylene. RFs at an actual concentration of 10,000 ppmv have been published by the EPA in a document entitled "Response Factors of VOC Analyzers Calibrated with Methane for Selected Organic Chemicals."

Method 21 requires that any selected detector meet the following specifications:

- The VOC detector should respond to those organic compounds being processed (determined by the RF)
- Both the linear response range and the measurable range of the instrument for the VOC to be measured and the calibration gas must encompass the leak definition concentration specified in the regulation
- The scale of the analyzer meter must be readable to ±2.5% of the specified leak definition concentration
- The analyzer must be equipped with an electrically driven pump so that a continuous sample is provided at a nominal flowrate of between 0.1 and 3.0 L/min
- The analyzer must be intrinsically safe for operation in explosive atmospheres
- The analyzer must be equipped with a probe or probe extension not to exceed 0.25 in. outside diameter with a single end opening for sampling

TABLE 2 – FEDERAL REGULATIONS THAT REQUIRE A FORMAL LDAR PROGRAM WITH METHOD 21

40 CFR		Regulation Title
Part	Subpart	
60	VV	SOCMI VOC Equipment Leaks NSPS
60	DDD	Volatile Organic Compound (VOC) Emissions from the Polymer Manufacturing Industry
60	GGG	Petroleum Refinery VOC Equipment Leaks NSPS
60	KKK	Onshore Natural Gas Processing Plant VOC Equipment Leaks NSPS
61	J	National Emission Standard for Equipment Leaks (Fugitive Emission Sources) of Benzene
61	V	Equipment Leaks NESHAP
63	H	Organic HAP Equipment Leak NESHAP (HON)
63	I	Organic HAP Equipment Leak NESHAP for Certain Processes
63	J	Polyvinyl Chloride and Copolymers Production NESHAP
63	R	Gasoline Distribution Facilities (Bulk Gasoline Terminals and Pipeline Breakout Stations)
63	CC	Hazardous Air Pollutants from Petroleum Refineries
63	DD	Hazardous Air Pollutants from Off-Site Waste and Recovery Operations
63	SS	Closed Vent Systems, Control Devices, Recovery Devices and Routing to a Fuel Gas System or a Process
63	TT	Equipment Leaks – Control Level 1
63	UU	Equipment Leaks – Control Level 2
63	YY	Hazardous Air Pollutants for Source Categories: Generic Maximum Achievable Control Technology Standards
63	GGG	Pharmaceuticals Production
63	III	Hazardous Air Pollutants from Flexible Polyurethane Foam Production
63	MMM	Hazardous Air Pollutants for Pesticide Active Ingredient Production
63	FFFF	Hazardous Air Pollutants: Miscellaneous Organic Chemical Manufacturing
63	GGGGG	Hazardous Air Pollutants: Site Remediation
63	HHHHH	Hazardous Air Pollutants: Miscellaneous Coating Manufacturing
65	F	Consolidated Federal Air Rule — Equipment Leaks
264	BB	Equipment Leaks for Hazardous Waste TSDFs
265	BB	Equipment Leaks for Interim Status Hazardous Waste TSDFs

Federal regulations

There are federal regulations that pertain to monitoring for VOCs and require the implementation of a formal LDAR program in concert with the rules of Method 21. There are other federal regulations that require the rules of Method 21, but do not require a formal LDAR program. Tables 2 and 3 list those various regulations.

It is the manufacturer's responsibility to make the proper determination as to what regulations it needs to comply with. Those specific regulations, coupled with the Method 21 requirements, will define the LDAR program and help establish a comprehensive and detailed procedure.

RCRA

The Solid Waste Disposal Act of 1965 was amended in 1976 to include the Resource Conservation and Recovery Act (RCRA), which encompassed the management of both hazardous waste and solid waste. Prompted further by an ever increasing concern of underground water contamination, this act was again amended in 1984 to address underground storage tanks (USTs) and associated underground piping under Subtitle I. This Amendment

TABLE 3 – FEDERAL REGULATIONS THAT REQUIRE THE USE OF METHOD 21 BUT NOT A FORMAL LDAR PROGRAM		
40 CFR		Regulation Title
Part	Subpart	
60	XX	Bulk Gasoline Terminals
60	QQQ	VOC Emissions from Petroleum Refinery Wastewater Systems
60	WWW	Municipal Solid Waste Landfills
61	F	Vinyl Chloride
61	L	Benzene from Coke By-Products
61	BB	Benzene Transfer
61	FF	Benzene Waste Operations
63	G	Organic Hazardous Air Pollutants from SOCMI for Process Vents, Storage Vessels, Transfer Operations, and Wastewater
63	M	Perchloroethylene Standards for Dry Cleaning
63	S	Hazardous Air Pollutants from the Pulp and Paper Industry
63	Y	Marine Unloading Operations
63	EE	Magnetic Tape Manufacturing Operations
63	GG	Aerospace Manufacturing and Rework Facilities
63	HH	Hazardous Air Pollutants from Oil and Gas Production Facilities
63	OO	Tanks — Level 1
63	PP	Containers
63	QQ	Surface Impoundments
63	VV	Oil/Water, Organic/Water Separators
63	HHH	Hazardous Air Pollutants from Natural Gas Transmission and Storage
63	JJJ	Hazardous Air Pollutant Emissions: Group IV Polymers and Resins
63	VVV	Hazardous Air Pollutants: Publicly Owned Treatment Works
65	G	CFAR — Closed Vent Systems
264	AA	Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities — Process Vents
264	CC	Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities — Tanks, Surface Impoundments, Containers
265	AA	Interim Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities — Process Vents
265	CC	Interim Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities — Tanks, Surface Impoundments, Containers
270	B	Hazardous Waste Permit Program — Permit Application
270	J	Hazardous Waste Permit Program — RCRA Standardized Permits for Storage Tanks and Treatment Units

regulates the construction, monitoring, operating, reporting, recordkeeping, and financial responsibility for USTs and associated underground piping that handle petroleum and hazardous fluids.

As of 2011, there were 590,104 active tanks and 1,768,193 closed tanks in existence in the U.S. Of the still active tanks, 70.9% were under significant operational compliance. This means that they were using the necessary equipment required by current UST regulations to prevent and detect releases and were performing the necessary UST system operation and maintenance.

In 1986, the Leaking Underground Storage Tank (LUST) Trust Fund was added to the RCRA program. The trust financing comes from a 0.1¢ tax on each gallon of motor fuel (gasoline, diesel or biofuel blend) sold nationwide. The LUST Trust Fund provides capital to do the following:

- Oversee cleanups of petroleum releases by responsible parties
- Enforce cleanups by recalcitrant parties
- Pay for cleanups at sites where the owner or operator is unknown, unwilling, or unable to respond, or those that require emergency action
- Conduct inspections and other release prevention activities

In Figure 1 the progress being made by the program can readily be seen. In 2002, RCRA was looking at 142,709 LUST sites — sites that were flagged for cleanup. Throughout the following nine years, 2002 through 2011, 54,726 of those sites were cleaned, leaving 87,983 still targeted for cleanup.

Within the RCRA program there are requirements that impact design, fabrication, construction, location, monitoring and operation of USTs and associated underground piping. The EPA has provided a number of sites on the internet that provide a great deal of information on the various CFR Parts. 40 CFR Part 260 contains all of the RCRA regulations governing hazardous waste identification, classification, generation, management and disposal.

Listed wastes are divided into the following group designations:

- The F group — non-specific source wastes found under 40 CFR 261.31
- The K group — source-specific wastes found under 40 CFR 261.32
- The P and U group — discarded commercial chemical products found under 40 CFR 261.33

Characteristic wastes, which exhibit one or more of four characteristics defined in 40 CFR Part 261 Subpart C are as follows:

- Ignitability, as described in 40 CFR 261.21
- Corrosivity, as described in 40 CFR 261.22
- Reactivity, as described in 40 CFR 261.23
- Toxicity, as described in 40 CFR 261.24

Table 4 provides a listing of additional CFR parts that further

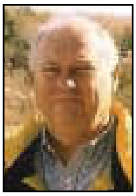
define the regulations under the Resource Conservation and Recovery Act.

Final remarks

I am fervently against overregulation and watch with keen interest the unfolding debate occurring on Capitol Hill over the amendment to the Toxic Substances Control Act (TSCA) for example. But the improved safety, clean air, clean water, and cost savings realized from the CAA and RCRA programs are four major returns on investment that come back to a manufacturer from the investment in a good leak-detection program. Whether monitoring and repairing leaks above ground, in accordance with the CAA, or below ground, in accordance with the RCRA, it is, simply put, just good business. As alluded to at the outset of this article, leaks in hazardous-fluid-service piping systems have served, in many cases, as an early-warning indicator of something much worse to come. At the very least, such leaks can contribute to air pollution, groundwater contamination, lost product revenue, housekeeping costs, and a risk to personnel — a few things we can all live without. ■

Edited by Gerald Ondrey

Author



W. M. (Bill) Huitt has been involved in industrial piping design, engineering and construction since 1965. Positions have included design engineer, piping design instructor, project engineer, project supervisor, piping department supervisor, engineering manager and president of W. M. Huitt Co. (P.O. Box 31154, St. Louis, MO 63131-0154; Phone: 314-966-8919; Email: wmhuitt@aol.com), a piping consulting firm founded in 1987. His experience covers both the engineering and construction fields and crosses industry lines to include petroleum refining, chemical, petrochemical, pharmaceutical, pulp & paper, nuclear power, biofuel and coal gasification. He has written numerous specifications, guidelines, papers, and magazine articles on the topic of pipe design and engineering. Huitt is a member of the International Society of Pharmaceutical Engineers (ISPE), the Construction Specifications Institute (CSI) and the American Society of Mechanical Engineers (ASME). He is a member of the B31.3 committee, a member of three ASME-BPE subcommittees and several task groups, ASME Board on Conformity Assessment for BPE Certification where he serves as vice chair, a member of the American Petroleum Institute (API) Task Group for RP-2611, serves on two corporate specification review boards, and was on the Advisory Board for ChemInnovations 2010 and 2011 a multi-industry conference & exposition.

TABLE 4 – RESOURCE CONSERVATION AND RECOVERY ACT (RCRA) INFORMATION

40 CFR Part	Regulation Title
260	Hazardous Waste Management System: General
261	Identification and Listing of Hazardous Waste
262	Standards Applicable to Generators of Hazardous Waste
264	Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities
265	Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities
266	Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities
267	Standards for Owners and Operators of Hazardous Waste Facilities Operating Under a Standardized Permit
270	EPA Administered Permit Programs: The Hazardous Waste Permit Program
272	Approved State Hazardous Waste Management Programs
273	Standards for Universal Waste Management
279	Standards for the Management of Used Oil
280	Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)
281	Approval of State Underground Storage Tank Programs
282	Approved Underground Storage Tank Programs

Unlocking the Secrets of Plate-and-Frame Heat Exchangers

An understanding of the design, sizing, specification and installation of plate-and-frame heat exchangers is necessary to evaluate vendors' proposed designs

Grittaya Srinaphasawadi
Process Equipment Technology

Wiroon Tanthapanichakoon
SCG Chemicals

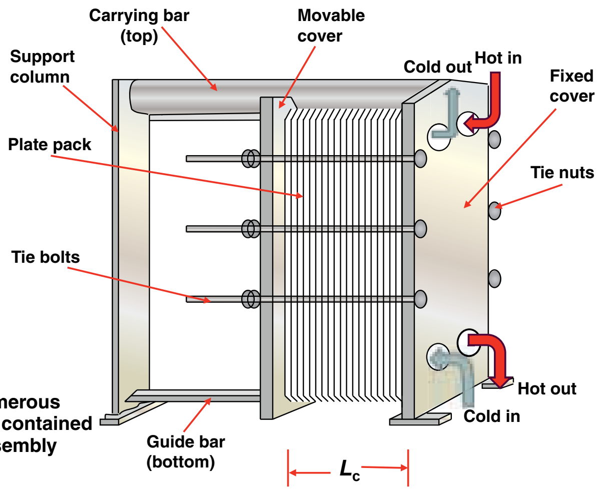


FIGURE 1. Numerous components are contained within a PHE assembly

Plate-and-frame heat exchangers, or plate heat exchangers (PHEs), are a type of compact heat exchanger. PHEs have been widely used in the food industries, mainly because they easily meet health and sanitation requirements due to their simple disassembly for cleaning. They have recently become more common in the chemical process industries (CPI) for certain applications and operational conditions. Generally, a PHE is designed and supplied by vendors exclusively, making them a proverbial "black box" for engineers. However, it is a poor practice to rely only on vendors, who, at times, may not fully understand actual fluid properties or process requirements at a specific site. This can lead to design mistakes or equipment inadequacies.

This article covers the practical design aspects of PHEs, and explains how to design a PHE using a generally accepted method derived from heat-exchanger design fundamentals. This method can be applied to the preliminary design of a PHE and can also be used to review vendors' proposed equipment for its suitability for a required service.

What engineers should know

Using convective heat-transfer principles, a PHE achieves heat transfer via two streams of fluid that are separated by a stainless-steel corrugated plate, forming a small (usually 2–5 mm in size) flow passage. This small flow passage, along with the geometry of the PHE plates, induces turbulence, contributing to a very high convective heat-transfer coefficient — much higher than that seen in shell-and-tube (S&T) heat exchangers. Figure 1 shows the major components of a PHE.

Plate-corrugation geometry is an important feature for PHEs. Figure 2 shows the two typical types of plate-corrugation geometry, intermating and chevron (herringbone). Chevron geometry produces greater heat-transfer enhancement for a given pressure drop and thus is more commonly used.

Gaskets are installed in a groove around the heat-transfer surface on a PHE plate to prevent fluid leakage to the outside and to avoid contamination of process fluids. Also, the gaskets help to control fluid movement by creating an alternating flow sequence between the two fluids in the plate channels. A fluid may be prevented from entering some plate channels, but will be required to enter others.

As mentioned previously, PHEs have much higher convective heat-transfer coefficients compared to S&T heat exchangers. Some additional advantages in using PHEs rather than S&T heat exchangers are as follows:

- True countercurrent flow is easily achieved
- Surface area per unit volume is very high — usually greater than 700 m^2/m^3
- Equipment is lightweight and compact; only a small plot space is required
- Modifications to meet specific process requirements can be achieved by simply changing the number or form of plates
- A wide range of fluids, including ones that are very viscous, can be processed with relatively little expense
- The heat-transfer area can be easily increased or decreased
- When leaks occur, contamination of the process fluid is prevented

NOMENCLATURE

A_{ch} Cross-sectional flow area of one channel, m²
A_e Total effective heat-transfer area, m²
A_1 Plate true surface area, m²
A_{1p} Plate planar projected area, m²
b Mean channel flow gap, m
β Chevron angle, deg
C_h Heat-transfer correlation coefficient
C_p Specific heat capacity, J/kg-K
D_e Hydraulic diameter, m
D_p Port diameter, m
Δp Pressure drop, Pa
f Fanning friction factor
F LMTD correction F-factor
F_m Fouling margin, %
h Convective heat-transfer coefficient, W/m²-K
k Fluid thermal conductivity, W/m-K
k_w Plate thermal conductivity, W/m-K
K_p Empirical coefficient of the Fanning friction factor for each type of chevron plate and Reynolds number
L_c Compressed-plate pack length measured between the two head plates, m
L_{horiz} Horizontal port-to-port center distance, m
L_p Vertical distance between top port bottom edge to bottom port top edge, m
L_{vert} Effective flow length between the vertical ports, m
L_w Effective channel width (between gasket grooves), m
$LMTD$ Log-mean temperature difference, °C
m_{ch} Mass flowrate through each flow channel, kg/s
μ Fluid viscosity, N-s/m²
μ_b Bulk fluid viscosity, N-s/m²
μ_w Fluid viscosity at the wall, N-s/m²
N_{cp} Number of channels per pass
N_e Effective number of plates
N_{pass} Number of passes
N_t Total number of plates
p Compressed pitch per plate, m
ϕ Surface enlargement factor
Pr Prandtl number
Q Heat duty, W
R_f Fouling resistance, m²K/W
Re Reynolds number
ρ Density, kg/m³
t Plate thickness, m
T_1 Hot side inlet temperature, °C
T_2 Hot side outlet temperature, °C
t_1 Cold side inlet temperature, °C
t_2 Cold side outlet temperature, °C
U Overall heat-transfer coefficient, W/m²-K
V_{ch} Fluid velocity in a flow channel, m/s
V_p Fluid velocity through the port, m/s
W Mass flowrate through either hot side or cold side, kg/s

Superscripts

m Power exponent for Reynolds number effect on pressure drop (for calculation of Fanning friction factor f)
n Power exponent for Reynolds number effect on convective heat-transfer coefficient

Subscripts

c Cold side
ch Channel
cl Clean
e Effective
f Fouled
h Hot side
p Port
t Total

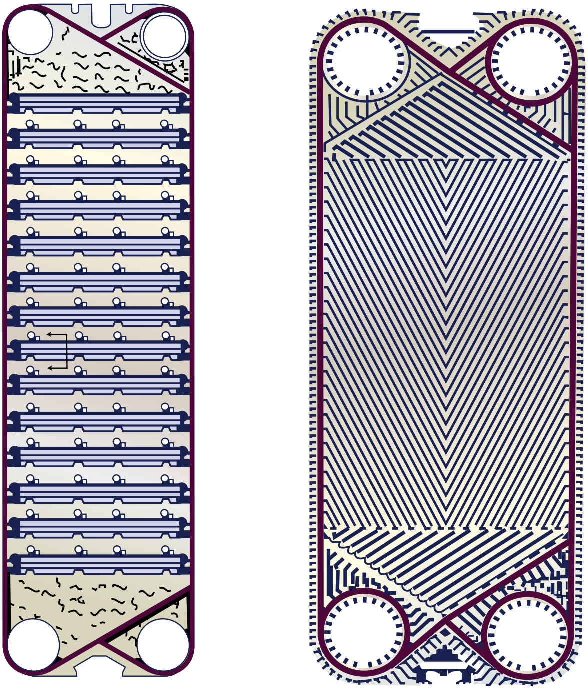


FIGURE 2. There are two typical plate types used in a PHE: intermating type (left) and chevron type (right)

TABLE 1. TYPICAL MAXIMUM OPERATING TEMPERATURES FOR COMMON GASKET MATERIALS

Gasket material	°C
Natural rubber/Neoprene	70–90
Nitrile/Viton	125–135
Butyl materials	100–155
Silicone	180–250

- Leaks are easily detectable
- The ability to individually remove and clean plates decreases maintenance and cleaning efforts for both fluid sides; S&T heat exchangers are more difficult to open, especially on the shellside
- Turbulence can be achieved at a relatively low Reynolds number, typically less than 500
- Lower sensitivity to vibration than S&T heat exchangers
- Very heat-sensitive process fluids can be capably handled

However, there are some applications where S&T heat exchangers are a better option than PHEs. Some of the disadvantages associated with the use of PHEs are as follows:

- If gaskets deteriorate, especially in the presence of hazardous fluids or hydrocarbon mixtures, the equipment is more susceptible to atmospheric leaks
- A higher pressure drop is required to induce turbulent flow at smaller flow passages (2–5 mm); at the same pressure drop, a PHE may not provide the desired heat-transfer enhancement effect.
- PHEs have limited use for gas-to-gas heat-exchanger or boiling services where volume expansion is large, because the required outlet nozzle will be too big
- Gasket materials selection can impose constraints on operating pressure and temperature (See Table 1 for specific tempera-

ture limitations); conversely, in S&T heat exchangers, the design temperature is based upon the metallurgy of the materials of construction

- Process fluids must be clean, nonflammable, non-toxic and nearly free of particulate matter; for dirty fluids, inlet strainers must be installed
- Non-corroding metallurgy, such as austenitic stainless steel, titanium, Inconel or Hastelloy, is a requirement; S&T heat exchangers may be constructed of less expensive carbon steel, since corrosion allowances are more relaxed
- Large exposed bolts and typically elastomeric (rubber-based) gasket materials decrease fire resistance; a fireproofing shroud should be specified if fire resistance is needed
- Suitable applications may be limited by the compatibility of gasket materials with operating fluids. For example, rubber or neoprene gaskets cannot be used with aromatic oils

Based on these advantages and disadvantages, one can begin to determine in which specific applications and under which operating conditions PHEs will be appropriate alternatives to S&T heat exchangers. While S&T heat exchangers remain ubiquitous across the CPI, PHEs are gaining ground in some specific applications, including food processing and lube-oil coolers for compressors and turbines. However, it must be noted that PHEs are not suitable for gas-to-gas heat exchange, and must be used with caution in boiling and condensation services, especially where there is a large volume expansion. S&T heat exchangers remain the preferred option for these phase-change applications. Table 2 compares, in further detail, the specific operating requirements of PHEs and S&T heat exchangers.

TABLE 2. COMPARISON OF OPERATING AND DESIGN REQUIREMENTS FOR PHE AND S&T HEAT EXCHANGERS

	PHE	Shell & tube (S&T)
Maximum design temperature, °C	250 (based on elastomeric gasket materials)	much greater than 250 (based on metallic material)
Maximum design pressure, barg	20–25	200–300
Heat-transfer area, m²	0.1–2,200	> 2,500–3,500 per shell is possible
Heat-transfer coefficient, W/m²-K	3,500–7,500 (mainly liquid and water service)	100–2,500 (gas-gas, liquid-liquid, gas-liquid and phase-change services)
Pressure drop, bars	2–3	usually < 1
Heat-transfer ratio	3–5	1
Plot-space ratio	0.2–0.5	1
Fouling-factor ratio	0.1–0.25	1
Temperature cross/ Minimum temp. approach, °C	Acceptable/ 1°C	Unacceptable or needs multiple shells/ 5°C
Operating weight ratio	0.1–0.3	1
Hold-up volume	Low	High
Design standards	API 662	TEMA, API 660

Design methodology

PHE design remains proprietary in nature, because exact design correlations used by vendors are often undisclosed. The PHE convective heat-transfer coefficient, h, can be calculated using an in-tube convective heat-transfer coefficient correlation, but the tube inner diameter must be changed to hydraulic diameter, D_e. This design method has been validated with commercial PHE design and rating software.

The following equations use heat-exchanger fundamentals to develop a methodology for designing a typical PHE. The nomenclature section, as well as Figures 3 and 4, explain the meaning of the parameters in the following equations. First, the process requirements must be defined for the heat duty (Q) on the hot and cold sides of the exchanger, as well as the log-mean temperature difference ($LMTD$).

$$Q_h = W_h C_{p,h}(T_1 - T_2) \quad (1)$$

$$Q_c = W_c C_{p,c}(t_2 - t_1) \quad (2)$$

$$LMTD = \frac{\left[(T_1 - t_2) - (T_2 - t_1)\right]}{\ln\left[(T_1 - t_2)/(T_2 - t_1)\right]} \quad (3)$$

Equations (4) through (13) define geometry for the PHE, beginning with the effective number of plates (N_e), which is two less than the total number of plates, due to the absence of flow between the end plate and the cover, shown in Equation (4). Equation (5) gives the compressed pitch (p), which is a function of the compressed-plate pack length measured between the two head plates (L_c).

$$N_e = N_t - 2 \quad (4)$$

$$p = L_c/N_t \quad (5)$$

Equations (6) through (9) regard channel parameters. The mean channel flow gap (b) is given by Equation (6), the vertical port distance by Equation (7) and the effective channel width by Equation (8).

$$b = p - t \quad (6)$$

$$L_p = L_{vert} - D_p \quad (7)$$

$$L_w = L_{horiz} + D_p \quad (8)$$

The flow area of one channel, shown in Equation (9), is the product of the channel's flow gap and its width.

$$A_{ch} = b \times L_w \quad (9)$$

The single-plate true heat-transfer area is defined as the ratio of the equivalent area and the number of effective plates. The total effective heat-transfer area of a PHE (or total effective area), A_e, depends on plate types and number of plates, as shown in Equation (10). The planar projected area is given in Equation (11).

$$A_1 = A_e/N_e \quad (10)$$

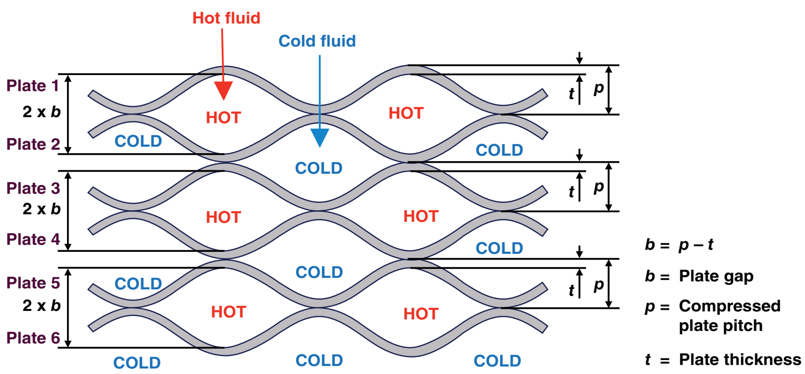


FIGURE 3. **The gasket is compressed until there is metal-to-metal contact between adjacent plates, forming flow channels on the hot and cold sides**

$$A_{1p} = L_p \times L_w \quad (11)$$

The surface enlargement factor, ϕ, is the ratio of plate true surface area to plate planar projected area. Defined in Equation (12), this value is normally between 1.20 and 1.25.

$$\phi = A_1 / A_{1p} \quad (12)$$

The hydraulic diameter is defined as four times the channel flow area divided by the wetted perimeter. In Equation (13), it is assumed that b is much smaller than L_w.

$$D_e = \frac{4bL_w}{\left[2\times\left(b+L_w\phi\right)\right]} = 2b/\phi \quad (13)$$

The expressions required for heat-transfer calculations for the design of a PHE are shown in Equations (14) through (24). Equations (14) through (16) relate to the channels. Equation (14) gives the number of channels per pass, Equation (15) gives the mass flowrate to each channel and Equation (16) defines the fluid velocity in a given flow channel.

$$N_{cp} = (N_t - 1)/2N_{pass} \quad (14)$$

$$m_{ch} = W/ N_{cp} \quad (15)$$

$$V_{ch} = (m_{ch}/\rho)/A_{ch} \quad (16)$$

The Reynolds Number (Re) and the Prandtl Number (Pr), defined in Equations (17) and (18), respectively, are important parameters in determining the flow behavior of the process fluids in a PHE. Note that flow is defined as laminar at $Re < 10$, transitional at $10 < Re < 500$ and turbulent at $Re > 500$.

$$Re = (\rho V_{ch} D_e/\mu) \quad (17)$$

$$Pr = (C_p\mu/k) \quad (18)$$

Equation (19) relates a heat-transfer coefficient, h, in terms of Re and Pr. C_h and n can be found from Table 10.6 in Ref. [*1*] at various Chevron angles (β) and different Reynolds number values.

$$(hD_e/k)_h = C_h(Re)^n(Pr)^{1/3}(\mu_b/\mu_w)^{0.17} \quad (19)$$

Equations (20) and (21) define the overall heat-transfer coefficient (U) for clean and fouled conditions, respectively.

$$1/U_{cl} = 1/h_h + t/k_w + 1/h_c \quad (20)$$

$$1/U_f = 1/h_h + R_{f,h} + t/k_w + R_{f,c} + 1/h_c \quad (21)$$

Fouling factors for S&T heat exchangers should not be used for PHE design, because the resulting area margin would be too large. Fouling factors for PHEs are typically only 10–25% of those for S&T heat exchangers of the same service. Alternatively, a fouling margin F_m can be specified, and is defined by Equation (22). Typically, a minimum of 10% fouling margin should be specified.

$$F_m = (U_{cl}/U_f - 1) \times 100 \quad (22)$$

Understanding the effects of fouling on PHE design is crucial. This is why the heat duty must be calculated for both clean and fouled conditions, as shown in Equations (23) and (24). Note that a PHE design is acceptable when $Q_{cl} > Q_c$ (= Q_h) and $Q_f > Q_c$ (= Q_h), where F is a correction factor applied to the $LMTD$. F is equal to one when flow is countercurrent.

$$Q_{cl} = U_{cl}A_eF(LMTD) \quad (23)$$

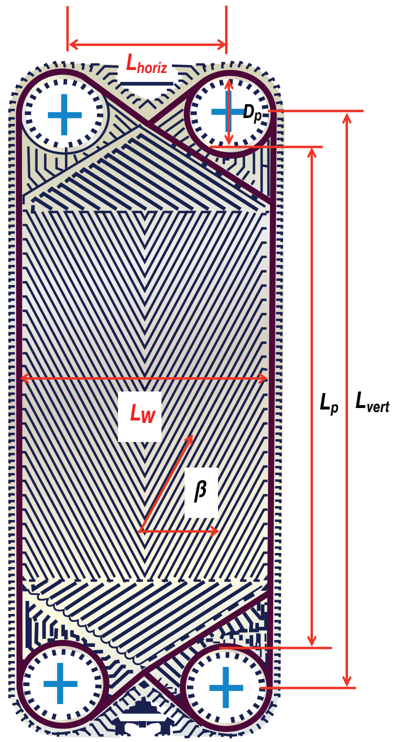


FIGURE 4. **The gasket is installed in the groove near the edge of each plate**

$$Q_f = U_fA_eF(LMTD) \quad (24)$$

Finally, equations (25) through (29) deal with pressure-drop calculations in a PHE. First, the Fanning friction factor is defined in Equation (25), where K_p and m are found in Table 10.6 in Ref. [*1*]. The friction factor is crucial in determining the pressure drop in the channels, which is defined by Equation (26).

$$f = K_p/Re^m \quad (25)$$

$$(\Delta p_{ch}) = 4f(L_{vert}N_{pass}/D_e)(\rho V_{ch}^2/2) \quad (26)$$

Equations (27) and (28) relate to flow at the port. Equation (27) defines the fluid velocity through the port and Equation (28) defines the pressure drop at the port.

$$V_p = (W/\rho)/(\pi D_p^2/4) \quad (27)$$

$$(\Delta p_p) = (1.4N_{pass}\rho V_p^2/2) \quad (28)$$

Finally, we arrive at the total pressure drop, shown in Equation (29), which is the sum of the pressure drop at the port and the channel pressure drop.

$$(\Delta p_t) = (\Delta p_c) + (\Delta p_p) \quad (29)$$

TABLE 3. PROCESS SPECIFICATIONS FOR A GIVEN PHE		
Parameter	Hot side	Cold side
Process fluid	Hot oil	Cold water
Mass flowrate, W, kg/s	140	130
Inlet temperature, T_1, t_1, °C	85	20
Outlet temperature, T_2, t_2, °C	45.0	41.5
Max allowable Δp, bars	3	3
Specific heat, C_p, J/kg-K	2,089	4,178
Viscosity, μ, N-s/m^2	5.11×10^{-4}	7.68×10^{-4}
Thermal conductivity, k, W/m-K	0.190	0.616
Density, ρ, kg/m^3	950	995
Prandtl number, Pr	5.618	5.210
Fouling margin, F_m (%)	10	10

TABLE 4. VENDOR'S PROPOSED PHE DESIGN (BASED ON 304 STAINLESS STEEL)	
Parameter	Value
Plate thickness, t, mm	0.6
Chevron angle, β, deg	45
Total number of plates, N_t	105
Enlargement factor, ϕ	1.25
Number of passes, N_{pass}	1
Overall heat-transfer coefficients, U_{cl}/ U_f, W/m^2-K	3,520/3,200
Total effective heat-transfer area, A_e, m^2	110
Port diameter, D_p, mm	200
Compressed plate pack length, L_c, m	0.38
Vertical port distance, L_{vert}, m	1.55
Horizontal port distance, L_{horiz}, m	0.43
Effective channel width, L_w, m	0.63
Plate thermal conductivity, k_w, W/m-K	17.5

Design example

The design method derived in the previous section will now be applied in an example scenario to confirm a vendor's design. In this example, cold water is to be heated by a hot oil stream in a PHE. Using the process specifications in Table 3 and the vendor's proposed design in Table 4, we can use Equations (1) through (29) to determine if the proposed exchanger satisfies the design requirements. Table 5 gives a summary of the calculation results using the previously derived design methodology. It can be seen from Table 5 that the proposed design is expected to achieve its desired heat transfer and not exceed the allowable pressure drop. However, it can be determined from the discrepancies between the proposed and the calculated values for the overall heat-transfer coefficients that the vendor's design (based on a proposed heat-transfer area of 110 m^2) is oversized for this service and can be further optimized to reduce costs.

Best practices

Design and installation. In addition to sizing a PHE, it is also beneficial for engineers to understand some practical considerations in the purchasing and installation of PHEs. A summary of best practices for installing PHEs is as follows:

- The frame and tie bolts of a PHE should be designed to permit future installation of at least 20% additional plates
- The nominal thickness of gasketed plates should be a minimum of 0.5 mm to meet design conditions. Gasketed plates shall be individually replaceable without removing any other plate
- The PHE must be designed to withstand the design pressure of each side when the pressure on the other side is atmospheric pressure, or vacuum, if specified. Thus, either hydrotest or pneumatic pressure tests can be undertaken on only one side at a time, with the other side at atmospheric pressure or vacuum
- A corrosion allowance shall be applied to unlined connections only, and there is zero corrosion allowance for plates
- Gaskets should be positioned in the groove around the heat-transfer surface
- Gaskets should be compressed to achieve metal contacts between the plates
- Each sealing gasket should be one integral piece to allow for better pressure resistance

Specifying and purchasing. Despite the dependence on vendors to provide PHEs, an understanding of PHE design data is crucial to purchasing engineers. For proper PHE design, the purchaser should specify the following design data to be provided by vendors:

- Completed datasheets
- Details of the construction and assembly
- Anticipated life of the gaskets in the specified service and in storage, and special storage guidelines, if needed to maintain gasket life
- The method used to support the removable cover
- Recommended spare-parts list
- Fireproof testing certificate for a fireproof shroud, if specified
- Verification of compatibility of the gasket material and glue with the specified fluids, including any specified chemical cleaning

Problems with very large PHEs

There are some hidden structural constraints that often cause problems with the use of PHEs. These structural issues are especially concerning when manufacturers offer very large equipment to purchasers. The constraints in question are the total number of plates used and the total weight of the plate pack assembly.

In a normal flanged joint, the stud bolts used to clamp the joint must be properly torqued to provide sufficient clamping force, giving the gasket the adequate seating stress to seal the internal pressure. With the required clamping force, the bolt stress will also be an ac-

TABLE 5. SUMMARY OF CALCULATION RESULTS			
Variable	**Equation**	**Calculations**	**Value**
Q_h	(1)	140 × 2,089 × (85–45)	11,698.4 kW
Q_c	(2)	130 × 4,178 × (41.5–20)	11,677.5 kW
LMTD	(3)	((85–41.5) – (45–20))/ln((85–41.5)/(45–20))	33.4°C
Heat balance: Q_h is within 1% of Q_c → Good			
N_e	(4)	105 – 2	103
p	(5)	0.38/105	0.00362 m
b	(6)	0.00362 – 0.0006	0.00302 m
L_p	(7)	1.55–0.20	1.35 m
L_w	(8)	0.43 + 0.20	0.63 m
A_{ch}	(9)	0.0030 × 0.63	0.00190 m^2
A_1	(10)	110/103	1.068 m^2
A_{1p}	(11)	1.35 × 0.63	0.85 m^2
ϕ	(12)	1.068/0.85	1.256
D_e	(13)	2 x 0.00302/1.256	0.00481 m
N_{cp}	(14)	(105–1)/2(1)	52
$m_{ch,h}$	(15)	140/52	2.69 kg/s
$m_{ch,c}$	(15)	130/52	2.50 kg/s
$V_{ch,h}$	(16)	(2.69/950)/0.00190	1.49 m/s
$V_{ch,c}$	(16)	(2.5/995)/0.00190	1.32 m/s
Re_h	(17)	950 × 1.49 x 0.00478/0.000511	13,320 (turbulent)
Re_c	(17)	995 × 1.44 x 0.00478/0.000768	8,230 (turbulent)
$(hD_e/k)_h$	(19)	From Table 10.6 in [1], at β = 45 deg and $Re > 100$, $C_h = 0.3$, $n = 0.663$ Assume $\mu_b = \mu_w$ → $0.3 \times (13{,}320)^{0.663}(5.618)^{1/3}$	289.4
h_h	(19)	289.4 × 0.190/0.00481	11,436 W/m^2-K
$(hD_e/k)_c$	(19)	$0.3 \times (8{,}230)^{0.663}(5.21)^{1/3}$	205.1
h_c	(19)	205.1 × 0.616/0.00481	26,272 W/m^2-K
U_{cl}	(20)	1/(1/11436+0.0006/17.5 + 1/26272)	6,258 W/m^2-K
U_f	(22)	100%/(100%+10%) × 6258	5,689 W/m^2-K
F		F = 1 for true countercurrent flow	1
Q_{cl}	(23)	6,258 × 110 × 1 × 33.4	22,993 kW
Q_f	(24)	5,689 × 110 × 1 × 33.4	20,903 kW
Heat transfer results: U_{cl} and U_f are greater than the vendor's proposed values → Good			
Q_{cl} and Q_f are greater than the required heat duty of 11,698.4 kW → Good.			
f_h	(25)	From Table 10.6 in [1], K_p = 1.441, m = 0.206 → $1.441/(13320)^{0.206}$	0.204
$(\Delta p_{ch})_h$	(26)	4 x 0.204 × (1.55 × 1/0.00481) × (950 × 1.49^2/2)	276,989 Pa
$V_{p,h}$	(27)	(140/950/($\pi(0.2)^2$/4)	4.69 m/s
$(\Delta p_p)_h$	(28)	1.4 × 1 × (950 × 4.69^2/2)	14,633 Pa
$(\Delta p_t)_h$	(29)	276,989 + 14,633	291,622 Pa (2.92 bars)
f_c	(25)	$1.441/(8230)^{0.206}$	0.225
$(\Delta p_{ch})_c$	(26)	4 × 0.225 × (1.55 × 1/0.00481) × (995 × 1.32^2/2)	251,810 Pa
$V_{p,c}$	(27)	(130/995/($\pi(0.2)^2$/4)	4.16 m/s
$(\Delta p_p)_c$	(28)	1.4 × 1 × (995 × 4.16^2/2)	12,046 Pa
$(\Delta p_t)_c$	(29)	251,810 + 12,046	263,856 Pa (2.64 bars)
Pressure drop results: $(\Delta p_t)_h$ and $(\Delta p_t)_c$ are less than 3 bars → Good			

ceptable value. With this principle, for the same internal pressure and the same type and size of gasket, the flanged joint with two gaskets would need more clamping force than the joint with a single gasket — this means that the total number of bolts will have to be increased to result in that same bolt stress. The softer gasket (the one with a lower gasket factor) would normally need less clamping force than the harder one. With the rubber gaskets typically used in PHEs, it is easier to provide a small clamping force and properly torqued tie bolts.

However, if a large number of plates is present, an even higher number of tie bolts (and a larger total bolt cross-sectional area) would be required. A large number of small tie bolts will give a more uniform gasket pressure and result in much better sealing performance than a small number of large bolts having the same bolt total cross-sectional area.

In one case, a manufacturer designed a PHE with 500 plates assembled into one pack. This makes it extremely difficult to have all 500 gaskets properly compressed to seal the internal pressure of the process — no matter the torque value or number of tie bolts, and even though the manufacturer applied an ample amount of adhesive to the gasket to provide the seal. Bear in mind that the total weight of the entire plate assembly is hanging on the carrying bar. The higher the number of plates used, the heavier and longer the plate assembly is, imposing an even greater weight on the bar, which acts as a uniformly distributed load beam. According to the beam theory, the deflection of the beam varies linearly with the load and with the cube of the beam length. This makes the plate assembly more susceptible to leakage, especially at its bottom. Therefore, the purchaser should ensure that the PHE is not too large, and take careful consideration in confirming the total number of plates in the assembly. Understanding the advantages and disadvantages of PHEs and S&T heat exchangers allows for more efficient designs for heat-exchange systems. Even though PHE design remains proprietary to vendors, plant engineers should be able to evaluate a vendor's PHE design for correctness using the methods explained above. ■

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FIRED HEATERS: Best Practices for the Control of Fuel Gas

Adopt these practices to ensure new project success, and to achieve safe control and reliable, efficient operation going forward

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Consultant

Large petroleum-refining complexes often have dozens of fired heaters, making broad-based competency in this area essential to overall reliability, safety and energy efficiency. Despite industry's widespread familiarity with fired heaters, they continue to pose significant challenges during initial control-system design and unless properly specified, operated and maintained, fired heaters can hinder good control and reliable operation going forward.

All fuel-gas-fired heaters have basic features in common, but no two applications are exactly the same, and an industry best practice for fuel-gas control has never emerged. Even one of the most basic questions — whether to use fuel-gas-flow control or pressure control — remains open, with little industry guidance available. A helpful approach to move toward industry standardization is to identify the most common and successful practices based on current technology and experience, for use as a design starting point and a reference point.

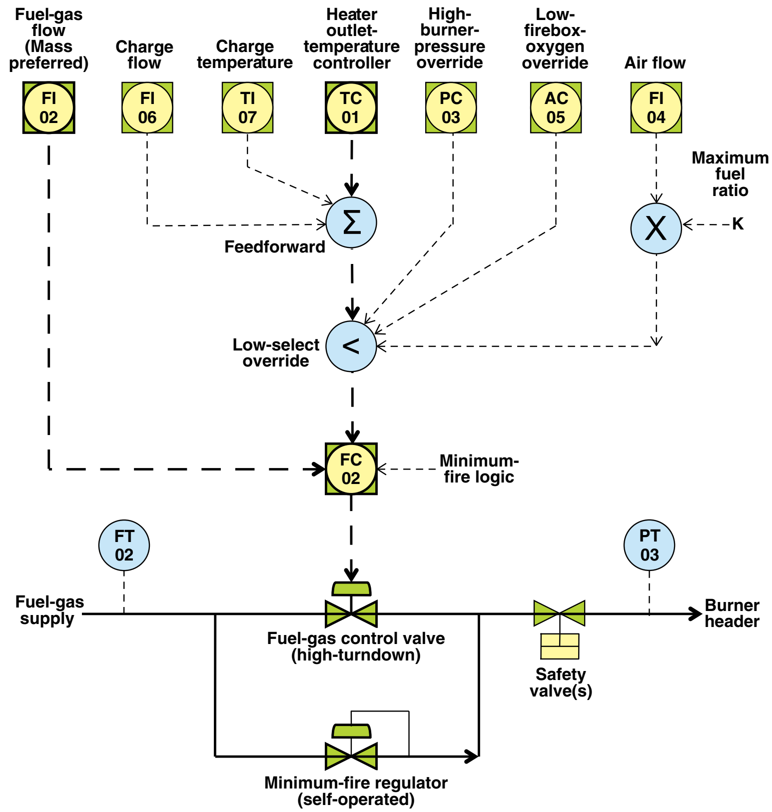

FIGURE 1. This figure provides a starting point for the design of fuel-gas control for fired heaters. The temperature-control elements and fuel-gas-flow cascade are shown in bold. Other items are optional, depending on the heater type and performance objectives

Figure 1 provides a proposed starting or reference point for fuel-gas control-system design for fired heaters. This figure encompasses some areas of judgment and compromise, and not everyone will agree with all aspects of it. In my professional experience, I have found that most sites tend to be strongly disposed toward the local practices they are familiar with. But based on a career of sorting through both new project designs and ongoing operational issues, the findings summarized in Figure 1 provide a high-value starting point, and in many cases a viable finishing point, for the design of many fired-heater, fuel-gas control systems.

Essentially all heater fuel-gas control systems have at their core a heater-outlet temperature controller that is cascaded to either a fuel-gas flow controller or a pressure controller. This is highlighted in Figure 1. All other control components in Figure 1, such as the overrides and feedforwards, are optional

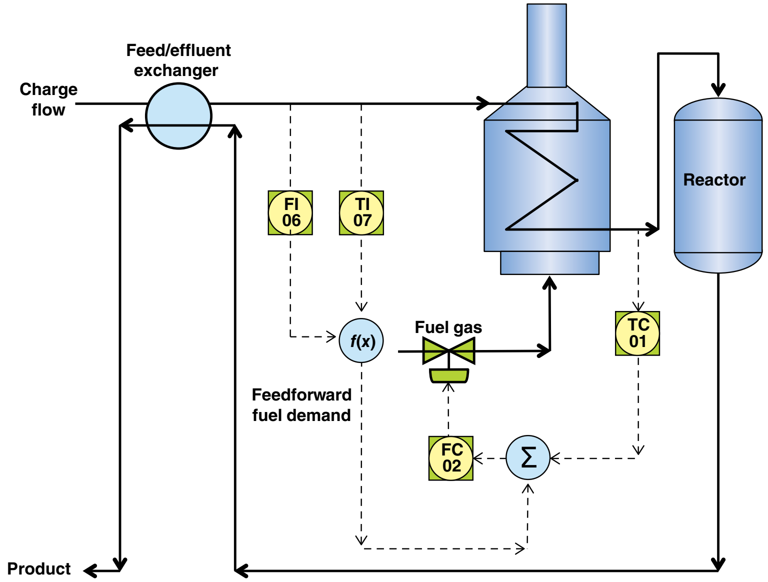

FIGURE 2. A strategy for hydrotreater temperature control is shown here. Feedforward elements proactively handle changes in feed flow and temperature, especially those resulting from process interaction of the reactor and feed/effluent exchangers

and will vary with each heater application, depending on the heater type and performance objectives.

Pressure versus flow control

As API Recommended Practice 556 (API556)* points out, one basic difference between fuel-gas pressure control and flow control is the dynamic response that occurs when adding or removing burners. With flow control, when adding a burner, the pressure will drop, potentially causing a heater trip on low burner pressure. With pressure control, when adding a burner, flow will increase, potentially causing a high-temperature spike.

But this is only half of the story. With flow control, the flow controller will normally restore proper flow in a matter of seconds. Thus, assuming a low-pressure trip is avoided, heater stability is minimally disturbed. But with pressure control, the increase in flow can be substantial, and it is corrected not by the relatively fast pressure controller, but by the relatively slow temperature controller, and this normally takes several minutes. This can introduce a very large temperature excursion, making pressure control highly problematic in applications where operation is near critical metallurgical or process temperature limits, or on processes such as hydrocracking heaters, where the temperature spike could trigger a runaway reaction.

A second area of concern regarding flow versus pressure control has to do with the stability of control during low-firing or startup conditions. The conventional thought is that pressure control is more stable under low firing conditions. For example, API556 suggests that one option is to use pressure control for startup and then switch to flow control after reaching operating conditions. But the quality of modern instrumentation has changed this situation, so today, in most cases, flow control not only performs better at operating conditions, but it is also more stable under low-firing conditions and under load changes and other disturbances.

Traditional instability of flow control during startup or low-firing conditions stems from old-style control valves and orifice-type flowmeters, which are notoriously and inherently unstable under low-flow conditions. Modern high-turndown valve designs with sturdy and precise electronic positioners, combined with high-turndown flowmeters, such as vortex or mass meters, make flow control as stable as pressure control under low firing conditions. Traditional globe-valve and orifice-meter turndown ratios are 3:1, while modern designs achieve 10:1 or even 100:1. And because flow control lends itself to more precise tuning, flow control is arguably more stable than pressure control. Pressure controllers are known to require de-tuning for startup conditions, while flow controllers are not (in the author's experience).

A third area of performance difference between flow control and pressure control is precision of tuning. Not only is flow control easier and more accurate to tune compared to pressure control, but the temperature controller itself can also be more precisely tuned when using flow control, rather than pressure control, as the cascade secondary control loop. It is straightforward to analyze a historical dataset in a spreadsheet and arrive at a very reliable value for the amount of fuel gas flow that is needed to raise a given heater charge flowrate by a given number of degrees. This provides a nearly perfect gain parameter for the temperature controller (especially if a mass flowmeter is used). The same cannot be said for pressure control, where the amount of flow for a given burner pressure depends upon, among other things, the number of burners currently in service.

By the same token, flow control lends itself to the accurate application of feedforward, which is effective in eliminating control variance in the heater-outlet temperature caused by changes in the charge rate or temperature. Feedforward is especially effective in breaking the interaction that occurs in many processes, such as hydrotreaters, that

* API Recommended Practice 556, Instrumentation, Control, and Protective Systems for Gas Fired Heaters, American Petroleum Inst., Second Ed., April 2011.

have feed-effluent heat exchangers. In this case, the temperature controller is tuned for heater response in the "minute" domain, but the feed-effluent feedback loop can be in the "hour" domain, which often results in large sustained temperature oscillations after an initial disturbance, such as an abrupt change in charge rate or to a more exothermic hydrotreater feed. Figure 2 depicts a hydrotreater process with feedforward control action to eliminate this type of temperature feedback cycle.

The main advantage of pressure control over flow control is that, with pressure control, setpoint limits can be directly configured to help prevent heater trips caused by low- or high-pressure conditions in the burner. This is a potentially important advantage, but overall it probably does not outweigh the several ongoing performance advantages of flow control. A compromise, increasingly popular today as a result of the ongoing emphasis on safety systems, is to use a combination of flow control with pressure overrides. This is also mentioned in API556, but in practice this approach has some drawbacks. In particular, it is inherently hazardous to put a low-pressure override (high selector) on fuel gas. Also, this solution is problematic from a DCS configuration and operational standpoint (see the discussion of "override placement" below). Moreover, a low-pressure override is unnecessary if a minimum fire regulator is used (see "minimum fire" below).

Mass versus volumetric flow

Traditionally, fuel-gas flow is measured with an orifice plate, using volumetric units of standard cubic feet per hour (std. ft^3/h). This has also been a traditional limitation, because the heating value of fuel gas commonly varies by as much as 700–1,500 Btu/std. ft^3, due to varying amounts of hydrogen and heavier hydrocarbons, such as propane and butane, which often enter the fuel gas system in bursts, sometimes upsetting every heater in the refinery. Many refineries have installed analyzers to monitor fuel-gas heating value to understand the problem, but such analyzers are too slow to be used in actual heater temperature control, so the difficulty has persisted.

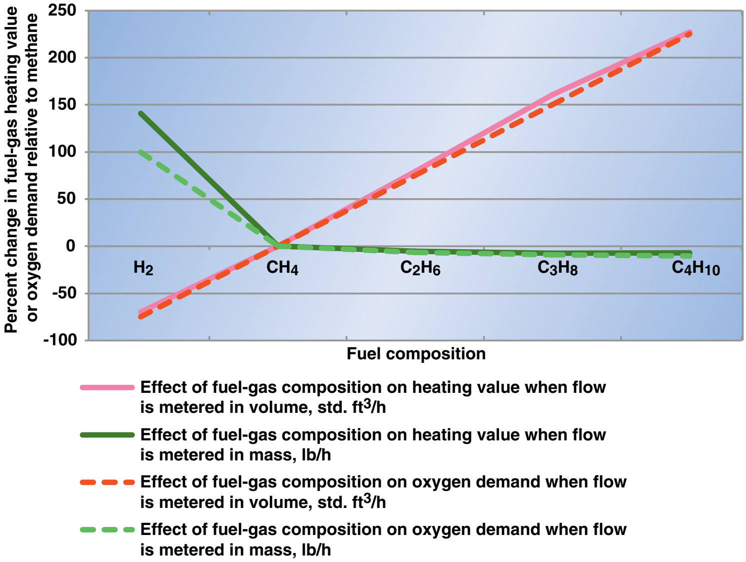

FIGURE 3. The effect of varying fuel gas composition on heating value (akin to temperature control) and on oxygen demand (akin to fuel/air limiting) is shown here for mass versus volumetric flow. The curves are nearly completely flat (not sloped) when fuel gas is metered in mass units, although large changes in hydrogen content can still pose a non-linearity

A good solution based on today's technology is to measure fuel gas flow with a mass flowmeter, such as a Coriolis meter, as mentioned in API556. Modeling fuel gas as a mixture of hydrogen, methane, ethane and propane, Figure 3 illustrates that heating value varies enormously with composition when metered volumetrically, relative to methane. But the heating value is essentially flat for variations in hydrocarbons when metered in mass, although there is still a strong nonlinearity due to hydrogen. (Volumetrically speaking, for an ideal gas, atoms of each type are equivalent, while from a mass standpoint, each atom's heating value is roughly proportional to its molecular weight; hydrogen has a disproportionately high heating value for its small weight.)

The dashed lines in Figure 3 show the effect on oxygen demand (as opposed to heating value). For fuel-to-air ratio limiting, when fuel gas is metered in mass, a single ratio setting can be effective over the full operating range of fuel gas conditions. This complication (the lack of a single valid setting when fuel gas is metered volumetrically) has traditionally limited and usually completely defeated the use of this essential safeguard on balanced or induced-draft heaters. But with mass metering of the fuel gas, a single "set and forget" ratio setting can be employed, resulting in a highly reliable and available safeguard. As Figure 3 shows, where sudden high levels of hydrogen are possible, arriving at an optimum universal setting may still pose a concern, but for variations due to hydrocarbon species and normal or small amounts of hydrogen, mass metering overcomes this traditional limitation to this important safeguard.

Readers should note that limiting the maximum fuel-to-air ratio is the "important half" of full-blown air/fuel cross-limiting, which is common on fired boilers and in the power-generation industry, but is usually considered unnecessary and impractical on simpler fired heaters, and in applications that may have dozens of such heaters, as opposed to a single power boiler.

Overrides (and their placement)
Figure 1 shows three of the most common and high-utility fuel-gas-control overrides. The low-oxygen override responds to fuel-gas flood conditions or potentially to other fuel or air supply faults, depending on the type of heater draft, and is especially important where other excess air controls are absent or may not always be in normal mode. (The low-oxygen override should not be mistaken with excess oxygen control, as this latter option, when used, is applied to air flow or heater draft controls, rather than the fuel-gas controls.) The high-burner-pressure override, like low-pressure protection, is finding increased use due to modern focus on safety systems.

As important as which overrides are employed in each application, is where they are placed, in terms of both the control strategy design and the DCS graphics presentation. For instance, the low-select override in Figure 1 is purposefully placed above the gas flow controller. Moreover, there is no compelling reason to show most overrides, feedforwards, or other control enhancements, on the Level 2 (operating) DCS graphic. In this way, the core concept of temperature cascaded to flow remains intuitive on the DCS graphic and operators see clearly how to take direct control of the valve when necessary, without the need for heater-specific training or the potential for mis-operation. The override setpoints can be connected to their alarm or alert settings so that operators are informed whenever an override becomes active, and to navigate to the Level 3 (detail) heater display, which would include the full control strategy representation, similar to Figure 1 or Figure 2.

The use of a framework such as this — in terms of appropriate override placement within the control strategy design and DCS graphics presentation — is often missing, but it is a much-needed industry best practice. Current habits across industry tend to be much more random, often to the point of creating potential hazards. What happens too often is that overrides are placed below the base-layer controller, or some are placed above and others below, and all are shown in careless arrangement on the DCS graphic. For the operator, this can result in a confusing puzzle that is prone to misunderstanding and mis-operation, rather than as an intuitively obvious heater-temperature-control standard practice. Operator interviews during heater-incident investigations frequently reveal feedback about such "confusing" control configurations and graphics.

The DCS control configuration itself can also create override potential hazards when multiple selectors are introduced into the control design. Correct functionality becomes dependent on a number of DCS configuration parameters that historically are unsecured — that is, are not addressed in management-of-change procedures and may be routinely changed by control engineers or even operators. Not only does this present the DCS console operator with an array of choices for taking direct control of the fuel-gas valve, but each choice may function differently (or not at all) depending on the current state of the others. This also creates a hazardous situation. Intuitively obvious and operable controls should be a high-priority criteria in any control design, especially something as critical as fuel-gas control for fired heaters.

Preventing burner trips
In Figure 1, the minimum-fire self-operated regulator should not be mistaken with the past practice of installing a restriction orifice around the control valve to provide the right amount of stable flow for initial burner light-off, although the regulator does serve this purpose, as well as two others, in a simple and reliable manner.

The minimum-fire regulator also protects against trips resulting from low burner pressure, by having a setting slightly above the trip threshold. This replaces the need for a low-pressure override control and its attendant problems, while at the same time physically limiting the amount of flow the regulator could potentially deliver in the event of regulator failure (in addition to the pressure setting, the regulator orifice size and maximum flow are sized similarly to the traditional restriction orifice). Optionally, the minimum-fire regulator can be supplied by natural gas, rather than by fuel gas, to assure clean and reliable operation This concern is mentioned in API556. It is also worth noting that under ongoing operation, the regulator will remain fully closed, so that relatively expensive natural gas is not continuously consumed.

A third purpose of the regulator is to facilitate easy implementation of minimum-fire trip logic. Minimum-fire trip logic is initiated when process heat needs to be removed, but there is no integrity issue with the heater itself. By tripping to minimum fire, rather than completely tripping the heater, burners will be maintained and restarting is greatly simplified. This can have substantial economic and safety benefits and is a widely under-utilized technique in industry to avoid full heater trips. With a minimum-fire regulator in place, tripping to minimum fire is easily accomplished by soft-tripping the control valve, which is a built-in function in most of today's DCS control systems. ■

Edited by Suzanne Shelley

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Three Insights for Managing Legacy Data

Safety, maintenance and acquisitions efforts demand rigorous engineering due diligence and access to complete, accurate engineering information

Jamie Flerlage
Intergraph Corp.

Existing chemical process industries (CPI) facilities possess years, if not decades, of legacy engineering information. The data exist in a myriad of formats and are typically siloed across multiple systems and locations. In cases where the engineering data are either lost or damaged, undocumented, or limited to the institutional knowledge of the local operations team, control documents related to piping and instrumentation diagrams (P&IDs), equipment data sheets, and maintenance or inspection documents, rarely reflect the as-built state of the asset.

Delays associated with finding accurate, usable engineering information can cripple management's ability to make the most timely, cost-effective decisions. As a result, information-intensive operations — such as process hazard analyses, regulatory audits, due-diligence efforts required for acquisition activities, unplanned shutdowns, catastrophic events, and insurance-validation exercises — are exacerbated by inaccurate engineering information. This can lead to scheduling delays, added labor costs, human error, potential fines and lost production.

This article offers three recommendations to help engineering and operations stakeholders manage legacy engineering data in existing facilities.

A three-step approach

1. Capture and centralize both physical and digital P&IDs and datasheets. An important first step to capturing and centralizing legacy engineering data is determining where the data "live" for any given asset. The data will most likely reside in two forms: physical and digital. For microfilm, paper or photographs, management should agree on a standard means of digitizing the information and then invest the time and effort to convert relevant input data to a ubiquitous format (for instance, PDF). Many organizations choose to scan these documents into a central repository and output the results in an OCR-compliant format (OCR = optical character recognition).

FIGURE 1. As-built engineering information, like this P&ID handwritten on an I-beam, is often locked up as part of the institutional knowledge of the plant's operations team. To mitigate the numerous risks posed by unstructured information, invest the time and effort needed to capture, centralize and digitize your relevant, authoritative data sets

Once the physical data are captured, owners should shift their focus to collecting and consolidating all digital forms of engineering data that may exist throughout the facility, such as P&IDs, 3D models, laser scans, Microsoft Word and Excel documents and PDFs. If future plans call for the ability to intelligently link supporting documents (such as process data sheets, instrument and equipment data sheets, vendor data and more) to the P&IDs, be sure to include the latter in this data-capturing phase.

To automate the data collection and organization processes, use a commercial, off-the-shelf (COTS) software solution that consists of pointers and search technologies that can be used to search workstations, servers and document management systems by file type, extension or name. Realize that with document management systems, the cabinet-folder-file paradigm is susceptible to duplicates, mis-filings, inaccuracies and missing documents. You can mitigate these issues later on by identifying the master documents, but only after all the data has been captured and centralized.

2. Identify authoritative or near-authoritative P&IDs and related information. Once the data have been captured and centralized, local operations teams can begin the process of identifying authoritative drawings and their associated documents. Most owner-operators focus on the integrity of the P&IDs and using a combination of automated COTS solutions and visual inspection, owners can qualify and compare P&IDs for inconsistencies and eliminate duplications (For more on P&IDs, see *Chem. Eng.*, April 2014, pp. 62–71).

It is possible that some of these data sets may be categorized incorrectly, due to missing data, human error or outdated information. Be-

FIGURE 2. A portal-centric, dashboard interface that offers a visual representation of the P&IDs, laser scans and document management, lowers training and administration costs and can facilitate rapid user access and acceptance

fore the organization stumbles upon one of these data sets, it should establish decision criteria that will predetermine whether or not the gaps in information need to be filled. If the missing data elements need to be redlined, reworked or recreated, ensure that current engineering standards and naming conventions are incorporated into the changes, to harmonize the captured data.

For many organizations, an automated solution for querying, compiling and reviewing legacy engineering information does incur costs, but it also incurs a substantial return on investment. Be sure to ask your vendor to identify reuse scenarios (such as acquisition due diligence) to help you justify the project. To improve overall communication and project management, consider offering key stakeholders — including your partners, engineering, procurement and construction (EPC) contractors and internal support organization — access to this repository via a secure Internet portal.

3. Build intelligent, tag-centric images and P&IDs that enable document linking. Legacy engineering information that has been centralized, virtualized and sanitized, becomes increasingly valuable to asset-management teams, engineering managers, and safety and maintenance planners. The data collected thus far should be representative of the current operating configuration and should accurately reflect the state of the asset.

At this point, owners can use a COTS solution to automate the creation of intelligent, object-oriented, tag-centric P&IDs, laser scans or images (Figure 2). These solutions usually include functionality for enabling the inclusion of hotspots (underlying software code that enables multiple documents to be related) within the P&ID or scanned image, thus allowing the knowledge worker to link these hotspots to related documents used by operations, maintenance, safety and procurement teams.

Today's software solutions offer standalone platforms that can help to not only organize the data, but also integrate the digitized data into existing engineering data management (EDM) solutions. For maximum flexibility, owners should focus their attention on vendor-agnostic software systems that offer multi-format data interoperability and integration. If system integration is warranted, align the solution architecture with solutions that enable automated change management and avoid egregious (and expensive) customization.

Leverage business intelligence

The engineering information associated with an existing facility has "lived" within that particular plant and its operations team for years. As the organization builds its plant information-management strategy, it should involve the onsite engineering knowledge of workers early on in the initiative, and conduct interviews with the IT staff, to compile a detailed picture of systems — both commercial and homegrown — to determine the appropriate integration scenarios for maintenance and operations systems, and to reduce the need for in-depth customization wherever possible.

The spectrum of information for a given plant or facility, once organized, centralized and quality-controlled, can be more easily accessed, and thus reused and repurposed throughout the life of the asset. By capturing the legacy engineering information for a brownfield asset or fleet, management will possess a valuable new source of business intelligence that can be used to unite partners and EPC firms, control costs, improve project performance, mitigate regulatory non-conformance and improve operational effectiveness. ■

Edited by Suzanne Shelley

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Plan and re-plan

FRI is lucky to have survived a simple valve-tray project. A few years ago, the low-pressure (LP) test column stood empty, because there were no trays ready to be installed. The intention was to install a set of new valve trays of a very simple design, but when the column was empty, neither a design nor the actual trays existed. It took five months for the trays to be designed, drawn, fabricated, shipped, received and installed. For five months, the FRI membership received no data. In retrospect, those trays should have been designed at least six months ahead of the projected installation date. In retrospect, FRI had not planned.

In March of 2013, the FRI long-range test plan was reviewed by the staff. A huge gap was identified. From January to June of 2014, FRI had nothing to test, while the second half of 2014 was fully booked! At the Technical Committee (TC) meeting, the plan gap was brought to the attention of the members. A list of project possibilities was broached. Following a long discussion, the TC recommended a project to determine the liquid-distributor pour-point requirements of large-surface-area structured packings. Thereafter, following a month of careful project considerations, in July, packings and distributors were ordered. That equipment was delivered to our Stillwater, Okla. location in time for a January 2014 installation. The FRI staff had planned!

Looking back, many small and large projects were fully planned for the recent May 2013 turnaround.

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

One of those projects was the installation of two windows on the LP kettle reboiler. Early during the turnaround, a section of the kettle was stripped — the amount of surface rust was surprising. Ultrasonic thickness (UT) readings had been inconsistent. The kettle was entered and numerous small erosion and corrosion dimples were found. The kettle plan needed re-planning. Ultimately, input was sought from 21 different non-FRI consultants including the following: UT technicians, weld-overlay workers, corrosion specialists, heat-exchanger manufacturers, safety professionals, experienced plant-maintenance technicians, an authorized inspector of pressure vessels and Oklahoma's highest-ranking pressure vessel inspector. *Every* Stillwater employee assisted with the re-planning. Ultimately, weld-overlay work was performed in the LP kettle, the four main heat exchangers were stripped and painted, two old nozzles were changed and the system was successfully hydro-tested at 150 psi. The LP kettle shell will be changed in 2014, as a result of the re-planning.

Late during the 1970s, a large electrical company executed a plan and built a huge manufacturing building south of Batavia, N.Y. Before the plant was occupied, that company re-evaluated the original plan. Global and market situations had changed during the two years in which the plant was being built. The company executives bravely decided to walk away from the new building. The re-plan yielded a conclusion opposite to that of the original plan.

Woody Allen is credited with saying, "If you want to make God laugh, just tell him about your plans." Do not be over-influenced by Allen. Plan and re-plan — or perish. ■

Mike Resetarits

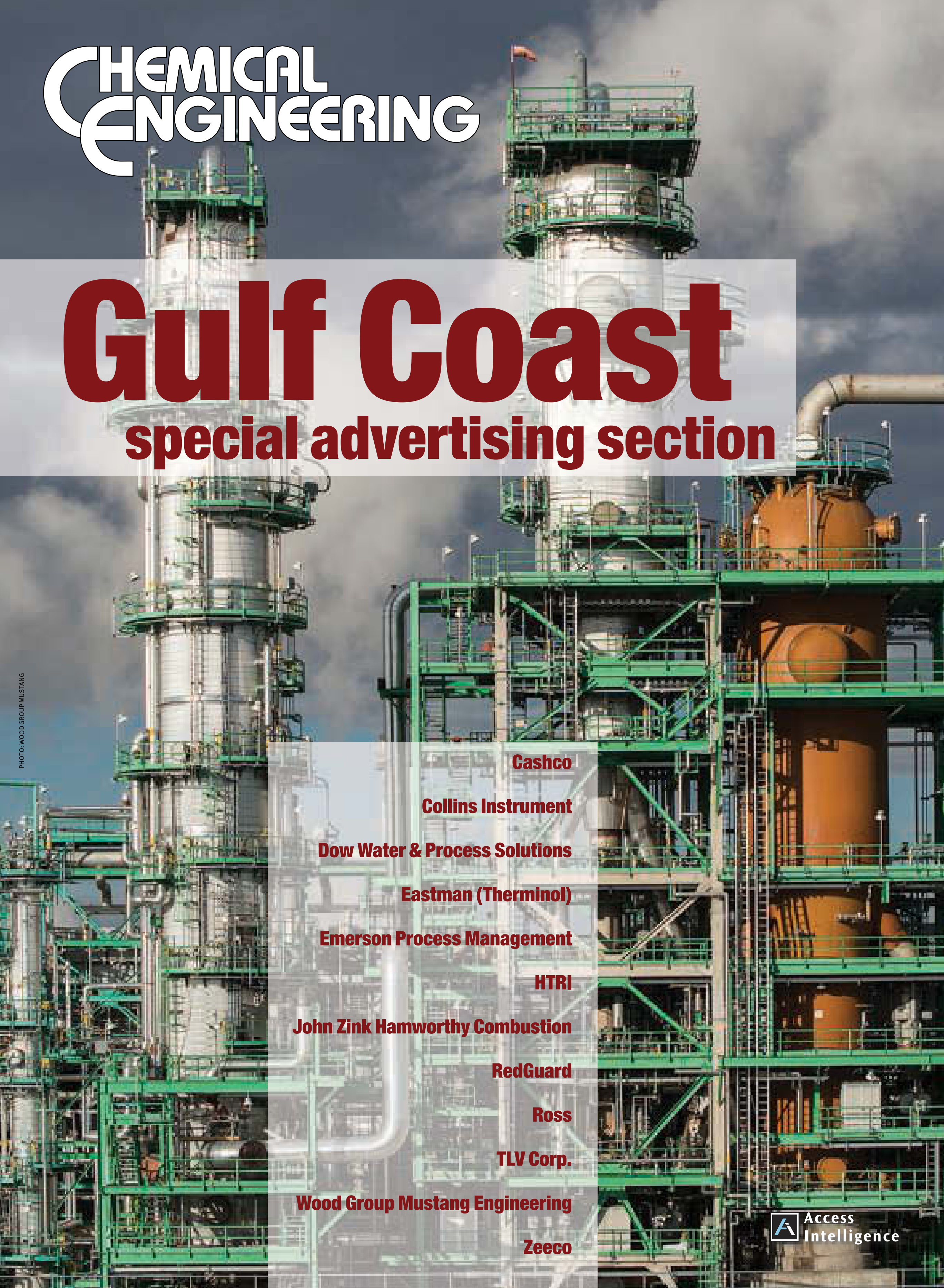

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PHOTO: WOOD GROUP MUSTANG

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Not all blast-resistant buildings are created equal

RedGuard is the only manufacturer to have successfully blast tested its blast-resistant buildings to meet a low or medium response rating, says Dr. Ali Sari, PE

My team was called in to investigate the Texas City, Texas, refinery disaster in 2005. The wood-frame office trailers at the site had been reduced to splinters, and 15 people had died in and around them. I thought to myself, there has to be a better way.

Around the same time, ConocoPhillips approached **RedGuard**, a Kansas-based company that had been supplying ConocoPhillips with ground-level offices, to ask if the company could build a more rugged office design to protect personnel in a blast zone. RedGuard contacted me, and we set out on a mission to save lives.

There were other companies selling blast-resistant buildings, so the first step was to research their products. I was surprised to learn that no testing had been done on these designs, so no one really knew how they would stand up in a blast. I was even more alarmed to learn that every blast-resistant building on the market was designed to hold together as a structure but gave little attention to protecting the personnel inside. Some petrochemical plants were buying them based on interior amenities like attractive lighting fixtures and even glass mirrors in the restrooms, which could injure or kill personnel in a blast. This is still true of many blast-resistant buildings being sold today.

The unit was designed, built, and then RedGuard did something unprecedented in the field of blast-resistant buildings – they tested it. If you like to watch Hollywood-quality explosions, visit redguard.com/blast-tests. It speaks for itself, in terms of the product's ability to survive a close-proximity explosion.

RedGuard: safety from explosions proven through field tests

What you don't see in the video is the most important part of the process. When tested, it wasn't just an empty structure. Lights, furniture, office equipment and a test dummy were added, then hit with 1,250 lb. of ANSI high explosive. The building moved less than two inches and suffered no structural damage. The same was true of the test dummy. With designs like these available today, there never has to be another "deadly refinery disaster."

www.redguard.com

A classic mixing tool for the petroleum industry

Ross LPD Static Mixers are rugged, reliable devices for inline mixing at minimal pressure loss

Ross Low Pressure Drop (LPD) Static Mixers are used throughout the oil and gas industry for turbulent-flow mixing applications. These heavy-duty low-maintenance devices serve in continuous operations where high performance and accuracy are required, such as on-line water determination of crude oil; dosing of various additives into gasoline; blending different kinds of fuel oils; gas-gas blending; and pipeline reactions, among others.

Shown are removable LPD mixing elements supplied with a retainer ring which goes between two mating flanges to keep the mixer from spinning or moving downstream

Static mixers have no moving parts and the energy for mixing is available in the form of pressure. Pressure loss – a natural consequence of static mixing – sometimes becomes the deciding factor in mixer selection. The LPD Static Mixer remains a classic choice for many inline blending requirements due to its simple and durable design capable of uniform mixing with little pressure loss. The mixer elements consist of semi-elliptical plates carefully positioned in series to split and rotate the product 90 deg. in alternating clockwise and counterclockwise directions.

LPD mixers in diameters from 1 in. through 2.5 in. are welded to a central rod, while larger elements are welded to four outside support rods for maximum rigidity and stability. Units as large as 48 in. diameter can be supplied as stand-alone mixer elements or as modules complete with a mixer housing and injection ports.

Established in 1842, Ross is one of the oldest and largest mixing equipment companies in the world. Ross mixing, blending, drying and dispersion equipment is used throughout many industries in the manufacture of foods, adhesives, electronics, coatings, cosmetics, pharmaceuticals, plastics and composites.

www.staticmixers.com

A smart approach to SIS

Safety Instrumented Systems (SIS) just got a whole lot smarter, says Emerson

The DeltaV SIS modern process safety system – whether stand-alone or integrated with a control system – helps operators reliably protect their assets and improve process availability.

Emerson's DeltaV SIS system with its game-changing electronic marshaling technology gives unprecedented flexibility to provide safety when and where it is needed – and with dramatic savings, the company claims. The system is designed to be smart: to shut down the plant when necessary for safety, but to keep it running safely when components fail.

Designed to enable easy compliance with the IEC61511 international standard, DeltaV SIS lowers the up-front costs of engineering, installing, and commissioning. It also reduces ongoing maintenance and management costs.

The system's electronic marshaling with signal characterization modules (CHARMs) allows much shorter cable runs from field devices to localized junction boxes, which then connect multiple control loops to the control room via two redundant Ethernet cables. Traditional marshaling cabinets and cross-wiring – with fault-prone connection points and screws – are eliminated. This reduces not only engineering and wiring costs, but also weight on offshore platforms. Refineries are achieving similar engineering savings when applying DeltaV SIS CHARMs in remote instrument enclosures (RIEs) in Class 1, Div 2 hazardous areas. Because DeltaV SIS CHARMs give complete flexibility to accommodate any signal type, late engineering changes or facility expansions can be accommodated easily.

The DeltaV SIS system helps to improve process safety by continuously monitoring and diagnosing the ability of sensors, logic solvers, and final elements to perform on demand as required. To increase process availability, the DeltaV SIS system detects component failures and keeps the facility running when other systems might shut it down.

The system provides dedicated safety hardware, software and networks; and integrated configuration, operations, and maintenance with the DeltaV system. This approach provides unmatched visibility into the process, by enabling direct access to all SIS information across the entire safety loop.

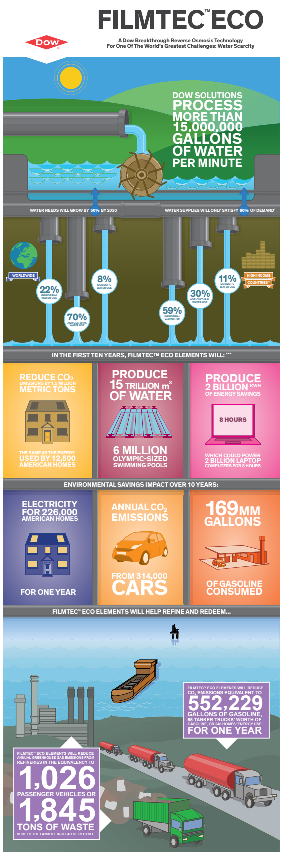
The DeltaV SIS can also be transparently and independently integrated with an existing BPCS from any vendor using Modbus TCP, OPC, and OPC.net. **www.EmersonProcess.com/DeltaVSIS**

Water: a vital resource

Dow's reverse osmosis membranes cut energy consumption by up to 30%

Water is as important to the refining process as oil itself, points out **Dow Water & Process Solutions**. Water is paramount in managing heating and cooling systems, removing salt, sulfur and impurities from crude oil, and cleaning and protecting equipment from corrosion. In steam cracking, water even plays a vital role as a change agent. And, water is again used to cool down petroleum in its final stage. In fact, in the U.S. alone, the refining industry uses 1–2 billion gal/d of water.

That said, water is also a depleting resource that must be managed efficiently in order to maximize usage, deliver cost savings, and promote sustainability. While the cost of water used in refining operations is less than 0.1% of the total cost of production, optimized water management can provide substantial cost reductions, especially in light of the rising cost of water treatment, depleting freshwater availability, and the importance of water reuse. As energy is inextricably linked to water in the refining process, helping move the commodity through the facility, utility savings are directly connected. Major oil and gas producers recognize the importance of sustainable refining operations, and of effectively monitoring and reporting their water usage.



Dow Water & Process Solutions offers innovative technologies to reduce the total cost of ownership of water treatment at refineries. The latest breakthrough, FILMTEC ECO reverse osmosis (RO) elements, deliver up to 40% higher water quality while consuming 30% less energy. FILMTEC ECO enables robust performance over a longer lifetime through lower energy use, and reduces regeneration costs of the downstream mixed bed, with operational savings up to 19%. FILMTEC ECO is ideally suited for industrial RO plants and replacement systems, allowing improved energy efficiency across a broad temperature range, optimized performance at a lower feed pressure, and higher fouling resistance compared to standard elements. Refineries that switch from conventional elements to FILMTEC ECO have less impact on the environment and less strain on their bottom line, resulting in an ecological and economic win.

Dow's inaugural Water Academy on water treatment in refining takes place June 2014, Houston, Tx. **www.dowwaterandprocess.com**

Combustion authority for 80+ years

John Zink Hamworthy Combustion provides proven emissions-control and clean-air systems to a variety of industries worldwide

John Zink Hamworthy Combustion solutions include:

Flare systems: advanced flare design and clean flare technologies set the standard for upstream, downstream and biogas flaring. John Zink Hamworthy Combustion has more than 700 biogas flare systems in operation, including the ZULE Ultra Low Emissions flare system.

John Zink Hamworthy Combustion has installed thousands of flare systems

Thermal oxidation: More than 3,500 thermal oxidation systems installed around the world destroy up to 99.9999% of a variety of hazardous industrial wastes.

Process burners: A broad range of conventional low-NOx and ultra-low-NOx process burner systems reduce pollution and maximize heating performance for the ethylene, refining and reforming industries.

Boiler burners: John Zink Hamworthy Combustion's customized boiler burners accommodate variable fuels, emissions levels, boiler types and flame geometry for industrial steam generation, power generation and marine markets worldwide.

Flare gas recovery: John Zink Hamworthy Combustion flare gas recovery systems reduce normal flaring by nearly 100%. This near-zero flaring allows the recovered gas to be reused as fuel or feedstock, combining environmental control with an immediate return on investment.

Vapor control: John Zink Hamworthy Combustion has more than 2,000 vapor combustion and vapor recovery installations worldwide. The firm's vapor control technologies are recognized as the "Best Demonstrated Technology" and the "Maximum Achievable Control Technology" by the U.S. Environmental Protection Agency.

Marine and offshore: With thousands of installations, John Zink Hamworthy Combustion is a world leader in gas and oil combustion systems for the marine and offshore sector. Specialized burner systems handle a variety of fuels and cover a wide range of applications including main and auxiliary boilers, thermal heaters, flare systems and well-test burners.

Research and development: John Zink Hamworthy Combustion's three R&D centers (Tulsa, Okla.; Luxembourg; and Poole, England) make up the largest and most advanced testing complex in the industry, with a team of PhD engineers using advanced CFD to solve turbulent flow problems involving multiple-step chemical reactions and non-linear heat transfer.

www.johnzinkhamworthy.com

Enduring guidance in heat transfer technology

The road continues for HTRI, as the heat transfer R&D leader gains new staff and equipment to better support its global membership

For more than half a century, **Heat Transfer Research, Inc.** (HTRI) has been leading the chemical process industry in heat transfer research and development. The company recently has been meeting the challenge of future growth by investing in new staff and equipment, in order to ensure continued value to its nearly 1,500 corporate member sites located in 60 countries.

Founded in 1962, the industrial research and development consortium is a leader in providing process heat transfer and heat exchanger technology, research, and software. Its acclaimed software, HTRI ***X****changer Suite*, is the most advanced available for the design, rating, and simulation of heat exchangers. It is used to help predict the performance of heat transfer equipment. HTRI also provides technical support to all members and offers training, consulting, and contract services to both members and non-members.

HTRI conducts proprietary research to develop methods and software for the thermal design and analysis of heat exchangers and fired heaters. It uses specially-designed rigs to conduct studies at its state-of-the art HTRI Research & Technology Center, and augments these studies with computational fluid dynamics (CFD) and quantitative flow visualization.

Recent developments include the addition of two new research rigs and the release of ***X****changer Suite* Version 7, which brings 50 years of meticulous research to the end-user. ***X****changer Suite 7* uses an integrated graphical environment to deliver modules for:

- shell-and-tube exchangers;
- jacketed-pipe and hairpin exchangers;
- plate-and-frame exchangers;
- plate-fin exchangers;
- spiral plate exchangers;
- fired heaters;
- air coolers and economizers; and
- tube vibration analysis.

HTRI continues to develop rigorous, incremental models that are based on extensive experimental research. This dedication to excellence assures customers the highest level of operating confidence in equipment designed with HTRI technology. **www.htri.net**

New pressure gas regulator is a first

Cashco, Inc.'s latest product meets a customer demand – and honors outgoing company President Phil Rogers

Customers of the new PGR-1 valve from **Cashco, Inc.** may think they're looking at a new Pressure Gas Regulator, and they would be correct. Available in five different body sizes, the PGR-1 is a high accuracy, pressure loaded, pilot operated, pressure reducing regulator that is unlike anything previously available from Cashco, Inc.

However, the PGR-1 designation has a hidden meaning. The initials "PGR" are also a way of honoring Phillip Galen Rogers for his nearly 30 years of service as President of Cashco, Inc. Having started with the company in 1976 in the purchasing department, Rogers has worked his way through the ranks as Purchasing Manager, General Manager and, ultimately, President of the company in 1985.

"We've had a lot of interest and requests over the years for a final control regulator for natural gas applications," says Clint Rogers, General Manager, Valve Division, Cashco, Inc. "However, up to now, we simply had to pass on those opportunities. Yet, we were still getting requests from current customers who didn't want to go elsewhere to fulfill the remainder of their valve and regulator needs. We felt Cashco had to do something.

"The PGR-1 allows us to serve the burner and natural gas market more effectively, while paying tribute to Phil's years of service at the same time," Rogers adds, noting the new product will be released during Cashco's 100th year in business. "The PGR-1 design includes an internal pressure balancing piston-cylinder providing high flow capacity with performance that will meet or exceed other competitive pressure loaded or pilot-operated designs."

The PGR-1 is already available in 1, 1½, 2, 3 and 4-in. body sizes, with more to follow, and can be ordered in four basic materials with multiple trim material combinations. It can be configured for operating temperatures from –70° to +250°F and outlet pressure set points between 2 in. w.c. and 200 psig depending upon body/cover and dome/diaphragm material combinations. **www.cashco.com**

Delivering predictable results in E&C

Wood Group Mustang prides itself on the ability to give customers what they want – with no surprises – in engineering, procurement, and construction management

Wood Group Mustang delivers predictability on engineering projects of all sizes

Wood Group Mustang is a recognized leader in engineering, procurement and construction management for the refining, chemicals, and polymer industries. Their process engineers and project managers average more than 20 years in the process industry, with extensive knowledge of all project execution aspects of the refining, chemicals, petrochemicals, and polymers industries. All designs are backed by a strong support team and the latest in project control and 3D design tools. Wood Group Mustang has vast experience with the industry's leading technology licensors and providers, while remaining technology neutral, allowing them to offer the best solution for the project in hand.

Clients' projects are managed from concept through operation; and personnel have experience in most licensed and proprietary petrochemical, chemical and polymer processes, and regularly assist clients with the introduction of "first of a kind" technologies. In addition, they also offer comprehensive technical and economic studies, technology evaluation, experimental program design, pilot plant programs, and acquisition of physical and chemical property data aimed at delivering predictable results.

With a proven track record of providing solutions that minimize expenditures and optimize production, Wood Group Mustang contributes significantly to their clients' profitability. As an example, the Wood Group Mustang website includes a snapshot of how the company completed the largest expansion project in a particular client's history, on time and within budget, with zero safety incidents, and increased capacity by 45%.

Wood Group Mustang has regional offices in Houston, TX; Greenville, SC; Martinez, CA; and Deer Park, TX that are fully supported by on-site teams and virtual support, including the latest in project tools and shared resources of all disciplines.

http://marketing.woodgroupmustang.com/predictable

Cracking furnace burners and olefin plant flares

A sound understanding of combustion fundamentals allows Zeeco to design and supply burners and flare systems meeting the highest standards for performance

Zeeco multi-point ground flares are often used in olefin facilities

From wellheads to chemical and petrochemical facilities worldwide, **Zeeco** designs and delivers innovative burners, flares and thermal oxidizers for the petrochemical and chemical industries. Zeeco combustion experts engineer applications for olefin plants on time, on budget, and with guaranteed performance.

With more than three decades of combustion experience, Zeeco understands the complex interaction of flame, fuel, emissions, and public perception. Zeeco flare systems for olefin production are designed to operate smokelessly at significant flowrates for long periods of time. If a plant is near a population center, environmentally sensitive area, or has limited space to expand, the Zeeco team will design an enclosed multi-point ground flare system to eliminate visible flaring and reduce environmental impacts without sacrificing efficiency, safety or reliability.

Because Zeeco is a combustion specialist and not just a flare or a burner company, its engineers bring to projects a more complete view of plant processes and interactions. The rise in shale gas feedstocks means many olefin facilities are working to increase capacity. Retrofitting or equipping ethylene furnaces with the latest low-emission burner technology can be difficult due to burner spacing issues and their resulting effect on flame quality. As existing furnaces are upgraded to achieve higher capacities, more floor burners are added. Designed for compact operation with no flame rollover, patented Zeeco Ultra Low-NOx GLSF Min-Emissions Enhanced Jet Flat Flame burners are often used to increase heating capacity in cracker retrofits. The GLSF Min Emissions burner provides a stable flame over a wide range of operating conditions and does not require any stabilization metal in the burner throat. GLSF Min-Emissions burners can achieve NOx emissions levels as low as 44 ppmv without sacrificing flame quality. Even heat transfer reduces the possibility of hotspots or flame interaction issues.

Companies trust the track record of Zeeco's thousands of installed burners, flares, and thermal oxidizers worldwide, and the thousand-strong Zeeco team of combustion experts. With the largest presence of any major combustion company in the area, Zeeco Gulf Coast services include heater tuning, burner cleaning, flare tip replacement, controls/pilot upgrading, and more. **www.zeeco.com**

Ensure long life for oil and gas heat transfer systems

Therminol heat transfer fluids from Eastman have been used in gas processing, refining, and oil and gas pipeline operations for over 50 years

Therminol heat transfer fluids are commonly used in offshore and onshore oil and gas processing, fractionation, refining, transportation,and recycling operations. Therminol 55, Therminol 59, Therminol 62, Therminol 66 and Therminol VP1 have successfully demonstrated low-cost, reliable, and safe performance in these applications for five decades.

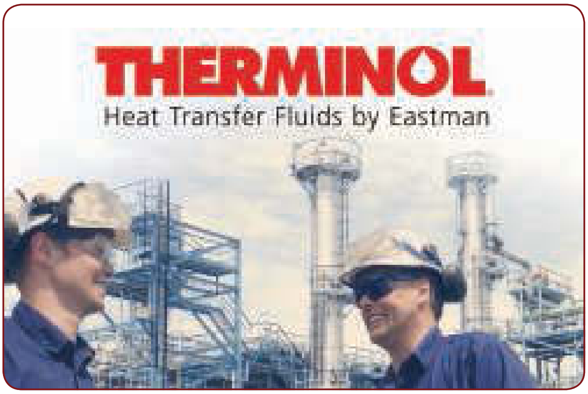
Therminol fluids are selected because they provide lower capital and operating costs, and better temperature control, than other heat transfer options.

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

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

Therminol heat transfer fluids have applications in transportation too. Pumping stations along oil and gas pipelines often require heating to control the viscosity of oil streams, and to prevent condensation of components from gas streams.

Therminol heat transfer fluids have proven capable of meeting



these requirements in virtually any environment. And the reprocessing of used lubricating oils involves operations at very high temperatures and high vacuum, for which Therminol heat transfer fluids are ideal.

A variety of Therminol fluids are available with low vapor pressure, high thermal stability, and good heat transfer performance, supporting process needs at virtually any temperature.

www.therminol.com

Alleviate headaches caused by faulty steam traps

The TrapMan system from TLV uses a combination of ultrasonic and temperature measurement, backed up by a powerful database, to diagnose steam trap condition

Leaking and blowing steam traps with resulting energy loss and back pressure can hurt operating performance. Condensate backing up in a steam system from a blocked trap can potentially cause damage to critical equipment or reduce process performance. Opened bypass valves, to drain the steam system to grade, create a waste of energy and potential safety issues. All of these headaches can be relieved through a steam trap management program based on **TLV's** TrapMan system for testing and reporting.

TrapMan is the first diagnostic instrument combining both ultrasonic and temperature readings for accuracy to make an automatic judgment of a steam trap's operating condition. TrapMan records both readings of the operating steam trap, compares it to a specific signature developed for that actual trap model, and diagnoses its condition based on empirical data. The TrapMan system has over 4,200 unique signatures for different makes and models of steam traps, providing superior capability to make an accurate, automatic judgment of specific steam trap model performance.

The TrapMan system includes powerful TrapManager database software. TrapManager provides the capability to retain historical test and installation records, allowing for detailed analysis and reporting. The software can also be configured to a user's needs to predetermine inspection routes, capture plant data that is unique to the site, then track and plan preventative maintenance. TrapManager software is compatible with Windows XP/Vista/7 and is functional (not yet fully supported) with Windows 8.

The TrapMan is easy to learn, weighs only 2 lbs and is intrinsically safe. TrapMan hardware eliminates variations in testing caused by human error, and its accuracy is validated by Lloyd's Register. Potential users can learn more about TrapMan's ability to enhance productivity, reliability, safety, and energy efficiency benefits.

www.tlv.com

Properly-working steam traps save time and money, and increase safety

Plastic control valves handle corrosive chemicals

Collins 2-in. valves and actuators are specially designed to handle corrosive fluids – acids, bleaches, chlorine, pH control – and aggressive environments

Collins Instrument Company's line of economical 2-in. flanged plastic control valves handle corrosive liquids including hydrochloric acid, caustic, sulfuric acid, and many others. With bodies of either PVDF or polypropylene, these highly-responsive control valves are specifically designed for use with corrosive media and/or corrosive atmospheres.

Suitable for applications in numerous industries, including chemical, petrochemical, pulp and paper, and municipal, these valves are extremely corrosion-resistant, and feature fast-acting positioning (stroke rate approximately ½ in./s). They are available with a wide selection of trim sizes, in globe, angle, and corner configurations.

The differential-area piston eliminates the necessity for auxiliary loading regulators. All actuator parts apart from the integral positioner are molded of glass-filled, UV-inhibited polypropylene. Before shipment, the aluminum positioner and a portion of the cylinder are immersed in Dip Seal to provide atmospheric protection.

Plastic valves and actuators from Collins

The integral positioner eliminates the need for external linkages which are subject to corrosion and malfunctioning. Valves may also be furnished without a positioner for on/off applications.

Collins also offers a plastic pneumatic actuator. The combination of a plastic actuator and a plastic valve body provides an effective way to handle both corrosive materials flowing through the valve, and harsh environments that can attack the outside of the valve and actuator. Collins plastic control valve packages withstand salty marine atmospheres as well as industrial environments that are too corrosive for metal valves and actuators.

Collins actuators incorporate a unique internal locking ring to attach the cylinder to the yoke. A semicircular groove is machined inside the lower edge of the cylinder, and a matching groove cut in the yoke. When the yoke and cylinder are assembled, a flexible polypropylene rod is inserted into the groove through a slot in the side of the cylinder, securing the two sections together.

Along with its corrosion resistance the Collins control valve features a stem packing arrangement that virtually eliminates the problem of fugitive emissions, thereby protecting the environment.

Located on the Texas Gulf Coast in the town of Angleton, Collins Instrument Company has been serving the chemical and petrochemical industry for over 65 years.

www.collinsinst.com

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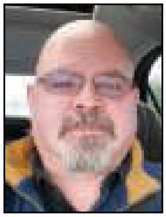

Boyle

Udit Batra becomes president and CEO of **EMD Millipore** (Boston, Mass.), the Life Science Div. of Merck KGaA and a supplier of solutions for biopharmaceutical research, development and manufacturing.

Antwan McMillian is named manager of testing and services, for **Greene's Energy Group LLC** (Houston), a provider of integrated testing, rentals and specialty services for drilling, completion, production and pipeline operations.

Packaging Coordinators, Inc. (PCI; Powys, Wales), a provider of packaging services for biotechnology and pharmaceutical customers, names *Steve McCairns* director of operations for its U.K. business.

Paul Martin is named director of business development for the Americas for **List USA** (Charlotte, N.C.), a provider of solutions for reaction kinetics for high-viscosity, polymer-processing operations.

Jo Ellen Freedman is named engineering coordinator for **Cashco, Inc.** (Ellsworth, Kan.), a maker of throttling rotary and linear control valves, pressure-reducing regulators and back-pressure regulators. The company also names *Jamaica Sheridan* compliance specialist.

Kalenborn Abresist Corp. (Houston), a custom manufacturer of wear-resistant linings for chemical process equipment and piping, welcomes *William Boyle* as senior vice president of operations. ■

Suzanne Shelley

BUSINESS NEWS

PLANT WATCH

Lanxess inaugurates new high-tech plastics plant in Brazil
April 10, 2014 — Lanxess AG (Cologne, Germany; www.lanxess.com) inaugurated its new high-tech plastics plant in Porto Feliz, Brazil. The company has invested around €20 million in the facility, which will initially have a capacity of 20,000 metric tons per year (m.t./yr). In the new plant, polyamide and polybutylene terephthalate are mixed and refined with special additives and glass fiber to make high-tech plastic products that are used in the automotive sector.

Borealis invests in capacity expansion for crosslinked polyethylene
April 10, 2014 — Borealis AG (Vienna, Austria; www.borealisgroup.com) is investing in a capacity increase for crosslinked polyethylene (XLPE) at its Stenungsund, Sweden plant, which serves the wire and cable industries. The expansion raises the overall XLPE capacity by 20,000 m.t./yr. The project is scheduled to come onstream in 2015.

Styron plans to convert Ni-BR rubber-production line to Nd-BR
April 9, 2014 — Styron (Horgen, Switzerland; www.styron.com) plans to convert its nickel butadiene rubber (Ni-BR) production train in Schkopau, Germany, to neodymium butadiene rubber (Nd-BR). The conversion of the Ni-BR production line is expected to be completed in the fourth quarter of 2015.

Saipem awarded contract for expansion of Versalis plant in Italy
April 9, 2014 — Saipem S.p.A. (Milan, Italy, www.saipem.com) has been awarded a €200-million contract for the engineering, procurement and construction of the expansion of Versalis' ethylene propylene diene monomer (EPDM) production plant in Ferrara, Italy. The project will increase the site's production capacity of EPDM rubber to 130,000 m.t./yr, and is expected to be completed by the second quarter of 2016.

Lubrizol breaks ground for new CPVC compounding facility in India
April 7, 2014 — The Lubrizol Corp. (Wickliffe, Ohio; www.lubrizol.com) broke ground for a new chlorinated polyvinyl chloride (CPVC) compounding plant in Dahej, India. The estimated investment in the new plant is over $50 million, and it will produce approximately 55,000 m.t./yr of CPVC.

Outotec to deliver technology for high-purity alumina plant in Canada
April 2, 2014 — Outotec Oyj (Espoo, Finland; www.outotec.com) has agreed with Orbite Aluminae Inc. to deliver a new calcination system for Orbite's high-purity alumina production facility in Cap-Chat, Québec. The plant is scheduled to be commissioned in the beginning of 2015.

Synthos to build a neodymium polybutadiene rubber plant in Brazil
April 2, 2014 — Synthos Group S.A. (Oswiecim, Poland; www.synthosgroup.com) is planning to build a neodymium polybutadiene rubber plant in the Triunfo Petrochemical Complex in Rio Grande do Sul, Brazil. The plant's production capacity will be 80,000 m.t./yr.

Praxair will build a new steam-methane reformer at Niagara Falls
April 1, 2014 — Praxair, Inc. (Danbury, Conn.; www.praxair.com) is planning to build a new steam-methane reformer to increase the supply of hydrogen for its liquid hydrogen plant in Niagara Falls, N.Y. When complete in 2015, Praxair's Niagara Falls liquid-hydrogen production capacity will be increased by 50%.

MERGERS AND ACQUISITIONS

Huntsman sells European commodity surfactants business to Wilmar
April 10, 2014 — Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com) has announced that Wilmar Europe Holdings B.V. will purchase Huntsman's European commodity surfactants business. Under the terms of agreement, Huntsman plans to sell to Wilmar its ethoxylation facility in Lavera, France.

Clariant and Ashland to sell ASK Chemicals JV to Rhône
April 9, 2014 — Clariant (Muttenz, Switzerland; www.clariant.com) and Ashland Inc. (Covington, Ky.; www.ashland.com) have agreed to sell their joint venture (JV), ASK Chemicals (Hilden, Germany; www.ask-chemicals.com), to Rhône, a private-equity investment firm. The enterprise value of the transaction is around €257 million.

BASF and Toda Kogyo enter negotiations to form a JV for CAMs
April 3, 2014 — BASF SE (Ludwigshafen, Germany; www.basf.com) and Toda Kogyo Corp. (Tokyo, Japan; www.todakogyo.co.jp) have announced that they will enter negotiations to form a Japan-based JV for cathode active materials (CAMS). The proposed JV will focus on the production, marketing and sales of cathode materials.

Solvay completes acquisition of ERCA, doubles surfactant capacity in Brazil
April 3, 2014 — Solvay S.A. (Brussels, Belgium; www.solvay.com) has completed the acquisition of the specialty chemical assets of ERCA Química, Ltda., enabling Solvay to more than double its surfactant production capacity in Brazil. The transaction includes ERCA's local specialty chemical assets and its portfolio of agrochemicals, as well as home and personal-care products.

Sulzer acquires German polymer foams specialist Aixfotec
April 1, 2014 — Sulzer Chemtech (Winterthur, Switzerland; www.sulzer.com) is taking over Aixfotec GmbH (Aachen, Germany; www.aixfotec.de), a technology company specializing in extrusion systems for the production of polymer foams. The acquisition was signed and concluded on March 31, 2014.

Foster Wheeler acquires Siemens Environmental Systems
March 20, 2014 — A subsidiary of Foster Wheeler AG (Zug, Switzerland; www.fwc.com) has signed an asset purchase agreement with Siemens Energy, Inc. (Erlangen Germany; www.energy.siemens.com) to acquire the Siemens Environmental Systems and Services business. The transaction is expected to close in 2014's second quarter.

Lanxess divests its Perlon-Monofil subsidiary to Serafin Group
March 19, 2014 — Lanxess AG has divested its wholly owned subsidiary Perlon-Monofil GmbH to the Munich-based Serafin Group for an undisclosed amount. Perlon-Monofil sells polyamide and polyester monofilament products used mainly in the paper, shipping and agricultural industries.

Unilever acquires Chinese water-purification company Qinyuan
March 11, 2014 — Unilever PLC (London, U.K.; www.unilever.com) has acquired a majority stake in the Qinyuan Group, a Chinese water-purification business, for an undisclosed amount. In 2013, Qinyuan generated sales of around €140 million. ■

Mary Page Bailey

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

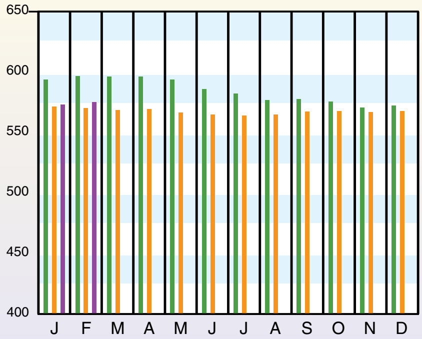
2012 — 2013 — 2014

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

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Feb.'14 Prelim.	Jan.'14 Final	Feb.'13 Final
***CE* Index**	575.0	572.8	569.9
Equipment	697.6	695.6	690.9
Heat exchangers & tanks	637.3	632.6	627.4
Process machinery	663.9	657.5	653.8
Pipes, valves & fittings	881.9	883.5	887.6
Process instruments	413.1	412.7	417.0
Pumps & compressors	931.7	928.7	917.4
Electrical equipment	515.5	515.9	513.5
Structural supports & misc	759.6	762.3	739.3
Construction labor	321.5	318.1	318.9
Buildings	541.4	537.7	530.9
Engineering & supervision	323.3	323.1	326.6

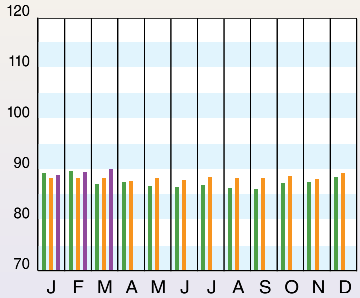
Annual Index:
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3



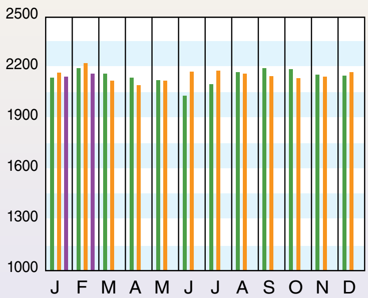
CURRENT BUSINESS INDICATORS*

	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2007 = 100)	Mar.'14	=	90.1	Feb.'14	=	89.5	Jan.'14	=	88.9	Mar.'13	=	88.3
CPI value of output, $ billions	Feb.'14	=	2,166.7	Jan.'14	=	2,148.0	Dec.'13	=	2,176.6	Feb.'13	=	2,228.4
CPI operating rate, %	Mar.'14	=	76.0	Feb.'14	=	75.6	Jan.'14	=	75.2	Mar.'13	=	75.3
Producer prices, industrial chemicals (1982 = 100)	Mar.'14	=	293.7	Feb.'14	=	299.6	Jan.'14	=	294.0	Mar.'13	=	309.6
Industrial Production in Manufacturing (2007 = 100)	Mar.'14	=	98.7	Feb.'14	=	98.2	Jan.'14	=	96.8	Mar.'13	=	96.0
Hourly earnings index, chemical & allied products (1992 = 100)	Mar.'14	=	156.3	Feb.'14	=	157.2	Jan.'14	=	157.9	Mar.'13	=	154.6
Productivity index, chemicals & allied products (1992 = 100)	Mar.'14	=	107.3	Feb.'14	=	108.0	Jan.'14	=	106.4	Mar.'13	=	104.7

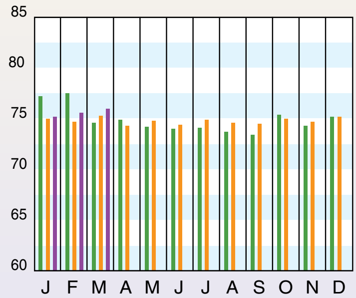
CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



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

HIGHLIGHTS FROM RECENT ACC ECONOMIC DATA

Strengthening chemical equity prices drove solid gains in the American Chemistry Council's (ACC; Washington, D.C.; www.americanchemistry.com) monthly Chemical Activity Barometer (CAB), released in late March. March's reading featured a gain of 0.3% over February on a three-month moving average basis (3MMA), rebounding past the average 0.2% gain in late 2013, and pointing to modest but continued growth in the U.S. economy through the fourth quarter of 2014, the ACC says.

Strengthening chemical equity prices in February and March are a positive signal and a major factor in this CAB reading. The economic indicator, shown to lead U.S. business cycles by an average of eight months at cycle peaks, is up 2.5% over a year ago, at an improved year-earlier pace. The CAB reading for February was revised upwards slightly from earlier reports, the ACC says.

"Winter weather extremes have carried into March and continue to impact many of the economic readings, but all signs point to an expanding U.S. economy through 2014," says Kevin Swift, chief economist at the ACC. "Strengthening chemical equity prices, combined with the expansion of sales in intermediate goods, which constitute roughly 85% of overall chemical sales, are encouraging signs for the continued health of the U.S. economy."

Overall results in the four primary components of the CAB were mostly positive, with production, equity prices and new orders up, while product/selling prices were flat. Production-related indicators such as construction-related coatings, pigments and plastic resins all improved.

A new CAB was expected to be released in late April, after press time for this issue. ❑

CURRENT TRENDS

The *CE* Plant Cost Index (CEPCI; top) preliminary value for February 2014 is available, and is 0.4% higher than the final values from January. The Equipment, Labor, Buildings and Engineering sub-indices all saw small increases, although some of the individual equipment subcategories, such as pipes, valves and fittings, electrical equipment and structural supports saw slight decreases. The overall PCI value for February 2014 stands at 0.9% higher than the value from February of last year. Meanwhile, updated values for the Current Business Indicators (CBI) from IHS Global Insight (middle) saw both the CPI output index and the CPI value of output edge higher compared to the previous month. ❑

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