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May 2013

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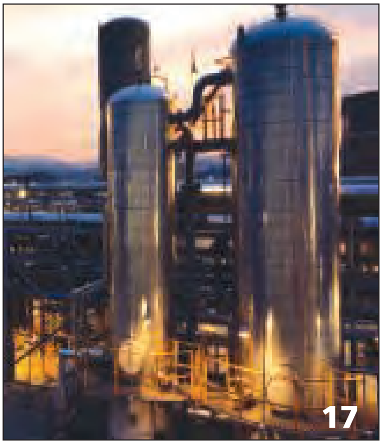

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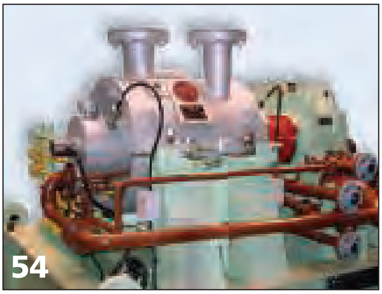
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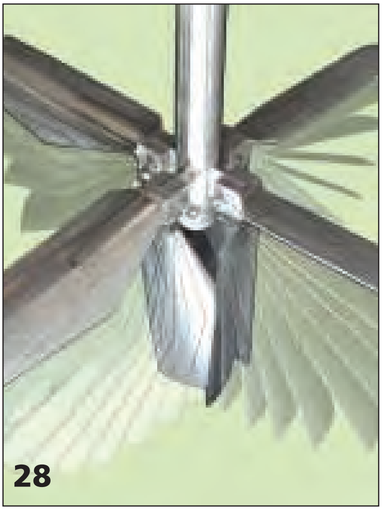
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Editor's Page

Recognizing excellence

As it has done for more than 85 years, the Society of Chemical Industry (SCI; London, U.K.; www.soci.org), America International Group awarded the SCI Chemical Industry Medal to an individual whose leadership, commitment and contributions have been responsible for substantial progress and performance in the chemical industry. This year's recipient, Andrew Liveris, received the medal in March at a dinner in his honor at the Waldorf Astoria Hotel in New York.

Liveris is the chairman and CEO of The Dow Chemical Company (Dow; Midland, Mich.; www.dow.com). His impressive 37-yr career with Dow has spanned roles in manufacturing, engineering, sales, marketing, business and general management. His career has also spanned the globe, with beginnings in Australia and formative roles in Asia that included 14 years in Hong Kong, general manager for the company's operations in Thailand, and president of all Asia-Pacific operations. Liveris was named CEO of Dow in 2004, and was elected as chairman of the Board in 2006.

Liveris also served as co-chair of President Obama's Advanced Engineering Partnership in the U.S., and is the author of "Make It in America," a book released in 2011. The book presents a set of practical policy solutions and business strategies that outline the Dow vision for an advanced manufacturing economy. The Chemical Industry Medal was presented to Liveris in recognition of his leadership skills, public policy advocacy and many contributions to applied chemistry that have contributed to the progress of the industry.

Readers of this magazine may be particularly interested to know that Liveris graduated with a bachelor's degree in chemical engineering. He is a chartered engineer and a fellow of The Institute of Chemical Engineers, as well as a fellow of the Australian Academy of Technological Sciences and Engineering.

Awards, such as the Chemical Industry Medal, recognize achievements that excel above others. This year, *Chemical Engineering*'s Kirkpatrick Award will be honoring those who have developed the most-noteworthy new chemical-engineering technology to recently become commercial. More will be written about the Kirkpatrick Chemical Engineering Achievement Award in these pages in the coming months.

It is inspiring to learn of those who have made great strides in their careers, thereby advancing the chemical processing industries, and to know that their accomplishments have been recognized and honored with awards. While only a few will achieve such prestigious honors, there are many individuals in our daily lives who deserve, but may rarely receive, accolades for their contributions. These are the people whose accomplishments may not seem necessarily huge on the grand scale of things, but whose contributions keep our work flowing each day. We often don't even notice those who are consistently doing a good job, as we typically focus on problem areas and not those areas that are running smoothly.

We would do well to notice what and who keeps the wheels turning in our own organizations and circle of co-workers, and acknowledge those who deserve recognition by giving credit where credit is due. We can find everyday excellence and inspiration closer to home than we may think — in the next office or next cubicle, or across the table in a meeting — if we just look for it. ■

Dorothy Lozowski, Executive Editor

Letters

Lessons learned

Your Editor's Page in today's *Chemical Engineering* [March 2013, p.5] intrigued me because I too served as a TA in a physical chemistry lab but long before 1980 and we did not have the luxury of a Fourier-transform infrared spectrometer. But you certainly have the experience to comment on the following:

The earth, according to Weil's law at an average temperature of 15°C, radiates heat at 10 µm, which Planck teaches is a 3–30 µm band centered around 10 µm. The principal CO_2 absorption bands are at 14.99 and 4.26 µm.

But spectroscopic studies indicate that atmospheric transmittance of infrared radiation is about 80% from 8 to 12 µm. That is the so called "longwave window" where the earth is said to vent off excess energy.

It appears that the importance of CO_2 as a greenhouse gas may be overstated. . .

Gerald McDonald

In your article in the March issue, you indicated that both CO_2 and water vapor have similar IR absorption bands. I am curious, as perhaps are other readers, as to their relative percentages of the atmosphere. Since their IR absorptions are similar, would their percentage numbers be a factor in their contribution to any warming effect? Thanks for any insight you can shed on this.

Rick Smith, P.E.
Applied Thermal Engineering, Inc.

Your Editor's Page piece in the March 2013 magazine was / is good. If I were your editor, I would have moved the last two paragraphs to the top, thus leading with "Words like 'myth', 'hoax' . . .". I see this as grabbing the reader more effectively. Indeed, we need all the "grab" we can get on a critical issue like this.

Nicholas Sheble
Engineering writer / Technical editor

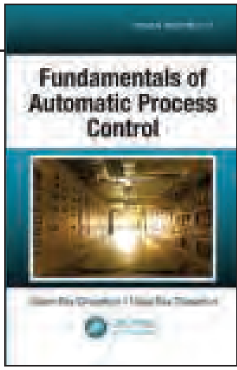
Editor's response:
A good article that addresses queries of the first two letters is "Infrared radiation and planetary temperature," Raymond T. Pierrehumbert, *Physics Today*, January 2011, pp. 33–38. This author points out that CO_2 accounts for about a third of the greenhouse gas effect.

Postscripts, corrections

April, Nano-engineering infuses growing coatings market, on pp. 17–22, requires a clarification. On page 22, the article discusses the liquid repellent coating from Ultratech International Inc. The highly textured coating reduces the surface energy such that liquids are prevented from wetting the surface. Liquids are not actually prevented from contacting the surface, as the article states.

April, in Focus on Seals & Gaskets, on p. 30, the correct company name and location for the second item is A.W. Chesterton Co., Woburn, Mass. Revised versions of both articles can be found at www.che.com.

Circle 30 on p. 72 or go to adlinks.che.com/45772-30



Fundamentals of Automatic Process Control. By Utpal Chaudhuri and Uttam Chaudhuri. CRC Press Inc., Taylor & Francis Group. 6000 Broken Sound Parkway, #300, Boca Raton, FL 33487. Web: crcpress.com. 2012. 303 pages. $139.95.

Reviewed by Douglas White,
Emerson Process Management,
Houston, Tex.

Professors Uttam Ray Chaudhuri from Calcutta University (Kolkata, India; www.caluniv.ac.in) and Uptal Ray Chaudhuri from Jadavpur University (Kolkata, India; www.jadavpur.edu) have authored a preparatory textbook on automatic process control. The target audience for the book seems to be students in an introductory process-control course.

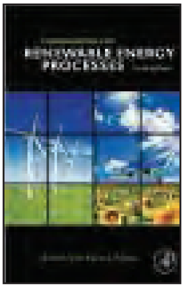
After an opening introduction, the book offers an open-loop-system dynamic analysis using Laplace analysis and continuous time differential equations. This analysis is followed by material on closed-loop-control dynamic analysis and PID (proportional-integral-derivative) tuning. The book includes a chapter on advanced single-loop regulatory control techniques, such as cascade, feed-forward, adaptive and fuzzy logic, among others, as well as a chapter on computer control.

The book comes with a CD containing a software simulation package that permits experimentation with the different techniques. The book also includes a comprehensive guide to the simulation system along with suggested exercises.

A particularly strong point of the book is an extensive set of worked examples in each chapter. The book also includes an appendix containing problems and worked solutions in process control from previous versions of the Indian Graduate Aptitude Test in Engineering (GATE).

Some suggestions for the next version of the book include the following. The preface states that "cost of controlling instruments at a plant is about 40–60% of the initial investment of the plant." Automation costs for large continuous-process plants in the chemical process industries (CPI) actually are typically 3–5% of the total capital investment. Also, the photographic reproductions in the book are of low quality and difficult to interpret.

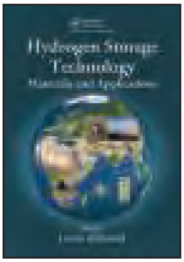
While practitioners may have differing opinions on the proper approach to PID tuning, there are much more widely accepted and newer methodologies than the Ziegler-Nichols and Cohen-Coon techniques presented in the book. In the reviewer's opinion, since virtually all process-plant control systems execute digitally, students should have an introduction to discrete time dynamic analysis. Very few loops in the plant are fully standalone, and some introduction to interacting and multivariable analysis should also be part of the curriculum.



Fundamentals of Renewable Energy Processes. 3rd ed. By Aldo da Rosa. Elsevier Science and Technology, 30 Corporate Drive, Burlington, MA 01803. Web: elsevier.com. 2012. 908 pages. $120.00.

Practical Guide to Structures, Properties and Applications of Styrenic Polymers. By Norbert Neissner and Daniel Wagner. Smithers Rapra Publishing, Shawbury, Shrewsbury, Shropshire, SY4 4NR, U.K. Web: smithersrapra.com. 2013. 156 pages. $90.00.

Introduction to Chemical Computing. 2nd ed. By Bruce Finlayson. John Wiley & Sons Inc. 111 River Street, Hoboken, NJ 07030. Web: wiley.com. 2012. 402 pages. $59.95.



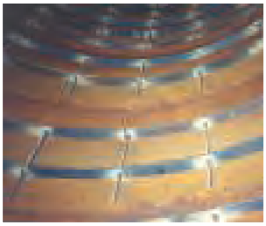
Hydrogen Storage Technology: Materials and Applications. By Lennie Klebanoff. CRC Press Inc., 6000 Broken Sound Parkway, #300, Boca Raton, FL 33487. Web: crcpress.com. 2012. 520 pages. $159.95.

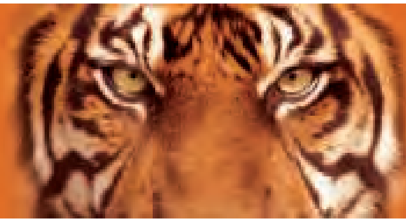
The Elements of Polymer Science and Engineering. 3rd ed. By Alfred Rudin and Philip Choi. Elsevier Science and Technology, 30 Corporate Drive, Burlington, MA 01803. Web: elsevier.com. 2012. 584 pages. $119.00.

Practical Process Research and Development: A Guide for Organic Chemists. 2nd ed. By Neal Anderson. Elsevier Science and Technology, 30 Corporate Drive, Burlington, MA 01803. Web: elsevier.com. 2012. 488 pages. $125.00.

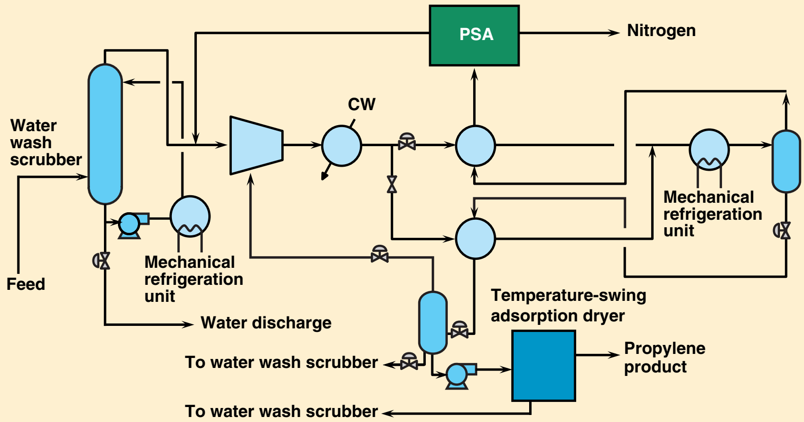
Advances in Fluorine-Containing Polymers. Edited by Dennis W. Smith, Jr. and others. Oxford University Press. 2001 Evans Road, Cary, NC 37513. Web: oup.com. 2012. 224 pages. $150.00. ■

Scott Jenkins





A waste-free monomer recovery process is licensed



Last month, Air Products (Allentown, Pa.; www.airproducts.com) announced that it has licensed its proprietary adsorption-based, monomer recovery process to custom process equipment supplier Cryo Technologies (Allentown, Pa.; www.cryotechnologies.com). The hybrid Air Products technology combines a partial condensation unit with a pressure-swing adsorption (PSA) process to recover unreacted ethylene and propylene coming from the degassing step at a polyolefin production plant. The recovery technology reduces production costs by $10 per metric ton (m.t.) by recovering valuable olefins, solvents and nitrogen and leaving no waste. "The process can achieve essentially 100% recovery of unreacted hydrocarbons, so no flaring is required," says Jeffrey Knopf, Air Products licensing and technology transfer manager. Also, the recovery process recaptures high-purity nitrogen gas that was originally used in the degassing step and that can be re-used for further degassing.

After compressing the unreacted monomer-laden nitrogen gas stream to 200 to 300 psi, the compressed stream is cooled in a partial condensation unit, condensing the majority of the unreacted hydrocarbons. The remaining hydrocarbons flow with the nitrogen gas into the PSA unit, where more hydrocarbons are removed, leaving a nitrogen gas stream with 50 to 1,000 ppm hydrocarbons by weight, the company says. Hydrocarbons recovered from the PSA are recycled in a low-pressure tailgas stream to the feed compressor.

Air Products' monomer recovery technology was originally developed with a grant from the U.S. Dept. of Energy's Industrial Technologies Program, and was installed in three commercial polyolefin facilities in the mid-2000s by Air Products before the company placed its focus elsewhere, Knopf explains. Now, Cryo Technologies will offer the technology to polyolefin makers around the world.

Gas-phase option for NOx abatement

The first commercial application of a newly developed process for the treatment of oxides of nitrogen (NOx) waste gas has been established at a milling operation in Los Angeles, Calif. Developed by Pacific Rim Design and Development (PRDD; Reno, Nev.; http://prdd.net), along with DuPont (Wilmington, Del.; www.dupont.com), the process uses gas-phase chlorine dioxide to react with both NO and NO_2 to form nitric and hydrochloric acids.

Because of the low solubility of NO, traditional liquid-phase scrubbers need to employ multiple stages to convert the NO to NO_2 and then to react the NO_2. "Carrying out the reactions in the gas phase allows high removal efficiencies with short residence times," says Robert Richardson, president of PRDD. The reaction speeds make it possible to eliminate a stage from the process and reduce equipment costs.

The major innovation of the technique is the proprietary method for mixing the ClO_2, which is generated onsite via several possible routes, with the waste gas. The ClO_2 reacts with NO to form NO_2 and with NO_2 to form nitric and hydrochloric acids. The mixed acid waste can be used for neutralizing high-pH solutions, Richardson notes.

The gas-phase scrubbing technique can work with existing air-pollution control processes as either a pre- or post-treat option. The lighter equipment loads mean that such a process could be mounted on the roof or in the rafters of a building, rather than requiring ground space. Richardson says the method can be used in chemical milling, etching, aluminum brightening and pickling applications, among others.

Heap-leaching for REs

Studies conducted by Texas Rare Earth Resources Corp. (Sierra Blanca, Tex.; www.trer.com) indicate that heap leaching with 15% (~150 g/L) sulfuric acid has the potential to dissolve minerals containing rare-earth (RE) elements from host rock at an RE mineral site near El Paso, Texas. Research conducted by the heavy RE exploration company on the minerology, geochemistry and kinetics of direct-acid leaching demonstrated that this technique is effective at recovering more than 80% of targeted heavy RE elements from host rock. If further technical results and economic assessments prove favorable, the company says that combining open-pit mining and heap leaching could significantly reduce capital and operating costs for a heavy rare-earth facility. Texas Rare Earth is investigating different host-rock particle sizes, as well as acid strengths to further optimize the extraction method.

Anti-scalant

BWA Water Additives Ltd. (Manchester, U.K.; www.wateradditives.com) introduced a biodegradable anti-scalant product for reverse osmosis (RO) membranes that prevents common inorganic deposits from forming

(Continues on p. 12)

Note: For more information, circle the 3-digit number on p. 72, or use the website designation.

A step closer to commercialization for a new 'green' solvent

The Circa Group (Melbourne, Australia; www.circagroup.com.au) and the Green Chemistry Center of Excellence at the University of York (U.K.; www.york.ac.uk) have signed an agreement to develop and commercialize a novel "green" solvent called Cyrene. Cyrene is a polar aprotic solvent — a solvent that lacks an acidic hydrogen and has a high dielectric constant and a high dipole moment — targeted at pharmaceutical and chemical manufacturers, to help them avoid using petrochemical based solvents.

Circa is now supplying samples from its third-stage pilot plant, and is finalizing a project to upgrade to about 5 kg/d, which is planned to come onstream within the next six months, in preparation for large-scale production, says the company.

Cyrene has been produced from levoglucosenone (LGN), a platform chemical that can be the basis for many products. Circa has produced LNG using its Furacell process that recycles cellulose waste. Circa's chief scientist Warwick Raverty says the process differs from existing processes used to convert biomass into liquid products in that the Furacell technology produces a single product that is easy to isolate and purify. Conventional thermochemical processing of biomass can also produce a liquid product, but the liquid is an extremely complex mixture of hundreds of organic chemicals that no one so far has managed to separate and purify on a commercial scale, he says.

In the Furacell process, cellulose in the form of wood or straw is heated to about 450°C in a vacuum in the presence of a catalyst consisting of water, phosphate and an inexpensive organic solvent. The process takes place in a specially designed reactor, allowing continuous addition of small amounts of wood or straw in a vacuum. The product, LGN, is a molecule with a rigid shape that can be converted chemically into anti-cancer drugs, anti-HIV drugs, plant growth promoters, herbicides, insecticides and environmentally benign solvents, says Raverty.

Bioengineers make an 'ideal' hydrogel for antimicrobial applications

Although several antimicrobial hydrogels have been developed in recent years, they all have one or more drawbacks, such as possible toxicity, insufficient stability and biodegradability, and high costs. These and other drawbacks have been overcome with a synthetic hydrogel being developed by researchers from the Institute of Bioengineering and Nanotechnology (Singapore; www.ibn.a-star.edu.sg) and IBM Almaden Research Center (San Jose, Calif.; www.ibm.com).

The new hydrogel evolved from the IBM nanomedicine polymer program, with the mission of improving human health, based on materials developed for semiconductor technologies. The researchers looked for a long-lasting substance that should destroy specific types of bacteria but leave healthy skin and cells intact, and be applicable to medical facility surfaces, and surgical and diagnostic instruments.

The researchers developed macromolecules that combine the properties of water solubility, a positive charge and biodegradability. When mixed with water and heated to normal body temperature, the polymers self-assemble, swelling into a synthetic gel that is easy to handle. When applied to contaminated surfaces, the hydrogel's positive charge attracts and ruptures negatively charged microbial membranes.

The new gel is formed from stereocomplexation of biodegradable poly(L-lactide)-b-poly(ethylene glycol)-b-polyL-lactide) and a charged biodegradable polycarbonate triblock polymer. The stereocomplexes exist as soluble micelles at room temperature in aqueous solution, but upon heating to about 37°C, form gel-like materials with distinctive fiber/ribbon structures. This change in the material's properties was accompanied by a significant increase in antimicrobial activity.

The ability of the gels to disperse biofilms was tested against *Staphylococcus aureus*, methicillin-resistant *S. aureus* (MRSA), *Escherichia coli*, and *Candida albicans*. After gel exposure, more than 60% of film biomass was removed, and nearly 80% of bacterial cells were killed with a single treatment, the researchers say.

(Continued from p. 11)

on RO membrane surfaces. The specially designed polycarboxylic acid material maintains the scale-inhibition performance of alternatives and can break down by 55% in 35 days, says Nozi Hamidi, BWA's VP of marketing. The product, tradenamed Flocon 855, is free of phosphorous and nitrogen, and is suited to areas where regulatory restrictions on phosphorous- and nitrogen-containing waste apply, such as the Great Lakes region of the U.S. and the North Sea.

Detecting bioparticles

Bioengineers at the National University of Singapore (NUS; www.nus.edu.sg) have developed a microfluidic device for the rapid separation and detection of non-spherical bioparticles, such as pathogenic bacteria and malaria-infected red blood cells. The shape-sensitive technique is significant because most separation techniques are designed for spherical particles. The device has been shown to complete a diagnosis in less than an hour, compared to the traditional detection, based on bacterial culture, which needs 24–48 h before bacteria are detected.

The microfluidic device uses an I-shaped pillar array, which induces rotational motion of the non-spherical particles. This, in turn, increases the effective hydrodynamic size of the bioparticles, allowing sufficient separation. The design achieves 100% separation of red blood cells from blood samples, and has also been tested successfully on rod-shaped *Escherichia coli*, says NUS.

Dandelion rubber

Last month, the biotech companies Kultevat (Carlsbad, Calif.; www.kultevat.com) and KeyGene (Wageningen, the Netherlands; www.keygene.com) entered into collaboration for production of rubber based on the Russian dandelion, *Taraxacum koksaghyz*. This plant has demonstrated potential as

(Continues on p. 14)

Improved coating for hydraulic fracturing proppants

Two new coating products for sand proppants used in hydraulic fracturing operations in the oil and gas industry overcome the challenges of traditional phenolic coatings, which can leach environmentally hazardous chemicals. The coatings, developed by Preferred Sands LLC (Radnor, Pa.; www.preferredsands.com), are based on a specialized polyurethane developed over the past three years with partner The Dow Chemical Company (Midland, Mich.; www.dow.com).

In hydraulic fracturing, sand used as a proppant increases the contact area between particles, which effectively strengthens them against the crushing pressures inside the fractures. Also, coated proppants keep particle fines from the sand grains in place when water and oil or gas flows back up the well.

Proppant coatings based on phenolic resins leach phenol, formaldehyde and others, explains Michael O'Neill, CEO of Preferred Sands LLC. Further, current proppant coatings require activator compounds to help curing once the proppants are injected into the well, with the intention that they will cure fully inside the fractures of the deposit. "But if the fractures close before the coatings cure, then they lose their ability to bond," says Bob McDaniel, of Preferred Sands.

The company's new coatings have the ability to adhere to other particles, independent of temperature, and without the need for activator compounds," McDaniel says. "The phenolics require that a good deal of chemistry happen downhole, and that is the toughest environment to make coatings work well." The Preferred Sands formulation requires the closure stress of the fractures to fully cure, which allows the coated sand to penetrate fractures in the deposit before curing. This feature allows the coated proppant to maintain 100% of its ability to prevent sand from flowing back into the well when extraction begins, says O'Neill. "This is a new type of chemistry that hasn't been used for this purpose before," said McDaniel.

The company's coating-application method requires lower temperatures than that for phenolics, and does not produce volatile organic compounds (VOCs). These features allow for a lower-cost process, because you don't need as much energy and don't need scrubbers, says O'Neill.

One-pot synthesis of sugars from biomass

Researchers from the group of Atsushi Fukuoka at the Catalysis Research Center of Hokkaido University (Sapporo; www.cat.hokudai.ac.jp), and Showa Denko K.K. (SDK; Tokyo, both Japan; www.sdk.co.jp) have developed a new catalyst that efficiently decomposes biomass into sugars. The activated-carbon-based catalyst achieves high yields of both C6 and C5 sugars in a single reaction step.

To perform the saccharization, the researchers use alkaline-treated activated carbon (K26). The catalyst is then ball-milled together with cellulose or biomass, such as bagasse, in aqueous 0.012% HCl solution, and heated to 453K. After 20 min, 80% of the cellulose is depolymerized to glucose, and more than 90% of the xylose is released as xylan.

Studies have shown that the active sites of the carbon are weakly acidic functional groups, in which vicinal carboxylic and phenolic groups synergistically work for the hydrolysis reaction. The milling serves to improve the contact between the solid catalyst and solid biomass, and the researchers have shown that the new catalyst is durable. The scientists believe the simple process and inexpensive, readily available catalyst has potential for utilizing wood-based cellulose for biofuels (such as bioethanol), biodegradable plastics (such as polylactic acid) and the artificial sweetener, xylitol.

Making 1,3-PDO from glycerin

The research groups of Keiichi Fujishige at Tohoku University (Sendai, www.che.tohoku.ac.jp/~erec) and Daicel Corp. (Osaka, both Japan; www.daicel.com) have developed a process for making 1,3-propanediol (1,3-PDO) from glycerin, a byproduct of biodiesel-fuel production. The researchers improved a catalyst developed by Fujishige to be applied to a rather simple reaction process. They are expecting that their catalytic synthesis is scalable and the stable production of 1,3-PDO will contribute to the effective utilization of byproduct glycerin and might open a new market.

In 2010, Fujishige developed a catalyst for the hydrogenolysis of glycerol to 1,3-PDO, whereby a powder-type Ir–ReOx/SiO2 catalyst is dispersed in the reaction solution. At that time, the selectivity achieved for 1,3-PDO was 60%. Fujishige also demonstrated that the reaction mechanism formed 1,3-PDO via a 2,3-dihydroxypropoxide intermediate.

Now, Daicel and Fujishige have developed a pellet-type catalyst using an optimized silica-gel support, which enables the reaction to take place in a simple fixed-bed reactor. The stability of the catalyst has been improved, and leaching of metal has been suppressed. In a continuous fixed-bed bench-scale plant — operating in Daicel's R&D laboratory in Himeji since August 2012 — Daicel has achieved similar selectivity as that found at the university, and also confirmed that the catalyst system maintains its activity and selectivity after more than 300 h of continuous operation. The researchers believe this process is scalable as an industrial route to 1,3-PDO, and that the propanol — a byproduct of the reaction — can be marketed as a solvent.

Sensors with a transmitter built in

Last month, Krohne Messtechnik GmbH (Duisburg, Germany; www.krohne.com) launched SmartSens, the first family of two-wire, loop-powered analytical sensors with integrated transmitter technology. Prior to this, analytical sensors have required an external proprietary transmitter onsite to deliver the sensor signals to the process control system. Krohne has miniaturized the transmitter and fitted it into the sensor head, thereby eliminating sources of error caused by false installation, cabling or configuration of the transmitter.

The first sensors available are for pH, ORP (oxidation-reduction potential) and conductivity, with other process parameters to follow. These sensors can be connected directly to the process-control system, and feature direct communication via 4–20-mA HART. The company claims to be the world's first provider to offer a direct connection from the sensor to the process control system via a standardized fieldbus. The digital sensors also have advantages over traditional analog sensors in that they can store calibration data (generated offline) and simply be plugged into the process, onsite. For offline calibration, the sensor can be connected directly to a PC running the same PACTware (FDT/DTM) as applied in the asset-management system, using a USB interface cable for bi-directional HART 7 communication and power supply.

(*Continued from p. 12*)

a domesticated crop for the U.S. and Europe; the origin of the species is the southeastern part of Kazakhstan.

Kultevat and KeyGene will invest in the development and commercial introduction of new dandelion varieties that are enriched for latex in their roots and are suitable for large-scale production of natural rubber. KeyGene will be responsible for developing new varieties using state-of-the-art molecular breeding technologies while Kultevat will develop appropriate production practices and large-scale latex extraction and rubber production in North America. KeyGene will use the newly developed varieties and its production technologies for production of rubber in other global locations. The collaborators believe the "improved" dandelions will solve the world's need for sufficient amounts of high-quality natural rubber within a period of 5 to 10 years.

CO_2-free H_2 production?

Researchers from KIT's Karlsruhe Liquid-metal Laboratory (KALLA; www.kit.edu) and the Institute for Advanced Sustainability (IASS; Potsdam, both Germany; www.iass-potsdam.de) have recently started a project to investigate a process to thermally crack methane into hydrogen and carbon. Part of IASS' Earth, Energy and Environment (E3) Cluster, the project aims to produce H_2 without any CO_2 emissions.

At KALLA, construction has begun on a liquid-metal bubble-column reactor. The column will be filled with liquid metal and heated up to 1,000°C. As CH_4 is fed through a porous disc at the bottom, bubbles will rise upwards, decomposing CH_4 into H_2 and carbon, which deposits on the walls of the bubble to be released at the top.

A similar approach was described by researchers at Argonne National Laboratory (Argonne, Ill.; www.anl.gov) about ten years ago, but the process has not been developed further, says KIT. ❑

This biodiesel process requires no pre- or post-treatment

Naomi Shibasaki-Kitagawa at Tohoku University (Sendai, Japan; www.che.tohoku.ac.jp/~rpel/) has developed a continuous reactor for making biodiesel fuel from low-quality waste, such as cooking oil. Her production process uses an expanded-bed reactor packed with an anion-exchange resin that has both catalytic and adsorption capabilities.

The waste oil and methanol, with a 3-to-1 mole ratio, are continuously fed to the reactor, where the main components of the feedstock (triglicerides) are transesterified by the resin's catalytic ability. Byproduct glycerin, as well as impurities in the feedstock (free fatty acids, water and dark brown pigment) are simultaneously removed from the product by adsorption onto the resin. Product eluded from the reactor nearly meet — without further purification — biodiesel quality standards (EN14214 in Europe and ASTM D6751 in North America).

Shibasaki-Kitagawa has demonstrated the process in a fully automatic, flow-type pilot plant with a capacity of 50 L/d. This process simplifies the conversion of waste cooking oil into biodiesel because it does not require upstream processing to remove the impurities (free fatty acid and water), nor the downstream processing to remove the catalyst and byproducts (glycerin and soap).

Togni reagent is reclassified

A team of researchers from Novasep (Pompey, France; www.novasep.com) has discovered and characterized the explosive properties of the so-called Togni reagent II and intermediates at the Novasep Leverkusen site in Germany. Invented by professor Antonio Togni at the Laboratory of Inorganic Chemistry, ETH Zürich (Switzerland; www.eth.ch) Togni reagent II [1-(trifluoromethyl)-1,2-benzoidoxol-3(1H)-one, 1] is a versatile reagent for the electrophilic introduction of trifluoromethyl groups, and is used in pharmaceutical manufacturing and widely used in universities, says Novasep.

At its "kilolab", Novasep performed a Koenin test — a steel-sleeve test used to evaluate the safety of a compound during transport — that showed the reagent to be highly explosive. Another critical property of the reagent clarified by the researchers is its fast combustion when ignited. The combustion factor was measured as BZ6, the same classification as black powder (gun powder). This discovery has led to a revised classification for handling and transporting the Tongi reagent II, which must now be approved by national authorities, says Novasep.

The findings were published last month in the March issue of *Organic Process Research and Development*. Novasep's Leverkusen plant has German government authorization to handle energetic materials and operate hazardous reactions from laboratory to thousands -of-tons scale. ■

Cover Story

PETROLEUM REFINING OUTLOOK

Petroleum from shale and oil sands offers opportunities for North American refiners, but the shifting crude diet also presents challenges, as refiners look to match product output with demand

Increasing production of crude oil from shale deposits in the U.S. and oil sands in Canada offers North American petroleum refiners opportunities to access cost-advantaged feedstock. However, shifting product demand and hurdles in transportation logistics, along with technical issues associated with the properties of the crude from those areas, present challenges as refiners optimize their product mix. Crude oil from shale was among the many refining-related trends and issues discussed at the recent annual meeting of the American Fuel and Petrochemical Manufacturers (AFPM; Washington, D.C.; www.afpm.org) in San Antonio, Tex.

At a press conference to open the meeting, AFPM president Charles Drevna emphasized the potential presented by increased development of hydrocarbons from shale deposits. "There's tremendous opportunity for the nation right now, not just for refiners," he said. "We're at the proverbial fork in the road, where decisions have to be made for the future. These decisions will determine the course of the 'manufacturing renaissance' in the U.S." Pointing out the importance of policy decisions in the near future, he said, "There's a window of opportunity now, but it won't last forever."

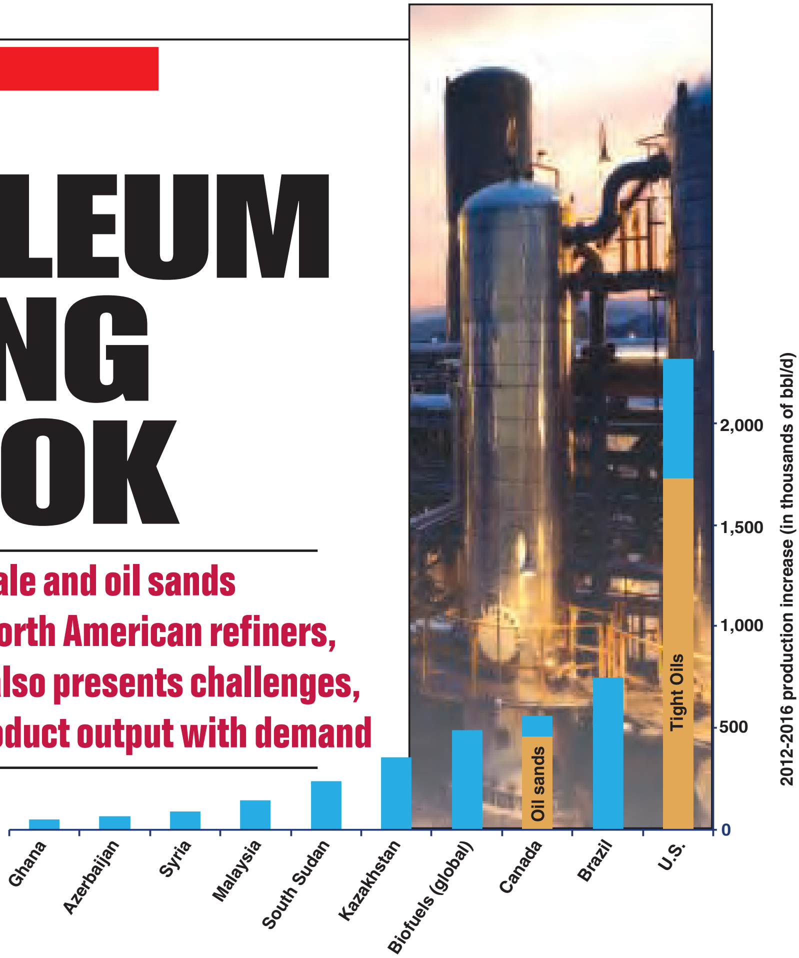


FIGURE 1. Tight oil in the U.S. represents the largest share of the increased petroleum production, and of non-OPEC production increases Source: Wood Mackenzie

Tight-oil tidal wave

Hydraulic fracturing of shale deposits has been widely associated with natural gas production in the recent past, but a large price differential between gas and crude oil has driven producers in the oil-and-gas industry to apply horizontal drilling, hydraulic fracturing and other modern extraction technologies to areas containing so-called "tight oil," referring to crude oil that resides in low-permeability geologic formations, such as shale deposits.

A number of speakers discussed the increasing tight-oil production at the AFPM meeting, including Michael Wojciechowski, an economist with Wood Mackenzie (Edinburgh, U.K.; www.woodmac.com), who called the increase "a tight-oil tidal wave" (Figure 1).

Praveen Gunneseelan, of Vantage Point Advisors (Houston; www.vantageptllc.com) says that production of tight oil in the U.S. is projected to grow from the current 1.5 million barrels per day (bbl/d) to between 2.8 and 4.2 million bbl/d by 2025, before declining to 2 million bbl/d by 2040 (Figure 2). Further, tight oil production will account for between 20 and 40% of total U.S. oil production through 2040 and will comprise a significant portion of the crude slate for U.S. petroleum refineries. The majority of this surge in tight-oil crude will be refined domestically, Guneseelan says.

The International Energy Agency (Paris; www.iea.org) says that crude oil from shale could allow the U.S. to produce as much as 11 million bbl/d overall by 2020, which would push the U.S. past Saudi Arabia as the world's largest oil producer.

The major production areas for tight oil, and those where much of the production growth will occur, are the Williston Basin in North Dakota and Montana, which contains the Bakken formation, and the Western Gulf

Wood Mackenzie

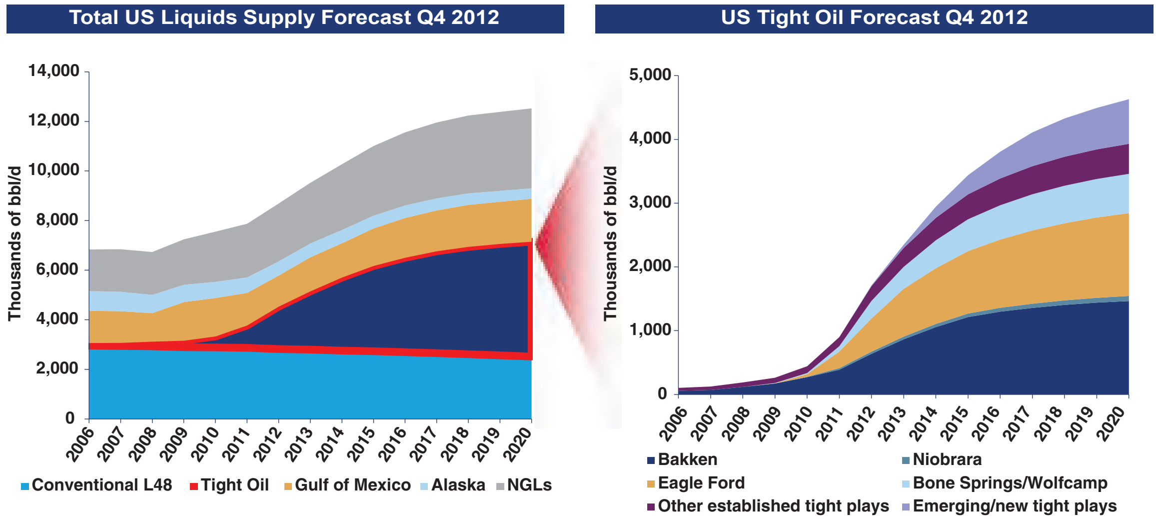


FIGURE 2. The largest fraction of the tight oil increase in the coming years will be from the Bakken and Eagle Ford formations

Basin in Texas, which contains the Eagle Ford formation. According to the U.S. Energy Information Administration (EIA; Washington, D.C.; www.eia.gov), annual production of crude oil from the Bakken formation already more than doubled between 2010 and 2012. Other areas that are attracting significant investment for tight oil production include Niobrara shale in Colorado and Wyoming, the Utica shale, especially in parts of Ohio, the Permian Basin in West Texas and the Monterrey shale in California.

The new technologies for extracting oil and gas from shale have radically changed the oil-and-gas supply picture in the U.S., says Daniel Lippe, founder of Petral Consulting Co. (Houston; www.petral.com). U.S. petroleum refiners stand to benefit, because of the steady supplies that will be available to them via pipelines, rather than relying on imports shipped by sea.

Despite the opportunities, however, tight-oil crudes present unique technological challenges to petroleum refiners. Unlike most crudes, tight-oil crudes tend to be light, sweet crudes with high paraffin content and low acidity, according to a presentation from Bruce Wright, a senior technical engineer from Baker Hughes Inc. (Houston; www.bakerhughes.com).

The significant molecular weight distribution of paraffin in tight oil is a major potential problem for downstream processing, he says, because of the potential for fouling due to wax deposition. Tight-oil crudes also generally have a minimal asphaltine phase, and varying amounts of filterable solids, hydrogen sulfide and mercaptans. Aside from paraffin wax deposits, tight oils can also create difficulties with corrosion, bacteria growth and destabilized asphaltenes, Wright points out.

Pipeline infrastructure

Aside from technology concerns, taking full advantage of tight oil requires corresponding transportation-logistics infrastructure, several speakers at the AFPM meeting indicated. Currently, existing pipeline infrastructure for transporting petroleum is not sufficient to handle the surging volumes of crude oil from shale deposits in the U.S., particularly from Bakken and Eagle Ford. This situation is placing the shale oil at a discount compared to other benchmark crudes.

"Because of the dramatic growth in tight-oil production from Bakken and Eagle Ford shale plays, there have been pipeline pinchpoints that push people toward non-traditional modes of transport for crude," such as rail and barge, says Wood Mackenzie's Wojciechowski.

"The market needs more 'relief valves' to ease bottlenecks at pipeline hubs," Wojciechowski comments. The question is becoming, "how much domestic tight-oil crude can be absorbed [by refineries] before starting to erode its value."

A wave of pipeline investment has ensued to address the logistics challenges. A host of new pipelines have either been recently completed or are under development, including several projects to transport crude oils to and from the major petroleum supply hub of Cushing, Okla. For example, phase 2 of the TransCanada Keystone pipeline, completed in 2011, delivers crude oil from Hardisty, Canada and the Williston Basin to Cushing, while the Enbridge/Enterprise Seaway expansion was completed earlier this year to expand an existing pipeline that brings crude oil from the Cushing hub to the U.S. Gulf Coast. Other pipelines to further increase take-away capacity from Cushing are planned to begin service in late 2013 (TransCanada Gulf Coast Project) and early 2014 (Seaway Twin), according to the EIA.

Declining gasoline demand

The market for petroleum-derived products is also shifting. A number of factors, including increased CAFE (corporate average fuel economy) standards for automobiles in the U.S., mandates for including ethanol in gasoline as well as other factors have combined to create the conditions for a projected decline in gasoline demand in the U.S. Some estimates, including those from the EIA, project a decline in gasoline demand at an annual rate of about 1%. At the same time, diesel fuel demand will grow by about the same rate.

For petroleum refiners, this shift means closer attention must be paid to the amounts of gasoline and diesel they produce, relative to the crude they are processing. As Vantage Point's Guneseelan says in a discussion of his presentation at AFPM, "As diesel crack spreads are expected to be superior to gasoline and U.S. diesel demand is expected to increase as gasoline demand shrinks, U.S. refiners that choose to process increasing amounts of tight oil will need to consider the potential impact on the gasoline-diesel ratio and optimize their facilities and operations appropriately to align with market demand."

John Boepple, a principal at Nexant, Inc. (San Francisco, Calif.; www.nexant.com) says, "Maximizing diesel production will be important for refiners using tight oils in their crude feedstock diet."

To navigate the gasoline-to-diesel demand shift, as well as increased price volatility and low natural-gas costs, Daniel Thomas, from UOP (Des Plaines, Ill.; www.uop.com) emphasized the importance of flexibility and agility of refineries to be able to take advantage of price differences of gasoline and diesel. At AFPM, he discussed the approach of converting hydrotreater units into mild hydrocracking operations to achieve the flexibility to optimize overall product mix. He discussed examples of refineries that have taken that approach using UOP technology.

Low-sulfur fuels

Worldwide, fuel-quality standards are tightening, and sulfur content of fuels has been steadily declining. It is likely that eventually, sulfur content in fuels will settle around 10 ppm for most of the world. The need to further reduce sulfur in transportation fuels is driving the need for additional hydrotreating capacity to produce ultralow-sulfur diesel and gasoline. Hydrotreating refers to the removal of heteroatoms (effectively sulfur and nitrogen) and the saturation of olefins and aromatic compounds.

Jean-Luc Nocca, CEO at Axens S.A. (Rueil-malmaison, France; www.axens.

net) points to technologies that add hydrogen and remove sulfur compounds, such as thiols, thiophenes and organic sulfides, as growing in importance.

Several new announcements made at the AFPM have relevance for production of low-sulfur fuels with hydrodesulfurization catalysts. Axens recently announced that its Impulse brand of hydrotreating catalysts is now being manufactured at full scale. Impulse is a series of a cobalt-modified, molybdenum-based catalysts for hydrotreatment of refined product streams.

The Impulse catalysts are designed to minimize the occurrence of inactive Mo- and Co-containing compounds at the catalyst surface, making more Mo atoms available for incorporation into mixed cobalt-molybdenum active sites, which have the highest catalyst activity, Axens says. Also the company's Impulse technology forms smaller-sized MoS_2 slabs, which increases the number of mixed active sites without increasing the total number of atoms. With the new Impulse catalysts, Axens also narrowed the distribution of pore sizes in the catalyst support material, fostering maximum activity towards refractory species, the company says.

In pilot- and full-scale tests of ultralow-sulfur diesel fuel, Axens says it confirmed an increase in hydrodesulfurization activity with the Impulse technology compared to its previous catalyst product.

Haldor-Topsøe A/S (Lyngby, Denmark; www.topsoe.com) discussed a recent offering to its hydrotreating catalyst product line that is designed to improve the company's existing hydrotreating catalyst technology. HyBrim catalyst is produced using a proprietary preparation step that leads to optimal interactions between the active metal structures and the catalyst carrier, the company says, leading to higher activities.

Criterion Catalysts and Technologies (Houston; www.criterioncatalyst.com) announced the first commercial application of a product desinged to prevent poisoning of hydrotreating catalysts by arsenic, a potent poison for hydrotreating catalysts. The product, MaxTrap[As]syn, traps the arsenic that can be present — sometimes in high levels — in some crude oils, such as those from the Athabasca region in Canada.

Max Ovchinikov, a senior research chemist at Criterion, says that the deposition of only 0.1 wt.% arsenic on a hydrodesulfurization and hydrodenitrogenation catalyst reduces catalyst activities by as much as 50%. Historically, arsenic poisoning has been treated as a part of natural catalyst deactivation, Ovchinikov noted. For the past nine years, his company has introduced a series of arsenic guard catalysts, and its MaxTrap[As]syn is the latest offering. The catalyst exhibits a 70% better volumetric arsenic uptake capacity compared to its predecessor, Ovchinikov says. The improve-

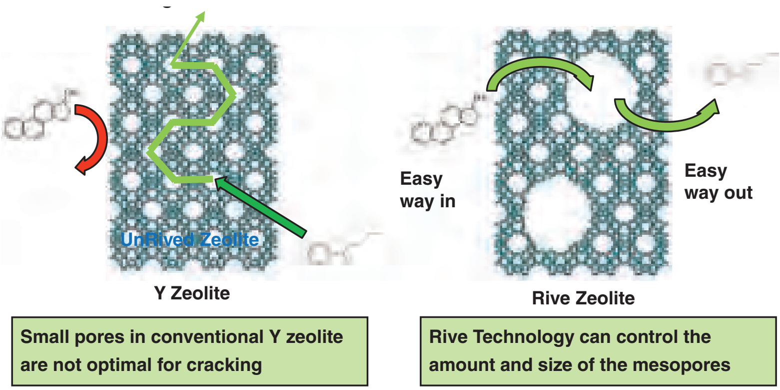


FIGURE 3. The first commercial results for Rive Technology's Molecular Highways technology, where networks of larger-sized pores are integrated into the zeolite structure, were announced at the AFPM meeting in March

ment is due to an improved catalyst manufacturing process that enhances the kinetics of arsenic capture, he explains. The first commercial application was established in Q1 of 2013.

New developments

At the AFPM meeting, a number of companies announced new advancements in other areas.

For example, zeolite technology firm Rive Technology Inc. (Monmouth Junction, N.J.; www.rivetechnology.com), announced the second commercial use of its Molecular Highway technology for fluid catalytic cracking (FCC) catalysts. Deployed commercially at the Alon Refinery in Big Spring, Tex., Molecular Highway catalyst generated a $2.50/bbl increase in value, according to a presentation by Larry Dight, vice president of research and development at Rive.

Rive first introduced the technology in 2011 (*Chem. Eng.*, May 2011, pp. 17–22), when it was used at the CountryMark refinery in Mount Vernon, Ind. Molecular Highway technology is brought to market in collaboration with W.R. Grace and Co. (Columbia, Md.; www.grace.com), which formulates and manufactures the catalyst. "We've had six commercial-scale manufacturing runs so far," says David Aldous, CEO of Rive. "This technology offers a rare chance for refiners to realize gains in profitability without large capital expenditures and without higher operating costs," he says.

Using surfactant micelles, Rive is able to create a zeolite structure with larger, mesoporous openings interspersed along with the microporous zeolite structures. The larger openings allow improved mass transfer of hydrocarbon molecules into and out of the catalyst material, says Andrew Dougherty, Rive's vice president for sales and marketing. "By getting gasoline- and diesel-range molecules out of the zeolite quickly, we are able to prevent secondary cracking," Dougherty explains, resulting in less dry gas and less coke formation (Figure 3).

Also at the meeting, Auterra Inc. (Malta, N.Y.; www.auterrainc.com) announced that it has successfully completed pilot-scale testing of FlexDS, its oxydesulfurization technology for upgrading and decontaminating heavy and sour crude oil and oil distillates. "There's an environmental paradox with desulfurization, where the more sulfur you try to remove, the more energy you use and the more carbon dioxide you generate," says Eric Burnett, president and CEO of Auterra. The catalytic FlexDS technology uses a proprietary molecule whose structure allows selective reactions with sulfur and nitrogen in hydrocarbon streams, while reducing energy costs, Burnett explains, so petroleum producers can field-upgrade their heavy sour oil while improving their economics. FlexDS can be used for off-loading hydrogen demand for heavy cuts and distillates in existing refineries.

"Following the completion of pilot-scale tests, we are looking to conduct field tests of the technology in early 2014 with a partner in the Canadian oil sands," says Burnett. ■

Scott Jenkins

Newsfront

COMBUSTIBLE DUST SAFETY

While understanding combustible dust regulations can be difficult, experts stress the importance of compliance

United Air Specialists

FIGURE 1. Reputable air-pollution-control experts can recommend appropriate systems like United Air Specialists' SFC cartridge dust collector, which can be equipped and installed to safely handle hazardous dusts

The U.S. Occupational Safety and Health Admin. (OSHA; Washington, D.C.; www.osha.gov) has flagged combustible dusts as one of its top issues since the Imperial Sugar Mill explosion in Port Wentworth, Georgia, that killed 14 employees and injured many others in February 2008. Combustible dust is, in fact, one of OSHA's National Emphasis Programs (NEPs).

The situation today

Despite the attention, however, OSHA does not yet actually have its own standard pertaining to combustible dust (see sidebar, "Combustible Dust 101"). Instead, the agency cites combustible dust hazards — including fire deflagration, explosion and related hazards — under its General Duty Clause (5(a)(1)). General Duty Clause citations related to combustible dust may be issued for deflagration, explosion or other fire hazards that may be caused by combustible dust within a dust collection system or other containers, such as bins or mixers. Compliance officers may rely upon National Fire Protection Agency (NFPA; Quincy, Mass.; www.nfpa.org) standards for evidence of recognition of the hazard, as well as consult relevant NFPA standards for evidence of feasible means of abatement. OSHA inspectors can also cite hazards not addressed in consensus standards under the General Duty Clause. This includes the statement that employers must furnish each employee with a place of employment that is free from recognized hazards that are causing, or are likely to cause, death or serious physical harm.

According to the Status Report on the Combustible Dust NEP, 11% of combustible-dust-related violations pertain to the General Duty Clause.

Citations can also be issued for deflagration, explosion or other fire hazards that may be caused by combustible dust within a dust collection system or other containers, such as mixers and bins. In addition, citations can be issued for conditions such as improper deflagration venting, ductwork-related problems, make-up air system and improper work practices.

What this means, in a nutshell, is that although there is currently no OSHA standard for combustible dusts, based upon a National Emphasis Program established by OSHA and Congress, OSHA can fine facilities that aren't in compliance with relevant NFPA standards during routine inspections or inspections under the NEP, which generally occur in facilities that have accidents, fatalities or complaints related to combustible dust or in industries with a higher potential for combustible dust explosions and fires. (And, you can bet many chemical processors are in this category.)

Confused? You aren't alone. Suppliers of dust collection equipment and systems say the uncertainty surrounding combustible dust compliance is the biggest challenge the chemical — or any other combus-

COMBUSTIBLE DUST 101

What is a combustible dust? According to both OSHA (CPL 03-00-008) and NFPA 654, a combustible dust is a combustible particulate solid that presents a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape.

The most common categories of combustible dust include organic dusts, such as sugar, flour, paper, soap and dried blood; wood dusts, including sawdust; metal dusts, such as aluminum and magnesium; plastic dusts and carbon dusts.

When it comes to knowing how to handle these dusts, there are four main standards for a variety of industries and several consensus standards related to equipment that apply.

The four main combustible dust standards are as follows:

- Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities (NFPA 61-2008)
- Standard for Combustible Metals, Metal Powders and Metal Dusts (NFPA 484-2009)
- Standard for the Prevention of Fires and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids (NFPA 654-2006)
- Standard for the Prevention of Fires and Dust Explosions in Wood Processing and Woodworking Facilities (NFPA 664-2007)

Additional Combustible dust consensus standards are as follows:

- Explosion Protection by Deflagration Venting (NFPA 68-2007)
- Explosion Prevention Systems (NFPA 69-2008)
- Classification of combustible Dusts and Hazardous (Classified) Locations (NFPA 49902008) ❏

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tible-dust-producing — industry faces. "There really are no clear-cut guidelines," says Jamie Scott, vice president of Air Handling Systems (Woodbridge, Conn.; www.airhand.com). "And this makes awareness and understanding the two biggest obstacles to compliance when it comes to combustible dust. It's a double-edged sword, because although some processors don't know exactly how to be in compliance due to a lack of an OSHA standard, they still can be cited during random or NEP inspections without even realizing they're doing anything wrong."

In an effort to avoid these citations, many chemical processors now are beginning to upgrade their dust collection equipment, but that also presents challenges. "There are so many different aspects of a system in terms of capturing, conveying and collecting the material in a safe and effective way. These steps include proper hood design, duct layouts, equipment selection, blower sizing, safety considerations for the workers and the combustible dust or explosion hazards of the collected material," says Travis Haynam, director of business development and technical sales with United Air Specialists, Inc. (Cincinnati, Ohio; www.uasinc.com). "Every one of these aspects is critical and if one is not done correctly, the system may not meet the performance requirements or customer expectations."

Compounding that problem is the issue that dust collection is what is considered by many to be a non-value-added expenditure. "Everyone knows they need to make their process safer and that knowledge is pushing processors to upgrade their dust collection equipment, but if they are barely making a profit at the moment, they don't want to spend money on something that is not going to make them money," says Matt Caulfield, Canadian sales director and Northeast regional manager with Camfil APC (Jonesboro, Ark.; www.farrapc.com). "But they must [invest in upgrades] because they also don't want to get shut down…or worse."

Aerodyne

FIGURE 2. The GPC Cyclonic Dust Collector offers cyclonic action that is initiated by a sloped spiral inlet and vortex reversal is accomplished by the use of a solid ground plate. The unique design provides a high-efficiency, compact unit that is available in horizontal or vertical configurations

Taking action

The first step in overcoming the confusion — and getting the right equipment with the lowest possible capital

FIGURE 3. SplitStream is a counter-cyclonic dust collector that has no major moving components and is capable of handling a wide range of materials, while requiring minimal maintenance

outlay — is to analyze the dust and determine potential hazards, as well as what is required to achieve compliance with applicable regulations. Determining what the contaminant is and what regulations and permissible exposure limits or safety hazards are associated with that dust is crucial, notes United Air Specialists' Haynam.

During this stage, it is critical to know what you're dealing with, including the K_{st} value of the material, which will determine if there is a combustible dust issue. K_{st} is the dust deflagration index, and it measures the relative explosion severity compared to other dusts. Any material with a K_{st} value greater than zero is considered to be at risk of an explosion. Other than silicon or sand, every kind of dust is potentially combustible to some degree.

Most dust collection companies offer testing via an outside laboratory. If the laboratory finds that the dust is explosive, it will test the dust to determine the K_{st} value and then issue a report stating the exact value. If it is not combustible, the report will state this. Documentation is important during an OSHA inspection to show that appropriate steps are being taken for the type of dust existing in the facility. "If there are several different K_{st} values present in a facility's dust, we suggest taking the worst case scenario for the dust with the highest K_{st} value and, based on what NFPA requires, size the system for that K_{st} value," says Camfil's Caulfield.

Once the type and combustibility of the dust are identified, processors must ascertain which regulations apply and which permissible exposure limits or safety hazards are associated with that dust. The next step, according to Haynam, is to review the source of the dust and identify the best way to capture and contain it. From there, airflow requirements, ducting design and equipment type can be discussed. Keep in mind that different dusts require different solutions when selecting and configuring equipment. And, of course, combustible dusts require adequate means of protection, such as explosion venting or suppression systems.

"Unfortunately there's not a one-size-fits-all solution. Each material, each process and each facility has different dust-collection and dust-safety needs and requirements," explains Caulfield.

Other issues to keep in mind

However, experts warn that even a properly selected, sized and installed dust-collection system is not enough.

Camfil APC

FIGURE 4. Camfil APC's Integrated Safety Monitoring Filter (iSMF) requires no additional floor space and prevents collected dust from re-entering the workspace should there be a leak in the primary filtering system

Other steps are needed to achieve complete compliance, and to protect employees and assets.

Housekeeping is the first line of defense in fighting the dust battle, no matter the type of dust. "Fugitive dust is often a problem because it collects on hung or dropped ceilings, flat ducting and flat hanging lights," says Scott. "Anywhere that dust can accumulate out of sight is a problem because if there is a fire or explosion in a facility, the initial explosion shakes the building, which releases the dust sitting on these surfaces and, as the flames from the initial fire tear through the facility, this released fuel (the fugitive, dispersed dust) can be ignited, creating additional explosions. For this reason, it is imperative to collect dust at its source and keep up with housekeeping to prevent it from accumulating on these surfaces."

While dust collection equipment is often viewed as a necessary evil, Daniel Novicky, sales engineer at Aerodyne Environmental, Inc. (Chagrin Falls, Ohio; www.dustcollectorhq.com), says there are ways to minimize the expense associated with it. "Look for equipment that limits downtime, reduces the frequency of maintenance and the cost of working on that equipment, as well as well-made equipment that does not need frequent replacement."

Worker training is also very important. "OSHA interviews your employees," says Scott. "They want to know if the workers are aware of, trained about and know how to handle issues. So training your employees on hazardous dust handling goes a long way toward avoiding OSHA citations and loss related to explosions." ■

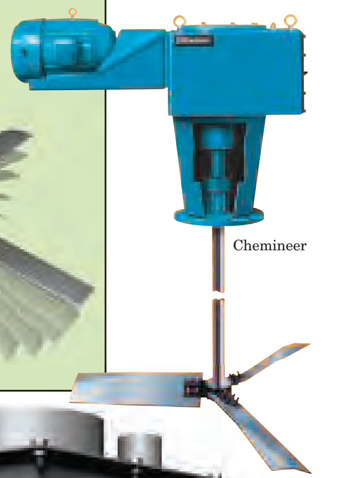
Joy LePree

FOCUS ON

Mixing

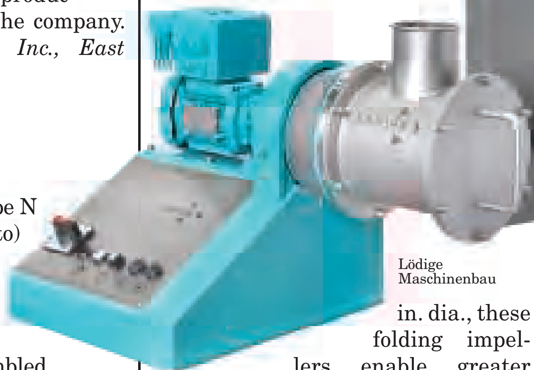
Silverson Machines

Sharpe Mixers



Chemineer

Hapman



Lödige Maschinenbau

A laboratory mixer that supplies data for scaleup

The L5 Series laboratory mixers (photo) are suitable for R&D, quality analysis and standard laboratory work. The mixers have a capacity range from 1 mL up to 12 L, and are able to mix inline with flowrates up to 20 L/min. Each machine is constructed with wetted parts in grade 316L stainless steel. The L5M-A laboratory mixer features touchscreen control with digital tachometer, programmable integral timer and amperage display, which is invaluable in scaling up production, where validation and reproducibility are crucial, says the company. — *Silverson Machines Inc., East Longmeadow, Mass.*

www.silverson.com

This drum mixer fits on a laboratory bench

The new Ploughshare Type N 5 laboratory mixer (photo) features a drum with a volume of 5 L. The mixer was conceived as a compact, table-top model, and comes completely assembled, tested and thus ready for use. The control unit is an integral part of the housing. The speed of the mixer shaft is infinitely adjustable. The detachable front plate can be rotated for filling and emptying the mixing vessel through the same neck, which also facilitates cleaning. A range of optional accessories is available, including a feeding hopper or spray lid for dosing liquid products. — *Gebr. Lödige Maschinenbau GmbH, Paderborn, Germany*

www.loedige.de

If the port is too small, consider this folding impeller

This new high-performance folding impeller is suitable for new and retrofit installations where tank entry is not practical or too expensive. The Folding Blade Hyflo 218 Impellers (photo) feature a hydrofoil-style, four-blade design that folds for easy installation, and opens with centrifugal force, locking in place when fully opened. Available in sizes up to 210-in. dia., these folding impellers enable greater flexibility in tank designs, and the blade-locking mechanism can be accessed from outside the tank for removing the mixer, if necessary. Retrofit applications include side entry for large storage tanks, or top entry when the tank service has changed and a new mixer is required. — *Sharpe Mixers, Seattle, Wash.*

www.sharpemixers.com

Blending can also be performed by this screw feeder

This new Screw Feeder (photo) is designed to efficiently measure ingredients and consistently deliver material to the process. Available with either volumetric or gravimetric controls, the feeder features an optional integral agitator, which enables the feeder to effectively operate as a dry material mixer. The unit can blend multiple dry materials, combine thick, wet mixes, and break up solid lumps. The trough is available in 304 or 316 stainless steel, carbon steel, or special alloy material, and can be customized for specific applications. — *Hapman, Kalimazoo, Mich.*

www.hapman.com

A robust agitator that comes in many sizes

The HT Turbine Agitator (photo) features a unique design that results in high strength, low wear, quiet operation and minimal maintenance, says the manufacturer. The device has output speeds of 5 to 350 rpm; a compact, right-angle gear drive; and tapered roller bearings with service rated to over 100,000 hours (L-10) life. Thirteen standard drive sizes are available, from 1 to 1,000 hp. A wide variety of mountings, shaft seals and impellers are available. — *Chemineer, Inc., Dayton, Ohio*

www.chemineer.com

A blender for mixing hot, sticky materials

The new high-temperature, high-intensity continuous blender, Model HM-165-AR (photo), mixes asphalt, paints, resins adhesives and other

Note: For more information, circle the 3-digit number on p. 72, or use the website designation.

Munson Machinery

Westfall Manufacturing

abrasive, sticky or tacky compounds, slurries, emulsions and pastes that require heat to maintain consistency. The unit's horizontal, cylindrical vessel with a single agitator is supported by externally mounted flange-block bearings. It can blend at rates up to 2,000 ft^3/h without sacrificing retention time for homogeneous blending or coating, says the manufacturer. Homogeneous blends can be achieved in 15–60 s residence time, depending on the material characteristics. — *Munson Machinery Company, Inc., Utica, N.Y.*
www.munsonmachinery.com

A static mixer for adjusting bitumen viscosity and density
This company has introduced a static mixer for bitumen processing that mixes multiple diluents to the correct viscosity and density, which allows pumping over a wide range of flowrates. The Model 290 Variable Flow Static Mixer (photo) is combined with the company's wafer-style static mixer to achieve a low coefficient of variation (CoV) of injected diluents. Capable of achieving a uniform concentration of injected materials within a short downstream distance, while meeting the maximum pressure-loss criteria, this mixer reduces consumption of the bitumen diluents, says the company. Accommodating flowrates at up to a 20-to-1 turndown ratio, the mixer is made from 316L stainless steel and is available in sizes from 2- to 60-in. dia. — *Westfall Manufacturing Co., Bristol, R.I.*
www.westfallmfg.com

This mixer is also an energy-efficient dryer
The Pegasus Mixer features a double-shaft paddle mechanism that gently throws powders, granules and granulates into the air during mixing. The fluidized zone created allows the multifunctional processing unit to mix ingredients extremely gently, quickly and energy-efficiently, says the company. The new drying functionality built into the mixer also takes advantage of this fluidized zone, and prevents agglomeration during the drying process. — *Dinnissen B.V., Sevenum, the Netherlands*
www.dinnissen.nl

Mix solids of modest bulk density with this ribbon blender
The 42B Model Ribbon Blenders (photo) are used for blending of powders or other solid raw materials with a bulk density of 35 lb/ft^3 or lower. The blender features stainless-steel wetted parts (polished to 60-grit finish);

a solid-shaft double-ribbon agitator designed for center discharge; a knife-gate discharge valve; clamps to eliminate dusting and fume migration; safety limit switches to prevent operation when covers are raised; and more. Units are available from 0.5 to 1,000 ft^3 of working capacity. — *Charles Ross & Son Co., Hauppauge, N.Y.*
www.mixers.com


Charles Ross & Son

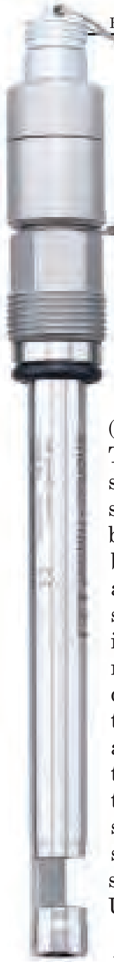
Side mixers with fixed-angle and swivel configurations

The Cutlass side-entry mixers now include the BSE-R fixed-angle and BSE-R swivel models. The mixers' design features an easy-to-remove, cartridge-style mechanical seal that allows more room to access and maintain bearings and seals. The shaft is precision-machined to reduce vibration and to increase bearing life. Vibration and temperature sensors can be mounted on pads cast into the housing to monitor the unit while in operation. The drive is protected by a rigid belt cover with quick-release captive fasteners and a polycarbonate viewing window for checking the belt. When coupled with a Lancer Advanced Pitch Propeller, the Cutlass can yield energy savings of 30% or more for elimination of basic sediment and water in crude-oil tanks, says the company. — *Philadelphia Mixing Solutions, Ltd., Palmyra, Pa.*
www.philamixers.com

A micro static mixer improves bromination reactions

This company has released an application note that describes a continuous flow methodology for electrophilic bromination that offers "excellent" control of both temperature and mixing using a proprietary mixer chip. Using the static mixer chip on a FlowSyn flow-chemistry system controls both mixing and temperature, which makes bromination become a titration and the reaction can be performed under elevated temperatures. The chip-based bromination can be scaled to 28 g/h, says the company. The FlowSyn is a compact, integrated continuous flow-reactor system designed for easy, safe and efficient operation. The FlowSyn range includes models for performing single or multiple homogeneous or heterogeneous reactions, either manually or automatically. — *Uniqsis Ltd., Shepreth, U.K.*
www.uniqsis.com ■

Gerald Ondrey


Endress + Hauser

MAY New Products

SICK


Mott


Brookfield Engineering Laboratories

Vindum Engineering

Monitor cell growth with this sensor

The OUSBT66 sensor (photo) is designed for cell-density measurements using near-infrared (NIR) absorbance technology. The non-intrusive, hygienic sensor can monitor cell growth in life science processes, fermentation biomass measurement and algae biofuel applications. The sensor allows rapid and accurate measurement of cell growth activity in cultures and can be used for realtime, in-situ cell-production optimization and to identify the end-of-log-growth phase and the achievement of stationary growth. The body of the OUSBT66 sensor is constructed of 316L stainless steel and uses proven optical sensor technology, the company says. Using an LED light source, the sensor filters the light to 880 nm, the detection of which is correlated to the density of cells in the process. — *Endress + Hauser, Greenwood, Ind.*
www.us.endress.com

Position this safety light curtain anywhere

The deTec4 Core safety light curtain (photo) is a guard-only safety light curtain with this company's QuickFix and Flexfix brackets that can be positioned in any location on machinery housing without causing blind zones. The product is designed for hazardous point protection and single-sided access protection, and can be used in machine-building and storage and conveyer applications. With a unique, built-in automatic range detection of 10 m, the deTec4 Core is able to automatically determine distance to the sender, which eliminates manual setup of the sensing distance, the company says. The deTec4 Core is available in heights from 300 to 2,100 mm, with 14- and 30-mm resolutions. — *SICK Inc., Minneapolis, Minn.*
www.sickusa.com

Get touchscreen navigation with this viscometer

The DV2T viscometer (photo) is now available with touchscreen technology, which creates an advanced user experience, the company says. The 5-in., full-color display guides users through test creation and data gathering for fast and easy viscosity measurements. The DV2T also offers powerful new programming capabilities and results analysis, including data analysis and quality-control limits with alarms. Program generator software can create multi-step test protocols. — *Brookfield Engineering Laboratories, Middleboro, Mass.*
www.brookfieldengineering.com

This valve handles very high pressures

This company's CV Series valves (photo) are capable of continuous operation at pressures up to 20,000 psi. The valve is available as either an on-off position model or a three-way, four-position model. In addition to high pressures, the patented valve design can be used in high-temperature applications and with corrosive fluids. The CV Series valves are pneumatically operated via a set of small, low-voltage pilot valves. The CV valves maintain a constant internal fluid volume and do not trap any fluid within the valve body when switched, the company says. — *Vindum Engineering Inc., San Ramon, Calif.*
www.vindum.com

These gas-sampling filters allow particle-free samples

All-metal inertial gas-sampling (IGS) filters (photo) from this company allow the collection of particle-free samples from virtually any gas stream. Even heavily contaminated gas streams and extreme-temperature samples can be handled by the durable filters, the company says. Typical applications include gas sampling in stack testing, utility coal pulverizers, lime or cement kilns, fluid catalytic crackers, coking-oven offgas atmospheres and general emissions-control monitoring. The IGS filters feature a crossflow design that keeps most particles in the gas stream greatly reducing obstruction of the filter element. The company's porous-metal filter media is durable and can be used in highly corrosive environments. — *Mott Corp., Farmington, Conn.*
www.mottcorp.com

This dust-collection system has a low profile

Two dust collector hoppers, called the Low Pro (photo) and the Low Boy, are designed for use where space constraints require a low-profile dust-collection system. The Low Pro hopper is best suited to the collection of dust and fumes from cutting, blasting, welding and thermal spray operations, the company says, while the Low Boy hopper is designed for use in applications with heavier dust loads involving a variety of dry dusts. Depending on the model, the low-profile hoppers can reduce overall collector height by as much as 36 in., the company says. The Low Pro hopper comes with either a 55-gal drum or a half-size drum, and has a drum-lid mechanism that readily latches open and shut to expedite emptying or change-out. The Low Boy consists of a clamp-on angled hopper and low-profile bin. — *Camfil APC, Jonesboro, Ark.*
www.camfilapc.com

Camfil APC

Use this hose reel in harsh environments

The 9000 Series industrial manual or power rewind hose reel is designed for harsh environments in chemical processing, food processing and bottling applications. The reels handle hoses with inner diameters of between 2 and 3 in., and have a gear-driven crank rewind or a chain-and-sprocket drive. The unit can be powered by an electric, hydraulic or compressed-air motor. It has a standard 90-deg, ball-bearing swivel joint and 3-in. female pipe threads. The 9000 Series operates at pressures up to 300 psi and is able to withstand temperatures from –20 to 225°F. The product can also be customized to fit other special requirements. — *Hannay Reels, Westerlo, N.Y.*
www.hannay.com

This thickness gage offers more transducer choices

The EHC-09A thickness gage offers a number of features, including field-upgradable options for more transducer choices, the capability to ignore coatings and a live A-scan. It is said to be the only entry-level thickness gage available with this capability. The device has three probes, a default, as well as others for thicker materials, and smaller-diameter, thinner materials. — *Danatronics Corp., Danvers, Mass.*
www.danatronic.com ■

Scott Jenkins

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Control Valve Performance

Minimizing process variability is an important component of a plant's profitability. The performance of control valves within process control loops has a significant impact on maintaining consistent processes. This refresher outlines some of the important aspects of control valve performance, including parameters of both the static response and the dynamic response.

Static response

A valve's static response refers to measurements that are made with data points recorded when the device is at rest. Key static-response parameters for control valves include travel gain, dead band and resolution (Figure 1).

Travel gain (G_x). This term represents the change in position of the valve closure member divided by the change in input signal. Both quantities are expressed as a percentage of the full valve span. The closure member is part of the valve trim (the combination of flow-control elements inside a valve). Travel gain measures how well the valve system positions its closure member compared to the input signal it receives. Without signal characterization in the valve system, the travel gain should be 1.0. [*1*]

Dead band. This term can be defined as the range through which an input signal may be varied, with reversal of direction, without initiating a response (an observable change in output signal). With respect to control valve performance, if the process controller attempts to reverse the position of the control valve, the valve will not begin to move until after the controller output has reversed an amount greater than the dead band. A large dead band will negatively impact control performance.

Resolution. This term can be defined as the minimum amount of change in valve shaft position when an input is applied. Resolution will cause the control valve to move in discrete steps in response to small, step input changes in the same direction. This occurs as the valve travel sticks (when the starting friction on the valve shaft is greater than the friction when the shaft is in motion). Similar to dead band, a larger resolution will negatively impact control performance.

Dynamic response

Dynamic response for a control valve is the time-dependent response resulting from a time-varying input signal.

Dead time. This term refers to the time after the initiation of an input change and before the start of the resulting observable response.

Step response time. This term represents the interval of time between initiation of an input-signal step change and the moment that the dynamic response reaches 86.5% of its full, steady-state value [*1*]. The step response time includes the dead time before the dynamic response.

Overshoot. This term is the amount by which a step response exceeds its final, steady-state value. Overshoot is usually expressed as a percentage of the full change in steady-state value. Figure 2 shows the dead time, step response time and overshoot for a control valve response to a step input change. In this case, stem position in percent of travel is used as the control valve "output."

Step-change size. The dynamic response of a control valve varies depending upon the size of the input step change. Four "ranges" of step sizes to help understand the static- and dynamic- response metrics are defined by ANSI/ISA standards:

- Small input steps (Region 1) that result in no measurable movement of the closure member within the specified wait time
- Input step changes that are large enough to result in some control-valve response with each input signal change, but the response does not satisfy the requirements of the specified time and linearity (Region 2)
- Step changes that are large enough to result in flow coefficient changes, which satisfy both the specified maximum response time and the specified maximum linearity (Region 3)
- Input steps larger than in Region 3 where the specified magnitude-response linearity is satisfied but the specified response time is exceeded (Region 4)

Region 1 is directly related to dead band and resolution. Region 2 is a highly nonlinear region that causes performance problems and should be minimized. Region 3 is the range of input movements that are important to control performance [*1*].

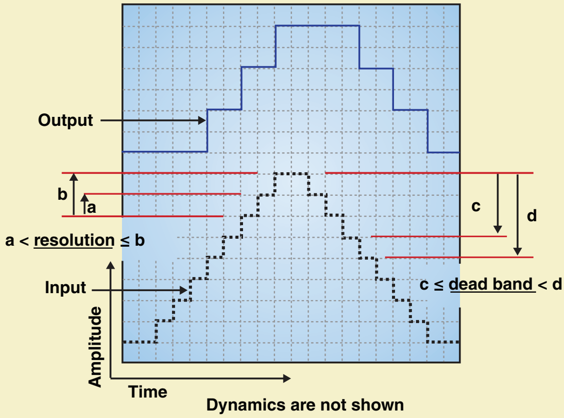


FIGURE 1. Dead band and resolution, illustrated here, are key static-response parameters for control valves

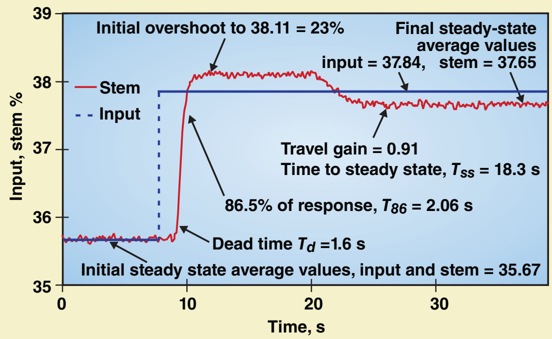


FIGURE 2. This graph shows the response of a control valve to a step input (reprinted with permission from EnTech Control Valve Dynamic Specification V3.0)

Process gain

Process gain is the ratio of the change in a given process variable to the change in controller output that caused the change. To achieve effective process control, the process gain should ideally fall within a certain range, and should be consistent throughout the operating range of the valve. When the process gain is too high, valve non-linearities are amplified by the process gain and process control performance deteriorates. When the process gain is too low, the range of control is reduced. Changes in the process gain over the range of operation result in poorly performing regions in the closed-loop controller response.

Two control-valve features impact process gain: the size of the valve trim and the inherent flow characteristic of the valve. If the valve trim is oversized, the process gain will be higher than it would be for an appropriately sized valve. The valve's flow characteristic refers to the curve relating percentage of flow to percentage of valve travel. Inherent flow characteristic applies when constant pressure drop is maintained across the valve. Typically linear, quick opening or equal percentage, this will impact both the magnitude and the consistency of the process gain over the operating range [*1*]. Good control-valve performance depends on proper valve sizing and trim characteristics.

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Editor's note: Portions of this page were adapted from the article in Ref. 1.

DO YOU HAVE WHAT IT TAKES?

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Nominations are now being accepted for the 2013 *Chemical Engineering* and ChemInnovations Awards. Winners will be announced during the 2013 *Chemical Engineering* & ChemInnovations Awards Banquet on **Tuesday, September 24, 2013** at the **Moody Gardens Hotel** and **Convention Center**.

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Technology Profile

Polypropylene Production via Gas-Phase Process

By Intratec Solutions

Polypropylene (PP) is one of the world's most widely used polymers, second only to polyethylene in terms of global demand. The global market for polypropylene is over 60 million metric tons per year, and it is utilized in a broad and diverse range of end-uses — from injection-molding applications to films and sheets, as well as synthetic raffia and other fibers, among others. Traditionally, the most representative types of propylene polymerization are the following: hydrocarbon slurry or suspension, bulk (or bulk slurry), gas phase and hybrid (uses bulk- and gas-phase polymerization reactors).

The Unipol PP process, a leading gas-phase process technology, was recently offered for sale by Dow Chemical Co. (Midland, Mich.; www.dow.com). The company is looking to focus on high-margin areas, and is seeking buyers for its polypropylene licensing and catalyst business.

The process

PP is a thermoplastic material formed by the polymerization of propylene, resulting in a macromolecule that contains from 10,000 to 20,000 monomer units. The production of a polypropylene homopolymer via a gas-phase process similar to Dow Unipol is depicted in the diagram (Figure 1). The process shown is capable of productiing homopolymer and random copolymer PP. For impact copolymer production, a secondary reaction loop is required. In this process, gaseous propylene contacts a solid catalyst in a fluidized-bed reactor. The process can be separated into three different areas: purification and reaction; resin degassing and pelletizing; and vent recovery.

Purification and reaction. Fresh polymer grade (PG) propylene is sent to fixed-bed dryers to remove water and other polar impurities. The purified propylene, a recycle stream from the vent recovery system and comonomers (in case of copolymer production) are then fed continuously to the reactor. A gas compressor circulates reaction gas upward through the reactor, providing the agitation required for fluidization, backmixing and heat removal. No mechanical stirrers or agitators are required in the process reactor. The overhead gas from the reactor passes through a cooler for reaction heat removal. Catalyst is continuously fed to the reactor.

Resin degassing and pelletizing. Resulting granular polypropylene is removed from the reactor by the discharge tanks and sent to a purge bin where residual hydrocarbons are stripped with nitrogen from the resin and are sent to the vent recovery system. The resin from purge bin is combined with additives and then flows to the pelletizing unit. The pellets are dried, cooled and sent to product blending and storage.

Vent recovery. The vent gas is processed to separate hydrocarbons and nitrogen purge gas, which is returned to the process. The condensed components are separated into a propylene stream, which is returned to the reaction system, and a propane stream.

Economic performance

An economic evaluation of the process was conducted for two distinct integration scenarios:

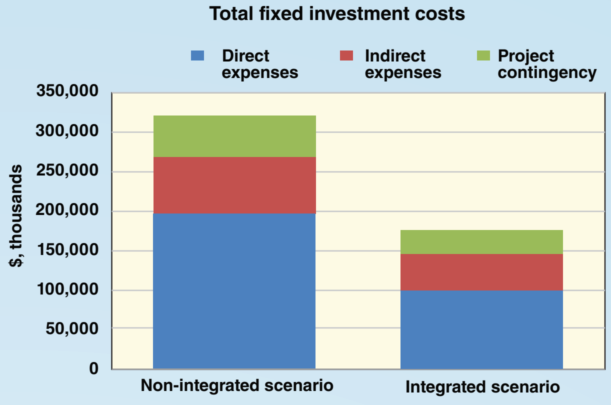

FIGURE 2. Elevated propylene prices make it unprofitable to operate a standalone PP unit

- The integrated scenario is based on the construction of a plant linked to a propylene supplier. In this case, storage for propylene is not required. However, the estimated investment for the integrated scenario includes storage for PP equivalent to 20 days of plant operation
- The non-integrated scenario is based on the construction of a grassroots PP processing unit. Thus, a time period of 20 days of operation was considered for storage of both products and raw materials

The economic evaluation was based on data from the third quarter of 2011 and a plant nominal capacity of 400,000 ton/yr erected on the U.S. Gulf Coast (only the process equipment is represented in the simplified flowsheet).

The level of integration with nearby facilities significantly impacts the total fixed investment required for the construction of a PP plant, as represented in the graph (Figure 2).

More than that, the elevated market prices for propylene in the U.S. make it unprofitable to operate a stand-alone PP unit. However, PP units that are integrated upstream with a propylene production plant may purchase propylene at prices below the market average, reaching EBITDA (earnings before interest, taxes, depreciation and amortization) margins of above 20%. ■

Edited by Scott Jenkins

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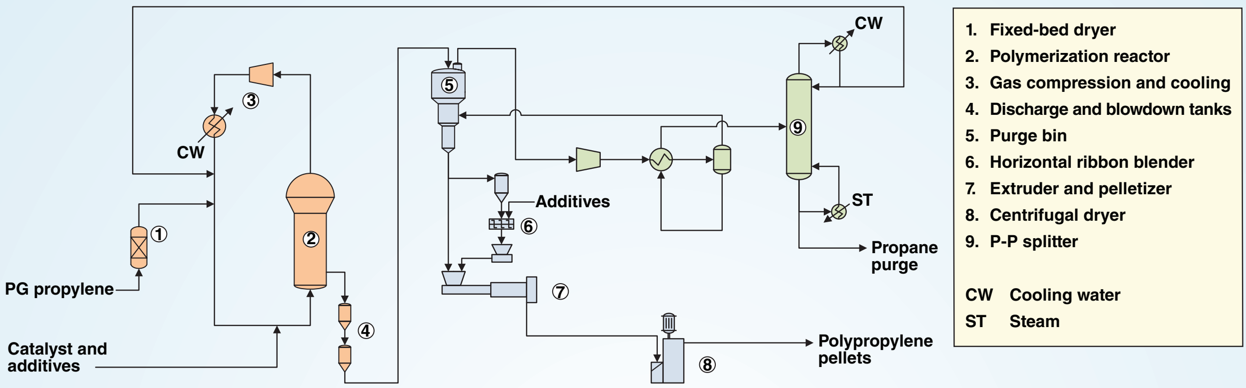

FIGURE 1. Homopolymer PP production process similar to Dow Unipol

Feature Report

Inline Viscosity Measurements

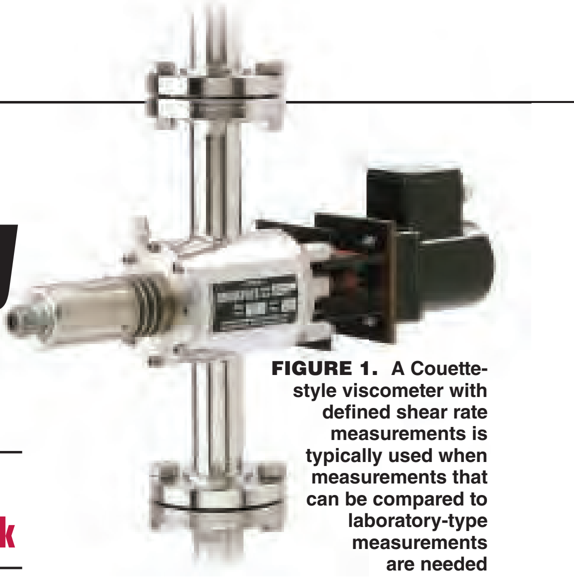

FIGURE 1. A Couette-style viscometer with defined shear rate measurements is typically used when measurements that can be compared to laboratory-type measurements are needed

Process viscometers can help keep process control and product quality in check

Steve Cicchese
Brookfield Engineering Laboratories

Inline viscosity measurements can give continuous, realtime readings of a fluid's viscosity during processing and consequently, can provide a means to automate the viscosity control of process fluids. While it is difficult to control all factors in the process that can affect a fluid's viscosity (such as temperature, air bubbles, shear history, turbulence and so on), if these factors are kept relatively constant, then good control can be achieved. This article presents the applications for inline viscosity measurement and the means by which they are achieved. Let's first discuss the subject of viscosity.

The basics

Viscosity is a property that is often considered by process engineers, but seldom completely understood. It is generally not a subject that is covered in much detail in many engineering curricula. Most engineers know what viscosity is, but may have trouble explaining it or even understanding the full implications of the measured number. Scientifically, viscosity is the property of a fluid that causes it to resist flow.

For materials that flow, either while being processed (for pumping, spraying or coating) or in an end-use (like shampoo, detergent or paint), it is important to think about the material's flow characteristics or viscosity. Engineers and quality-control personnel need ways to measure viscosity so that they can quantify whether a material will flow the way it needs to for the process or for the application.

Plant personnel may have an indication of the viscosity or "consistency" of a material by looking at it, rubbing it between their fingers, or having it drip off a stick or shovel. This type of practical "measurement" of a material's characteristic was eventually developed into a somewhat more scientific approach by using cups with holes in the bottom and a stopwatch to measure how much time it would take to drain the fluid. The cups (for example efflux cups) are relatively inexpensive and easy to use. This type of test uses the force of gravity to drain the fluid out of the cup. The shearing action on the fluid takes place at the orifice on the bottom of the cup. As the level in the cup goes down, the shear rate at the orifice decreases because the weight of the fluid remaining in the cup is lower. This type of measurement is referred to as kinematic viscosity. This method was one of the earliest quality control (QC) tests that checked viscosity in a quantifiable way.

But the cup method could not always discriminate successfully between materials that proved acceptable and those that were marginal or even poor performers because of the varying shear rate. Understanding a defined "shear rate" and how it can affect the viscosity of the fluid is important. Imagine that the fluid you want to test is sandwiched between two plates separated by a known distance. Keeping the bottom plate stationary and moving the top plate at a defined velocity, shear rate is the ratio of the moving plate velocity, V, to the distance separating the plates, X. The use of a rotational viscometer running at different speeds can simulate, in part, what is happening to the fluid during processing. This analytical procedure for simulating the shearing action with an instrument is the key to predicting flow behavior.

Rotational viscometers (Figure 1) are widely accepted tools for the measurement of viscosity across most industries. The spindle of a rotational viscometer, when inserted into the liquid, rotates at various fixed speeds, thereby shearing the material continuously at defined shear rates. Simultaneously, the viscometer measures the amount of torque resistance experienced by the spindle at each speed of rotation. This torque measurement is quantified as a "shear stress," which acts across the surface area of the immersed portion of the spindle. These two key concepts — torque resistance and shearing action — are combined in an equation that defines apparent or dynamic viscosity as the ratio of shear stress to shear rate.

The unit of measurement used to quantify rotational viscosity is the centipoise (cP) in the western hemisphere, and the milliPascal second (mPa-s) in other countries, although there is some degree of overlap in useage. The good news is that the two units are interchangeable because 1 cP equals 1 mPa-s. There is a way to correlate viscosity measurements made with dynamic and kinematic methods for materials that are Newtonian, using the following equation: Dynamic viscosity = kinematic viscosity × density (for more on the fundamentals of viscosity, see Viscosity: The Basics, *Chem. Eng.*, August 2009, pp. 34–39).

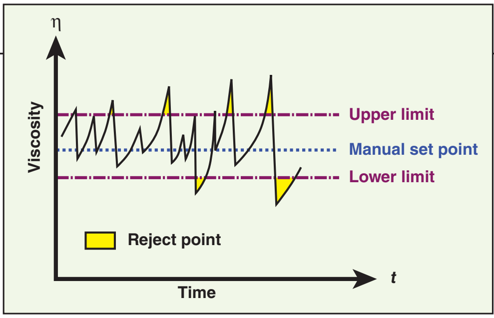

FIGURE 2. With manual control, upper and lower control limits can often be exceeded, allowing for out-of-specification product

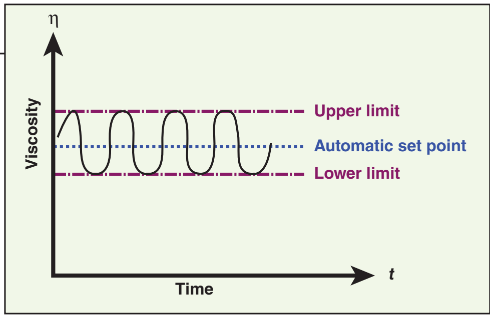

FIGURE 3. Better product and process control can be obtained with inline measurements

Process measurements

Automatic control of process fluid viscosity ensures consistent product all the time, reduces product hold times, and can eliminate human errors and expensive sample testing (Figures 2 and 3). Also, it provides for a complete record of how the process varied over a span of time, instead of at just one point in time. In a plant environment, there are many ways that viscosity can be measured, such as by a rotational viscometer, a vibrating element and by a falling object. Understanding whether a true, defined shear-rate measurement is needed, or if you are really just looking for set-point control, is beneficial when choosing the right type of instrument for your application.

Process measurements are made inline or in a flow loop. A bench-top rotational viscometer can be used for off-line or near-line measurements, where a sample of the process fluid is drawn and tested under controlled conditions (using the same bath temperature, shear history, shear rate and so on). Inline viscometers are immersed in the process stream and measure continuously under process conditions. Installation can be in a side-stream, in the main flow stream or in a tank. It is important to consider how cleaning and maintenance of these devices might occur, if necessary, when deciding on the installation.

It is also important to make sure that a representative sample of the fluid will be measured. Possible concerns about stratification, mixing and turbulence should be considered. The instrument will measure the product with which it makes contact, so making sure the fluid that the instrument "sees" is the material that you want it to measure, is a primary consideration. The demands of laboratory versus process environments are different, so it is unlikely that the same equipment can be used for both styles of measurement or that the exact same measured value will be generated. However, if done properly, the results of both laboratory and inline measurements will follow the same trend, making inline measurement useful for ensuring consistent production quality.

Choosing an instrument for inline measurement. When evaluating an instrument for inline viscosity control, there are several parameters that must be considered to provide the proper installation. The answers to these questions will eliminate some types of viscometers, and aid in defining the specifications of the final instrument. These questions include the following:

- What are the minimum, maximum and average pressure and temperature requirements for the application?
- What is the expected viscosity range, and control set-points desired?
- What are the minimum, maximum and typical flowrates in the process?
- What is the area electrical classification (NEMA 4; NEMA 7; ATEX, for example)?
- What are the necessary materials of construction, and recommended seal and elastomer materials? (This can often be determined based on what the plant is using for other process equipment in the area, such as pumps.)
- Where will the instrument be mounted? This will determine the style of instrument to be used. Examples include a tank/flange mount (Figure 4); a flow-through housing (Figure 1); a probe style for barrels (Figure 5); and mounting from the top of an open tank

For process control measurements, the critical factors are stability, repeatability and sensitivity to changes in viscosity. A stable, repeatable reading from an instrument that is sensitive to change in the process will allow the engineer to properly control the process.

Applications

Most products are formulated to flow, spray or coat in a controlled manner. Monitoring viscosity at critical shear points ensures that the product will act the same way every time for the user. This is the most tangible indicator of quality. With the increase in standardization initiatives, such as ISO 9000 and process analytical technology (PAT), there is an increasing use of viscometers to establish and document the desired properties of products. To a much larger extent, the use of viscometers for quality control, and in particular, the use of inline viscometers, wherever possible, to automate the process of controlling desired fluid properties is on the rise. Quality, consistency and customer acceptance require testing and control of key parameters, of which viscosity is certainly an important one.

Some typical operations where process viscosity control can be important include the following:

Determining the endpoint. For applications involving chemical reactions, viscosity of a product is continuously monitored in-tank and the process is either stopped, or the next steps are taken once a specific viscosity limit is reached.

In addition to determining the endpoint of chemical reactions, this approach is also used to determine the endpoint of blending operations, such as the blending of multiple ingredients in a batch process. One example is synthetic-fiber manufacturing. Latex, spandex and other synthetic materials are used to manufacture fibers, which are stretchable, rugged and used in many applications such as clothing. The manufacturing process is carried out in a reactor, where both temperature control and tight viscosity control are required over the steps and additions made during the process.

Carrying properties in oil and gas. In many oil and natural-gas production applications, viscosity is monitored and controlled to make sure that the fluids have the proper rheological properties to carry solids. For example, hydraulic fracturing fluid must have the proper viscosity under various shear conditions to carry the proppant downhole, and deposit it at the required location. For drilling fluids, the viscosity must be correct to carry the cuttings away from the drill bit and out of the hole, as well as to lubricate the bit.

Field engineers in oil-and-gas drilling operations can experience operating problems if the viscosity specifications of fluids pumped downhole are incorrect. This complicates testing procedures, increases the risk of costly errors and wastes time. Consequently, it is necessary to ensure fast, accurate viscosity measurement, data collection and analysis of fluid samples before they are pumped downhole.

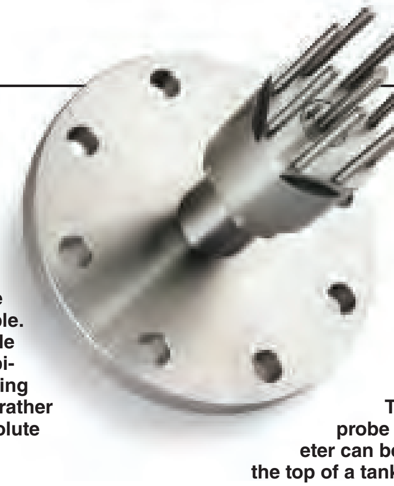

FIGURE 4. This vibrating-probe style viscometer can be mounted to a flange on the side of a tank, for example. Vibrating-probe style viscometers are typically used for trending viscosity changes, rather than obtaining absolute viscosity values

FIGURE 5. This vibrating-probe style viscometer can be mounted on the top of a tank, for example

The inline couette viscometer (Figure 1) gives field engineers reliable viscosity measurement, onsite at the well. This simplifies complicated test procedures, minimizes human error and ensures quality control without delay. The instrument output allows for constant monitoring and reporting of fluid viscosity or for use in ECD (equivalent circulating density) calculations by oil-rig engineers.

Oil-delivery systems, such as for burners. In this application, the viscosity of a fluid is controlled so that when it is pumped through a spray nozzle, proper atomization of the material occurs. Proper atomization through spray nozzles, which requires continuous and accurate viscosity measurement and control, ensures the best combustion efficiency in oil-delivery systems. To burn fuel oil at the high-volume flowrates demanded of modern boiler units, the

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FIGURE 6. This vibrational viscometer is commonly used in printing and coating applications

oil must be atomized (dispersed into the furnace as a fine mist). This assures high-speed vaporization and ignition. Most burners atomize oil by shearing the oil into small droplets. Burner manufacturers recommend that the oil be supplied to the burners at a specific viscosity to maintain consistent atomization. Failure to maintain proper atomization results in the following: poor fuel burning due to carbon and soot buildup; higher fuel consumption and costs; increased stack emissions and possible fines from government agencies.

The inline process viscometer monitors and controls viscosity and temperature in pressurized oil-delivery systems. Repeatable viscosity measurements are necessary to maximize the efficient atomization and delivery of a variety of paraffin-based oils, asphaltic-based oils, as well as heating fuels and waste oils. The process viscometer can include additional design considerations, which may also be of interest to other spray-type applications, such as spray-drying operations. Some of these considerations are the following:

- Bypass loop for viscometer installation for fail-safe operation
- Use of viscosity feedback to control the heat rate to the oil-feedline heat exchanger
- Output from the viscometer may go to a single-loop controller that instantly responds to inline viscosity changes

Quality control. To ensure consistent quality of many different products, it is important that the viscosity be constantly measured and controlled during the production process. Inline measurement ensures consistent quality control in realtime. It saves on laboratory testing times, and reduces hold-up of product in tanks waiting for evaluation. Examples of quality-control and quality-assurance applications include shampoos, detergents and yogurts to name a few. In these cases, too thin a product might appear to be of poor quality (such as a runny yogurt, or a shampoo that pours like water, without any body). Here it is a matter of consumer perception where specifications of final products are written by companies based upon consumer test groups, and the product must fall within these specifications in order to be shipped.

Other quality-related applications where viscosity is important are in coatings, such as paint applications. A few more examples follow.

Roll-coating thickness control. When dealing in any large-volume coating and printing applications where millions of products are being printed per day, the payback on the cost of inline control can be very short when measured against costs of wasted ink, varnishes, or coatings from too high a viscosity or from wasted product if the viscosity (and hence the color) are too light.

In printing applications, constant maintenance of proper ink viscosity ensures the quality of the printing, which reduces rejects and waste, while also keeping ink costs to a minimum. To assure the uniform application of inks on a variety of substrates (boxes, newspapers, cartons) it is necessary to control viscosity. Continuous monitoring and control of the ink reservoir viscosity using an inline viscometer (Figure 6) can provide viscosity measurement and control at multiple stations and save money by using less ink. Similar controls are needed in the coating of, and the printing on soda and other beverage cans.

Dip-coating thickness control. The thickness or consistency of a fluid is controlled to provide a dependable and uniformly coated item when dipped, then removed, from a coating tank. In this application, the thickness or consistency of a fluid is controlled so that when something is dipped in it and pulled out, it is uniformly and consistently coated.

Dipping applications are designed in automated systems whereby an item is brought over a tank or pan, dipped into the bath, removed and allowed to drip dry before proceeding through the process. The main problem with the open tank or pan is with the evaporation of fluids to the environment. Viscosity control is used for addition of water, solvents or other modifiers as needed to control viscosity to a set point. In pharmaceutical capsule manufacturing, for example, if the fluid is too thin, the capsule will break during filling, or dissolve too soon when swallowed, which would release medicine in the throat instead of the stomach. If it is too thick, then there is raw material waste on millions of capsules that will raise product costs, and it may not dissolve properly when swallowed.

For food batter applications, too thin a batter will mean improper coating and product quality. Too thick a batter will mean bad product quality, longer cook and dry times, and raw material waste. You can easily imagine a chicken nugget with too much batter. This can be from too viscous a batter during the coating process. ■

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Correcting Improper Performance of Direct Fired Heaters

A practical, step-by-step approach for finding the root cause and troubleshooting burner problems

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Tarahan Naftoon Arya Engineering Co.

Hamidreza Najafi
Farayand Sabz Engineering Co.

FIGURE 1. Faulty burner performance and continuous flame impingement have caused excessive tube-metal temperatures and coke buildup in heater tubes

FIGURE 2. Faulty burner performance and improper flame-shape problems could not be solved by operators for a long period of operation time due to lack of troubleshooting knowledge

Occasionally, direct fired heaters that have operated satisfactorily for long periods of time subsequent to startup develop operating problems that do not allow for operation at design conditions, as specified in the manufacturers' API data sheets for the heater.

Performance that may be guaranteed, or otherwise specified by the supplier would include the type and characteristics of the feedstock processed, the heater duty, inlet and outlet temperatures and pressures, heat flux, tube-metal temperature and any other process conditions that are measurable by instrumentation provided with the heater or calculable through the use of the heater instrumentation data.

In many cases, operators cannot identify the cause of an operating problem by simply comparing the specified data and faulty data obtainable from the heater instrumentation. For example, although the measured tube-metal temperatures demonstrate no significant increases, an unexpected pressure drop may occur in heater passes because of internal fouling, mainly caused by coke formation. In many cases, operators are unable to achieve the design heater duty and overall thermal efficiency, while the cause of faulty performance is unknown to them. Most of these cases may be due to faulty burner performance. Such performance could be caused by heating surface burner-flame impingement, improper excess air-fuel ratios, damaged burner tiles or tiles of improper diameter, improper burner spacing and other causes.

For example, continuous flame impingement with heater tubes in places where no tube-skin thermocouple is installed can be the cause of unexpected coke buildup, as shown in Figure 1. In cases such as this, the main question is: Why has the operator ignored the problem for such a long period of time so that it has eventually led to disastrous coke buildup and heater shutdown?

For the most part, human factors, such as inadequate training, improper scheduling of visual inspections and the lack of troubleshooting skills are to be blamed. While many firms do believe that the first two reasons are the most important, one should not forget the significance of effective troubleshooting procedures, too.

In many cases, recognizing the problem and observing indications of it are not enough, because without proper knowledge and understanding of the troubleshooting sequence, any attempts to solve the problem will fail. For example, in one of our experienced case histories, despite many trial-and-error efforts, operators were unable to tune improper flame shapes (Figure 2) because of two reasons. First, they couldn't diagnose the root cause of the problem according to its symptoms (that is, a lack of knowledge for performing root-cause analysis); and second, they didn't know how to treat the problem following a logical, stepwise procedure (in other words, a lack of knowledge for taking corrective action).

Such situations are not unfamiliar for fired heater operators and field engineers, because these problems happen frequently in many petroleum refineries or petrochemical plants.

A proper root-cause analysis of burner performance problems and a proper troubleshooting algorithm can be a great help to operators for overcoming problems. In this article we have proposed a simple root-cause analysis and also a computerized troubleshooting algorithm that sequentially directs the heater operator from one burner problem to another, indicating how each of the

TABLE 1. TYPICAL FIRED-BURNER PROBLEMS AND ROOT CAUSES

Problem category	Problem subcategory (Root Cause →)	Improper amount of combustion air	Improper draft	Improper primary or secondary air adjustment	Burner tip damaged	Burner tip plugged	Burner-tip improper drilling diameter	Burner-tip improper drilling angle	Burner-tip poor installation or assembly practice	Burner tile damage	Improper fuel pressure	Improper amount of atomizing steam	Frequent changing of fuel composition	High content of impurities in fuel	Improper fuel temperature	Rapid temperature changes in firebox	Excessive firing	Improper dry-out practice or wrong material selection	Electrical problem	Fuel oil spoilage	Choked fuel ring
Unsteady flame pattern	Erratic flame	✓			✓					✓											
	Pulsating flame	✓	✓																		
	Loose or hazy flame	✓	✓								✓										
	Cloudy flame	✓									✓	✓									
	Non-definitive shape	✓	✓		✓						✓										
Undesirable flame height	Long flame			✓	✓		✓				✓						✓				
	Short flame			✓	✓		✓				✓										
Fame lift off	—		✓				✓				✓		✓								
Flame flashback	—		✓				✓				✓		✓								
Undesirable fuel gas flame color	Luminous blue	✓	✓																		
	Yellow	✓	✓		✓																
	Dark orange or brown	✓	✓																		
Undesirable fuel oil flame color	Luminous yellow	✓	✓									✓		✓							
	Dark orange or light brown	✓	✓			✓					✓	✓			✓						
Flame impingement	—	✓	✓		✓	✓		✓	✓			✓			✓		✓				
Mechanical damages or problems	Burner tip damages								✓	✓			✓	✓		✓	✓			✓	
	Burner tile damages				✓			✓	✓							✓	✓	✓			
	Pilot ignition problem									✓			✓						✓	✓	✓
	Improper air entrance								✓	✓						✓	✓			✓	
Burner goes out	—	✓	✓	✓		✓														✓	✓

improper performances for a given cause is to be corrected, and continues in this vein until all possible causes for improper burner performance are corrected.

Typical problems & root causes

Based on our field experience and the valuable information found in References 1–3, typical fired-heater-burner problems can be classified into the following eight main categories:

1. Unsteady flame pattern
2. Undesirable flame height
3. Undesirable flame color
4. Flame liftoff or blowoff
5. Flame flashback
6. Flame impingement
7. Mechanical problems & damages
8. Burner extinguished

Each of these categorized problems can be divided into many subcategories. In order to analyze each category and its subcategories in the most concise and efficient way, a root-cause-analysis table has been proposed (Table 1).

Troubleshooting actions

Understanding the root causes of burner operating problems is the

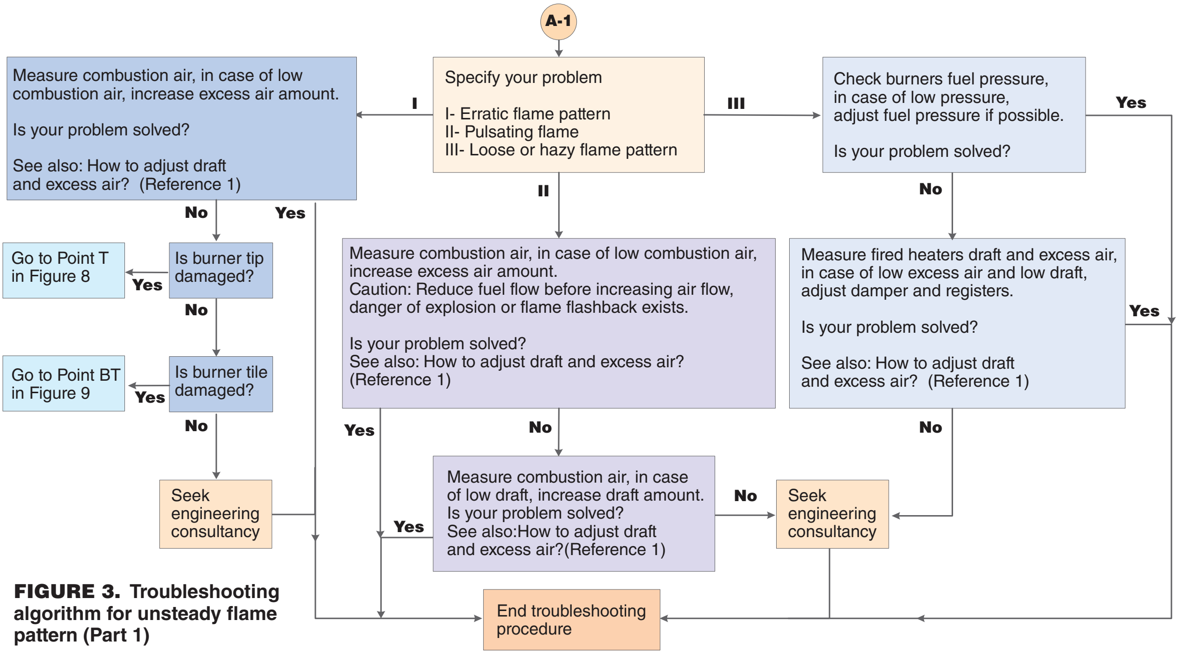

FIGURE 3. Troubleshooting algorithm for unsteady flame pattern (Part 1)

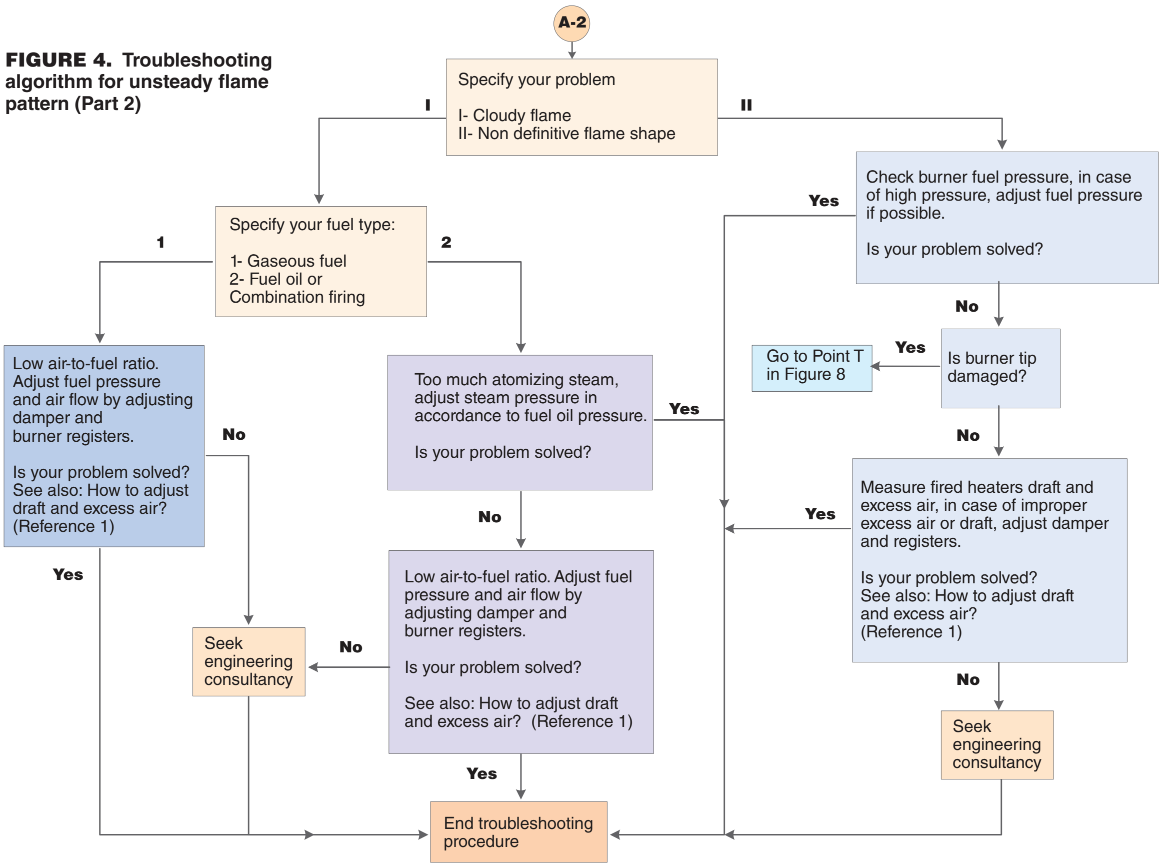

FIGURE 4. Troubleshooting algorithm for unsteady flame pattern (Part 2)

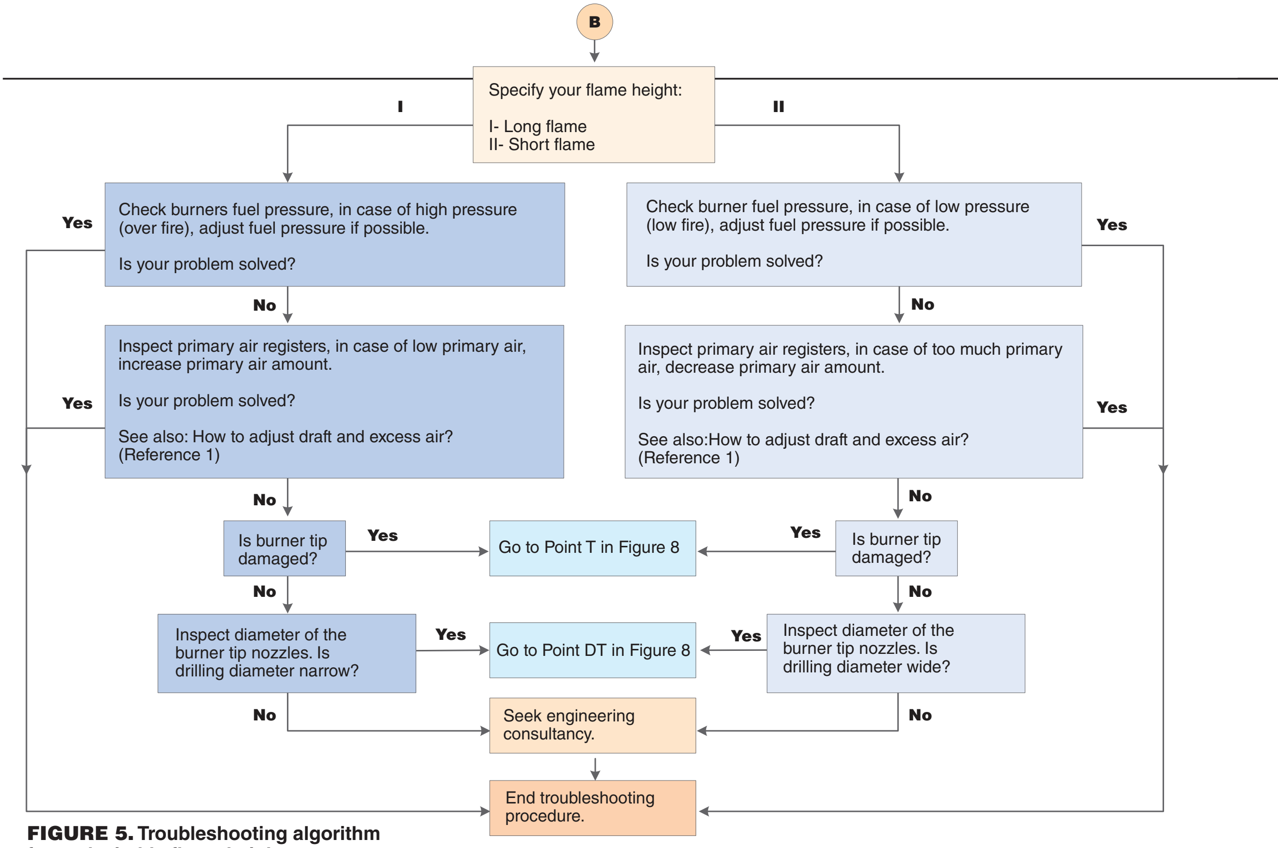

FIGURE 5. Troubleshooting algorithm for undesirable flame height

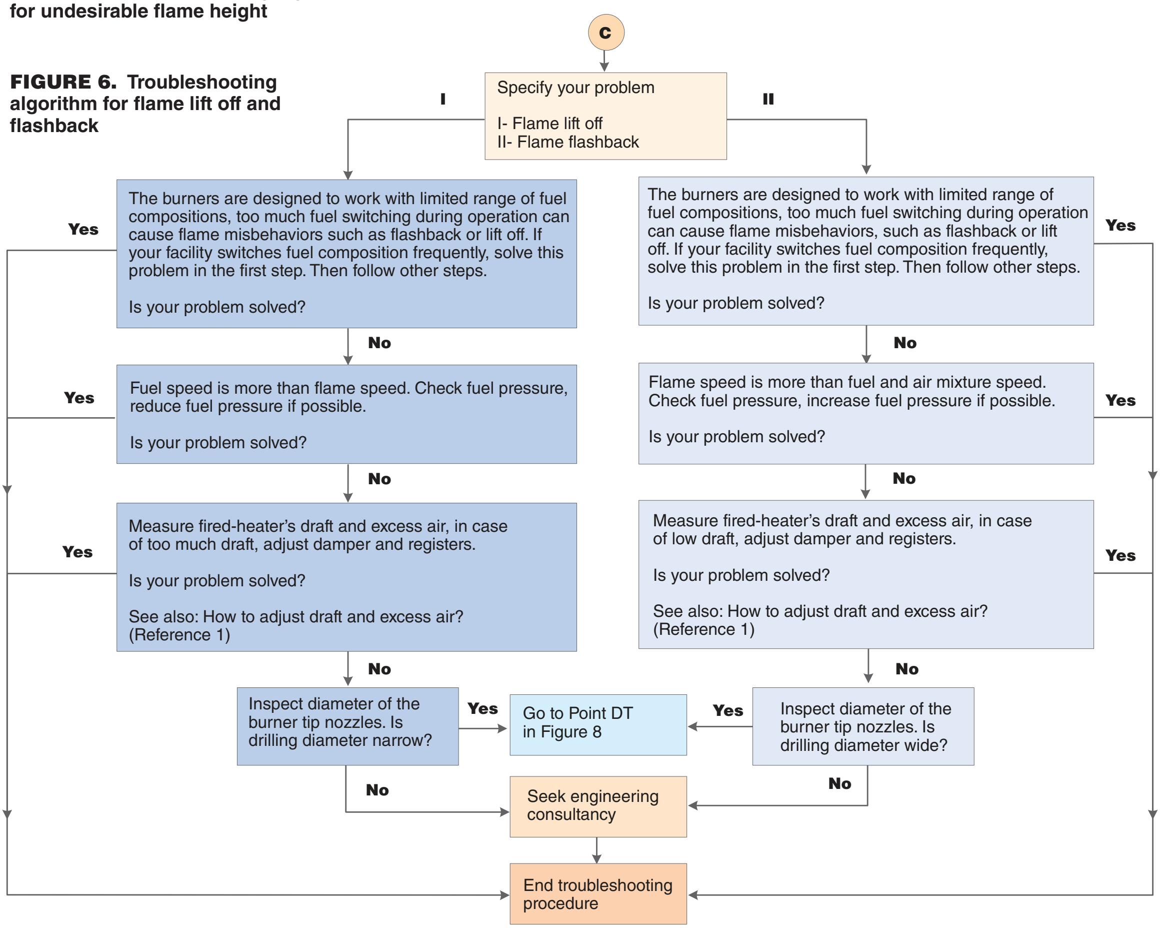

FIGURE 6. Troubleshooting algorithm for flame lift off and flashback

primary step of burner troubleshooting. Now what matters the most is the proper sequence of troubleshooting actions, which are provided by a set of comprehensive algorithms presented here.

These troubleshooting algorithms are based on the logic depicted in Figures 3 to 12, and have been successfully used to both recognize what a burner problem might be, indicate the cause of the problem and correct the burner defect, so as to achieve the desired heater performance.

A practical example

Let's assume that an operator tries to solve a burner firing problem like the one depicted in Figure 1. As it can be seen, the firebox of the specified fired heater (which is a crude charge heater) has suffered from long-term flame impingement to tubes and

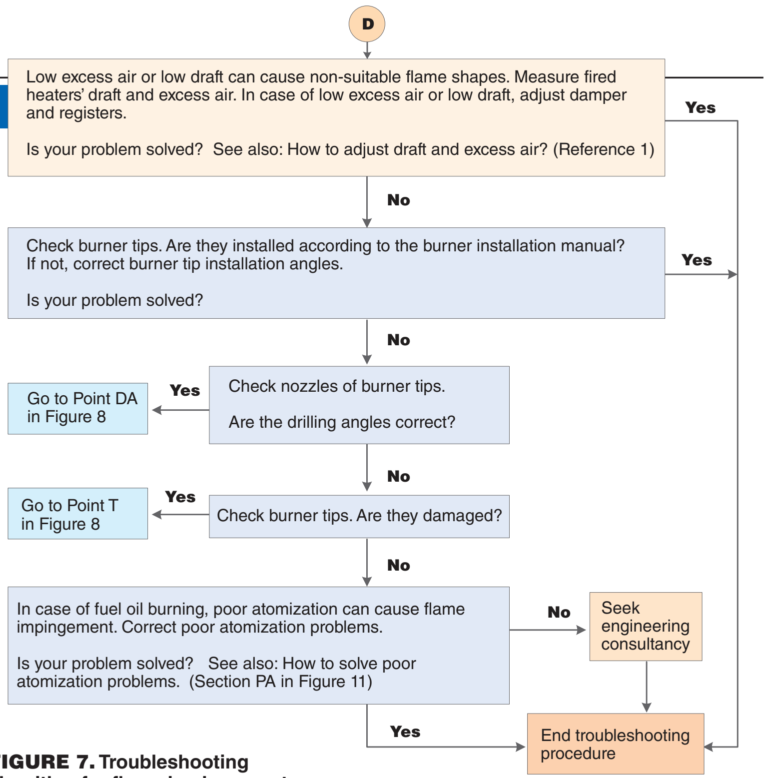

FIGURE 7. Troubleshooting algorithm for flame impingement

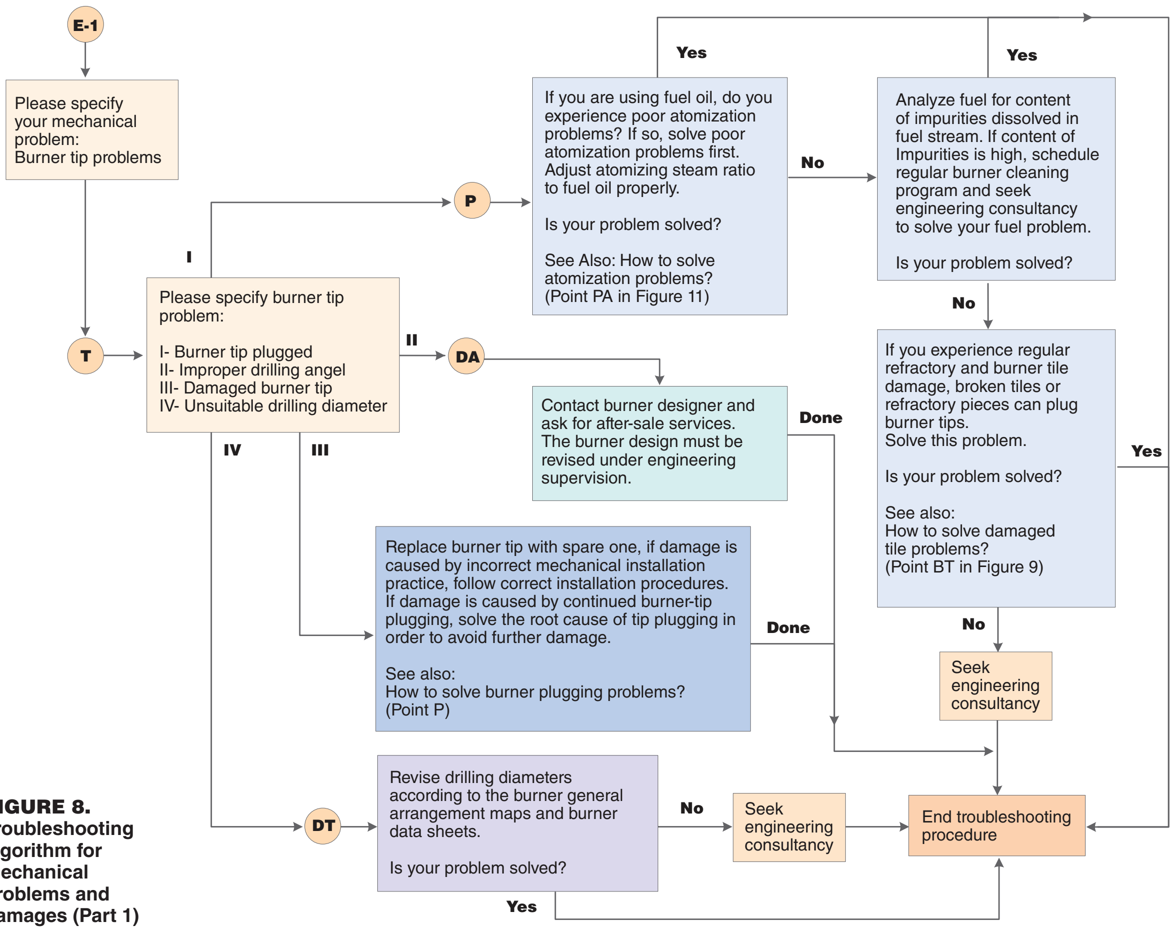

FIGURE 8. Troubleshooting algorithm for mechanical problems and damages (Part 1)

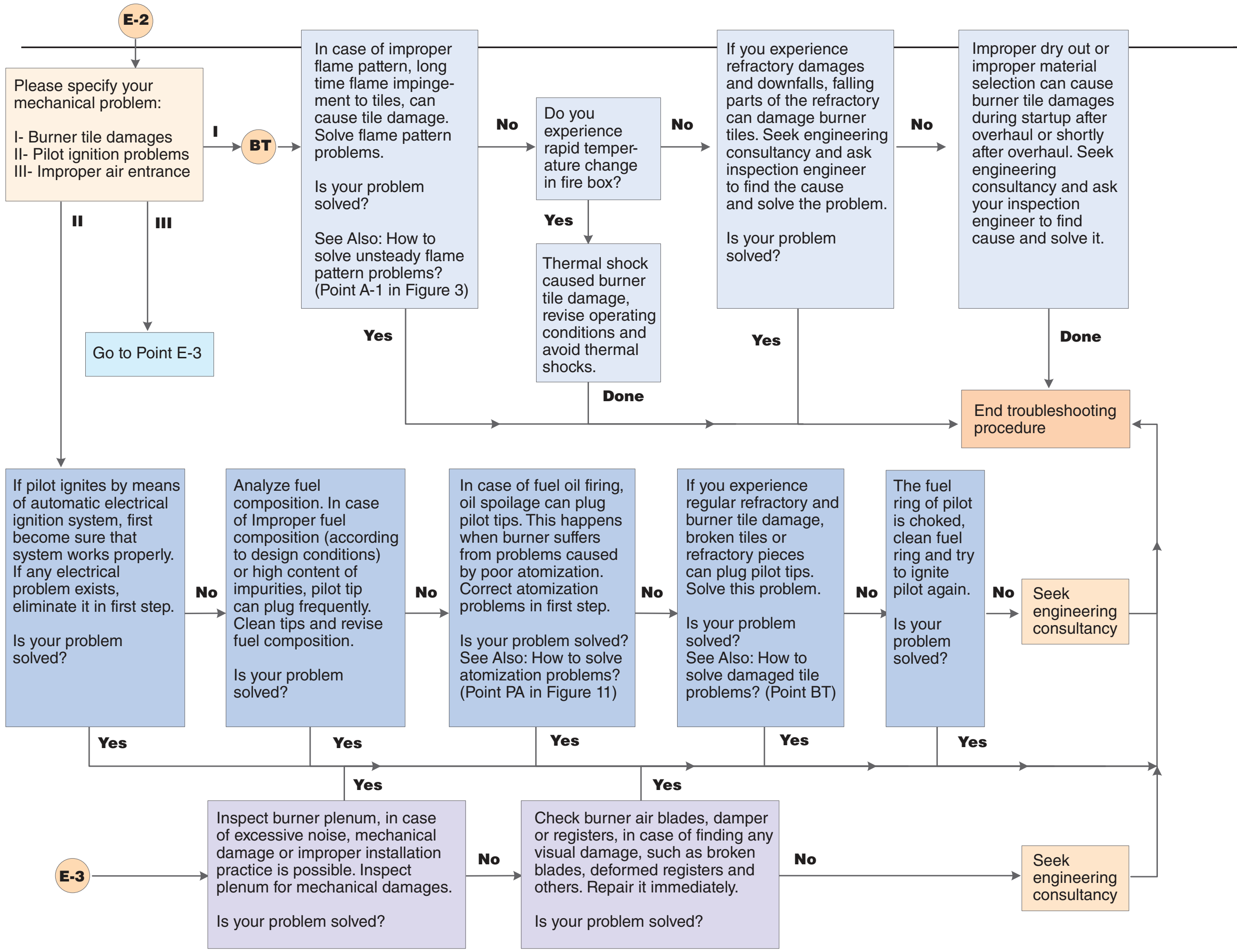

FIGURE 9. Troubleshooting algorithm for mechanical problems and damages (Part 2)

needs immediate corrective action to prevent further tube damage and possible internal coke buildup.

By taking a look at Table 1, one can find the root causes of flame impingement problems, which are as follows:

1. Improper amount of air or draft
2. Burner tip problems (either damaged or plugged)
3. Poor installation or maintenance practices
4. Improper fuel oil atomization
5. Excessive firing.

Except for Point 5 (excessive firing) in some cases, all the other causes can be treated by stepwise troubleshooting procedure outlined in Figures 3–12. As for the excessive firing, if it happens only in few burners or in combination firing cases, the operator can easily tune fuel pressure and control excessive firing rate; but if it is due to heater overdesign operating conditions, the solution would not be that easy.

Occasionally, some refineries try to process as much crude oil as the equipment can withstand during operation. This means pushing the equipment to its overdesign limits. For fired heaters, this limit is often 20% over normal operating conditions. In many cases this means excessive firing. It is impractical to ask the operator to reduce the firing rate in order to tune flame patterns, while the vapor quality of outlet stream and its temperature limit are vital to downstream separation processes. In such cases engineering precautions must be given to the refinery management team. If the furnace design parameters show limitations for satisfactory operation within demanded new heat release amounts, solutions like building parallel fired heaters must be taken into account.

In order to solve flame impingement problems, the operator can start with the troubleshooting procedure given in Figure 7. This procedure starts with the simplest solution, which is tuning excess air and draft amounts. Low excess air or low draft can cause undesired flame patterns, which can lead to flame impingement. It should be noted that excess air and draft are interrelated and should be tuned simultaneously to achieve proper results, therefore the operator is asked to use the procedures described extensively in Ref. 1 to tune draft and excess air to proper amounts.

If the problem still exists, the operator is asked to check burner-tip installation practices and their drilling angles according to burner tip general drawings and data sheets. Sometimes after overhaul or maintenance services, burners are assembled in a rush in order to startup fired heaters as soon as possible. This rush can lead to poor assembly or installation practices. Such shortcomings could be solved according to guidance given in the specified troubleshoot-

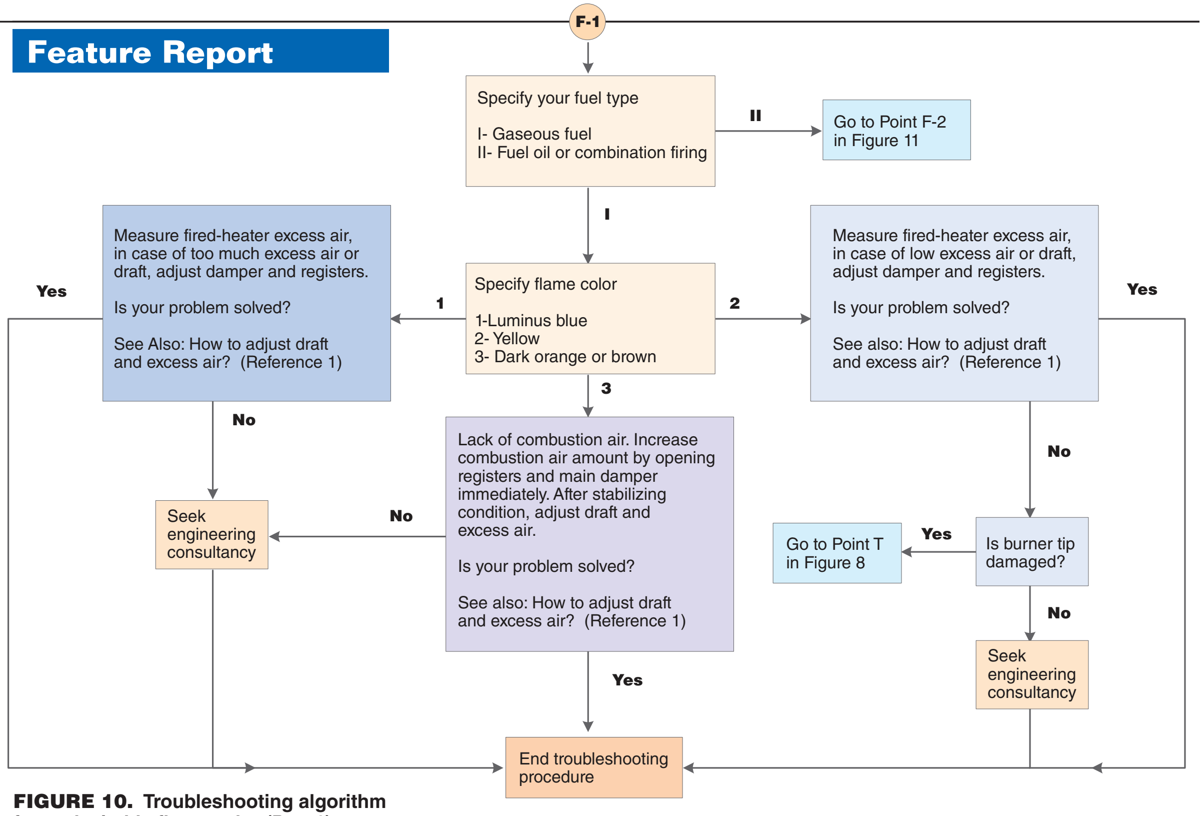

FIGURE 10. Troubleshooting algorithm for undesirable flame color (Part 1)

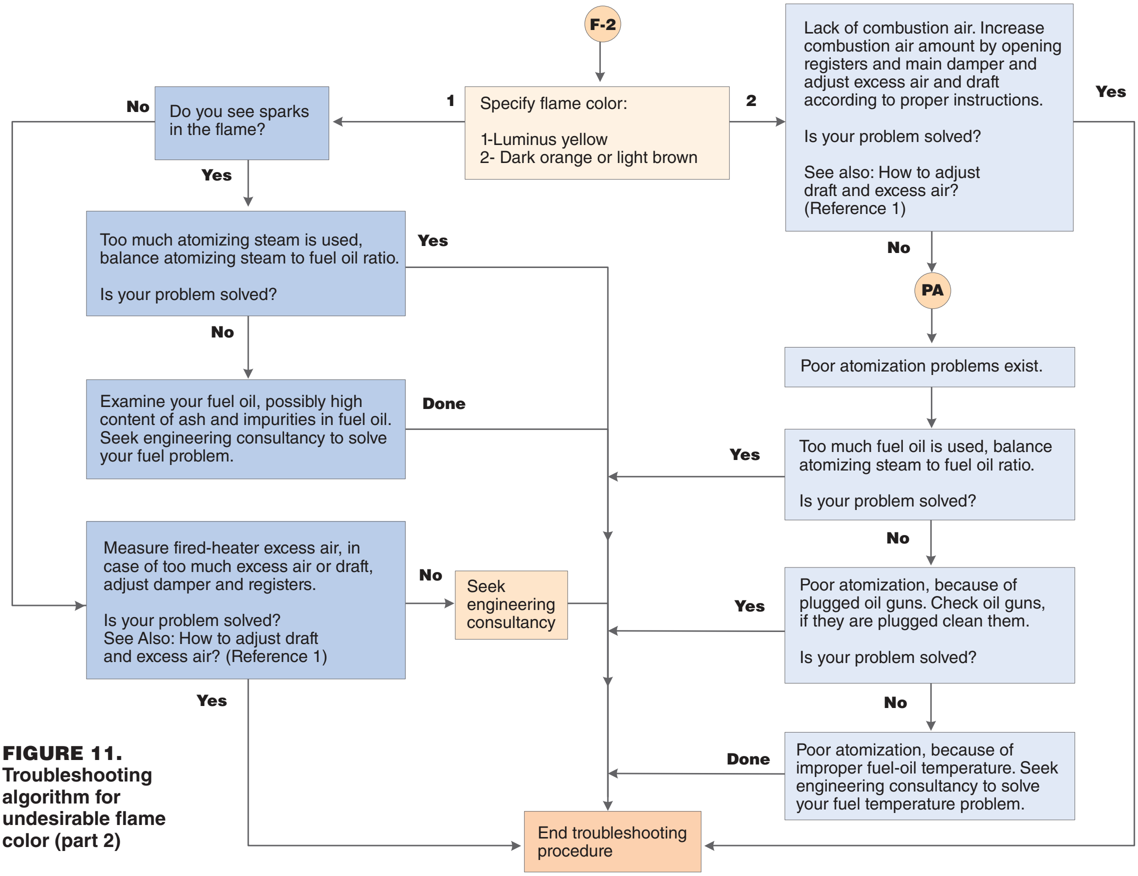

FIGURE 11. Troubleshooting algorithm for undesirable flame color (part 2)

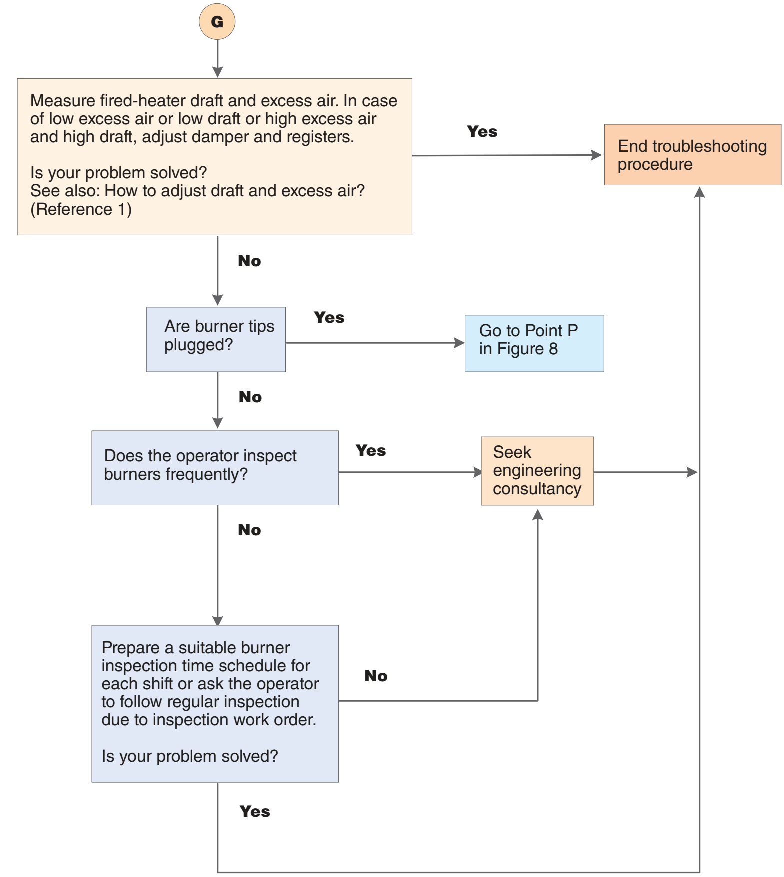

FIGURE 12. Troubleshooting algorithm for burner goes out

ing algorithms. If the problem is still not solved, operators can check the burner tips for damages, either by mechanical or thermal means. If this is the case, proper guidance is given in Figure 8. In case of fuel oil or combination firing, poor atomization can be the cause of flame impingement, and proper corrective actions are given in Figure 11.

Following this procedure will usually eliminate flame impingement problems. For the situation shown in Figure 1, tuning the amount of draft and excess air solved the problem totally. In exceptional cases where a problem cannot be eliminated by following the steps described in this paper, professional engineering consultancy must be sought.

Computerized algorithm

A computer program (computer wizard) was developed based on logic described in Figures 3 to 12. By using this program in industrial environments, like petroleum refineries and petrochemical plants, operators have been able to identify and correct the burner operating problems faster and more efficiently. There were fewer complaints about faulty burner operations, and, as result, less maintenance operations were needed.

It should not be forgotten that the main cost-saving benefits of this program are the following:

- Less fuel consumption due to proper levels of excess air and draft
- Less damage due to overheated tubes
- The possibility of increasing throughput and decreased downtime for decoking operations ■

Edited by Gerald Ondrey

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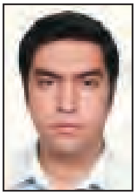

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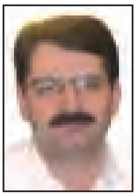

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Specifying Shell-and-Tube Heat Exchangers

Understand what heat exchanger design specialists need to know — and remember, you know your process best

Asif Raza

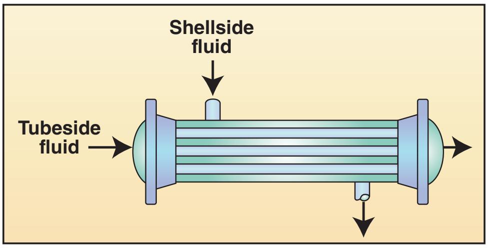


FIGURE 1. Which fluid goes on the shellside and which on the tubeside? There is no straightforward answer, but the guidelines presented here will help you decide

Shell-and-tube heat exchangers are one of the most important and commonly used process equipment items in the chemical process industries (CPI). If you are working on a project during either the basic or the detailed engineering phase, there is a good chance that you will need to specify one or more shell-and-tube exchangers — and perhaps many of them.

While the actual design will likely be done by a specialist at an equipment vendor or within your own company, you still need to fill out a process datasheet for each heat exchanger and in due course, review the vendor's detailed proposal. You know your process best, and it is a bad idea to rely on the vendor always to make the right decisions. This article shows you the basics of specifying and selecting shell-and-tube heat exchangers: the process information and preliminary design decisions needed to fill out the datasheet, and how to check any corresponding assumptions made by the vendor. Although it does not go into detail on the design procedure, the article is also a good starting point if you intend to design the heat exchanger yourself.

Datasheet information

Though every company is likely to have its own heat exchanger datasheet, most of them look much like the sample shown in Figure 2 (p.49). To complete the datasheet you will need to know:

1. The composition and normal flowrate of the process fluid(s), and the temperature change required. Refer to heat and material balances.
2. Process fluid properties — density, viscosity and thermal conductivity — at the operating temperature and pressure.

Which fluid on which side?

Next comes your first design decision: Which fluid goes on the shellside and which on the tubeside (Figure 1)? There is no straightforward answer, but some considerations and rules of thumb outlined in an online reference (http://smartprocessdesign.com) and incorporating the author's experience are summarized here:

- Corrosive fluids are best kept to the tubeside. Since the tubeside has less metal than the shellside, this will minimize the use of expensive metals that may be needed to withstand the fluids' corrosive properties.
- Fluids at extreme pressures and temperatures are preferably kept to the tubeside, because they are likely to require a greater metal thickness, or more expensive materials of construction. The tubes, being smaller in diameter than the shell, withstand higher pressures.
- Fluids that need to be kept at a high velocity, such as water or propylene glycol for cooling, should be kept on the tubeside.
- Dirty fluids, or streams that are otherwise likely to cause fouling, should go on the tubeside. This is because the tubes are easier to clean than the shell. For instance, it is often possible to clean the tubes by water jetting, having simply opened the head of the exchanger, without needing to remove the tube bundle. The shell and the outside of the tube bundle, on the other hand, are harder to clean mechanically, and chemical cleaning is often the only option.
- The shellside offers a larger cross-section for vapor flow, and hence lower pressure drops. Process vapors to be condensed are therefore normally placed on the shellside, though the tubeside is generally used for condensing steam.
- The baffles on the shellside help to ensure good mixing, which reduces the effects of laminar flow and therefore tends to increase heat-transfer coefficients. Hence you will get better heat transfer if viscous fluids are kept on the shellside — I confirmed this recently on a project involving a very viscous polymer.
- Twisted tubes, static mixers or tube inserts increase turbulence and thus heat-transfer coefficients on the tubeside by reducing the effects of laminar flow. Because these are usually proprietary technologies, however, your ability to check the vendor's performance claims may be limited. If you think you would benefit from one of these technologies, work closely with the vendor and be sure to evaluate all the options.
- In heat exchanger designs that fea-

ture gaskets or floating heads, the shellside typically is not a suitable location for fluids that are hazardous, corrosive or especially valuable, because the risk of leaks is too high. Such fluids should therefore normally go on the tubeside. Exchangers featuring all-welded construction can safely carry hazardous fluids on the shellside, though you should remember the difficulty of cleaning the shellside.

- Thermal expansion may be an issue if one of the fluids undergoes a temperature change of more than 150–200°C (300–400°F). In this case you would normally put the high-temperature-change fluid on the shellside, which is better able to handle large temperature changes in certain exchanger designs.
- In summary, the fluids preferred on the tubeside are the following:
  - – Cooling water
  - – The more-fouling, erosive or corrosive fluid
  - – The less-viscous fluid
  - – The fluid at higher pressure
  - – The hotter fluid
  - – The smaller volumetric flowrate.

Remember, however, that none of the suggestions above is definitive. Use them as a starting point, but if they indicate a different fluid arrangement from what has been used in the past in your plant or industry, you may find that there is a good reason. If two suggestions conflict, or the performance of your initial configuration looks unsatisfactory — because the predicted pressure drop or heat-transfer performance does not meet your requirements — do not be afraid to reverse the arrangement of the two fluids and see whether that improves matters.

More key decisions

Allowable pressure drop. You will have to understand the process thoroughly before you can attempt to specify the pressure drop on each side of the heat exchanger. As a rule of thumb, start with 10 psi on both the shellside and the tubeside. If there is a pump upstream of the heat exchanger, there probably will be no concern about pressure drop as long as the pump can handle this. For gases, if there is a compressor upstream, check with your equipment-design engineer that it can provide the necessary pressure drop. For cooling water, check for constraints on the allowable return pressure at the battery limit of the unit.

Sometimes the need to optimize the heat exchanger means that you will have to take a higher pressure drop than originally specified. A higher pressure drop means higher velocity, which in turns gives a higher Reynolds number and a higher heat-transfer coefficient. Give the heat exchanger vendor an allowable pressure drop as high as realistically possible to allow flexibility in optimizing the design. Once the designer has confirmed the calculated pressure drop, pass this value on to your rotary equipment engineer, who will need it for sizing pumps and compressors.

Fouling factors. These are very important in sizing the heat exchanger. Do not expect the vendor to provide you with fouling factors. A higher fouling factor translates to a lower design heat-transfer coefficient (U_d) and a larger required surface area. Fouling factors can often be taken from existing plant data. If these are not available, you will have to assume a value taken from company guidelines or published sources (Table 1). Make sure that your customer — whether internal or external — is in agreement with your assumed fouling factor. Designing with a too-high fouling factor will result in an oversized heat exchanger that will cost you more and probably will not work as intended.

Excess area. The difference between the design heat-transfer coefficient and the service heat-transfer coefficient provides a safety factor, often known as "excess area" because it is equivalent to specifying a larger heat-transfer area than necessary. The excess area is usually a minimum of 10%, but can be up to 30%. Choose a value from your plant's or unit's design basis, or ask your customer.

Heating and cooling curve. If the heat exchanger will be used to condense or vaporize process fluids, the vendor will require a corresponding heating or cooling curve showing how the vapor fraction varies with temperature, and the corresponding thermal properties of the liquid and vapor fractions. A heating or cooling curve with 8–10 points can easily be generated using simulation software.

Design temperature and pressure. Calculate the design temperature and pressure on both the shellside and the tubeside by adding an appropriate safety margin to the maximum values

TABLE 1. TYPICAL FOULING FACTORS

Fluid	Typical fouling factor ($ft^2\cdot°F\cdot h/Btu$)
Fuel oil	0.005
Steam (clean)	0.0005
Exhaust steam (oil bearing)	0.001
Refrigerant vapors (oil bearing)	0.002
Compressed air	0.002
Industrial organic heat-transfer media	0.001
Refrigerant liquids	0.001
Hydraulic fluid	0.001
Molten heat-transfer salts	0.0005
Acid gas	0.001
Solvent vapors	0.001
MEA and DEA solutions	0.002
DEG and TEG solutions	0.002
Caustic solutions	0.002
Vegetable oils	0.003
Lean oil	0.002
Cooling water	0.001
Natural gas	0.001
Atmospheric tower overhead vapors	0.001
Vacuum overhead vapors	0.002

Specifying appropriate fouling factors is important but not always easy. In the absence of operating experience, pick figures from reliable published sources.

Source: TEMA

1				Job No.		
2	Customer			Reference No.		
3	Address			Proposal No.		
4	Plant Location			Date	Rev.	
5	Service of Unit			Item No.		
6	Size	Type	(Hor/Vert)	Connected in	Parallel	Series
7	Surf/Unit (Gross/Eff.)		sq ft; Shells/Unit	Surf/Shell (Gross/Eff.)		sq ft
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid Allocation		Shell Side		Tube Side	
10	Fluid Name	(In|Out)				
11	Fluid Quantity Total	lb/hr				
12	Vapor		|		|	
13	Liquid		|		|	
14	Steam		|		|	
15	Water		|		|	
16	Noncondensable		|		|	
17	Temperature	°F	|		|	
18	Specific Gravity		|		|	
19	Viscosity, Liquid	cP	|		|	
20	Molecular Weight, Vapor		|		|	
21	Molecular Weight, Noncondensable		|		|	
22	Specific Heat	BTU / lb °F	|		|	
23	Thermal Conductivity	BTU ft / hr sq ft °F	|		|	
24	Latent Heat	BTU / lb @ °F				
25	Inlet Pressure	psia				
26	Velocity	ft / sec				
27	Pressure Drop, Allow. /Calc	psi	/		/	
28	Fouling Resistance (Min.)	hr sq ft °F / BTU				
29	Heat Exchanged		BTU / hr LMTD (Corrected)			°F
30	Transfer Rate, Service		Clean			BTU / hr sq ft °F
31	**CONSTRUCTION OF ONE SHELL**				Sketch (Bundle/Nozzle Orientation)	
32			Shell Side	Tube Side		
33	Design / Test Pressure	psig	/	/		
34	Design Temp. Max/Min	°F	/	/		
35	No. Passes per Shel					
36	Corrosion Allowance	in				
37	Connections	In				
38	Size &	Out				
39	Rating	Intermediate				
40	Tube No. OD	in;Thk (Min/Avg)	in;Length	ft;Pitch	in	30 60 90 45
41	Tube Type			Materia		
42	Shell	ID	OD in	Shell Cover	(Integ.)	(Remov.)
43	Channel or Bonne			Channel Cover		
44	Tubesheet-Stationary			Tubesheet-Floating		
45	Floating Head Cove			Impingement Protection		
46	Baffles-Cross	Type		%Cut (Diam/Area)	Spacing: c/c	Inlet in
47	Baffles-Long			Seal Type		
48	Supports-Tube	U-Bend			Type	
49	Bypass Seal Arrangemen			Tube-to-Tubesheet Joint		
50	Expansion Joint			Type		
51	ρv^2-Inlet Nozzle	Bundle Entrance			Bundle Exit	
52	Gaskets-Shell Side			Tube Side		
53	Floating Head					
54	Code Requirements			TEMA Class		
55	Weight / Shell	Filled with Water		Bundle		lb
56	Remarks					
57						
58						
59						
60						
61						

FIGURE 2. **A typical datasheet for a shell-and-tube heat exchanger lists all the information required for a detailed design**

Source: TEMA (Tubular Exchanger Manufacturers Association, Inc.; Tarrytown, N.Y.; www.tema.org).

Source: TEMA

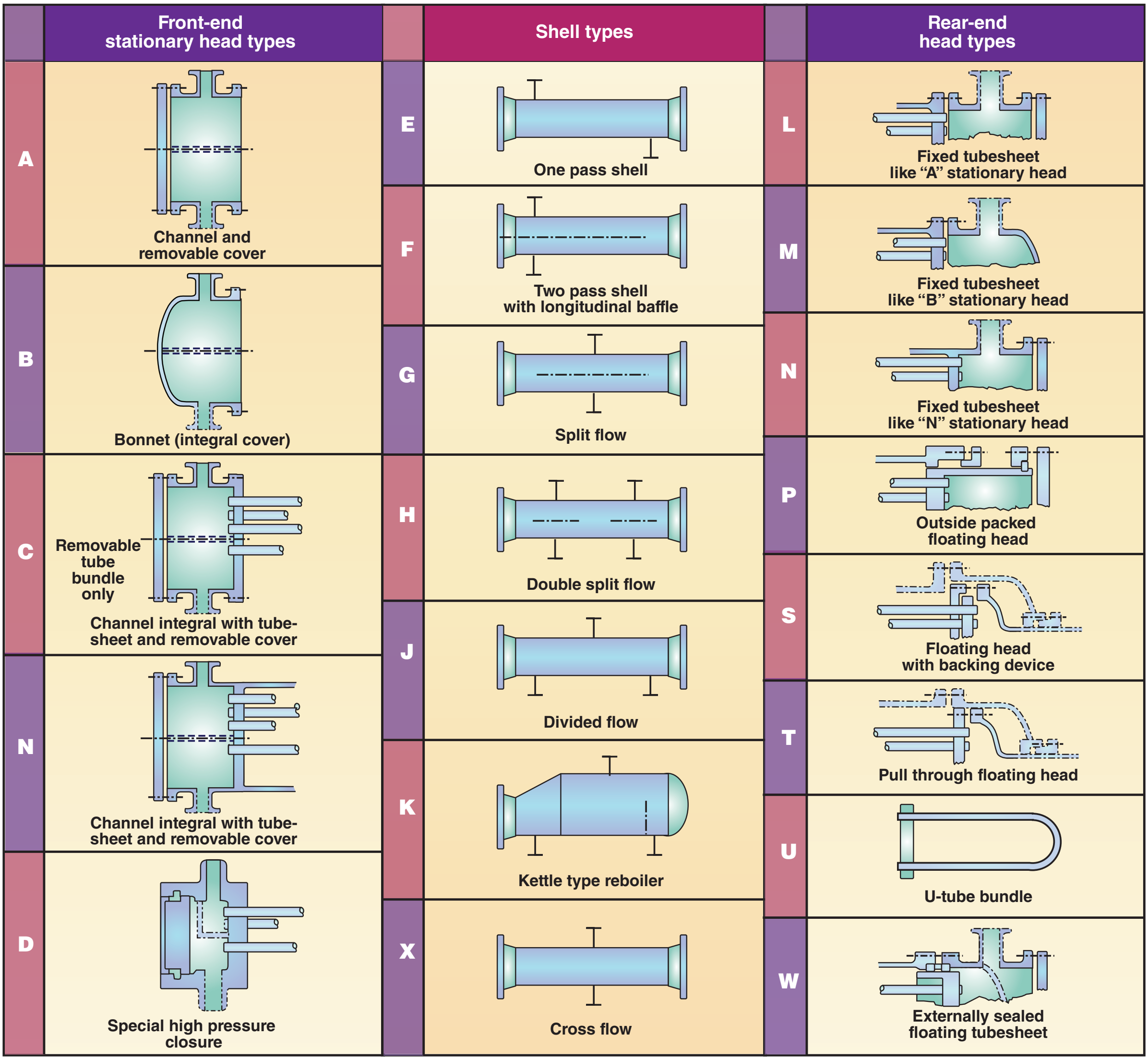


FIGURE 3. TEMA exchanger-type codes provide a shorthand for different basic designs and construction methods

expected in service. Consider the following guidelines:

1. To arrive at the design temperature, add a margin of 30°C (50°F) to the maximum allowable operating temperature of the exchanger.
2. Similarly, the design pressure can be calculated by adding an appropriate margin to the maximum allowable operating pressure.
3. If the process hazard analysis has identified tube rupture as a hazard, to avoid the need to design a pressure relief valve for the tube rupture case, the shellside design pressure must be at least 77% of the tubeside design pressure (the "10/13" rule). For instance, if the tubeside design pressure is 500 psig, the minimum shellside design pressure should be 500 × 10/13 = 385 psig. The logic of this is that ASME codes require the shell to be hydraulically tested at 1.3 times its design pressure, so tube rupture — which is generally considered an unlikely event — would not pressurize the shell beyond its test pressure.
4. When deciding the design temperature, consider routine operations such as steaming of the heat exchanger during maintenance.

Design codes. Under ASME rules, if the operating pressure is higher than 15 psig, then the heat exchanger is considered a pressure vessel, and the pressure-vessel design code ASME section VIII, Div. 1 or 2 applies. Similar logic applies to different pressure vessel codes used outside the U.S. and Canada; make sure you use the code appropriate to the country in which the equipment will be used.

The Tubular Exchanger Manufacturers Assn., Inc. (TEMA; Tarrytown, N.Y.;

TABLE 2. TYPICAL DESIGN HEAT-TRANSFER COEFFICIENTS		
Hot fluid	**Cold fluid**	**U_d (Btu/h·°F·ft^2)**
Water	Water	250–500
Aqueous solution	Aqueous solution	250–500
Light organics	Light organics	40–75
Medium organics	Water	50–125
Heavy organics	Heavy organics	10–40
Heavy organics	Light organics	30–60
Light organics	Heavy organics	10–40

If a vendor's calculated heat-transfer coefficients are reasonably close to reliable published values, the thermal design is probably correct. Do not expect an exact match. Light organics are fluids with viscosities less than 0.5 cP. Medium organics are 0.5–1 cP, and heavy organics are above 1 cP.

Source: "Process Heat Transfer", Donald Q. Kern, McGraw-Hill Companies, 1950.

www.tema.org) issues its own design and manufacturing codes. There are three categories: TEMA C, B and R. In simple terms, TEMA C applies mostly to water, oil and air at low or moderate pressures and temperatures, and is the most cost-effective standard in cases where it is applicable. TEMA B is for chemicals and petrochemicals at higher temperatures and pressures. TEMA R, for severe service involving high pressures and temperatures, is widely used in petroleum refineries, and is the most expensive option. Inappropriate TEMA ratings will significantly increase the cost of a heat exchanger, so choose carefully based on existing plant data or suitable guidelines.

Keep in mind that you do not necessarily have to design your heat exchanger to TEMA standards. In particular, TEMA B and R standards enforce a minimum tube diameter which could lead to too-low velocities if the tubeside flowrate is small. The resulting low heat-transfer coefficient may require a large and expensive heat exchanger. In such situations, it may be best not to design your heat exchanger to TEMA standards.

Heat exchanger type. It is very important to specify the correct type of heat exchanger for the application

(Figure 3, p.50), and in this case there are no right or wrong answers. Here is a list of criteria that will help you in making a decision:

1. If the fluids are relatively clean and the difference in temperature between the shellside and the tubeside is not very high (around 100°C/200°F), then consider a BEM (fixed tubesheet) design. Typical applications are condensers; liquid-liquid, gas-gas, and gas-liquid heating and cooling; and vertical thermosyphons.
2. If the heat exchanger must accommodate a significant amount of thermal expansion between shell and tubes (more than 100°C/200°F), consider type BEU, in which the tubes are free to expand. Keep in mind that BEU exchanger tubes can only be cleaned chemically, not mechanically, so these exchangers are best suited to clean service on both the shellside and the tubeside.
3. For a chiller with refrigerant evaporating on the shellside and cooling a process fluid on the tubeside, consider a heat exchanger of type BKU.
4. Similarly to Point 2 above, if the difference in operating temperature between shellside and tubeside is more than 100°C (200°F), consider a design with hairpin tubes, a floating head or a floating tubesheet (types P–W). These types are best suited to dirty fluids, and may be either horizontal or vertical.
5. If you encounter a temperature cross — that is, if the outlet temperature of the hot fluid is below the outlet temperature of the cold fluid — then you cannot use a single BEM or BEU type heat exchanger. Consider a BFS type with a two-pass shell and a longitudinal baffle, or two shells in series. Other types of heat exchanger, such as spiral and plate types, are fully countercurrent and so better suited to handling temperature crosses.

Material of construction. Do not trust the vendor to pick the right material of construction for your service. That is your job. That said, do not take responsibility for the material of construction unless you have agreed it with the user or verified it with an appropriate expert.

Tube-to-tubesheet joints. These determine the integrity of your shell-and-tube heat exchanger. The basic guidelines are the following:

1. For a design pressure of less than 300 psig and a design temperature below 180°C (350°F), use rolled and expanded tube-to-tubesheet joints. These are used primarily for water, air and oil service.
2. For higher design pressures or temperatures, use grooved, rolled and expanded tube joints.
3. When dealing with light hydrocarbons or other flammable fluids, even at low pressure and temperature, consider seal welding.

4. For hydrocarbons or flammable vapors at high pressures and temperatures, consider additional welding for strength.

Special instructions. This category covers specifications including the tube pitch, baffle type, minimum tube diameter, tube length and orientation of the heat exchanger. Use customer specifications or guidance where available, and ask vendors whether these will have any implications. If no specifications are available, use your judgment. For instance, if your shellside fluid is very fouling, use a square tube pitch to aid cleanability. Decrease baffle spacing to increase turbulence, and thus heat-transfer coefficient, on the shellside. If you have a height limitation, ask the vendor to limit the tube length.

Reviewing vendor quotes

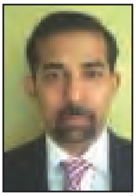
After you have received your quotes it is time to review them and select a vendor. Here are the most important points to look for:

- Basic process requirements: For both fluids (shellside and tubeside), the vendor's specification should match your specified flowrate, operating temperature and pressure, and properties such as density, viscosity, and thermal conductivity.
- Materials of construction, design pressure and design temperature as per your instructions.
- Fluid velocity: Should generally be in the range of 3–8 ft/s on both the tubeside and the shellside. Lower velocities will mean lower heat-transfer coefficients and larger required surface areas.
- Compare the calculated clean heat-transfer coefficient (U_c) and the design heat-transfer coefficient (U_d) with typical values from your company sources or published literature (Table 2, p. 51). Do not expect close matches — each application is different, and heat-transfer coefficients depend on many factors. If the U values proposed by the vendor are very different from what you would expect, however, then the design may be at fault. In such a situation, review the design with the vendor.
- Check the heat-transfer area. Different vendors will propose different values based on varying exchanger geometry and calculated heat-transfer coefficients. Pick a geometry that meets your requirements best.
- Check the heat duty and make sure it matches your specified value.
- Check the code requirements.
- Check that the vendor has complied with any special instructions including tube diameter, tube pitch, tube length, baffle type, baffle pitch, and excess area.
- Check the price and delivery schedule for the heat exchanger.
- Weigh all the options and select a vendor.

Close coordination with the heat exchanger vendor and a solid understanding of the process requirements are essential to heat exchanger design and selection. By understanding different kinds of heat exchangers and developing a solid understanding of heat-transfer coefficients, fouling factors and so on, you will be on the right track to design and select the most appropriate heat exchanger for your process. ■

Edited by Charles Butcher

Author



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Feature Report

Compressors:

Pursuing Lowest Cost of Ownership

FIGURE 1. This centrifugal compressor is an electric-motor-driven machine that uses a gear unit for the speed match

Proper specification, purchase, mechanical-run and shop performance testing, installation, operation and maintenance are all important

Amin Almasi
Rotating Machinery Consultant

A variety of technologies, methods and best practices are available to obtain the lowest total cost of ownership for compressors used in plants throughout the chemical process industries (CPI). This article discusses several critical areas in which concerted effort can help to reduce the overall cost of ownership.

Specifying compressors

The ability to carry out proper shop-based performance tests and mechanical run tests — that is, testing that is carried out by the vendor, before the unit is delivered to the CPI facility — can provide tremendous value for users. Shop-based performance testing is of particular necessity for any CPI compressor, because it allows for careful analysis of the compressor under conditions that closely simulate those of the actual installation, to help detect potential malfunctions and other problems before the compressor has been delivered. This is important because corrections and modifications at the CPI plant site tend to be costly.

A solid compressor specification outlines for the vendors what the compressor package must have, and how reliable the unit must be. Key aspects to be addressed in the specification include the following:

Proper sizing. Before the start of any compressor specification, the equipment must be sized, at least in a preliminary manner. For example, specifying a single-stage compressor when a multi-stage compressor is needed will have inappropriate consequences down the road. And, there is usually more than one compressor type that may be well suited for any given CPI application. For example, many modern CPI applications can use either the integrally geared centrifugal compressor or the conventional-type centrifugal compressor. Thus, the reliability and efficiency of the various competing compressor types should be evaluated early in the specification process.

Know the operating scenario. The first cost (that is, the initial purchase price) is an important factor that should always be considered during compressor selection. However, ongoing costs related to operation and maintenancemust also be evaluated to assess the total cost of ownership.

The operating conditions (as described in the compressor data sheet and specification) should be divided into two types — those that characterize normal operation, and those that characterize operating conditions that deviate from normal. The entire anticipated range of operating conditions should also be defined, either by range limits or by alternative operating conditions.

A common example of off-design conditions is the scenario in which the compressor encounters deviations in the molecular weight of the compressed gas, as might be encountered in a CPI plant during startup. Another situation that could lead to off-design conditions is the equipment holding period when a part of a process is not yet in operation. Such anticipated scenarios must be evaluated and noted during the specification stage.

Unusual operating conditions — even insignificant items — should also be mentioned. Examples include the presence of hydrogen sulfide or chloride in the gas, even if levels may be in the ppm range. Keep in mind that the compressor vendor's knowledge of your process will be limited. Keep the following facts in mind during compressor specification:

1. The compressor manufacturers specialize in compressor design and manufacturing and they are not focused on the intricacies of CPI processes.
2. If engineers at the vendor company have experienced a problem in another customer's process that is similar to the current job, he or she may be able to share that experience (by raising questions and seeking solutions) during the development of your specification. However, considering vendor-staffing policies, the vendor's overall philosophy in that regard, the fact that vendor engineers often only know a small part of any process (that is, the part of the process that is related to their machine), and many different processes (and process licenses) that exist for most CPI units, the ability to rely on the vendor for process-specific input tends to be the exception rather than the rule.

As a result, it is important that the compressor purchaser use its own deep knowledge of the process — in terms of the potential scenarios that could lead to unusual conditions or process upsets that could impact compressor operation during the life of the unit — during compressor specification. A good example is the gas-temperature runaway potential in hot-gas units. The specification should set forth the expected maximum temperatures, and ask the vendor to verify the maximum temperature the unit can handle.

Another example is the potential of sudden dead-ending of a compressor during switching of operations in the batch-type reactors. Generally, compressor operation in batch-type processes requires careful attention, and this potential impact of plant operation should be brought forth during the development of the specification.

Minimizing fouling. By accurately noting the likely opportunities for fouling, the compressor vendor may be able to incorporate a relevant solution into the compressor offering (such as a washing procedure and required provisions, the establishment of additional head margins or materials of construction).

Incorporate startup and shutdown conditions. Startup and shutdown considerations also influence various compressor components (and their specifications), particularly seals and thrust bearings. Regarding several design parameters (for example, the allowable speed), whatever is set forth in the specification is often considered by vendors to be the target. For some parameters, vendors will test the approximate value given by the purchaser, and then exceed it by some margin to see if a deviation in performance will result.

As a practical step, the maximum-allowable parameter values should be given by the compressor purchaser after thorough research and evaluation has been carried out of the most recent technology options and modern, reliable installations. These maximum allowable values for key parameters should be supplied consistently, from vendor to vendor, to allow for an apples-to-apples comparison among competitive bids.

In general, high speeds in compressors can increase the overall efficiency of the unit. However, high operating speeds can also raise the stresses on the system and could decrease the reliability of the unit over the long run, so a tradeoff must often be evaluated. High operating speed may also lead to bearing and seal problems, particularly if the speed exceeds the speed of similar compressors used in previous applications)

Consider materials of construction. Stating the minimum material requirements can help the vendor during the machine design phase. However, the specifications set forth by the purchaser should not be so rigorous that they prohibit the vendor from drawing from its vast experience with many materials. Such a limitation (imposed by the purchaser) may lead to operating problems later. By properly wording the specification, the minimum material requirements can be spelled out while still allowing the vendor's experience with the materials to come into play.

A large number of unscheduled shutdowns can be traced to issues that the vendor is responsible for, such as the compressor design, the material selection, the component selection (for instance, seal and bearings), excessive fouling, degradation, corrosion, erosion or similar. However, such problems are often more accurately a reflection of a lack of application knowledge and improper material selection, which could have been prevented if the purchaser had communicated the specification more thoroughly.

A good example is the use of austenitic stainless steels. These premium materials are often used for applications that require good corrosion resistance. However, an austenitic stainless steel cannot be used if chlorides may be present, because inter-granular corrosion and subsequent cracking problems will result.

Packaging and assembly considerations. The purchaser must also make a number of decisions related to the compressor package arrangement, delivery conditions, and extent of prefabrication and packaging. This part of the process begins with the specification of a sole plate versus a base plate. The first option (sole plate) is often specified for packages that must be delivered in pieces and assembled onsite. The second option (base plate) will result in skid-mounted components; for this scenario, installation is typically easier. This important decision should be noted in the specification.

For large compressor trains, the typical recommended arrangement is to install the compressor (and gear unit, if applicable) on a heavy-duty base plate. Large electric-motor drivers are usually supplied with sole plates. Large steam turbines or gas turbine drivers are most often installed on an individual base-plate-mounted skid.

Control considerations. The control panels that are required to integrate compressor control and operation into CPI facilities are typically quite complex, because a great amount of coordination is required to have them conform to CPI plant panel standards. Today, large CPI companies typically prefer that vendors only supply the sensors, and that the purchaser supplies the control panel, the condition-monitoring system and the control units. Small companies prefer to leave all items (control panels, condition monitoring, and other items) in the vendor scope.

Evaluating competing bids

A side-by-side comparison of competing bids should be made, considering such important aspects as the energy cost, the purchase cost and the reliability issues using suitable economic criteria. If data are available, the total cost of ownership can be estimated by evaluating competing bids.

However, it is absolutely necessary to fix all items and clarify all issues before placing the purchase order. Until the vendor is certain that it has the order, the purchaser will remain in an advantageous trading posture.

The winning bidder will be the vendor for the project once a contract has been written and accepted. This is important because the clock is started at this time and all future dates will be referenced back to this date. This is also the date from which delivery is counted.

Practical notes on compressors

Variable-speed centrifugal compressors (Figure 1) are the backbone of the CPI compression industry. This type of compressor should be considered as the first option for most CPI general applications.

Performance curves. Centrifugal compressors exhibit a relatively flat curve of head versus flow compared to other compressors. Compared to the steep curves of the axial compressors and positive-displacement compressors, the flat curves of most centrifugal compressors offer better operation. For instance, centrifugal compressors offer a relatively low head rise for a given flow change, compared to that of axial or positive-displacement compressors.

The curve shape is a function of the impeller geometry (mainly impeller-blade angles), and the process conditions. Radial impeller blades result in a (theoretically) near-flat curve (that is, close to a flat line).

An impeller with a more-backward angle will create a higher reaction (from the compressor wheel) and thus will yield a steeper curve. In general, centrifugal compressors are also more reliable compared to other compressors types.

On any performance curve, the operational area of a dynamic compressor (either centrifugal or axial compressor) is bounded on the left by the surge line, on the right by the choke line (stonewall effect), on the top by the maximum speed line, and on the bottom by the minimum speed line.

The orientation of the inlet piping and its influence on the compressor performance is also an important consideration during compressor specification. There should be neither pre-rotation, nor anti-rotation, in the flow suction of the dynamic compressors. The flow should be free from any random distortion.

Centrifugal compressors are somewhat more forgiving in terms of flow distortion in the inlet stream than other compressors (such as axial compressors); however, there are some limits. Based on the compressor design, gas velocities and process conditions, a minimum length of straight pipe is necessary ahead of any dynamic compressor inlet. As a rough indication, for the centrifugal compressors, this straight pipe length should be around four to six times the pipe diameter. When the minimum straight length of piping cannot be achieved, vaned elbows or straighteners may be used instead. However, these should only be used in very special cases, as the last solution because they may create additional operational problems.

Performance testing

There are two different types of performance tests available for dynamic compressors (centrifugal and axial compressors). A Type-1 performance test is carried out in the shop by the vendor, prior to delivery of the unit, under conditions that closely match those anticipated in the actual installation. Specifically, this test is conducted using the same process gas as will be found at the CPI site [the same gas with the molecular weight (MW) deviation below ±2%]. Generally, permissible deviations on pressures, temperatures, compressor speed and capacity are below ±4-8%.

By comparison, the Type-2 performance test is completely different. The Type-2 test permits the use of a substitute test gas and allows for extensive deviations between the shop test conditions and the specified operating conditions at CPI site. There are only a few limits on some essential gas dynamic parameters of the test conditions compared to the specified operating conditions. For a Type-2 test, the following limits are usually considered:

- The volume ratio and the flow coefficient are maintained within ±5%.
- The machine Mach number is maintained within ±0.1 deviation
- The Reynolds number of the Type-2 test arrangement should be within 0.1 to 10 times of the Reynolds number of the expected operating condition

When using the Type-2 test, the test speed, capacity, mass flow, pressures, temperatures, compressor power, and other operational details are often totally different from the specified operating condition speed.

For the Type-2 test, an alternative gas (generally an inert gas) should be selected — preferably, one that does not lead to an excessive power or a high discharge temperature and is readily and cheaply available. The substitute gases that are typically used are air, nitrogen, carbon dioxide, helium, or mixtures of these gases.

The safe operating-speed range, the critical speeds, the maximum allowable pressures, the allowable temperatures and other machine limits are considered when establishing suitable test conditions.

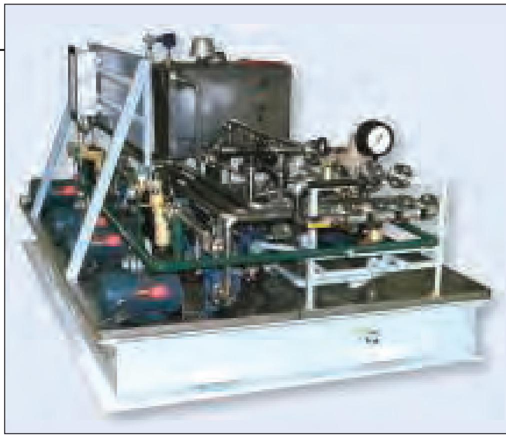


FIGURE 2. Shown here is an example of a compact lubrication skid for a shop test-stand facility

As noted, the ASME-PTC-10 Type-2 test allows for considerable deviations in the test conditions. For example, a natural gas (MW=16) compressor can be performance tested (Type-2 test) using CO_2 (MW=44) with around half the inlet flow, approximately 20% of the mass flow, around 50% of the speed, approximately 6% of the absorbed power and much less pressures (even less than 10%) compared to the specified operating conditions.

The idea behind the Type-2 performance test is to allow a test to be performed by the vendor using different gas and flow details (while still maintaining the major fluid characteristics within certain limits), and to use available knowledge and formulations of fluid mechanics to estimate the compressor performance in the specified operating conditions. The flow patterns of a dynamic compressor (centrifugal or axial compressor) are mainly a function of the major fluid characteristics, such as the volume ratio, the flow coefficient, the machine Mach number and Reynolds number.

Reynolds number. Fluid friction is mainly affected by the machine Reynolds number. In a Type-2 test, the Reynolds number during the test may deviate from that of the specified operating condition; however, it should stay within a range (for instance, within 0.1 to 10 times of the Reynolds number at the expected operating condition) to keep the governing friction model (and formulations) relevant.

Mach number. The machine Mach number is a measure of the maximum compressor capacity and is mainly associated with the "stonewall" effects (That is, the operation of a compressor at the maximum capacity, which is also known as operation at end of the curve; this corresponds to the far right-hand side of the normal operation point). The specific volume ratio and machine Mach number are closely related to the test speed. The molecular weight of the test gas is extremely important because a significant difference between the test gas MW and the actual gas MW can affect the gas density and the calculated compressor head.

As a rule of thumb, a deviation greater than 30–40% could be considered significant. Any significant difference in the molecular weights of the specified gas and the test gas can result in a test speed that is far from the rated speed. For the most relevant results, the test speed should be as close as possible to the rated speed. Ideally, a test speed at around 80–95% of the rated speed is always desirable (if other limits allow this speed range). Too often, the above-mentioned desired speed range is difficult to achieve for commonly used Type-2 test arrangements (particularly when a close match to the gas MW cannot be achieved).

Based on the Type-2 test theory, the modifications (often called corrections) to the test results are applied based on the available gas dynamic knowledge to estimate the compressor performance in the specified operating condition. All correction formulations are available in the ASME-PTC-10 for the estimation. In practical terms, this means that the vendor carries out the Type-2 test, and then applies the correction formulation found in ASME-PTC-10 to find expected performance in operating site conditions.

Balancing the tradeoffs

Some engineers do not trust the Type-2 method, because it allows for so many deviations from actual conditions. As a result, the ASME-PTC-10 Type-1 test is always preferred. However, if the ASME-PTC-10 Type-1 is not possible (for example, if the actual process gas cannot be supplied or used in the manufacturer's shop), then the only possible option is to carry out a Type-2 test using modified test conditions (the gas molecular weight, the speed, the capacity, the power, the pressures, and others) that are as close as possible to the specified operating conditions.

The arrangement and details of Type-2 tests should be fixed in the compressor bidding stage and before the machine order placement. Compressor vendors always prefer the simplest and cheapest arrangement for the Type-2 test. Unfortunately, the ASME-PTC-10 Type 2 code allows the vendor to use the simplest arrangement. In other words, the code gives vendors freedom to use simple setups and deviations, and vendors usually opt for the cheapest setup.

Often the Type-2 test gas selections and testing arrangements are discussed after the compressor order or even near the test time. This delay can usually cause considerable change-order costs or can lead to an unsuitable Type-2 test.

Ideally, the Type-2 test is most useful if a suitable substitute gas (one that closely approximates the actual gas) is used and the test procedure details (such as pressures, compressor speed, capacity, power and others) are properly matched within the specified ASME-PTC-10 limits and as close as practical to the actual operating conditions. When this is done, the Type-2 test can yield very useful predictions on the future compressor behavior, such as potential performance problems, operations close to the surge point, some types of aerodynamic excitations, and other performance and operational effects.

Establishing proper test conditions. For performance testing (whether Type-1 or Type-2 is used), the following limits should be confirmed:

1. ***Head and the capacity***: Zero negative tolerance (In other words, the head and the capacity in the shop test should be equal to or more than expected ones)
2. ***Power***: The consumed power should not exceed 104% of the predicted power. Often, when the CPI plant efficiency is critical, lower limits for the power tolerance — for instance, even 2% or 1.5% limits instead of the 4% power tolerance — could be negotiated before the compressor order
3. ***Surge***: The stable operation should be maintained near the calculated surge (typically around 6–10% above calculated surge flow).

Practical notes

Pressure and temperature transmitters should be located within around 0.5–1 m of the compressor nozzles, at least 10 pipe diameters from any valve, tee, elbow or other obstruction. The temperature-measurement accuracy has one of the largest effects on compressor power calculations because of its direct influence on the calculated enthalpy rise.

An incorrect flow measurement could cause the compressor to appear at the shop test with a head that is either too low or too high because the operating point could be indicated incorrectly on the performance map. The best way to determine if a flow measurement is incorrect is to obtain several data points to compare against the entire curve.

Seal leakage is normally around 1–2% or even less in the normal operation (as a rough estimation), but this can easily be calculated using proper instruments.

The shop test uncertainty should be calculated considering all test parameters. The required uncertainty limits should be understood prior to the shop performance test. For example, data with an uncertainty of 2% cannot yield conclusions requiring an accuracy of 1.5%. Thus, if 1.5% accuracy is required (for instance, by the CPI operator) for assessment of a shop performance test, then the entire shop test installation and test procedure should reflect the uncertainty goal.

The polytrophic efficiency (that is, the efficiency corresponding to theoretically reversible compression process) depends on many details, such as the impeller specific speed, but this is usually limited to approximately 74–80% for traditional 2D impellers, and about 80–87% for modern 3D impellers (usually with vaned diffusers). The most important performance checkpoint is a comparison between the driver power (compressor driver-generated power) and driven power (compressor absorbed power).

If the difference between the driver power and driven power is small, and the calculated head and efficiency are also lower than expected, then the shop performance data are likely correctly measured and the compressor likely has a performance problem.

However, if either the head or the efficiency is off, in terms of having large differences compared to the theoretical or expected values, but the powers (that is, the driver power and compressor power) do not agree, this often indicates inaccurate test data.

Mechanical run tests

A pressurized run test is always preferred (one that is pressurized usually with nitrogen), except for very special cases for which testing under vacuum conditions may be required. As far as practically possible, all job components should be used in a shop test, and the use of shop facilities should be minimized. If the use of a job coupling is not practical, the shop test can be carried out using a coupling simulator (to simulate the weight and the bending effects of the job coupling).

The shop mechanical run-test procedure is straightforward. The compressor is started and the speed increases to the maximum continuous speed. The operation continues until bearing metal temperatures, lubrication oil temperatures and shaft vibrations are stabilized. Then the compressor should be operated for 15 minutes at the trip speed. After that, the unit should be operated continuously for four hours at the maximum operating speed. The main focus of the shop run test is to evaluate vibration.

During the shop test of the lubrication oil system, the oil temperature rise through the bearing should not exceed certain limits (as an indication, oil temperature rise could be around 30°C). Vibration readings and bearing temperatures at the end of the four-hour run should essentially be the same as those recorded at the beginning of the test. After the test is complete, all bearings should be removed, inspected, and reassembled.

However, removal and inspection of the dry gas seal is not recommended. Many dry gas seals (particularly cartridge-type seals) require that the seal be returned to the seal manufacturer if removed for inspection. If traditional (old-fashioned) oil seals are used, they should be removed for inspection after the test (Note that such mechanical, oil-film-type shaft end seals are not typically used today for dynamic compressors).

Minor scuffs and scratches may occur on the bearings. Subsequent minor cosmetic repairs of these parts do not justify repetition of the test. However, if melting or smearing, overheating or distinct wear occurs in the Babbit layer of bearing shoes, then these parts should be replaced or repaired. The cause of the defect should be investigated and eliminated, so the test can be repeated.

After the run test, the compressor casing is gas-leakage tested to evaluate the joints and the seals. The assembled compressor is tested to the maximum operating pressure for a minimum of 30 minutes. The inert gas with MW less than the actual gas MW should be used for this test. Helium is usually employed as a substitute for a low-MW gas and nitrogen (or an inert refrigerant gas) is typically used as a substitute for a high-MW gas.

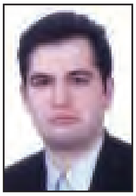
Varying the lubrication-oil conditions (such as the oil pressure and the temperature at the minimum and maximum values) during the shop test is strongly recommended to evaluate the impact of these changes on compressor performance. This will help to evaluate correctly the mechanical operation of the machine.

It is not recommended to perform a post-test-inspection of the internal casing, because most operators prefer to receive a proven-run and pressure-tested compressor.

When users and vendors work together as a team, and when all engineers involved give sufficient attention to the important details, changes and requirements, it is possible to specify reliable, high-performance compressors. ■

Edited by Suzanne Shelley

Author



Amin Almasi is a rotating machine consultant in Australia. He is a chartered professional engineer of Engineers Australia (MIEAust CPEng — Mechanical) and IMechE (CEng MIMechE). He holds an M.Sc. and B.Sc. in mechanical engineering and RPEQ (Registered Professional Engineer in Queensland). He specializes in rotating machines including centrifugal, screw and reciprocating compressors, gas turbines, steam turbines, engines, pumps, subsea, offshore rotating machines, LNG units, condition monitoring and reliability. Almasi is an active member of Engineers Australia, IMechE, ASME, Vibration Institute, SPE, IEEE, and IDGTE. He has authored more than 80 papers and articles dealing with rotating equipment, condition monitoring, offshore issues and reliability.

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The expert source for rental energy solutions

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

Cooling towers and generators are among the equipment available

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

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

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

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

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

www.aggreko.com/northamerica

Building valve solutions with the customer in mind

Inline Industries is celebrating 20 years of innovation in ball valves, having pioneered direct mounting of actuators

Inline Industries has been providing innovative valve solutions to the process industry for 20 years. The company has built a strong reputation for manufacturing high quality, consistent, and reliable products. From manual operation, to automated valve assemblies, to high performance control valves, Inline products help customers minimize total cost of ownership.

Inline is able to provide this economy by designing and building its own valve products as a vertically integrated manufacturer. The company pours its own castings, machines, then assembles and tests each valve to exacting industry standards.

Valves are cast to applicable ASTM material standards and designed and tested to ASME B16.34 specifications to assure that the products will perform at the pressures and temperatures for which they are designed. Each casting is heat stamped and documented through an ISO 9001:2008 quality control process to provide consistency and complete product traceability.

Innovation has been at the heart of Inline valve design since the company's founding. Inline introduced the integrally cast ISO-5211 direct mount pad 20 years ago. Today, versions of the Inline high-cycle/live-loaded design dominate the automated ball valve market. Direct mount technology can eliminate the cost and problems associated with an actuator mounting kit by directly coupling the actuator to the valve body. This system improves performance, reduces misalignment, side loading, and hysteresis, and shrinks the size of the valve package, saving up-front material costs as well as reducing long-term maintenance.

Direct mount technology has been integrated into the high-performance 334 Series ball valve which serves as the foundation for valve derivations designed for fire-safe, high pressure, high temperature and control applications. All Inline direct mount valves are available with locking lever handles or as complete pneumatically or electrically operated systems.

Inline 324 Series ball valve

Inline is also recognized for high-purity valves for the food and beverage (3A), bio-pharmaceutical (BPE-2009), and semiconductor industries. The company manufactures one of the broadest selections of multi-port valves in the process industry with a large inventory of diverter, 3-, 4-, and 5-way valves available from stock. Inline also offers a wide selection of end connections and seat and seal materials for compatibility with different process applications. **www.ballvalve.com**

Getting to the heart of large columns

Tiger Tower Services, operating within a tight timeframe, changes out the internals of a complicated multiple column turnaround; thus giving new life to old vessels

Tiger Tower Services answered a tall and logistically challenged order when a client needed to give new life to four existing columns

Four very large stainless steel columns needed alterations to accommodate new packing. Sounds simple enough, but this project had many challenges.

Column number one is 17 ft 6 in. in diameter and stands 184 ft high. All the distributors, bed limiters and existing random packing had to be removed and replaced with five beds of replacement packing, bed limiters, distributors and four sophisticated anti-foaming devices. Additionally, the flash gallery was replaced along with an H-type pipe distributor. New bed limiters also were installed above each new bed of packing, requiring hot work modifications at each bed level to accommodate the new design.

The other columns required similar alterations. One needed only one bed of packing, while another required six. In all, 81,782 cu. ft of packing was removed and replaced with new random packing. All of the distributors in each column were replaced and leveled to the manufacturer's precise specifications.

The tight time limit was not the only challenging feature of this job – a restrictive footprint around the columns also made the work logistically challenging. The tremendous quantity of internals had to be housed at a remote location. **Tiger Tower Services** worked closely with its own internal manufacturer alliance partner to create a precise materials control/delivery system that functioned smoothly as the project progressed.

The client's end-user engineering representatives worked in tandem with The Tigers to ensure that the turnaround resulted in a high-quality installation completed within the time schedule.

Tiger Tower Services is known for getting to the heart of any tower/column turnaround, revamp or emergency. The firm is well known for its ability to address tight footprint issues, using its Window Section Resection (WSR) in-situ technique as a more viable solution than the traditional "lift down top half" approach.

www.tigertowerservices.com

Cracking furnace burners and olefin plant flares

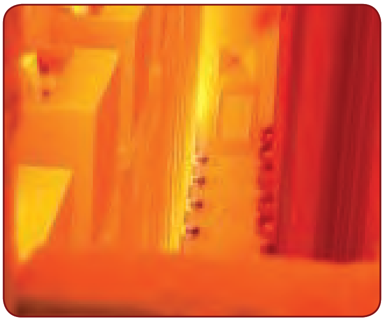
Describing itself as a combustion company, not just a flare or burner manufacturer, Zeeco takes an integrated approach to process design and retrofits

From the wellhead to chemical and petrochemical facilities worldwide, **Zeeco** has more than three decades of combustion experience. All of the company's activities relate to combustion, including innovative burners, flares and thermal oxidizers. Combustion experts design and deliver specifically engineered applications for olefin plants on time, on budget, and with guaranteed performance.

Zeeco understands the complex interaction of flame, fuel, emissions, and public perception. For instance, flare systems for olefins production are designed to operate smokelessly at significant flowrates for long periods of time. For plants near population centers, in environmentally sensitive areas, or with limited space, the experienced team at Zeeco 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 company and not just a flare or a burner company, the firm takes a more complete view of plant processes and interactions. The rise of shale gas means many olefin facilities are working to increase capacities. 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 burner 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 without flame interaction in ethylene cracking furnace 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 burner flame quality. The GLSF burner transfers heat evenly to the process tubes, reducing the possibility of localized hot spots or flame interaction.

Zeeco is dedicated to delivering on time and on budget worldwide. The Zeeco Houston Service Center provides local service to the Gulf Coast area 24/7, including heater tuning, burner cleaning, flare tip replacement, controls/pilot upgrading, and more. **www.zeeco.com**



Zeeco burners in an olefin furnace

Valve vendor seizes new international markets

Control valve and pressure regulator manufacturer Cashco has opened new sales and service offices to cover the South American, European, and western Asian markets

Spurred by the growth in international sales of its diversified line of control valves, regulators and tank equipment, **Cashco, Inc.** recently opened new sales and service offices in both Brazil and Germany to better serve its world-wide customer base. While the Brazil office, located in the outskirts of São Paulo, will initially service the customer base within the country, it will eventually provide service and support to Cashco customers throughout South America. The other office, located in Hoppegarten, Germany, will be a sales and service center for all of Europe and western Asia.

"In addition, the German location, which is actually near Berlin, provides us with engineering and design capabilities, as well as new manufacturing capabilities," explains Clint Rogers, General Manager, Valve Division, Cashco, Inc. "This will allow us to design and introduce new products that are unique to the European market, yet hold the potential for future use in the U.S."

Rogers says the plan is to eventually share some design capabilities between the U.S. and Europe and, hopefully, ship more U.S. products to Europe and vice versa. By collaborating on design capabilities, he relates, Cashco can better fit the needs of both markets with a broader line of products built in both countries.

"The new sales and service offices in Brazil and Germany, along with the new corporate headquarters in Ellsworth, Kansas, is just part of our commitment to growing our business and supporting our customers," Rogers continues. "We already have local people at both locations who understand the markets and languages. By having one or more technicians within the country, we can also deal with issues that come up in a much more timely and efficient manner than if we were to address them from the U.S." At the same time, Rogers insists customers in South America and Europe can be assured that Cashco products meet the highest standards and adhere to all compliances, no matter the import country.


Blue skies ahead

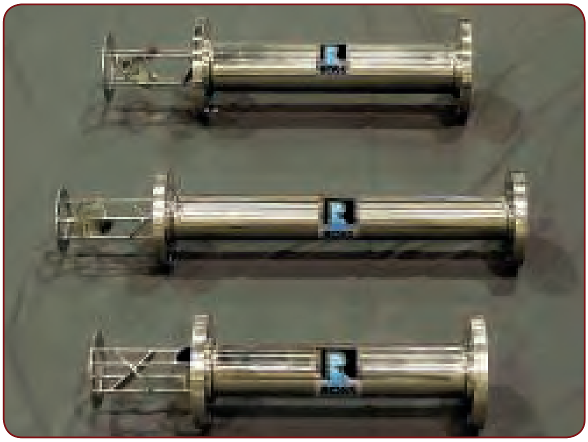
Cashco manufactures a broad line of throttling rotary and linear control valves, pressure reducing regulators, back pressure regulators and vapor control systems in a wide range of sizes.

www.cashco.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

Safety is a growing concern among process industries on the Gulf Coast and throughout the world. Government standards and new regulations make safety instrumented systems (SIS) a critical part of many operations.

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.

The DeltaV SIS system provides an integrated but separate architecture to meet IEC 61511 requirements for separation of safety and control.

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.

This seamless integration with the DeltaV system provides comprehensive process safety that leverages investment in automation. **www.EmersonProcess.com/DeltaV**

Five questions to ask about blast-resistant buildings

by Jeff Lange, Owner of A Box 4 U

There are no regulations governing the design and construction of blast-resistant buildings (BRBs), so it's important to educate yourself before making a purchase. Here are the five big questions to ask when you shop for a BRB:

1. Was the BRB designed and tested by a blast expert?
A surprising number of BRBs have not been proven safe through real blast testing. Make sure your BRB design has been taken "off the drawing board" and successfully blast tested under the supervision of a well-credentialed engineer.

2. Are blast-test reports specific and conclusive?
There are many interpretations of the term "blast-tested" (also see question 5), but a successfully blast-tested building has the proven ability to actually save lives. Pay special attention to psi ratings when you review blast test reports because different applications call for different specifications.

3. Was the building blast tested for non-structural – as well as structural – components?
If a structure survives a blast, but its interior walls, lights or other fixtures create shrapnel, the risk of casualties is still high. Always ask BRB vendors to provide data and rationale for non-structural items like wall finishes, cabinets, lights and electrical fixtures.

4. Can the following information be provided?
(These items are too technical to cover in the context of this article but should be on your list of discussions to initiate with any BRB vendor.)
- Was the BRB tested dynamically rather than statically?
- Was the BRB tested in a free-field environment?
- Was a pressure-impulse (P-I) curve generated to show the BRB's response over a wide range of blast loading?

5. Does the building's response level demonstrate its capability to save lives?
A BRB vendor can claim their product has been "blast tested," but if closer examination of test data demonstrates a high-response result, this is not the BRB you want protecting your personnel. Response level ratings have been established by the American Society of Civil Engineers (ASCE) to predict the extent of repair resources needed after an explosion:

Response level	Description
Low Response (Low Damage)	Localized building/component damage Building can be used, however repairs are required to restore the integrity of the structural envelope The total cost of repair is moderate
Medium Response (Medium Damage)	Widespread building/component damage Building cannot be used until repaired Total cost of repairs is significant
High Response (High Damage)	Building/component has lost structural integrity May collapse due to environmental conditions Total cost of repairs approach replacement cost of building

When you go shopping for a BRB, it's important to ask solid questions and expect solid answers; your employees' lives could depend on it. **www.abox4u.net**

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

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**

50 years of service for heat transfer fluid systems

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

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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

Delivering results for chemicals and polymers

Wood Group Mustang provides highly experienced process engineers and project managers for all types of process projects over the project lifecycle

Wood Group Mustang has a wide range of experience in chemical and polymer projects, facilitated by project management teams who have worked together for more than 30 years. Similarly, the company's process engineers average more than 20 years' experience. And, behind the scenes, superior support teams utilize the latest 3D modeling techniques, including laser scanning, to streamline projects and reduce costs. Additionally, Wood Group Mustang staff use their proprietary stage gate process and project management tool (PACESETTER) to ensure that projects are successful from start to finish.

Clients' projects are managed from concept through to operations. With field-proven processes and a focus on safety, the company execute projects with predictable results – on budget, on time and with flawless start-up. 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" or licensed technologies. Wood Group Mustang offers comprehensive technical and economic studies, technology evaluation, experimental program design, pilot plant programs, and acquisition of physical and chemical property data.

Founded in 1987, Wood Group Mustang has established a global reputation for quality engineering design, project management, procurement, and inspection services. Wood Group Mustang consistently leverages its global organization to deliver the best resources and most cost-effective solution for chemicals and polymer projects to its clients.

Wood Group Mustang has completed more than 11,000 engineering projects worldwide

www.mustangeng.com

Celebrating a century of mass transfer innovation

At Koch-Glitsch, the culture of innovation has been going strong for 100 years with brands that set the standards and are the preferred technology in the industry

For many years, equipment designers searched for the ultimate mass transfer device – one that could be used for any application. Over time, they reached the conclusion that there is no single device for all applications; rather, there is always a device that has distinct benefits and characteristics that make it the most suitable to meet the requirements for a particular application.

Koch-Glitsch put decades of practical knowledge, innovative thinking, and tremendous expertise into research and testing that led to the development of a comprehensive product portfolio. The line of products includes high-performance trays, random packing, structured packing, and severe-service grid to address the needs of plant operators.

Koch-Glitsch set the standards with IMTP random packing and FLEXITRAY valve trays, which were the preferred technology in the industry for many years.

PROFLUX severe-service grid and PROVALVE trays provide reliable unit operations in severe operating conditions, such as fouling, coking, erosion, corrosion, and frequent upsets.

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INTALOX ULTRA random packing provides higher capacity and efficiency and lower pressure drop compared to previous generations of random packing. It is applied in acid gas removal, demethanizer/de-ethanizer, sour water strippers and atmospheric and high-pressure distillation.

Koch-Glitsch continues its long tradition of innovation in developing new equipment designs that provide higher efficiency, higher capacity, improved plant performance, and increased reliability yielding significant capital and energy savings.

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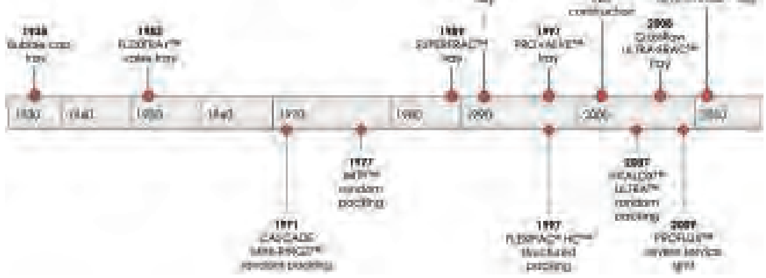

Not all blast-resistant buildings are created equal

A Box 4 U is the only manufacturer to have successfully blast tested its blast-resistant buildings to meet a low to medium response rating, says Dr Ali Sari, PE

Video evidence: testing a blast-resistant building from A Box 4 U

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 **A Box 4 U**, 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. A Box 4 U contacted me, and we set out on a mission to save lives.

There were other companies selling blast-resistant buildings, so our 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.

We designed our unit, built it, and then did something unprecedented in the field of blast-resistant buildings – we tested it. If you like to watch Hollywood-quality explosions, click on the blast test video links on www.abox4u.net. They speak for themselves, in terms of the product's ability to survive close-proximity explosions.

What you don't see in these videos is the most important part of the process. When we tested, we didn't just use an empty structure. We added lights, furniture, office equipment and a test dummy, then hit it 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.abox4u.net**

Heat transfer simulation software updated

HTRI releases version 7 of its industry-leading simulation suite for process heat transfer equipment

Heat Transfer Research, Inc. (HTRI) has released version 7 of ***X****changer Suite®*, the culmination of more than 50 years of research. ***X****changer Suite* is a comprehensive suite of modules that predict the performance of process heat transfer equipment. ***X****changer Suite 7* represents the largest increase in capabilities ever for HTRI software and includes simulation 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
- tube vibration analysis

New to version 7, the plate-fin module continues HTRI's practice of developing rigorous, incremental simulations that are based on extensive experimental research. In addition to this new module, version 7 incorporates significant additions and upgrades throughout. Ten major updates have been made to the predictive models, including shellside reflux condensation, horizontal tubeside condensation, tubeside convective boiling, kettle reboilers, and tubeside laminar flow. The graphical interfaces have been reorganized and streamlined to make data entry easier than ever before. Perhaps the single most significant upgrade is an interactive, behind-the-scenes mechanical design for shell-and-tube exchangers. Based on ASME codes, the shell-and-tube module automatically performs and updates a rigorous mechanical design of your exchanger as you enter data. This mechanical design provides the basis for the most flexible tube layout available.

Of course, software is just a part of the package. With experimental and analytical research, engineer-based technical support, and worldwide training, HTRI provides a complete solution for process heat transfer.

Heat Transfer Research, Inc. is a leading global provider of process heat transfer and heat exchanger technology, research, and software. Founded in 1962, this industrial research and development consortium serves the engineering needs of nearly 1500 corporate member sites in more than 60 countries. **www.htri.net**

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.

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

John Zink Hamworthy Combustion has installed thousands of flare systems

Small-company safety

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

Some injuries are permanent; some injuries are total. People who work for, or near, small companies need to be protected just as much as those associated with large companies. Small companies, however, usually cannot afford to employ full-time, certified, degreed, safety professionals. From my own career experiences, it seems as though a company with less than 50 employees cannot afford to employ an expert full time. FRI is such a small company.

One solution for a small company is to utilize consultants. For example, professor Jan Wagner has assisted FRI with process hazard analyses (PHAs), risk management plans (RMPs), relief system analyses and dispersion studies. Alan Drew, of Meridian Technology, teaches safety classes and performs "outside audits." Ming Yu, of Red River Environmental Laboratory and Consulting Co., performs an annual radiation audit that addresses FRI gamma-scan apparatuses and cobalt sources. The bulk of FRI's safety efforts, however, are performed on a part-time basis by four FRI employees, including myself. Not too long ago, we benefitted appreciably from a surprise all-day audit of our safety programs by the U.S. Environmental Protection Agency (EPA). According to that inspector, "FRI is doing a very good job — for a small company." In fact, every outside auditor seems to say just about the same thing.

Following the EPA audit, FRI created a safety tool that might be unique. FRI created an electronic Safety Journal. Every employee who performs any significant safety chore is encouraged to enter a dated sentence in the journal. One example, "TCT re-trained CWK regarding forklift operation"; "Safety meeting run by AD regarding PPE"; and "KM plugged insulation holes on reflux line." With the first two examples, other documentation of the event was, of course, prepared. This Safety Journal has many benefits, including the fact that it is word-searchable. Any FRI employee can search for objects like the following: CWK, forklift, PPE, KM, insulation, and so on. The Safety Journal has proven extremely valuable with external auditors when they have asked questions like, "When was the last time that you . . ." and "Is there any documentation regarding . . ." FRI's Safety Journal is also the place where FRI stores reminders regarding future safety/reporting deadlines. Some large companies employ "dashboards" and "scorecards", which are similar to FRI's Safety Journal, to keep track of process safety management (PSM) information. The idea for FRI's Safety Journal came from my MBA studies (many years ago) when I learned about the journals that accounting departments keep.

About a year ago, at a general safety meeting, I went around the room and asked several engineers, technicians and administrators the same question, "What is the key to safety?" The answers that came back included words like training, caring, documentation, pre-engineering, personal protective equipment, inspections, audits, follow-ups and communications. When I was done receiving input, I reached under the table and pulled out a string of 592 metal keys, which I held above the table. I stated, "There are many keys to a safe working environment." Now, whenever anybody enters my office, the first thing they see is the FRI safety keys hanging from my coat rack. ■

Mike Resetarits

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MAY WHO'S WHO


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Steve Edwards will become chairman, president and CEO of global engineering-and-construction company **Black & Veatch** (Overland Park, Kan.), when *Len Rodman* retires at the end of 2013.

John Rolando becomes president of specialty chemicals company **Evonik Corp.** (Parsippany, N.J.), succeeding *Tom Bates*, who is retiring.

Henri Haggblom becomes managing partner of consultancy **Sinclair Group** (The Woodlands, Tex.).

Nuclear and chemical-process safety company **Fauske & Associates, LLC** (Burr Ridge, Ill.) welcomes the return of *Michael Grolmes*, one of its founding principals and current owner of Centaurus Technology, as an exclusive consultant.

Richard Grenville joins **Philadelphia Mixing Solutions, Ltd.** (Palmyra, Pa.) as director of mixing technology.

SVF Flow Controls, Inc. (Santa Fe Springs, Calif.) appoints *Russ Chomiak* director of sales.

John M. Brown joins **General Electrical Co.** (GECO; St. Louis, Mo.) as vice president of industrial and instrumentation.

ValvTechnologies, Inc. (Houston), manufacturer of severe-service isolation valve solutions, names *Julie Bodine* global director of marketing.

Bryan Burns becomes president and COO for **DeZurik, Inc.** (Sartell, Minn.), a global maker of municipal and industrial valves. ■

Suzanne Shelley

BUSINESS NEWS

PLANT WATCH

Neste Jacobs to expand enzyme production plant in Finland

April 5, 2013 — Neste Jacobs Oy (Porvoo, Finland; www.nestejacobs.com) has signed a contract to expand an enzyme plant operated by Roal Oy (Rajamäki, Finland; www.roal.fi). Enzymes produced at the Rajamäki plant are used to make foodstuffs, clothing, animal feed, pulp and paper. The contract, which is worth several million euros, started in April and will be executed in phases, finishing in June 2016.

ThyssenKrupp to build a second cement plant in Indonesia

March 27, 2013 — ThyssenKrupp Polysius (Beckum, Germany; www.thyssenkrupp-resource-technologies.com) has won a contract from PT Holcim Indonesia Tbk., Jakarta, to build a second 1.7-million ton/yr cement plant near the town of Tuban on the northern coast of Java. The contract is worth around $250 million and the plant is scheduled to start production in 2015. The Tuban 1 plant, also being built by ThyssenKrupp Polysius, is due to start up in June.

UOP propylene technology chosen for plants in Canada and China

March 26, 2013 — UOP LLC (Des Plaines, Ill.; www.uop.com), a Honeywell company, says that its UOP C3 Oleflex propane dehydrogenation (PDH) technology has been selected by Williams (Tulsa, Okla.) for a plant in Alberta, Canada. The 1-billion lb/yr facility will convert propane recovered from oil sands offgas into polymer-grade propylene. This is Canada's first PDH facility and the sixth successive win for Honeywell's UOP Oleflex technology in North America.

Uhde Inventa-Fischer commissions polyamide 6 plant in Belarus

March 25, 2013 — Uhde Inventa-Fischer (Domat/Ems, Switzerland; www.uhde-inventa-fischer.com) and JSC Grodno Azot PTC Khimvolokno (Belarus) have successfully commissioned a 91,000-metric tons (m.t.)/yr polyamide 6 plant in Grodno, Western Belarus.

Toyo wins EVOH plant contract in Texas and refinery modernization in Tatarstan

March 18, 2013 — Toyo Engineering Corp. (Toyo; Chiba, Japan; www.toyo-eng.co.jp) has won a contract to construct a 15,000-ton/yr ethylene-vinyl alcohol copolymer (EVOH) plant in La Porte, Houston, for Nippon Synthetic Chemical Industry Co. Construction is scheduled to begin this summer and to be completed at the end of 2014. The project will add a third production line to Nippon Synthetic's two existing lines.

The previous week, Toyo Engineering Corp. was awarded a contract with TAIF-NK (Nizhnekamsk, Republic of Tatarstan, Russian Federation) to provide detailed engineering and procurement for the modernization of an oil refinery in Nizhnekamsk. TAIF-NK belongs to TAIF PSC Group (Republic of Tatarstan, Russian Federation), and is one of the largest petroleum refineries in Russia. The project, which is due to be completed in 2016, will see the world's first use of the VCC (Veba Combi Cracker) process from KBR (Houston; www.kbr.com) on a Heavy Residue Conversion Complex (HRCC).

Jacobs awarded contract for sulfuric acid regeneration plant

March 12, 2013 — Jacobs Engineering Group Inc. (Pasadena, Calif.; www.jacobs.com) was awarded a contract by Jiangsu Sailboat Petrochemical Co. for the design of a sulfuric acid regeneration plant in Lianyungang, Jiangsu, People's Republic of China. The plant will treat spent acid from a new methyl methacrylate (MMA) and acrylonitrile (AN) production facility.

Ineos and Sinopec form JV agreement for chemical complex in Nanjing

March 11, 2013 — Ineos Phenol (Rolle, Switzerland; www.ineosphenol.com) and Sinopec Yangzi Petrochemical Co. (Sinopec YPC) have formed a joint venture (JV) to build and operate a 1.2-million m.t./yr cumene, phenol and acetone complex at Nanjing Chemical Industrial Park in Jiangsu Province, China. Capacity will be at least 400,000 m.t./yr of phenol, 250,000 m.t./yr of acetone and 550,000 m.t./yr of cumene, making it the largest plant of its kind in China. Startup is planned for the end of 2015.

Pöyry awarded EPCM assignment in a pulp mill project in Brazil

March 11, 2013 — Pöyry Oyj. (Helsinki, Finland; www.poyry.com) has won an engineering, procurement and construction management (EPCM) contract from CMPC Celulose Riograndense for the expansion of the company's Guaiba pulp mill in Rio Grande do Sul state, Brazil. Under the Balance of Plant (BOP) assignment, Pöyry will work on integrating the different processes of the mill. Startup of the new 1.3-million m.t./yr mill is planned for early 2015.

MERGERS AND ACQUISITIONS

CB&I acquire Phillips gasification technology and signs Korean PDH deal

March 21, 2013 — CB&I (The Woodlands, Tex.; www.cbi.com) has agreed to acquire the E-Gas gasification business from Phillips 66. E-Gas technology is a commercially proven way to convert coal or petroleum coke into synthesis gas. The previous week, CB&I announced a contract from SK Gas for the license and engineering design of a propane dehydrogenation (PDH) unit to be built in Ulsan, Korea, for startup in 2016. The 600,000-m.t. /yr plant will use Catofin technology from Lummus.

BASF to start up new FCC catalysts testing and research laboratory in Heidelberg

March 13, 2013 — BASF Corp. (Iselin, N.J.; www.basf.com) says it will open a new multimillion euro fluid catalytic cracking (FCC) catalysts testing and research laboratory at the hte AG (www.hte-company.com) facility in Heidelberg, Germany. hte is a wholly owned subsidiary of BASF SE (Ludwigshafen, Germany) and provider of services to enhance productivity in research and development. The new BASF laboratory will begin operating in the first half of 2014.

Davy Process Technology and SEKAB E-Technology form strategic partnership

March 13, 2013 — Davy Process Technology Ltd. (Davy; London, U.K.; www.davyprotech.com), a Johnson Matthey company, and SEKAB (Rotterdam, the Netherlands; www.sekab.com), a leader in ethanol-based chemicals and biofuels, announced that they will collaborate to develop and market CelluTech, SEKAB's lignocellulosic-based biorefinery technology.

AkzoNobel and Solvay establish a partnership on renewable solvents

March 12, 2013 — Solvay S.A. (Brussels, Belgium; www.solvay.com) has agreed to supply bio-based chemicals for use in paints and coatings made by AkzoNobel (Amsterdam, the Netherlands; www.akzonobel.com). The agreement covers the manufacture of biobutanol and bio-acetone and their derivatives, and the Solvay Coatis Augeo family of solvents, in volumes of up to 10,000 ton/yr by 2017. ■

Charles Butcher

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

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

2011 — 2012 — 2013

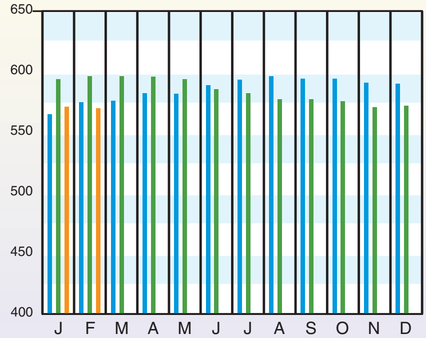
DOWNLOAD THE *CEPCI* TWO WEEKS SOONER AT WWW.CHE.COM/PCI

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Feb. '13 Prelim.	Jan. '13 Final	Feb. '12 Final
***CE* Index**	569.9	571.2	596.3
Equipment	690.9	692.8	730.6
Heat exchangers & tanks	627.3	630.1	689.9
Process machinery	653.6	657.6	677.7
Pipe, valves & fittings	887.6	890.4	933.5
Process instruments	417.1	416.5	433.8
Pumps & compressors	917.4	913.9	919.6
Electrical equipment	513.5	513.3	514.2
Structural supports & misc	739.3	741.6	772.9
Construction labor	318.9	319.2	321.7
Buildings	531.0	530.9	524.4
Engineering & supervision	326.6	326.8	328.4

Annual Index:

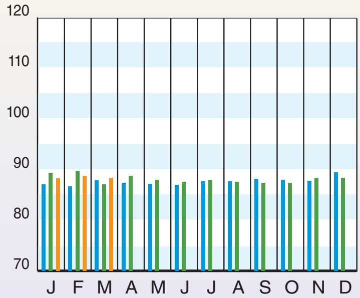
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6



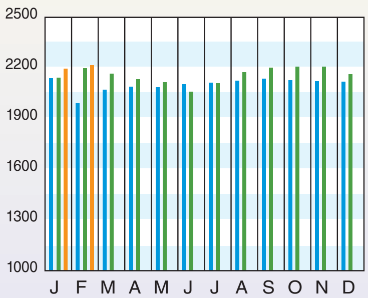
CURRENT BUSINESS INDICATORS

	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2007 = 100)	Mar. '13	=	88.3	Feb. '13	=	88.7	Jan. '13	=	88.2	Mar. '12	=	87.0
CPI value of output, $ billions	Feb. '13	=	2,218.0	Jan. '13	=	2,195.4	Dec. '12	=	2,164.3	Feb. '12	=	2,199.3
CPI operating rate, %	Mar. '13	=	74.7	Feb. '13	=	75.1	Jan. '13	=	74.9	Mar. '12	=	74.6
Producer prices, industrial chemicals (1982 = 100)	Mar. '13	=	313.5	Feb. '13	=	314.2	Dec. '13	=	299.7	Mar. '12	=	327.3
Industrial Production in Manufacturing (2007=100)	Mar. '13	=	95.7	Feb. '13	=	95.9	Jan. '13	=	95.0	Mar. '12	=	93.4
Hourly earnings index, chemical & allied products (1992 = 100)	Mar. '13	=	155.2	Feb. '13	=	155.2	Jan. '13	=	155.0	Mar. '12	=	157.3
Productivity index, chemicals & allied products (1992 = 100)	Mar. '13	=	105.5	Feb. '13	=	105.1	Jan. '13	=	105.6	Mar. '12	=	106.3

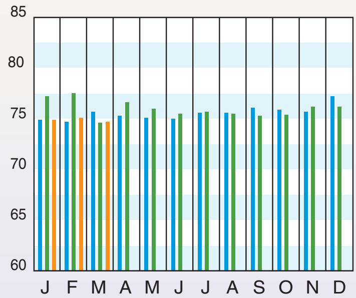
CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



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

CURRENT TRENDS

Preliminary data for the February 2013 *CE* Plant Cost Index (CEPCI; top), which is the most recent available, indicate that capital equipment prices declined from January to February, by 0.2%. The current February 2013 preliminary Plant Cost Index stands at 4.4% lower than the PCI value from a year ago (February 2012). Within the equipment subcategories, costs for pumps & compressors, process instruments and electrical equipment edged higher, while costs in other areas, including process machinery and heat exchangers & tanks, fell. Meanwhile, the Current Business Indicators from IHS Global Insight (middle), show that the latest CPI output index value (March 2013) increased from the previous month. ■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