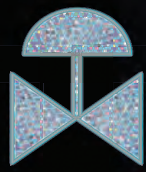
CHEMICAL ENGINEERING

November 2011



Control Valve Diagnostics

PAGE 42

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PAGE 32

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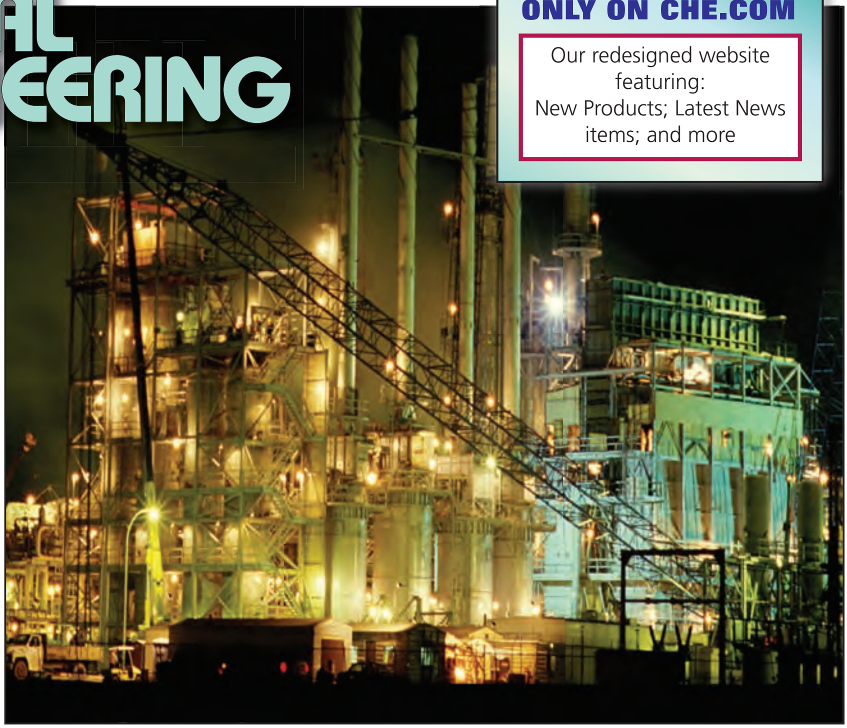

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CHEMICAL ENGINEERING

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Editor's Page

Mission: Detangle the IT knots

Ever since the advent of the first computer, the goals of information technology (IT) have been to simplify (as well as speed up and generally improve) the way we do things. As computer systems and software have evolved, however, many chemical engineers would argue that the results in chemical process plants have been far from simple. In the chemical process industries (CPI) there are systems for instrumentation and control, asset management, data recording and visualization, enterprise resource planning, process simulation, alarm management, regulatory compliance and reporting, calibration, maintenance management, and the list goes on and on.

As if the sheer number of systems — and jargon — were not complex enough, these days there is more and more pressure to integrate them all in hopes of squeezing out even better results than what each one offers on its own. The potential advantages are indeed significant, but so are the hurdles of interoperability and integration that are already at hand.

"[CPI] users have an existing frustration with the way things work," acknowledges Nick Barnett, industry solution manager, Worldwide Process Manufacturing Industry for Microsoft (Redmond, Wash.; www.microsoft.com). To help reduce these frustrations and ultimately minimize IT complexity in the CPI, Microsoft recently launched the Chemical Reference Architecture (ChemRA) initiative, which aims to develop an IT guide or blueprint that would guide vendors in their development and IT people in their systems integration.

ChemRA is based on a set of guiding principles (derived from industry standards and technology advancements) that support the most common-use cases of technology in the CPI. ChemRA initiative has three key goals:

1. To lower the total cost of ownership and increase the agility and longevity of chemical business solutions by ensuring faster development and deployment, easier integration and interoperability — speeding time to market and return on investment.

2. To provide a development and delivery framework that drives deeper, richer commonality within the customer environment by adherence to common principles, benefitting both solution providers and in-house development projects.

3. To accelerate delivery of industry solutions built on a common IT reference architecture to help meet evolving industry challenges.

ChemRA is based on the following set of principles that support the most common use cases of IT in the CPI:

- Natural user experience: Interacting with technology in more humanly intuitive ways
- Application interoperability: Facilitating cross-application business processes and extending them beyond enterprise walls to business partners, suppliers and customers
- Enhanced collaboration: Using unified communication tools, including portals, email, alerts, social computing and cloud computing, within the context of operations and business workflows
- Business insights: Monitoring operations to quickly identify, resolve, or even prevent problems
- Solid infrastructure: Secure, reliable, flexible, scalable, and high performing technology foundation to support 24/7, global operations and business

Admittedly, ChemRA will ultimately be followed by technology vendors and IT personnel, so you might wonder what a ChE needs to know or do about it. According to Barnett, it is simple, "ChEs can request that it be followed" and then wait to reap the results. ■

Rebekkah Marshall

Letters

Fight formaldehyde litigation

Perhaps enough has been written about the questionable science underlying recent U.S. government pronouncements concerning formaldehyde and human cancer of the lymphohematopoietic system ("LHPs—including the leukemias and the lymphomas)*. Now, suppliers of formaldehyde-containing product must face the uncertainties and high expense of defending questionable and likely meritless lawsuits asserting formaldehyde exposure and induction of an LHP malignancy. The opportunity for such lawsuits is clear: in the U.S. 150,000 new LHP malignancies are diagnosed annually, and at least hundreds of thousands of workers are occupationally exposed while hundreds of millions of others are non-occupationally exposed to formaldehyde daily.

Confused and frightened cancer victims turn to the Internet for guidance where they find an army of lawyers seeking to represent allegedly injured workers relative to formaldehyde-containing "defective products." (Google "formaldehyde cancer lawyer" and see what comes up.) Such lawyers trumpet the bumper-sticker conclusion of the governmental authoritative bodies ("formaldehyde causes leukemia!") while chalking up any challenge to the science as corporate dithering and double talk (or worse).

In the 21st century, judges are to serve as "gate keepers" on the admissibility of expert opinions — in theory, those without a meaty scientific basis do not get admitted and a jury never hears them. That can be the end of the case. (This is how a judge "throws a case out of court" — a result achieved far more easily in the popular imagination than in the actual practice of law.)

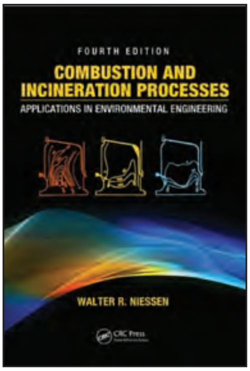
For inhaled formaldehyde to cause leukemia, the toxin must reach the bone marrow. So far science has not been able to articulate such a mechanism, although creative hypotheses have been suggested. For that reason, the plaintiff's expert who proclaims that inhaled formaldehyde in fact caused a particular plaintiff's leukemia ought not to be able to offer that opinion. But we ask much — perhaps too much — of our judges to "throw the case out of court" on that ground in the face of government pronouncements that necessarily imply the contrary.

This means, then, a jury trial or a settlement. What should a formaldehyde defendant do? Industry should fight formaldehyde cancer cases hard. In most places in the U.S., where a fair-minded jury can be selected, a defendant will win most of these cases on the merits and thereby change the risk-benefit calculation for the plaintiffs' bar. Industry's track record involving the compound benzene (a human carcinogen) is instructive: a large majority of such cancer claims actually tried have resulted in defense verdicts.

Lawrence P. Riff, toxic tort practice group leader
Steptoe & Johnson LLP, Los Angeles ■

* Formaldehyde is capable of causing leukemia in humans, according to the U.S. Department of Health and Human Service's Congressionally-mandated 12th Report on Carcinogens, released on June 10, 2011, and all LHP malignancies according to the U.S. EPA's draft IRIS Assessment of Formaldehyde released in 2010. But see, National Academy of Sciences's critical review of the IRIS Assessment ("NAS Reviewers Slam EPA's Formaldehyde Assessment", *New York Times*, April 8, 2011).

Bookshelf



Combustion and Incineration Processes: Applications in Environmental Engineering. 4th ed. By Walter R. Niessen. CRC Press, Taylor and Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487. Web: taylorandfrancis.com. 2011. 800 pages. $199.95.

Reviewed by Thomas F. McGowan,
TMTS Associates Inc.,
Atlanta, Ga.

Walter Niessen's book has a place as one of the seminal works for "pyro-practitioners." In the latest revision (4th ed.), Niessen adds new material on conversion technologies to his already wide-ranging discussion of combustion and air-pollution control found in earlier editions. This 800-page book is written largely for pryo-practitioners — folks who burn things for a living — and in particular, those who design new systems and retrofit and upgrade old ones. The book is particularly recommended for those beginning their careers at original equipment manufacturers (OEMs) of combustion and incineration systems, as well as others who work with high-temperature processes.

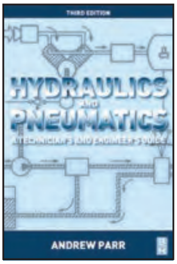
The book offers information on the design, operation and evaluation of combustion, incineration and gasification systems for hazardous and nonhazardous gases, liquids, fuels and wastes. Furnace and combustion enclosure design is covered in detail. End-of-pipe, air-pollution-control systems are also addressed, as are waste and residue characteristics, refractories, materials-handling and feed-preparation considerations, and energy requirements. The author presents design approaches to reduce pollutants both during and after combustion. The book also includes a CD, which provides heat and mass balances, ash-fusion temperature calculations, an enthalpy calculator and other handy programs for combustion applications.

The book starts with a critical subject — stoichiometry and heat and mass balances. Equilibrium and kinetics are addressed next, and both pyrolysis and combustion reactions receive plenty of attention. Chapter 12 provides new material on the latest "conversion technologies" for solid waste, with a focus on gasification. Historically, combustion and incineration are most common, but the future may see expanded use of gasification, which provides the potential for creating useful chemicals, and for fueling engines and turbines — if the engineering community succeeds in cleaning up the synthesis gas to the required levels. The goal of gasification is to convert solid fuels into a gaseous form that provides high fuel value (from its CO and H_2) and a low-carbon ash. Tar and oils are part of the mix, so their removal remains a major challenge.

The author discusses various gasification approaches, such as direct and indirect heat transfer, steam- and oxygen-injection routes, and plasma-based techniques.

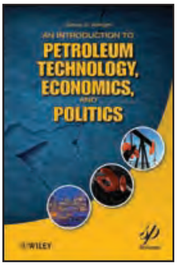
Despite the presence of unwanted pyrolytic tars, the gasified stream is smaller by roughly an order of magnitude compared to products of complete combustion, reducing the scale of gas cleanup equipment. The hot topic of cracking of the tars (using, for instance, reaction with dolomitic lime or exposure to high temperatures) is covered briefly. The unanswered question is whether the use of gasification is ultimately better than incineration when used for raising steam, with the exception of those processes that can generate a fused, glassy, stable ash.

Microfabrication for Industrial Applications. By Regina Luttge. Elsevier Inc., 30 Corporate Drive, 4th floor, Burlington, MA 01803. Web: elsevier.com. 2011. 312 pages. $220.00.

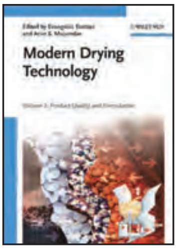


Hydraulics and Pneumatics: A Technician's and Engineer's Guide. By Andrew Parr. Elsevier Inc., 30 Corporate Drive, 4th floor, Burlington, MA 01803. Web: elsevier.com. 2011. 248 pages. $49.95.

Practical Guide to High Performance Engineering Plastics. By David J. Kemmish. iSmithers Rapra Publishing, Shawbury, Shrewsbury, Shropshire, SY4 4NR, U.K. Web: polymer-books.com. 2011. 134 pages. $130.00.

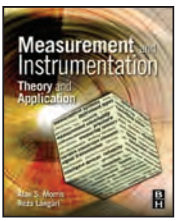


An Introduction to Petroleum Technology, Economics and Politics. By James G. Speight. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ 07030. Web: wiley.com. 2011. 334 pages. $79.95.



Modern Drying Technology, Vol 3: Product Quality and Formulation. Edited by Evangelos Tsotsas and Arun Mujumdar. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ 07030. Web: wiley.com. 2011. 430 pages. $210.00.

Contemporary Science of Polymeric Materials. Edited by Ljiljana Korugic-Karasz. Oxford University Press, 198 Madison Ave., NY 10016. Web: oup.com. 2011. 264 pages. $150.00.



Measurement and Instrumentation: Theory and Application. By Alan S. Morris and Reza Langari. Elsevier Inc., 30 Corporate Drive, 4th floor, Burlington, MA 01803. Web: elsevier.com. 2011. 640 pages. $99.95. ■

Scott Jenkins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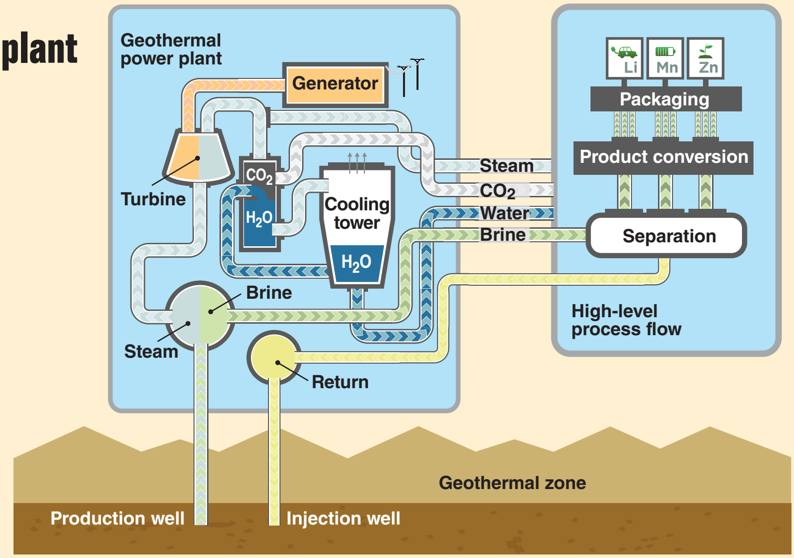


World's highest-purity lithium plant announces commercial launch

A facility that produces high-purity lithium carbonate for use in the growing market for electrolytes in electric-vehicle batteries has begun commercial operations in Imperial Valley, Calif. The 500-ton/yr plant, operated by Simbol Materials (Pleasanton, Calif.; www.simbolmaterials.com), is the only producer of high-purity Li_2CO_3 in the U.S., and one of three worldwide. "We can produce the highest-purity Li_2CO_3, up to 99.999% pure, at prices that are equal to or lower than incumbent producers," says Simbol Materials co-founder and CEO Luka Erceg. The company plans a threefold expansion of the facility that will begin in late 2012.

In addition to the recently opened facility to upgrade Li_2CO_3, Simbol is also commercializing innovative technology to extract lithium, manganese and zinc battery materials from geothermal brines in the Salton Sea region of California. "The Salton Sea area is geologically unique," explains Erceg, "The brine there contains 30% total dissolved solids, including high levels of lithium, zinc and manganese, which we can leverage with our integration to the geothermal power plant."

In Simbol's process (diagram), a proprietary brine-preparation step involving silica yields a pristine brine solution with high metals content, which is then subjected to a variety of chemical processes. Extraction of the metal salts includes membrane separation and precipitation, among others. "We do a lot of purification while materials are still in solution, and that lowers costs," Erceg says. The company is also able to use CO_2 generated by the geothermal plant to synthesize Li_2CO_3 from lithium chloride. The use of geothermal plant-derived brines, coupled with a proprietary process design, allows Simbol to avoid solar evaporation of brine in large pools, currently the most common method for lithium production.

Simbol plans to build upon the demonstration plant it currently operates with a commercial-scale facility to produce Zn and Mn compounds, along with Li, in the future.

Making formic acid by artificial photosynthesis

For the first time, an organic compound has been synthesized from water, carbon dioxide and sunlight — without any other external energy or reagents. The achievement, which was demonstrated by researchers at Toyota Central Research and Development Laboratories, Inc. (Toyota CRDL; Aichi Prefecture, Japan; www.tytlabs.co.jp), a subsidiary of Toyota Motor Corp., is said to be a major step toward artificial photosynthesis.

Toyota CRDL's method consists of an electrochemical cell with two electrodes immersed in water and separated by a proton exchange membrane. CO_2 is bubbled through the water. At one electrode coated with a TiO_2 photocatalyst, water is oxidized by sunlight into O_2, a proton (H^+) and an electron (e^-). Both charged products are transferred to the other electrode — H^+ through the membrane, and e^- via an external conductor — where they are used for the reduction of CO_2 into formate ions ($HCOO^-$). The CO_2 reduction takes place over a p-type, InP/Ru complex polymer hybrid photocatalyst. No external voltage is required.

A selectivity of more than 70% for $HCOO^-$ production was achieved, and the solar-to-chemical energy conversion was 0.03–0.04% — about one fifth that of natural photosynthesis. The researchers are now working to improve the energy conversion, as well as to develop catalysts for making other compounds, such as methanol.

New block copolymer

Nexar is the tradename of a block copolymer product recently commercialized by Kraton Performance Polymers (Houston; www.kraton.com) that has unique water-transport properties. Building on its earlier work in anionic polymerization of styrene-butadiene block copolymers, the company has developed a sulfonated, multiblock copolymer that allows a high level of selective moisture flow. Kraton vice president of technology Lothar Freund suggests that the hydrophilic sulfonate groups form "ionic channels" that facilitate water transport, and that can be adjusted based on polymer morphology. Nexar polymers are targeted for applications in membrane filtration systems and for high-performance breathable fabrics, including protective garments that can allow moisture transport while blocking harmful chemicals.

New Z-N catalyst

Last Month, The Dow Chemical Co. (Midland, Mich.; www.dow.com) introduced Consista C601 Polypropylene

(Continues on p. 13)

Note: For more information, circle the 3-digit number on p. 62, or use the website designation.

Predictive process control at a refinery wastewater treatment plant

To date, the difficult-to-treat contaminants and their related biological inhibition in petroleum refinery wastewater have defied efforts to bring predictive and mathematical process control to biological wastewater-treatment systems. Now, for the first time, engineers at Refinery Water Engineering & Associates Inc. (RWEA; Los Angeles, Calif.; http://refinerywater.zoomshare.com) have determined the key kinetic and metabolic microbial growth constants in a full-scale refinery wastewater treatment facility, and used them to populate a software model. The methodology allows for accurate, predictive process control in what previously has been a trial-and-error-based technique. The real-world demonstration builds upon conceptual work discussed in an article earlier this year (*CE*, May 2011, pp. 60–63).

"Oil refinery wastewater is the most difficult of all industries to handle, and because of the large number of process variables in biological wastewater treatment, effective process control is complicated," explains RWEA founder David Kujawski.

RWEA completed a study that quantified the site-specific kinetic and metabolic growth constants for the microbial population of a full-scale, activated-sludge biological-wastewater system in an Oklahoma refinery. The biokinetic constants for the full-scale operating plant — such as maximum substrate (contaminant) utilization rate (k) and the rate of new organisms produced under various conditions (cell yield; Y) — were determined in the field with biokinetic modeling equations, and then used to populate an activated-sludge software platform developed and calibrated by Hydromantis Environmental Software Solutions Inc. (Hamilton, Ont., Canada; www.hydromantis.com).

Combined with the software, the site-specific kinetic data produced a predictive software model that can be used to optimize wastewater treatment operations accurately and predict plant performance under hypothetical "what-if" conditions. The site-specific data are key, remarks Kujawski, because the biokinetic constants for refinery wastewater found in textbooks are often not representative of full-scale plants nor of modern day operating conditions.

"Among the biggest drivers for undertaking this process control tool is to help plants comply with their EPA [U.S. Environmental Protection Agency (Washington, D.C.; www.epa.gov)] wastewater discharge permits, which have become increasingly strict," says Kujawski. Another major benefit of the process control tool is to help plants realize operating cost savings, such as by increasing the efficiency of oxygen uptake.

Thin-film membranes promise a dramatic reduction in energy use

Researchers at the University of Minnesota (Minneapolis/St. Paul; www.umn.edu) have produced thin-film zeolite membranes that are only 200 nm thick, compared to 5–10 µm for conventional zeolite membranes. The new membranes could cut energy and capital costs by 90% for the production of petrochemicals, says Michael Tsapatsis, a professor of chemical engineering and materials science. "Instead of 1,000 m^2 of membrane you would need only 100 m^2 to do the same job," he says.

As in the case of conventional membranes, the new membranes consist of a layer of zeolite on a porous-metal support structure. Also, the synthesis is similar in that zeolite crystals are grown hydrothermally, in an aqueous solution, by mixing silica and a structure-directing agent (SDA) — an organic cation or surfactant that forms pores in the zeolite. The SDA is then removed by calcination to obtain porous crystals.

The difference, says Tsapatsis, is that the crystal growth is arrested before crystal formation is completed, leaving layers of porous clay floating in solution. Each layer is about 1-µm square and 2-nm thick. These layers are filtered from the water, suspended in a solvent (for example, toluene), and separated by a combination of centrifugation and sonification. The layers are deposited on a porous metal support, then calcined at about 500°C to remove all organic material.

So far, the researchers have produced membranes with pore sizes of 3 and 6 Å. They have used the former to separate hydrogen and helium and the latter to recover *p*-xylene and *o*-xylene from mixed xylenes. "Our next step," says Tsapatsis, "is to develop membranes between three and six Angstroms for the separation of other petrochemicals, such as ethylene and ethanol."

(*Continued from p. 11*)

Catalyst, the first sixth-generation Ziegler-Natta (Z-N) catalyst. The non-phthalate-based catalyst system requires no capital or upgrades to existing facilities, and enables polypropylene producers to make differentiated, high-performance resins. The new catalyst was used in production trials at Slovnaft Petrochemicals S.r.o. (Bratislava, Slovakia), where products were produced with improved properties at lower production costs due to the 40% higher catalyst yield compared to its existing system, says Slovnaft.

Magnetic algae

Scientists at Los Alamos National Laboratory (LANL; Los Alamos, N.M.; www.lanl.gov) have genetically engineered "magnetic" algae to potentially improve the efficiency of harvesting and lipid-extraction methods for biofuels. Current methods account for almost 30% of the total cost of algae-based biofuel prodution. Through the induction of paramagnetic properties in algae, the algae can be simply sepa-

(*Continues on p. 14*)

Waste biomass

Supercritical water process converts biomass to sugars

Sugar is a critical feedstock for many emerging bio-based-chemical and biofuel processes, but harvesting sugar from low-value, nonfood biomass cost-effectively and at large scale remains a challenge. Renmatix Inc. (King of Prussia, Pa.; www.renmatix.com) has developed a process that uses water above its critical temperature and pressure to hydrolyze a range of biomass materials to make C_5 and C_6 sugars. Unveiled at an event last month, the Renmatix process, known as Plantrose, offers what may be the lowest-cost approach to supplying sugar for the growing bio-chemical and renewable-fuel markets.

The company currently converts three dry-tons per day of waste hardwood chips into sugar at a demonstration facility in Kennesaw, Ga. Renmatix CEO Mike Hamilton says the company will announce next year the location of a planned commercial-scale facility that will be capable of producing 100,000 ton/yr of sugar. The first plant may be co-located with a bio-based chemicals maker that can use the sugar from Renmatix's process.

The Plantrose process is built around a supercritical hydrolysis platform, which capitalizes on the ability of supercritical water (SCW) to depolymerize cellulose, where water below the critical point cannot. Another unique aspect of the process is its two-step method that first separates the easier-to-breakdown hemicellulose before subjecting the tougher cellulose to SCW conditions that would destroy the C_5 sugar. Plantrose begins with a slurry of waste woodchips that enters a fractionation reactor, where hemicellulose is solubilized into a C_5 sugar stream. The remaining solids (cellulose and lignin) are then subjected to precisely controlled conditions that bring water above its critical point to generate glucose. The lignin is separated and collected as a solid.

Sugar liquor product

The speed of the SCW hydrolysis (seconds) contributes to lower capital expense, says Hamilton, adding that the Plantrose process requires no significant consumable materials and utilizes heat from burning the solid lignin, so production costs are low.

A polarizable membrane for improved energy storage

The two basic energy-storage devices — dielectric and double-layer capacitors — entail serious limitations. Dielectric capacitors have low capacitance, on the order of 0.1 to 1.0 μF/cm^2, while the double-layer capacitor has a high capacitance, on the order of 0.5 to 5.0 F/cm^2, but suffers from difficulties in scaling up and high fabrication costs. Now researchers from the National University of Singapore (www.nus.edu.sg), led by Xie Xian Ning, have developed a highly polarizable membrane for energy storage with a capacitance of 0.2 F/cm^2, a large open circuit voltage of 3 V, and which is simple, readily scalable, and of low fabrication cost.

The membrane consists of a fixed negative matrix and condensed positive ions. When the membrane is sandwiched between two metal plates and charged, the mobile cations are polarized (or decondensed), which means they are displaced in the direction of the charging voltage, while the immobile negative lattice remains intact. Thus the energy storage is based on bulk polarization, instead of surface double layer formation. The nominal specific surface area of the membrane (about 100 cm^2/g) is quite low. An important feature of the solid state membrane is that it does not require a liquid electrolyte or electrode materials.

The researchers fabricated the membrane by casting a poly lithium 4-styrenesulfonate solution onto a substrate according to a patented procedure. The membrane is soft, foldable, and can be easily cut into small pieces for device assembly. The researchers propose that ionic polarization is responsible for the membrane's high capacitance. The membrane structure can be viewed as an immobile negative lattice (or matrix) with mobile Li^+ ions.

Ning and his team have filed a U.S. patent for their invention. The research is supported by grants from the Singapore-MIT Alliance for Research & Technology (SMART), and the National Research Foundation.

(*Continued from p. 13*)

rated by using a permanent magnet, says LANL.

The researchers used a gene that is known to form magnetic nanoparticles in magnetotactic bacteria — anaerobic microorganisms that follow the Earth's magnetic field to avoid exposure to O_2 — and expressed it into green algae. The transformed algae could then be separated from solution with a magnet.

Removing trace metals

Last month, Siemens Industry Sector (Erlangen, Germany; www.siemens.com) introduced SCU Trace Metal Removal Media, which removes regulated metals from industrial wastewater, groundwater and storm-runoff water. The new media removes trace levels of copper, zinc, mercury, cadmium, tri-valent chromium, nickel and other metal ions to levels not possible with ion-exchange resins, says the company. The new SCU achieves levels below 1 ppb for most metals at flowrates of up to 5,000 gal/min. For mercury, the media can achieve levels below 12 ppt, which meet current U.S. targets for discharge into the environment, says the company.

A task for waste glass

Scientists from the University of Greenwich (London, U.K.; www.gre.ac.uk) have developed a process to convert waste glass that cannot be recycled (cullet) into an ion-exchange filter, which can be used as a barrier to prevent the lateral migration of heavy metals from industrial wastewater. In the process, a

(*Continues on p. 16*)

A new catalyst for asymmetric-transfer-hydrogenation reactions

The Fine Chemicals div. of Takasago International Corp. (Tokyo, Japan; www.takasago.com) has commercialized Deneb: Oxo-Tethered Ruthenium (II) Complex, which shows higher catalytic activities compared to conventional RuCl (arene)(N-sulfonylated diamine) catalyst systems. The higher activity enables a reduction in catalyst loading (down to 1/60th that of conventional catalysts), and thus lowers production costs for catalytic, asymmetric-transfer hydrogenation — an important reaction for making pharmaceuticals, fragrances and agrochemicals without H_2. Because less expensive Ru is used instead of Rh, the cost of the catalyst is also expected to be one tenth that of alternative catalyst systems.

Together with Professor Takao Ikariya at the Tokyo Institute of Technology (www.titech.ac.jp), the company has demonstrated that the new catalyst produces 2-phenethyl alcohol from acetophenone with 95% conversion efficiency, optical purity of 97% ee, and the reaction is two to three times faster than when conventional catalysts are used.

The company says the new catalyst can also be used for substrates that were not accessible before, while achieving a higher enantioselectivity.

New catalyst allows lower-temperature waste destruction

Base-catalyzed decomposition (BCD) is a commercially used process developed in the early 1990s by the U.S. Environmental Protection Agency (EPA; Washington, D.C.) for the destruction of persistent organic pollutants (POPs). It has been used as an alternative to incineration for handling hazardous waste streams. Now, an improved BCD process has been demonstrated. Using a low-cost catalyst, the new BCD process can reduce required temperatures from 300–350°C to 130–200°C. Developed by former EPA scientist Charles Rogers, the new BCD approach can shorten processing and cooling time and allow greater throughput of POPs in industrial waste streams. The lower-temperature process converts dioxins, PCBs (polychlorinated biphenyls), pesticides and other pollutants into carbon residue, anion salts and water. Concentrations of pollutants can be reduced from 50% to less than 1.0 ppm within 20 to 40 minutes, Rogers says.

Commercial debut for a new olefins-production process

Last month, KBR (Houston; www.kbr.com) was awarded a license and process-design-package contract for a new olefins-production unit using the Advanced Catalytic Olefins (ACO) technology. The contract represents the first license of the ACO process, which catalytically cracks naphtha and other "straight-run" feeds to produce higher olefins yields than traditional steam-cracking technology, says KBR.

Shaanxi Yanchang Petroleum Yanan Energy and Chemical Co. will construct and operate the plant, which will be constructed in Luoyang Village, Fucheng Town, Fu County, Shaanxi Province, China. The ACO converter will have a capacity of approximately 200,000 ton/yr of olefins (ethylene and propylene).

The ACO process — jointly developed by KBR and SK Innovation Co. (Seoul, South Korea; http://eng.skinnovation.com) — combines KBR's Orthoflow fluidized-catalytic-cracking reactor system with a proprietary zeolite-type granular catalyst developed by SK Energy (formerly SK Corp.), which selectively converts paraffinic feeds to large quantities of propylene and ethylene. The ACO system includes the Orthoflow configuration with dual riser, closed cyclones, a third-stage separator, a patented catalyst well (for continuous fuel firing) and a patented catalyst-removal system. ACO produces about 15–25% more ethylene plus propylene, and the propylene-to-ethylene ratio (about 1:1) is more than double that produced through steam cracking, says KBR.

The use of a catalyst enables the ACO process to operate at a lower temperature (about 650°C) than that used by conventional paraffinic crackers (about 850°C). As a result, the energy consumption and associated CO_2 emissions are reduced by about 20%. Investment costs for an ACO plant are also significantly lower that for a steam cracker with the same olefins production (*CE*, March 2007, p. 20).

The ACO process was first demonstrated in a 40,000-m.t./yr plant, which SK Innovation started up in October 2010 (*CE*, June 2010, p. 11) at its facility in Ulsan, South Korea. ■

(*Continued from p. 14*)

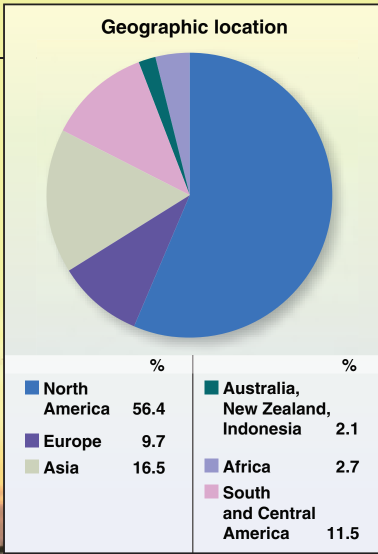
mixture of ground cullet, lime and caustic soda is heated to 100°C in a sealed stainless-steel vessel, which transforms the cullet into the mineral tobermorite — a hydrated calcium silicate. In the form produced — phase-pure 11Å — the mineral can be used as an ion-exchange material that can extract lead and cadmium ions.

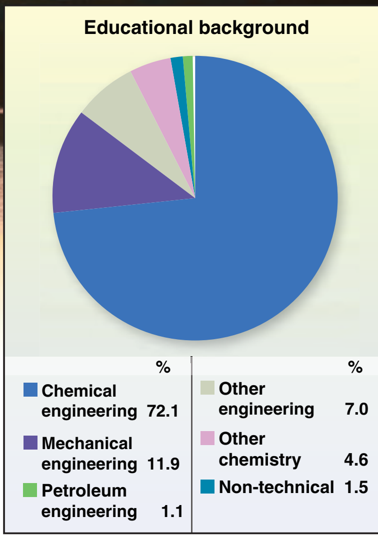
Bubbles for boats

A new bulk carrier that will enable reductions in CO_2 emissions by about 25% compared with conventional vessels has been developed by Mitsubishi Heavy Industries, Ltd. (MHI; Tokyo; www.mhi.com). The first commercial application of the new design will be to three grain carriers to be built for Archer Daniels Midland Co. (Decatur, Ill.). MHI's Air Lubrication System reduces friction between the vessel's hull and seawater using air bubbles produced at the vessel bottom, along with a high-efficiency hull form and enhanced propulsion system. ❒

ENGINEER DEMAND STRONG, BUT ECONOMY CONSTRAINS HIRING

A tight chem engineering labor market is tempered by delayed retirement and depressed housing





FIGURES 1–2. Just under half of respondents to the October *CE* salary survey (box, p. 19) live in North America, while more than a quarter live in Asia. Chemical engineering is by far the most common educational background

Significant demand persists within the chemical process industries (CPI) for those with engineering backgrounds and technical skills. Companies across many CPI sectors are finding it difficult to find enough individuals with chemical and engineering skills and expertise to staff their operations. But despite strong demand for technical skills, recruitment of chemical engineers is somewhat constrained by a stubbornly slow economic recovery and continued uncertainty over the future economic situation.

In the difficult economic environment, and depressed housing market, companies are generally not making broad hiring moves, and are very picky with those they do make, holding out for candidates with near perfect matches to the particular mix of experience for which they are searching. In addition, both individual engineers and companies face hurdles to job changes and staffing due to the difficulty selling homes in many markets.

"In almost every company I have dealt with, one of the top challenges is finding scientific and engineering talent," says Kevin Swift, chief economist and managing director at the American Chemical Council (Washington, D.C.; www.americanchemistry.com). For example, Kraton Performance Polymers (Houston; www.kraton.com) CEO Kevin Fogarty notes that his company has had a difficult time finding engineers for its business in styrenic block copolymers. "Overall, there may be high unemployment, but it's a different situation for technical talent — it's a very tight labor market for those folks," he says.

Strong demand appears to exist for entry-level workers as well, with chemical engineering graduates continuing to find work opportunities. In one case, Heather Fahlenkamp, assistant professor in the Chemical Engineering Department at Oklahoma State University (OSU; Stillwater, Okla.; www.okstate.edu) reports "100% placement" into the workforce of 2010 graduates who sought jobs, rather than graduate school. Department faculty noted that many graduates were offered signing bonuses, and starting salaries ranged from $50,000 to $90,000 annually.

Drivers of demand

Although a weak housing market and other forces have tempered the limited economic recovery, the prospects for medium- to longterm growth in the chemical industry are good, suggests Swift, and that bodes well for chemical engineers and their opportunities. There are a number of additional forces at play driving the need for engineers. For example, in the U.S., the effect of the shale gas supply has put this country in a stronger export position, and will be a force for job creation over the next three to seven years, Swift says.

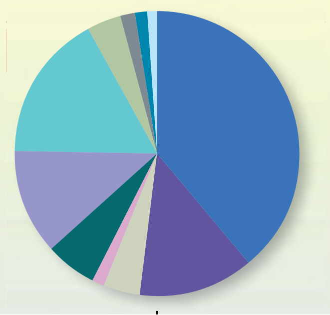
Larry Jacobson, executive director of the National Society of Professional Engineers (NSPE; Alexandria, Va.; www.nspe.org) sees an even wider trend in the need for engineering-trained workers. Engineers are becoming increasingly important to diverse aspects of the future of the planet, including national security and military operations, as well as economic growth and government projects. "Engineers are no longer seen as people who design and build stuff; they are seen as essential for solving the world's problems," Jacobson says.

Despite the demand for individuals

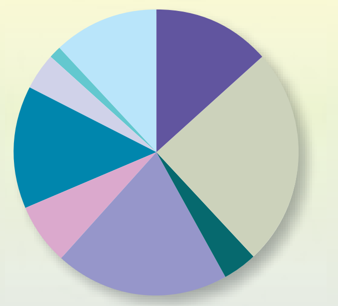
with engineering skills, and solid future prospects, an engineering degree offers no guarantees. In his experience leading a wide-ranging engineering professional society, Jacobson has observed two groups of engineers in the job market — those who are having trouble finding new work, and those who have a choice of opportunities. "Many engineers who are one-dimensional, having done the same thing for a long time, and who and have expertise only in one narrow area, are finding it difficult," Jacobson says. More than ever, companies seek potential employees who can draw upon a wide knowledge base to solve critical problems. "Many companies are looking for novel solutions to major challenges, and 'cookbook' solutions are not likely to work," Jacobson explains, adding, "there's real money where firms are tackling the biggest problems." To develop and implement those solutions, individuals with a broad set of experiences and a vast assortment of problem-solving tools that span several engineering disciplines are the most needed. Not only are experiences in a wide range of engineering subdisciplines important, but skills and knowledge from areas outside chemical engineering can be equally important. Knowledge in areas as far afield as medicine, music, religion and many others can prove valuable, Jacobson says.

Industry personnel confirm that skills outside engineering, as well as less tangible traits, are often crucial to chemical engineering jobs. Patrick Ropella, CEO of the Ropella Group (Milton, Fla.; www.ropella.com), an executive search firm specializing in the chemical industry and related high-technology areas, says his company's clients often place as much value on an individual's attitude toward a new job and interpersonal ability as they do on technical skills and experience. Russ Reinhart, OSU Chemical Engineering Dept. head, says industry is seeking chemical engineers who can write clearly and effectively, and who can deliver high-quality presentations.

John Peterson, a senior recruiter at Advanced Search Group (Willowbrook, Ill.; www.advancedsearch.com) who specializes in the specialty chemicals and petroleum refining sectors, also sees experience with a wide variety of different unit operations as a great help for job seekers and job changers. "Currently, there tends to be much less time for training," he says. "Companies really want people who can jump right in and be immediately effective without a lot of hand-holding."



	%		%
Chemicals & petrochem	36.4	Energy	17.2
Petroleum refining	18.8	Other	24.2
Pharma/ biotech	5.9	Food and beverage	5.4
Pulp & paper	1.9	Nonferrous metals	2.5
Specialty/fine chemicals	8.4	Rubber	2.0
		Glass and ceramics	1.4



	%		%
R&D	19.5	Environ. health safety	7.3
Process operations	26.4	Consulting	14.9
Automation/ process control	4.2	Plant manager	4.4
Process or product design	21.3	Academia	2.1
		Other	12.6

FIGURE 3–4. A larger portion of respondents (36.4%) than last year (30.2%) work in the chemicals and petrochemicals sector. Process operations and product and process design topped the list of common work sectors

Retirement delays

Also related to future demand for engineers is the much-discussed issue

CE SALARY SURVEY

In October 2011, *CE* asked readers* to respond to an online survey, supplying anonymous salary information along with details on their level of experience, education, CPI sector and geographic area. Close to 1,600 *CE* readers replied from all across the globe. More than 70% of the respondents had more than 11 years of professional experience, while the remaining 30% had 10 years experience or fewer. Over 52% of repondents hold a bachelor's degree, while 30% have a master's degree and 9% have earned a doctoral degree. A professional degree such as medical, law or business administration was reported by 5.7% of respondents. A fuller profile of the respondents can be found in the graphs (Figures 1–5). While the *CE* survey is a nonscientific survey, the results nonetheless provide a touchpoint for discussion of salaries and experience within the CPI.

The average salary for all respondents worldwide was $89,100, which includes respondents from six continents, and some with backgrounds other than chemical engineering specifically, including mechanical engineering and others. For those in the worldwide sample who reported a chemical engineering background, the average salary was $87,400. The total is significantly higher (by over $10,000) than that calculated from respondents to a similar survey conducted in late 2010. A number of factors are likely to be at play in the increase, so it is difficult to draw firm conclusions about the magnitude of the increase, but it seems as if salaries are generally at least somewhat higher than a year ago.

More than half of the survey respondents live in North America. Focusing on that group, the average annual salary was $110,000. As a comparison, last year, the U.S. Bureau of Labor Statistics calculated an average salary for chemical engineers of about $94,600 (May 2010). Also last year, The NSPE reported an average salary of $112,750 for licensed professional engineers in its membership. This population spans multiple engineering fields, and holds a licensure based on demonstrating on-the-job experience and passing an exam on engineering principles and practice.

By work function, those North American respondents who reported product or process design work in the *CE* survey had higher average salaries ($119,000) than those working in process operations or R&D ($100,000 and $101,300, respectively). Petroleum refining seemed to have higher salaries than those of chemicals and petrochemicals. Among those who work in the petroleum refining industry, the average salary was just over $120,000, while the average for those reporting work in the chemicals and petrochemicals area was $111,700. As expected, experience seemed to add significant value to workers — survey respondents with 11 to 30 years of experience had an average salary of $112,000, while those with zero to six years of experience had an average salary of $67,300. The less experienced group of respondents was much smaller.

A smaller sample size was also the case of respondents reporting a mechanical engineering background. However, the average salary of mechanical engineers ($97,000) topped that of chemical engineers ($87,400) when all regions of the globe are included.

***Editor's note**: Thank you to the almost 1,600 readers who responded ❑

of retiring engineers from the baby boomer generation, the replacement of whom is an issue not limited to companies in the CPI. However, the effects to date of retiring engineers have not been as pronounced as predicted, according to recruiters specializing in CPI markets.

Many older, experienced engineers have delayed retirement largely because of the shaky stock market — many a retirement account has lost value — and a depressed housing market, says Ropella. Other engineers in the CPI have retired, and then re-entered the chemical industry workforce as independent consultants, Ropella points out.

The problem of replacing experienced chemical engineering and related workers may have been delayed in some cases by the economic situation, but it has not gone away. Ropella projects an increased demand on the horizon to replace those workers. "There is a real and growing demand for young professionals with chemistry and chemical engineering degrees, and the talent pool for workers trained in science, technology, engineering and math (STEM) is shrinking," says Ropella. OSU's Fahlenkamp says that companies without specific job openings are still recruiting their graduates in anticipation of continuing retirements, which are likely to increase if the stock market improves.

In the energy sector, Al Thumann, executive director of the Association of Energy Engineers (AEE; Atlanta, Ga.; www.aeecenter.org), agrees, remarking that the challenge of finding enough engineers to meet Federal energy goals is the single biggest challenge faced by the energy enterprise. "Over the next five years, the engineer shortage will likely become an even bigger challenge because of the retirement of engineers in the baby boomer generation," he says.

Newsfront

As the retirement rate increases, the transfer of process and plant knowledge from older engineers to younger ones is going to become increasingly critical. For companies, the crucial aspect of that issue is not only the transfer of knowledge, Jacobson says, but the transfer of the sense of judgment that comes with experience.

Recruitment signs for future

Despite the current shortage of engineering talent and likely increased demand in the future, hiring activity among chemical industry workers is only mildly better than the same time last year, says Ropella. To a large extent, that is explained by an economic climate in the aftermath of the recessionary period in 2008 and 2009. Many company leaders are not feeling confident in the economy, and the U.S. Congress hasn't made progress on job-creation legislation. "There are clear signs that if the economy improves, hiring will increase," Ropella said.

Demand for workers in the upstream processing of natural gas is particularly strong right now, said Ropella, including positions related to drilling and hydraulic fracturing chemicals. Engineering positions having to do with renewable energy technologies also remain strong. For engineers willing to work abroad, there are many positions available in China, Ropella says. China's many infrastructure projects require a large supply of engineers, which China is unable to meet.

Recruiters at Engineering Resource Group (Morris Plains, N.J.; www.engineeringresource.com) point out that hiring activity is improved modestly from last year in New Jersey, but has slowed in recent months, paralleling the economic situation. Company president Jim Terkovich says that companies are increasingly searching for candidates that are exact matches with regard to experience and qualifications. "Some clients have staffing needs, but they are looking for that perfect match, and they are willing to wait for that person to come along," Terkovich commented.

Weak housing; strong influence

The sluggish housing market is playing a significant role in job-seeking and recruitment. "The economy has made it a real challenge to move," says David L. Barron, a labor and employment attorney with Cozen O'Connor, a Texas-based law firm specializing in labor and workforce issues.

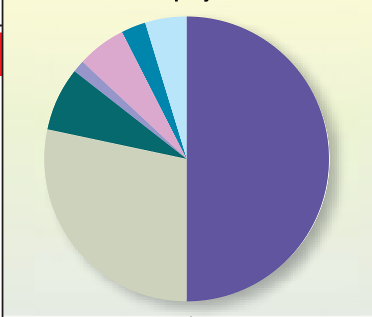
Peterson, who also sees a shortage of chemical engineers, suggests that the depressed housing market represents a significant hurdle in filling openings, mostly because of the difficulty in selling homes when relocation is required.

"Chemical engineers that are willing to relocate will have no problem finding jobs," Peterson says, pointing out that there are many jobs available in Texas and Louisiana, for example, especially for those workers with between five and 20 years of experience. However, in many cases, candidates are unable to sell their homes, or may be unwilling to sell at current prices to avoid losing equity that they have established. Meanwhile, cost-saving efforts on the part of many companies have meant that the relocation packages offered to potential employees are generally smaller and less comprehensive than they have been historically, notes Ropella.

One situation where relocation packages may get a boost is where a top-performing individual may have several companies interested. Peterson says he has seen cases where companies offer more attractive relocation packages, rather than significantly higher salaries, as enticements to attract candidates. ■

Scott Jenkins

Employer



	%		%
Chemical manufacturer	50.2	Regulatory agency	1.2
EPC company	28.4	Self-employed	5.7
Equipment manufacturer	7.2	Government laboratory	2.8
		University	4.5

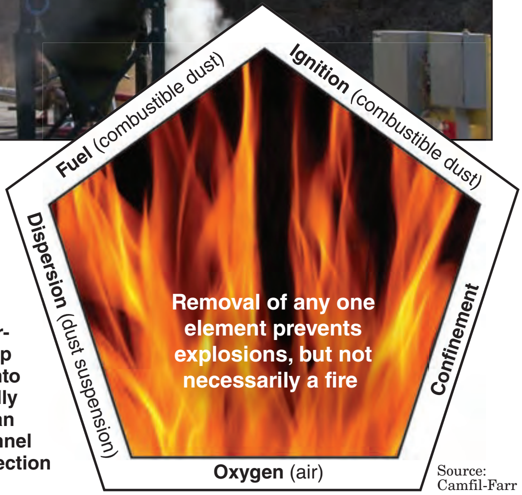
FIGURE 5. Almost 90% of survey respondents work for chemical makers, engineering, procurement, construction (EPC) firms, or are self-employed

COLLECTING DUST

As regulations tighten, more emphasis is being put on equipment that prevents catastrophe while providing cost savings

Camfil-Farr

FIGURE 1. This image was pulled from a video of an actual staged explosion that was performed to test whether a dust-collector explosion vent would work as intended. It did. The explosion vent, which has popped open here, is designed to relieve internal combustion pressure to keep the collector from blowing up into pieces. The collector will typically experience internal damage in an explosion like this, but if personnel remain safe, the explosion protection system has done its job



Source: Camfil-Farr

FIGURE 2. In order to have an explosion, five things are needed: containment, ignition source (combustible dust), fuel (explosive dust), oxygen and dispersion (dust suspension). By removing any one of these elements via a properly outfitted dust-collection system, an explosion may be prevented

One of the biggest issues related to dust collection is compliance with U.S. Occupational Safety Health Administration (OSHA) and U.S. Environmental Protection Agency (EPA) regulations regarding combustible dusts and air quality. And as both agencies up the ante with tighter regulations and more scrutinizing inspections, it is imperative that processors make sure their facilities are meeting the standards. But the question is, is it possible to meet more stringent standards while running a cost-effective dust-collection operation. The answer, according to dust-collection system providers, is "yes" — with forethought and investments in properly, and carefully selected equipment.

Meeting OSHA safety standards

At the current center of attention is OSHA's National Combustible Dust Emphasis Program (NEP), which was implemented to reduce the number of fatalities related to workplace explosions. While the program is technically not a standard at the moment, non-compliance with the program has already resulted in more than 5,000 violations nationwide along with fines and required process changes in industries affected by the change, according to Jim Orr, national sales manager with Micro Air (Wichita, Kan.).

While the main focus of the program is on organic dusts, plastic dusts, wood dusts, coal and other carbon dusts, biosolids, metal dusts and certain textile materials, OSHA inspectors look for potential ignition sources and the accumulation of dust in the plant that could fuel a secondary explosion, which can occur if an explosion takes place in a dust collector or other equipment.

Typically, primary explosions cause dust accumulations on rafters, floors and other flat surfaces to become airborne in a concentration that, if ignited, could cause a secondary explosion.

OSHA inspectors look for dust accumulations that are a least 1/32-in. thick over a surface area exceeding 5% of floor area. OSHA inspectors may also send a sample of dust to a testing laboratory to determine the level of explosiveness. If the dust is considered hazardous, any dust collector located in the building or outside the building must comply with all applicable National Fire Protection Assn. (NFPA) standards. In addition, the program emphasizes the need for prevention or capture of dust clouds forming from equipment such as grinders, mixers or other dust-producing equipment, making the need for properly outfitted dust-collection systems of utmost importance.

According to NFPA 654 (the standard for prevention of fire and dust explosions), there must be back-blast dampers or suppression systems inline for each process on an explosive application to prevent the propagation of flame waves. Clean air may be returned from the building if the filtration efficiencies are 99.9% or greater, or there is a mechanical damper or suppression system on the exhaust ductwork that meets NFPA standards.

And under NFPA 484, the standard on combustible metals for processes that include aluminum and tantalum, dry type collectors must have explosion venting or suppression and be outdoors. No air can be returned to the building. A wet collector can also be used. For processes using magnesium, niobium, titanium and zirconium, wet collectors must be used.

NFPA 68, the standard on explosion protection by deflagration venting, states that explosion vents shall be located adjacent to a wall within one hydraulic diameter and ducted outdoors to a safe location, or, an approved flameless vent can be used on non-metallic dusts.

Midwesco

FIGURE 3. TDC's Pleat-Plus pleated filter elements can revitalize a dust collection system by solving baghouse issues such as lack of capacity, short filter life and low efficiency

Micro Air's Orr says that existing dust collectors can be retrofitted to meet most of these standards via the addition of explosion venting, ledgeless hoppers and hard-pipe barrel lid kits, mechanical back-blast dampers, chemical isolation that includes intake and return air, fast acting valve intake and return, flameless vents for non-metallic dust only (used indoors) or rotary airlocks.

"There is a lot to consider for each application before deciding which approach will work in a particular facility, but it's important to remember that you don't cut corners when it comes to safety," says John Dauber, vice president of sales for U.S. and Canada with Camfil-Farr (Jonesboro, Ark.). "These explosions are dangerous. We test our dust collectors (Figure 1 and 2) to confirm our designs against NFPA standards, and it is amazing to see what a little baggie of cornstarch injected into a collector and blown up can do. It's sobering to say the least."

After witnessing some of these test explosions, says Dauber, his company and many others began to dig deeply

DUST COLLECTION EQUIPMENT AND SERVICE PROVIDERS

Aerodyne	www.dustcollectorhq.com	Micro Air	www.microaironline.com
Camfil-Farr	www.camfilfarr.com	Midwesco	www.midwescofilter.com
Imperial Systems	www.isystemsweb.com	TDC Filter	www.tdcfilter.com

into the NFPA standards in an effort to better assist customers with making the best choices regarding safety.

EPA's Clean Air Act

EPA is also ratcheting up its standards regarding emissions regulations. Under the Clean Air Act, the agency's Ambient Air Quality Standards (AAQS) and the Maximum Achievable Control Technology Standards (MACT) regulations are heading toward the control of fine particulate emissions, PM 2.5. This means more emphasis will be put on dust collection, says Tom Anderson, vice president of pleated products for TDC Filter, Midwesco company (Winchester, Va.).

"The smarter a processor can be with their longterm dust-collection investments, the better off they will be," he says. "A lot of short-term fixes have adverse effects that end up costing more money over the life of the element."

Historically, Anderson says, filter bags constructed from polyester felt have been the primary media used in baghouse systems for filtering process dust. However, these bags were designed to meet less stringent regulations and may not meet new emissions standards. In addition, the bags have to be changed frequently and often restrict the throughput of the collector, making it difficult to meet production goals.

"Sometimes buying the lowest priced filter is not the best choice," says Anderson. "For example, if your filtrate is gold dust and you install filters weighing 9 lb and remove the elements 120 days later and the filter weighs 16 lb that equals $168,000 of gold dust, rendering the filter cost insignificant. The same analogy can be made for efficiency, energy consumption, filter life and maintenance cost."

To combat this problem, he says, it is important to have a well-designed collector, properly designed filter and the right media. In many cases, filter bags can be replaced with non-woven, spun-bond pleated elements, which can produce a significant reduction in emissions. The pleated filter elements can also increase a collector's airflow, save energy and reduce maintenance costs. Additionally, pleated-element designs can reduce wear from abrasive materials, enabling them to last two to three times longer than felt bags in the same environment. They are also easier to change out. Change-out of pleated elements can be completed in about 25% of the time normally needed for conventional bag and cage replacement, lowering the cost of maintenance, says Anderson.

As a Midwesco company, TDC Filter offers Pleat+Plus pleated-filter elements (Figure 3) that can alleviate the baghouse issues described by Anderson, including lack of capacity, short filter life and low efficiency. The non-woven, spun-bonded filter media using a high-efficiency ePTFE-membrane laminate can helps processors achieve filtering efficiencies of

99.99927% for PM 2.5 compliance.

Anderson says that although these filters cost more, they are taking on a larger role in the chemical process industrirs (CPI) because of the value they provide in increasing through-put, higher efficiency, reduced energy cost and lower life cost from an existing baghouse.

Reducing the cost of ownership

Midwesco and TDC Filter aren't the only manufacturers who emphasize how higher-quality dust-collection equipment can drastically reduce the cost of ownership. Imperial Systems (Jackson Center, Pa.) also offers an improved cartridge filter that is touted as delivering a long filter life, cleaner air

Aerodyne

FIGURE 4. The design of Aerodyne's SplitStream dust collection system allows it to handle a range of materials at a high level of efficiency. During operation, a minimal amount of dust particulate comes in contact with the walls of the collector

and greater cost savings. The DeltaMaxx employs a nanofiber surface that stops submicron particles from entering and becoming embedded into the media beneath the fiber. With a MERV 15 filtration efficiency, the cartridge filter boasts less pulse cleaning. The reason is that dust is easily pulsed off the media because it remains on the surface and the surface loading technology enhances dust cake release, which leads to longer filter life, says Jeremiah Wann, president of the company.

In the same vein, Imperial offers a "next generation" cartridge collector called the CMaxx, which has 10% more filter media than same-sized vertical cartridge collectors, while the internal area of the unit offers 20% more area around the filters, causing more dust to drop in the hopper before attaching to the filters. The collector uses PD (pulse distribution) Technology, which Wann says delivers 100% total pulse distribution across the filter media. "While running tests on other products, we found up to a 30% dead zone across the wall of the filters, and that calculates into 30% less filter area and upwards of 30 to 40% more filter changes over the life of the collector," explains Wann.

This issue is eliminated with the CMaxx due to the 100% positive cleaning pressure across the wall of the filter. And, the PD cleaning technology also allows the fan to operate at design volume more consistently, which delivers constant ventilation to the source. Without this, users may see dust accumulation and processes that start to weaken over time. VFD technology and electrically actuated dampers are also employed on this collector, which saves energy and helps monitor the capture volume at the source. "It reduces costs, saves energy and helps maintain air pollution levels in the facility," says Wann. "These are definite ways to reduce the cost of ownership while meeting stringent air-pollution regulations."

Saving energy is only one way to reduce the total cost of ownership. Another major category is maintenance and disposal, or the time it takes to service the equipment and costs of disposing of the consumables. The consumables, such as filters and media that are replaced over the life of the equipment, are another major area of cost saving focus. Many equipment providers are making improvements in these areas as well to help processors reduce their cost of ownership.

"Cost is always a factor, but more important than the initial investment is the overall effectiveness and efficiency of the equipment," says Bart Eggert, product manager with Aerodyne (Chagrin Falls, Ohio). "Collection efficiency, operation costs and maintenance requirements are typically the main sticking points when selecting dust collection equipment."

With that in mind, the company launched its SplitStream Counter Cyclonic dust-collection system (Figure 4), which uses a secondary air stream to boost collection efficiency with fine particulate to meet stricter standards. But the unit also offers lower installation costs since it can be installed vertically or horizontally, and it extends the life of bag and cartridge filters, which reduces labor and material costs.

Camfil-Farr's Dauber agrees that this is important. "Yes, dust collectors and related filters and media are a necessary evil in that you have to have them to keep the process running, but it is possible to justify the cost with ROI over the life of the collector," he says. 'We have proven that our collectors will pay for themselves through reduced maintenance and reduced consumables spending."

He says that while the equipment offered by his company may be more expensive upfront, the media and cartridges often get double the life of less expensive versions due to the technology and configuration. "And it's not just the cost of the filter, but the maintenance requirements associated with changing it, as well as the disposal cost, which can be very expensive in the chemical industry depending on material collected and the associated hazards."

Dauber says when designing collectors such as the Gold Series, the company strives to make maintenance minimal through design. Simple, quick-open, heavy-gauge doors provide access to a cartridge change-out system that doesn't require entry into the collector. The door is fully reversible for access from either side and has a lock-out feature for worker safety. There are no knobs to lose or drop, no threads to bind, and a mechanically attached seal. No tools are required during change-outs due to the cam-bar system, which allows simplified change-out of the filter cartridges.

In addition to these maintenance savers, Dauber says studies have shown that with better dust collectors, maintenance costs can be further reduced simply by leaving the facility cleaner, which means workers don't have to spend as much time maintaining electric motors, controls or other equipment sensitive to dust and that employee health is often improved. ■

Joy LePree

Meissner Filtration Products

AdvantaPure

FOCUS ON

Pipes, Tubes & Fittings

Victaulic

Rex-Cut Products

Single-use tubing for biopharmaceutical applications

BioFlex tubing assemblies (photo) are designed for secure fluid transfer in critical biopharmaceutical processing applications. The assemblies are configured from this company's library of pre-qualified components, including its sterilizing-grade membrane filter capsule, and offer comprehensive documentation and traceability. Each assembly is serialized, which can reduce batch record requirements in some cases. All BioFlex tubing assemblies can be customized according to process requirements, and offer a range of connection options and tubing materials. — *Meissner Filtration Products Inc., Camarillo, Calif.*
www.meissner.com

Join stainless-steel pipe with fewer person-hours

The Vic-Press (photo) is a flame-free press system that joins pipe quickly and reliably. The press-to-connect system is designed for off-the-shelf ASTM A-312 Schedule 10S stainless-steel pipe. Vic-Press offers increased strength, durability and improved flow characteristics compared to light-wall tube systems, as well as safer, more efficient pipe assembly than with welding, threading and flanging. To operate the system, pipe is cut to size and deburred, then marked for visual verification and inserted into a lubricated coupling, fitting or valve. This company's handheld pressing tool is used to press the component onto the pipe end, resulting in a rigid, leak-tight joint. — *Victaulic Co., Easton, Pa.*
www.victaulic.com

Clean pipe threads with these abrasive wheels

Smooth Touch wheels (photo) are used for pipe-thread cleaning, polishing and blending. Made of cotton fiber impregnated with abrasives, the Smooth Touch wheels feature a proprietary bond that allows them to last up to five times longer than unitized wheels. The flexible and forgiving wheels will not change the geometry of pipe threads, the company says. Smooth Touch wheels are suited to cleaning oil-field pipe threads made of stainless steel, inconel, other hard alloys, as well as iron and aluminum. The Smooth Touch deburring, blending and finishing wheels are available with diameters of 2, 3, 4 and 6 in., and with thicknesses of 1/8, 1/4 and 1/2 in. They also can be imbued with coarse, medium and fine grits. — *Rex-Cut Products Inc., Fall River, Mass.*
www.rexcut.com

These hose fittings come in a variety of materials

Hose fittings from this company (photo) are available in a wide vari-

Note: For more information, circle the 3-digit number on p. 62, or use the website designation.

Crane ChemPharma Flow Solutions

ety of materials, including stainless steel, silicone, thermoplastic elastomer, Hytrel and polypropylene. The fittings are designed to mate with several types of hose, and are furnished already attached to the hose. Designed for high-purity and sanitary fluid-flow applications in the pharmaceutical, biologics, food and beverage industries, the fittings offer unique properties that can be matched to the needs of the application. For example, molded silicone fittings provide a smooth inner surface with a seamless transition for single-use applications. — *AdvantaPure, Southhampton, Pa.*
www.advantapure.com

Nonstandard welded tubes in several materials

Nonstandard welded tubes (photo, p. 28) from this company are available in stainless steel, duplex, nickel, 6-Moly (6% molybdenum) and Chrome-Moly (chromium-molybdenum alloy) materials, in both light-gauge and heavy-wall thicknesses. The company maintains an extensive inventory of plate and sheet materials to reduce lead times and manufacturing costs. Welded tube and pipe products are available in a number of grades and ASTM specifications. Stock sizes range from 1/8-in. to 24-in. outer dia., while made-to-order sizes extend to 96 in. Pipes can be constructed with wall thicknesses of 0.008- to 3-in. thick. — *Penn Stainless Products Inc., Quakertown, Pa.*
www.pipeandtubes.com

Extend service life with this tubing

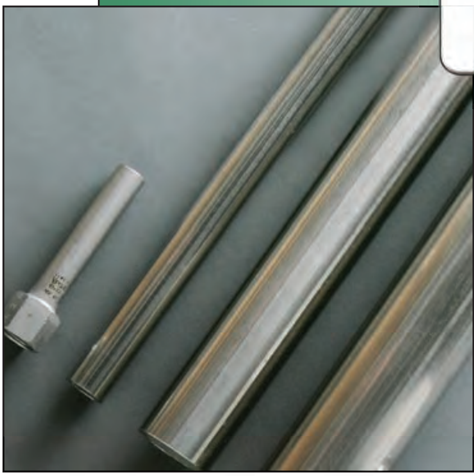
Tygon 2375 Ultra Chemical-Resistant Tubing is a clear non-DEHP [*bis*-(2-ethylhexyl) phthalate] tube that improves upon its predecessor, Tygon 2075. The new version of the high-purity tubing combines high chemical resistance with the ability to remain highly flexible over extended periods. The 2375 tubing improves pressure ratings by 30–50% compared to the preceding version. The 2375 material allows the tubing to be disposed of safely at the end of its operational life without harming the environment.

Penn Stainless Products

— *Saint Gobain Performance Plastics, Akron, Ohio*
www.plastics.saint-gobain.com

Flameless joining now available for this corrosion-resistant pipe

The ProPress system for joining pipe now can be used for ECO-Pipe, this company's thin-walled 304 stainless-steel pipe (photo). ECO-Pipe is designed as an economical solution for applications in which corrosion resistance and aesthetics are considerations. ECO-Pipe is available in 20-ft lengths, and comes in several sizes from 0.5 to 4 in. The ProPress technology generates water- and gas-tight pipe connections in less than seven seconds, with no need for welding. The ProPress system, with stainless-steel pipe, fittings and valves, is ideal for installations in chemical processing, food and beverage, oil and gas, mining and manufacturing. — *Viega LLC, Wichita, Kan.*
www.viega.com



Viega

These pipes withstand high temperatures

The Resistoflex ATL Lined Pipe System (photo, p. 27) is designed for the most difficult temperature- and pressure-cycling requirements. With an advanced PTFE (polytetrafluoroethylene) liner, the Resistoflex ATL has an outer layer that delivers superior permeation control up to 450°F. The PTFE liner offers a significant reduction in permeation rate for aggressive chemicals at elevated temperatures, and represents a cost-effective solution for handling corrosion in severe-service applications, the company says. Additional features include vent couplings and PTFE vent extention for improved housing protection. — *Crane ChemPharma Flow Solutions, Marion, N.C.*
www.cranechempharma.com

Asahi/America

This piping system works for the harshest applications

Chem Proline is a new crack-resistent polyethylene piping system (photo) designed for the harshest liquid chemical applications. Made from the latest-generation polyethylene resin, Chem Proline pipes and fittings provide the greatest resistance to slow-crack growth, and offer a lower-cost alternative to metal, lined-steel and fiber-reinforced plastic pipes. Chem Proline is a complete system that includes pipes, fittings, valves, leak detection, injection quills and chemical feed skids. The pipes are thermally fused and use no glues. The ultraviolet-radiation-resistant pipes can be installed above- or below-ground using socket, butt or electrofusion joining methods. — *Asahi/America Inc., Malden, Mass.*
www.asahi-america.com

An online resource for these polymer pipes

A microsite has been launched as an online resource for innovative solutions to pipe application problems, as well as access to experts. The new microsite (www.victrexpipes.com) features pipe and tubing products extruded from the company's high-performance Victrex PEEK (polyether ether ketone). Recently launched Victrex pipes are a lightweight alternative to metal pipes for harsh industrial environments. — *Victrex Polymer Solutions, West Conshohocken, Pa.*
www.victrexpipes.com

Improve clarity with this pipe inspection device

The DigiSewer III side-scan system for pipe inspection uses improved illumination and optics to capture pipe side-wall detail with enhanced clarity. The device is designed to deliver the benefits of side-scanning, such as faster, more detailed pipe inspection with fewer person-hours, at an affordable price, the company says. DigiSewer III captures detailed visual data for the entire pipe at speeds of 35–70 frames per minute, and presents multiple views that can be rapidly and thoroughly analyzed offline. Inspectors no longer need to detect defects using live video. — *Envirosight LLC, Randolph, N.J.*
www. envirosight.com ■

Scott Jenkins

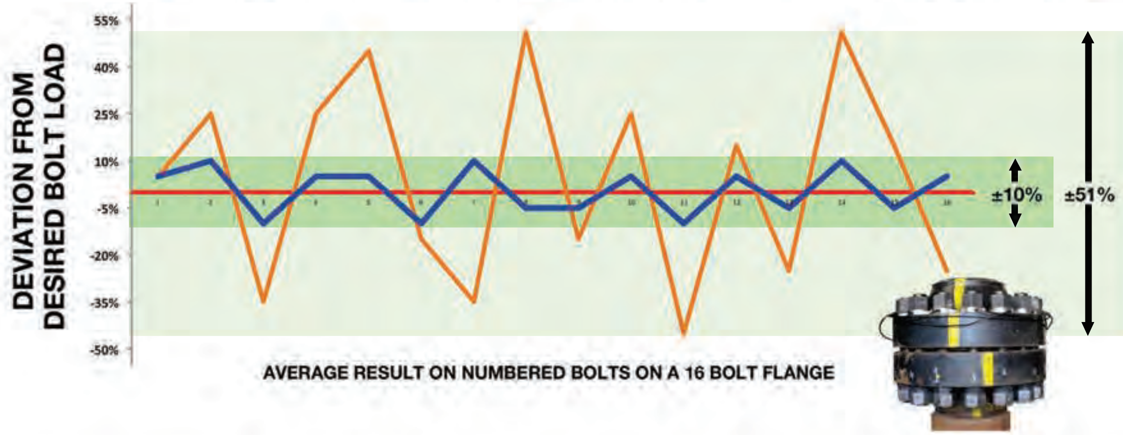
A SINGLE FAILURE ON A BOLTED JOINT CAN

STOP PRODUCTION!

So why are some maintenance teams still relying on systems like hydraulic tensioners and induction bolt heating, which often require measurements and post-tension torquing to ensure the nuts are tight? As the leader in the bolting tool industry, HYTORC has been involved in various studies conducted by independant testing agencies that prove, over and over again, that hydraulic tensioners can not achieve the bolt load accuracy claimed by most manufacturers. In fact, it is repeatedly proven that hydraulic torque wrenches provide a more consistent bolt load. However, the most interesting results have been shown in independant studies comparing hydraulic tensioners to the HYTORC Washer system, which allows a hydraulic torque wrench to react on a washer that is placed under the nut. This new system is installed with ASME compliant bolting practices and, in every comparison test completed, the washer maintains a bolt load variation within 10%, while the hydraulic tensioners are not able to achieve a maximum bolt load variance of less than ±51%. That variance can result in loose nuts and joint leakage, which can prompt an unscheduled shutdown that wastes valuable production time. The HYTORC Washer is a proven system with guaranteed results.

THE HYTORC WASHER -vs- HYDRAULIC TENSIONERS

Based on average results from multiple independant studies - HYTORC will reproduce these studies on demand and gladly take on any challengers.



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Preparing presentations for 'non-English' audiences

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

Giving a presentation in English in a non-English speaking country is not a right, it is a privilege. The option is not yours, but your hosts'. Your hosts decide whether English is acceptable for the audience. Foreign language audiences almost always prefer presentations and meetings in their language. When English is allowed, here is some advice.

Do not show the exact same slides as you would to an American (or other English speaking) audience. Reduce the word counts. Replace words like "increase" and "decrease" with up and down arrows. Information in slide titles should not be repeated in the bodies. Colors are always good, but avoid yellow and orange. An expert once told me that an excess of red actually angers people, even outside of bullfight arenas. Include local content when possible. Show photos, drawings and graphs. When showing those graphs, first name the axes. Each graph should have only one main theme. Relevant videos are best.

It is particularly difficult to simultaneously listen to and read a secondary language. Therefore, sometimes, let the slides speak for you. When you must speak, consider the following:

- Gauge the language capabilities of your audience as best you can. Generally, but not always, higher education levels and higher ranks indicate broader language skills. A lack of foreign language skills, however, does not indicate a lack of intelligence. Attendees at English language conferences have reasonably good English language skills. Attendees at meetings, sales calls and training sessions are often not as well equipped.
- Consider that classroom English lessons teach conversational English including sentences like, "Where is the library?" Your presentation comparing the Theory of Relativity and relative volatility employs a vocabulary at a totally different level.
- Do not speak in paragraphs. Use sentences or sentence fragments. For example, a sentence like, "More theoretical trays in a column means that the reflux requirement is usually reduced" can be replaced with "More trays, less reflux." Remember, your high school grammar teacher is not in the audience.
- Eliminate contractions. "Wouldn't" sounds like "woodent." "Would not" will always be more understandable.
- Use proper words. "Lotsa" was not in their vocabulary books. Neither was "Yada yada yada".
- Use simple words. Replace "validated" with "checked" and "presently" with "now" and "abscissa" with "*x* axis" and so on.
- Be careful about directing questions to foreign language listeners. They are often anxious, in front of their colleagues, about their English-language speaking skills. Do not assume that everybody completely understands you.
- As always, in front of all audiences, face them, not the slides. Speak loud enough so that the last row can hear you. Do not hesitate to eliminate or skip some slides.
- While on stage, smile. The worst that can happen is that your visa is revoked and you end up on a freight ship home. You will survive. ■

Mike Resetarits
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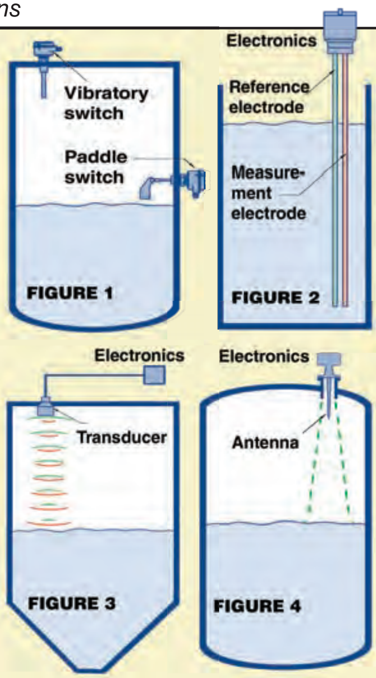
CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Level Measurement Devices

Effective level measurement helps ensure smooth, continuous processes by maintaining material inventory at economic quantities, and maximizes plant output by preventing spillage, system clogging and process upsets. In chemical process industries (CPI) applications, level measurement of liquids, powders and slurries are often complicated by the presence of steam, dust, foam, turbulence, caking or condensate, as well as high temperatures and pressures.

The diversity of challenging conditions dictates multiple technologies for level measurement, which can be divided into point-level measurement and continuous-measurement techniques. Point-level measurement monitors material level at a predetermined point, which could be a high level to avoid spillage, or a low level to avoid running empty. Continuous level measurement monitors materials constantly, noting any fluctuations and changes. Here, brief descriptions of common level-measurement technologies are presented.



Mechanical floats — A low-density float is attached to a horizontal rod that is mounted to a tank wall and linked to a switch. As the level rises and falls, the switch opens and closes. Mechanical floats are inexpensive, easy to install and work well for a variety of fluid densities. However, the float is calibrated to the density of the liquid it measures, so if the density changes, the float must be recalibrated. Another limiting factor for mechanical floats is buildup of material on the float.

Differential pressure — The high-pressure side of a differential-pressure instrument is connected to the bottom of the tank, while the low-pressure side is connected to the vapor space in the top of the tank. The measured pressure differential is the pressure of the liquid column of the tank. Changes in the liquid composition or temperature can create a false reading, but if the fluid density remains constant, this technique provides a true level reading. Differential-pressure devices require sealed fluid in pressurized vessels.

Electromechanical devices (Figure 1) — A motor-operated paddle inside a vessel stops rotating when its sensor becomes covered by liquid or solid material. The principle is also applied to vibrating forks that detect material when their vibration speed slows. Paddle sensitivity can be adjusted for varying material properties. The cost-effective and low-maintenance electromechanical designs are well-suited for solids, such as plastic pellets, carbon black, fertilizer, rubber and Styrofoam chips and beads. The paddle switch can handle bulk densities as low as 35 g/L. The technology is completely independent of material dielectric properties.

Capacitance (Figure 2) — A capacitor stores electrical energy and is made up of two parallel conductive plates separated by an insulator (dielectric material). The capacitor consists of a metal probe that typically contacts the material in a vessel. The metal probe senses the amount of material by measuring the difference in the probe's capacitance when either air or material is present. The measurement system also requires an earth reference to complete any circuit and allow current flow. Capacitance technology is widely used, can handle a range of applications, and produces accurate and repeatable results. Chemical compatibility with the device must be taken into account, since capacitance is a contact technique. Any changes due to temperature or chemical composition cause the dielectric property of the material to change, resulting in errors and the need to recalibrate. With one opening required in a vessel, capacitance technology is easy to install, and has no moving parts to wear out. Custom probes are available for aggressive chemicals. Calibration of capacitance instruments is best done manually, which can be time-consuming.

Ultrasonic (Figure 3) — Ultrasonic technology uses a piezoelectric crystal stored inside a transducer to convert an electrical signal into sound energy. The sound energy is fired toward the material, and reflected back to the transducer, which then acts as a receiving device, converting the sound energy back into an electrical signal. A signal processor analyzes the return echo and calculates the distance between the transducer and the target. The time lapse between sound burst and return echo is proportional to the distance from the transducer to the material in a vessel. Ultrasonic technology is a preferred option for continuous level measurement. Since ultrasonic instruments measure from top down, there is virtually no contact with the material. Ultrasonic technology is easy to install and has no moving parts. In addition, it is not affected by changing dielectric properties or vessel shape. However, dust, vapor or foam can affect even the most advanced devices.

Radar (Figure 4) — Radar devices transmit an electromagnetic wave toward a material, where it is reflected back to the source. The total transit time to and from the target is calculated and is directly related to the distance. Pulse radar is similar to ultrasonic, in that fixed-frequency pulses are transmitted to a material and reflected back to the source, and the time of flight is measured. Frequency-modulated, continuous-wave radar devices continuously transmit a range of frequencies, and a receiver monitors them. The difference between the transmitter and receiver frequency is directly proportional to the distance to the target. Since radar uses an electromagnetic wave, it does not require a carrier medium, and therefore is unaffected by environmental factors, such as temperature, turbulence, humidity, pressure, vapor, dust and others.

Radar is noncontacting, and easily installed without disrupting a process.

Magnetostrictive — Magnetostrictive level sensors measure the distance between a float magnet and the electronics-head end of the sensing rod. The float magnet is a permanent magnet, often in the shape of a ring, that travels along the sensing rod. The rod is mounted along the vertical axis of the vessel, and the head has an electronics module that transmits the float's position information to a controller. Magnetostrictive systems, which rely on magnetomechanical properties of ferromagnetic materials, such as iron, nickel and cobalt, are highly accurate and are not affected by vapor, foam, dust or dielectric variations.

Hydrostatic pressure sensor — This type of sensor measures level of a liquid in a tank by measuring the pressure exerted by the weight of the liquid. Hydrostatic pressure sensors are either externally mounted, where the measurement is based on the distance from the bottom of the tank, the pressure exerted by the liquid and the reference pressure, or submersible, which are used for open-air applications. ■

TABLE 1. AN OVERVIEW OF LEVEL MEASUREMENT TECHNOLOGIES AND SUITABLE APPLICATIONS

Technology	Application
Ultrasonic	Chemical storage tanks
	Wastewater effluent
	Plastic pellets
Radar	Chemical bulk-storage vessels
	Sulfur storage
	Agitated process vessels
	Reactor/process vessels
Guided wave radar	Liquid storage
	Plastic pellets
	Slurries
	Displacer replacement
Capacitance	Styrene and other aromatic compounds
	Acids, caustics
	Adhesives
	PVC pellets
	Interface in agricultural chemical production
Electro-mechanical	Plastic pellets
	Carbon black
	Fertilizers
	Styrofoam beads and chips

References

1. Schmidt, Karlheinz, Level Measurement Technologies for the CPI, *Chem. Eng.*, July 2008, pp. 34–37.
2. Aiken, Lee, Liquid-level Measurement Options in the CPI, *Chem. Eng.*, July 2008, pp. 38–42.

Energy Benchmarking

A method incorporating energy optimization and its viability is exemplified in a petrochemical application

Farbod Rikhtegar
IFCO Co.

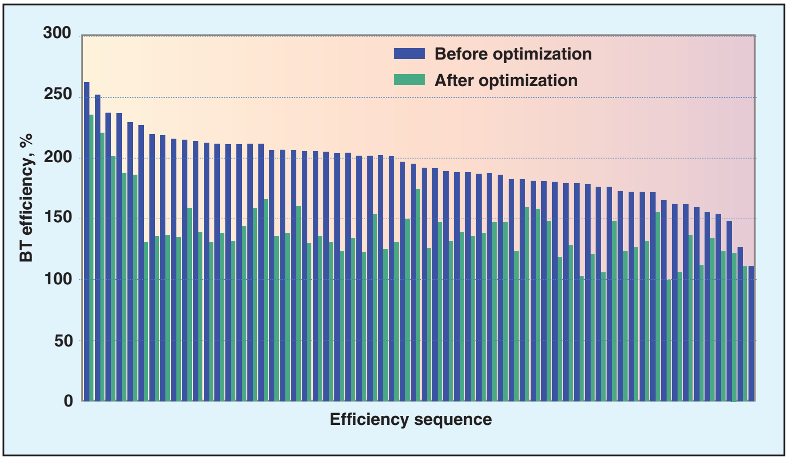


FIGURE 1. This graph shows the comparison of the best technology (BT) index for a number of petrochemical sites, both before and after implementing recommended energy-saving measures

TABLE 1. PLANT'S MEASURED ENERGY CONSUMPTION

Unit	Fuel import ton/h	Net steam consumption			Power import MW
		HP ton/h	MP ton/h	LP ton/h	
Aromatics	5.3	82.0	0.0	0.0	5.5
Olefins	2.6	173.0	0.0	0.0	6.4

In today's climate of increased energy prices and tightening environmental emissions requirements, petrochemicals producers around the world are continuing to focus on optimizing energy consumption at their facilities. Over the past few years, while energy prices have been increasing, petroleum refiners and chemicals producers have made progress toward improved, overall energy performance by implementing energy efficiency programs. In general, these programs and initiatives have focused on the relatively easy energy efficiency targets, such as furnace O_2 levels and minimizing slow-rolling steam turbines.

While these initiatives are an important step, a strategic approach is now required that focuses on implementing and sustaining the energy optimization program. After all, Energy is the petrochemical's largest single operating cost.

Recently, the author's employer used its continuous energy-improvement methodology to help the Iranian National Petroleum Co. achieve realistic energy-optimization targets. This article outlines the methodology required for a successful strategic approach to energy optimization, and includes specific case studies to illustrate the complexity of the challenge.

Methodology

There are two separate activities that link together to form the benchmarking program: the strategic energy review (SER) and the energy management system (EMS).

The SER is carried-out first, and it incorporates a number of activities, ranging from benchmarking to gap analysis, metric identification, and "road map" development. The purpose of the SER is to fully understand the energy situation at the operating site to suggest the best-suited strategic plan and identify all operational and investment improvement opportunities. A tailor-made energy management system follows the SER. The EMS incorporates improved best-practice documentation, enhanced organizational requirements and monitoring tools. This enables the operator to implement and sustain the energy optimization ideas from the SER.

Benchmarking

The first element of the SER is benchmarking. There are many different ways of benchmarking a site. Best technology (BT) methodology incorporates targets, which are developed through process simulations, proven designs and correlations based on the variation of key parameters affecting energy consumption. One of the keys to successful benchmarking is to ensure that the base case data that are used are valid and reconciled. For end users, the BT method chose two base case months with known swings in operation: A typical winter operation, and a typical summer operation. The balances required for the benchmarking are fuel balances (production and consumption), steam balances and power balance.

Best technology basics. The simulated best design features all economically justifiable options and incorpo-

TABLE 2. ENERGY CONSUMPTION									
Unit	Fuel – Offgas			Net Steam Consumption				Power import GJ/h	Total GJ/h
	Furnace GJ/h	Heater GJ/h	Total GJ/h	HP GJ/h	MP GJ/h	LP GJ/h	Total GJ/h		
Aromatics	0.0	1,044.9	1,044.9	231.0	3.5	0.0	234.5	55.6	1,336.0
Olefins	997.7	115.1	1,112.9	559.0	0.0	0.0	559.0	65.8	1,737.7

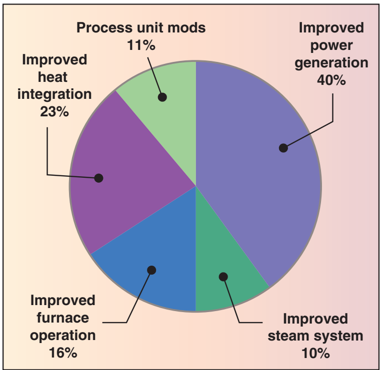


FIGURE 2. For the site under consideration, the largest "gap" is due to power generation and steam

rates all concepts of energy efficiency, including the following:

- Preheat trains designed for a minimum approach temperature of 20°C
- All fired heaters at 92% efficiency
- Yield-efficient operation
- Efficient utility systems
- All power generated internally at 80% marginal efficiency

Figure 1 shows some of the initial BT indices and the achievable BT after implementation of the recommended energy-saving projects for each site. The BT number shown corresponds to worldwide chemical plants that had been reviewed and where improvements were proposed for each site.

The improvement potential can then be carried forward to a gap analysis in order to identify where the chemical plant is falling short of the BT energy performance. The sum of the individual process-unit allowances is the BT allowance, which if compared with the actual unit-energy consumption, gives the plant energy-efficiency index, expressed as %BT.

Gap analysis

Once the benchmarking phase is complete, the next step is to perform a gap analysis to understand the difference between the current operation and the best-possible operation. The difference between the current operation and the BT target for the plant under consideration was significant at approximately 2,000-million Btu/h.

The gap analysis focused on the following four main areas:

- Fired heaters
- Heat integration
- Process
- Steam and power

For the fired heater gap, the 92% efficiency corresponds to 3% excess O_2 and a stack temperature of 160°C (320°F). According to the author's experiences, a significant portion of the gap is lost through poor stack-heat recovery. The heat integration gap can be defined as the difference between actual performance and the pinch targeted energy consumption. The process gap refers to the actual design compared to the BT design. Steam and power gap is normally the largest gap and where one of the biggest differences can be made, which is related to steam letdown inefficiencies and poor choices of turbines.

It is important to realize that defining and explaining the difference between actual operation and the best possible operation does not necessarily indicate that it will be economical to implement the project to close the gap. Further, a more detailed analysis on the individual projects must be undertaken to ensure that they are economical to implement. This is carried out during the road-map development phase of the SER.

Figure 2 summarizes the gap analysis for this example. As expected, the majority of the gap is caused by the operation of the steam and power system (50%). Furnace efficiency improvements would close the gap by a further 16%, improved heat integration would account for 23% and process unit modifications would account for the remaining 11%.

Project

The project is split into the following separate steps:

Step 1: Data collection. Collect, reconcile and validate data to aid the following steps; complete energy balances

Step 2: Benchmarking. Benchmark each plant using BT methodology. Compare the plant's performance against worldwide industry performance

Step 3: GAP analysis for selected sites. Energy audit; detailed steam model; rigorous pinch analysis; GAP analysis

Step 4: Specific energy criteria (SEC) for existing sites. Identify and set achievable SEC for existing plants

Step 5: Energy improvement program. Develop an energy improvement program based on the process road map, time, economics and resources

Step 6: Specific energy criteria for new plants. Identify key energy design factors. Define target SEC for new plants. Define criteria for new plants

Data validation/reconciliation

A number of different techniques can be used to validate and reconcile the supplied energy-consumption data. Some of these techniques are described here. Where applicable, commercial steam software is used to validate the following:

- Boiler and furnace efficiencies
- Boiler fuel consumption
- Site steam and power balance
- Measured fuel-gas rates
- Process data (for example, process furnace-fuel consumption and heat exchanger duties)

Finally the plant's total energy consumption is calculated as: Total energy = (total fuel consumption + steam import + power import)/(power-generation efficiency).

Fuel consumption includes fuel imported and any off-gas from the process that is routed to the furnaces for fuel. Steam that is internally generated and consumed has been accounted for as fuel consumed. Fuel, steam or power is exported then an energy credit is applied. There is also a credit if there is a significant high-temperature condensate return to outside of battery limits.

In Table 1, all the measured energy consumption is shown for a sampling of olefin and aromatic plants. Energy consumption broken down from total energy after validation and reconciliation is shown in Table 2.

A relatively simple method for determining the energy performance of an operating production unit is to calculate the existing specific energy consumption (SEC). SEC is the total energy consumption per unit product rate. Alternatively, the SEC can be calculated based on the amount of high-value products (HVPs). The calculated SECs for plants are shown in Table 3.

Use caution when reviewing SEC because it does not take into account either the site configuration (complexity) or the process unit operation (for example, a catalytic cracker or reformer severity). To accurately benchmark the energy performance of a site, these things need to be accounted for in addition to throughput and energy consumption.

TABLE 3. SPECIFIC ENERGY CONSUMPTION (SEC) FOR PRODUCTION PLANTS

Aromatics		Olefins	
Plant feed rate	**125.0 ton/h**	**Plant feed rate**	**108.7 ton/h**
Product rate		**Product rate**	
Benzene	47.6 ton/h	Ethylene	52.7 GJ/h
Xylene	16.9 ton/h	Propylene	16.7 ton/h
Total HVP	**64.5 ton/h**	**Total HVP**	**69.4 ton/h**
Energy consumption		**Energy consumption**	
Fuel	1,045 GJ/h	Fuel	1,112.9 GJ/h
Steam	235 GJ/h	Steam	559.0 GJ/h
Power	57 GJ/h	Power	65.8 GJ/h
Total	**1,336 GJ/h**	**Total**	**1,737.7 GJ/h**
Existing SEC		**Existing SEC**	
Benzene based	28.07 GJ/ton	Ethylene based	33.0 GJ/ton
Xylene based	79.06 GJ/ton	HVP based	25.0 GJ/ton
HVP based	20.71 GJ/ton		

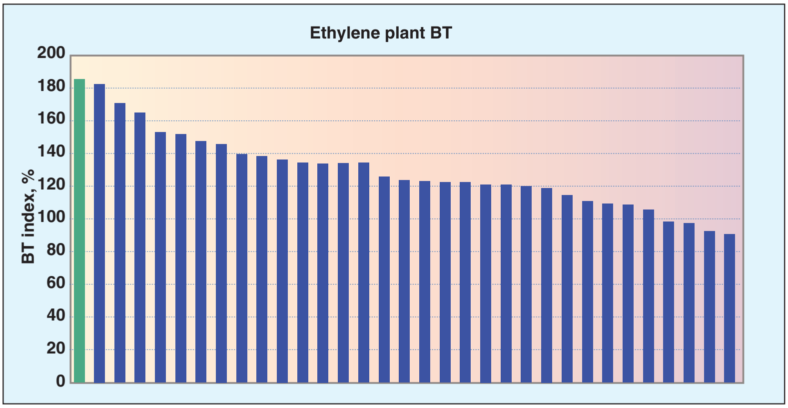


FIGURE 3. A comparison of olefin plants surveyed over the last ten years. The plant under investigation (green) falls in the lowest quartile

Best approach to benchmarking

To accurately benchmark the energy performance of a petrochemical plant, the following four key components need to be taken into account:

- Feed and production rates of the process unit
- Energy consumption of the plant
- Process units of the plant
- Operation of the process units (for example, reformer severity)

Experience shows that the ability to benchmark and monitor energy efficiency is essential for successful implementation of an energy efficiency-improvement program.

Energy benchmarking is the process of quantifying and comparing the energy consumption of a process unit or whole petroleum refinery or petrochemical plant to some pre-selected standard and to the rest of the industry. A system is needed to enable calculating and expressing each processing unit's energy efficiency as a single number so that performances of different units can be compared.

Specific energy consumption is not an accurate parameter, because the sites processing a difficult feed are expected to consume more energy compared to ones with a simpler feedstock. The SEC also does not assess the unit operation (for instance, furnace severity) where focus can be moved to one or more products.

The BT system is used to calculate and compare the energy efficiency of petrochemical plants of different configuration, capacity and yield performance, and to produce consistent and reliable results in these comparisons for each process.

The BT benchmarking process compares the actual energy usage of the processes onsite (including all fuel, team and power use) with that of a BT design. BT target efficiencies have been developed from first principles through fundamental basic designs on each type of unit and correspond

TABLE 4. SITE GAP CLOSURES

Bandar Imam Olefins	Gap GJ/h	Energy use GJ/h	BT Index, %	BT reduction,%
Current		1,748	185	
Fired heater efficiency	99	1,649	174	10.5
Heat integration gap	72	1,577	167	7.7
Process gap	237	1,340	142	25.0
Power and shaft-work efficiency	394	946	100	41.6
100% BT		946	100	

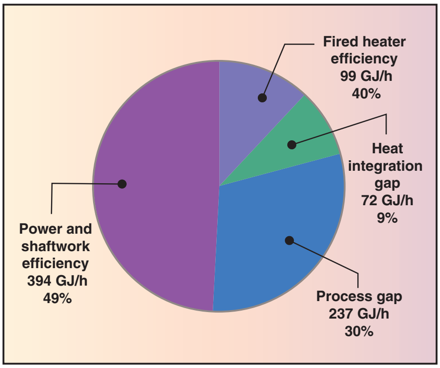


FIGURE 4. Site gap closures for the olefins plant under investigation

to the lowest energy consumption achievable for a new design with a three years payback.

These "best design" features are included as all power generated internally (using combination of backpressure turbines and gas turbines), heat exchanger networks designed using pinch technology (for more, see Part 2, Energy optimization using pinch analysis, pp. 32–37), fired-heater efficiency lower heating value (LHV) of 92%, no steam venting, all condensate from process heating is recovered, all rotating equipment operating at high efficiency and optimum fuel gas composition.

The sum of the individual process allowances is equal to the site BT allowance, which when compared with the actual site-energy consumption gives the overall energy efficiency index. The index is expressed as %BT. Therefore, for example, a BT number of 180% means that the actual site consumes 80% more energy than a best technology one for the same throughput, configuration, feed quality and yield.

The BT benchmarking process uses a calculated generation-efficiency value for power import based on fuel and power prices, rather than a fixed value. BT benchmarking converts the power price and the marginal fuel price to an equivalent generation efficiency using the price equivalent efficiency (PEE).

Steam

Commercial steam software is used to calculate the value of steam for the different BT steam levels. In principle, steam is valued based on its potential to generate power. The value of high-pressure (HP) steam is equal to the fuel required to generate one ton of steam in a utility boiler. The value of steam at lower pressures (LP) is equal to the value of steam at the higher pressure level, less the value of power generated by the steam, as its pressure is reduced (power credit).

Figure 3 compares the energy performance of the olefins process of the plant under consideration against other olefins plants surveyed in the rest of the world within the last 10 years. It can be seen that the current energy performance is fourth quartile.

Gap analysis methodology

The BT Index is the ratio of the existing process energy consumption to the energy consumption of a best technology process. The difference between the existing process energy consumption and the energy consumption of a BT process is called the inefficiency gap.

While BT analysis shows the energy benchmark of a process, gap analysis serves to identify the areas of inefficiency and quantify the contribution of each area in the overall inefficiency of a process.

Typically, the main areas where energy inefficiencies are examined in petrochemical plants are the following:

- Furnace and boiler efficiency (excess oxygen stack, stack temperature)
- Heat integration efficiency (pinch technology method)
- Process unit design and operation (identification of other inefficiencies in process)
- Power and shaft work generation efficiency (consider PEE concept)

Figure 4 and Table 4 present the results of the gap analysis for the olefins plant under consideration.

Concluding remarks

Energy systems at petrochemical plants are typically large and complex. Optimizing the energy operation requires a study of all areas. Using a strategic approach comprised of benchmarking, gap analysis and opportunity identification enables the investigating team to generate a clear and systematic plan.

The results indicate low standards of energy performance and reveal considerable saving opportunities. Some of the main reasons low energy efficiency of petrochemical plants are low energy cost, minimum capital-cost saving for investment, old design methods and so on. The improvement potential can be carried forward to a gap analysis in order to identify where the petrochemical plant is in best technology performance.

This method can be modified to be used for all types of plants in the chemical process industries (CPI) to identify the key factors that influence energy consumption of each process. These plants, including all utilities (fuel, steam, power, water) needed in the production of the high value products, are considered in order to calculate specific energy consumption per ton of high value product. ■

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Energy Optimization Using Pinch Analysis

Practical considerations on choosing the pinch temperature, utility temperatures and more

Richard Beaman and Cliff Reese
SSOE Group

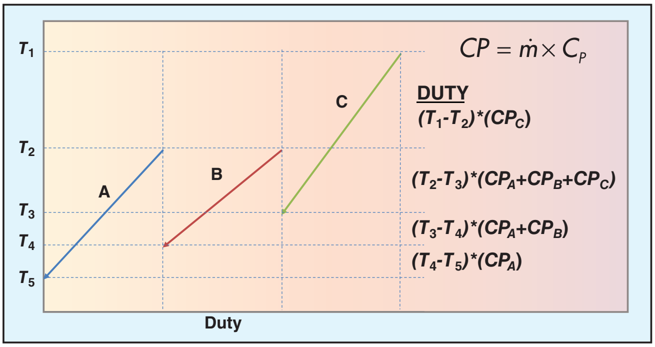

FIGURE 1. The temperatures (*T*) for each stream are plotted versus duty (enthalpy, *H*) to determine areas of overlapping temperatures

Pinch analysis is a systematic method to maximize energy recovery from process streams entering and exiting process equipment. Using this method, the minimum thermodynamic requirements for hot and cold utilities can be calculated for a process. This is useful to determine areas where savings can be realized and where savings are not available. It is a method that can be used during the design of a process or after startup. During the design phase, it is useful to set the temperatures of hot and cold utilities and the load requirements of those utilities. After startup, it can be used to take advantage of changing utility costs, or if a proper pinch analysis was not performed initially, it can be used to find and correct inefficiencies in the heat recovery.

Practical considerations to use these techniques effectively are illustrated in this article.

Introduction to pinch analysis

In pinch analysis, a temperature-enthalpy diagram (*T-H* diagram) is used to plot the hot and cold streams from the process and the temperatures where they are available. The benefit of this method is that multiple hot and cold streams can be plotted on the *T-H* diagram and be represented by a single hot stream and a single cold stream. This is called a composite curve. A composite curve is developed by compiling the temperature ranges, flowrates (dm/dt), and heat capacities (C_P) of the individual streams. This is illustrated in Figures 1 and 2. Composite curves show where the minimum temperature approach, between the hot and cold streams, is located. This is known as the pinch point. The composite curve also shows how much external hot and cold energy the utilities must provide. This method shows the minimum utility temperature required to achieve the necessary heat and the maximum utility temperature to achieve the necessary coldness.

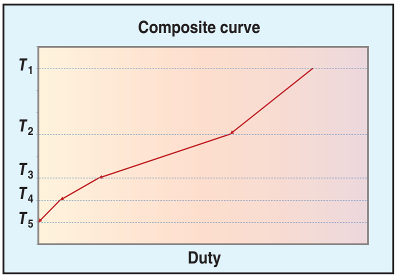

FIGURE 2. When the individual *T-H* curves are combined, a composite curve (CC) is created

The following analysis technique can be used for simple heat-exchanger networks (single hot or cold streams) or complex heat-exchanger networks for the streams that need hot or cold utilities. For the complex heat-exchanger networks, after all of the process streams are integrated into an efficient network, there may be a few streams that require one or more utilities in order to achieve the desired outlet temperatures. If you take each of these streams separately and plot the composite curves for that stream and the section of the streams that transfer heat to or from it, you will create a simplified network to which the following techniques can be far more readily applied. There are a number of

COMMON TERMS

- **Hot stream** – Any stream that needs to be cooled
- **Cold stream** – Any stream that needs to be heated
- **Pinch temperature** – The minimum temperature difference (approach) between the hot streams and the cold streams
- **Flowing heat capacity)** – $CP = \dot{m} \times C_P$
- **Composite curve** – The sum of the flowing heat capacity of all of the hot or cold streams, over the temperature range of the streams
- **Outlet temperature** – The "desired" or "required" outlet temperature of the stream

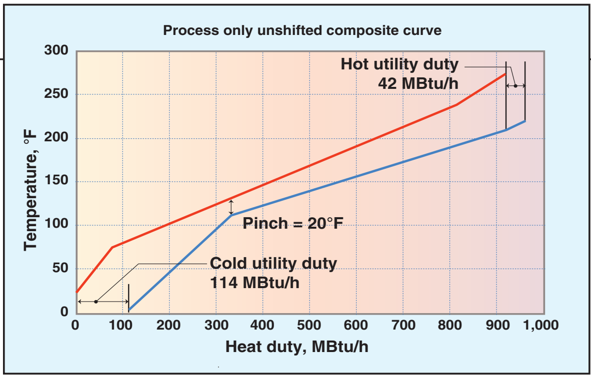

FIGURE 3. When the CCs for the hot and cold streams are plotted and aligned so that the desired pinch point is achieved, the utility requirements can be easily determined

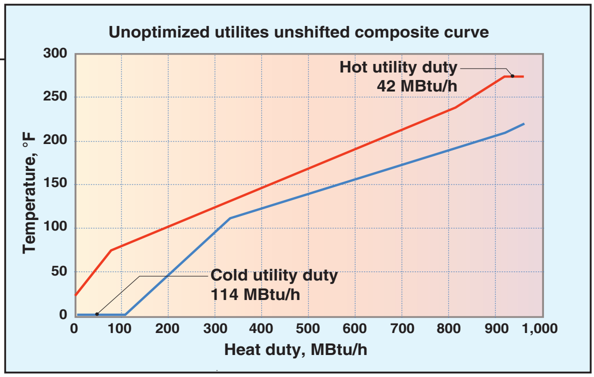

FIGURE 4. Adding the utilities to the ends of the respective hot and cold composite curves can sometimes lead to an unoptimized solution

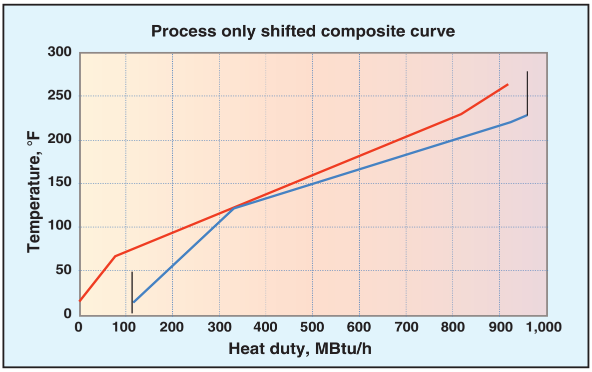

FIGURE 5. Shifting the hot composite curve down by 1/2 of the pinch temperature and the cold composite curve up by 1/2 of the pinch temperature creates a shifted composite curve

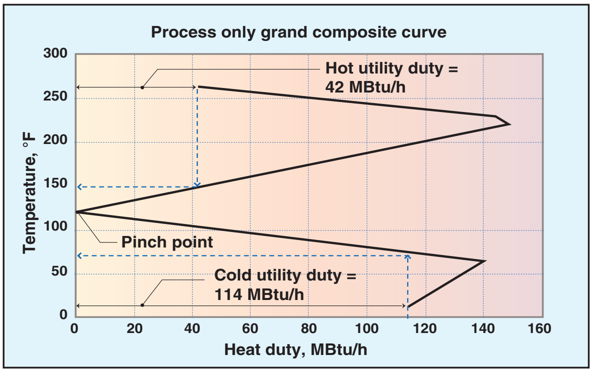

FIGURE 6. Subtracting the hot CC from the cold CC, at each temperature, creates a grand composite curve, which can be used to determine the temperatures required for the utilities

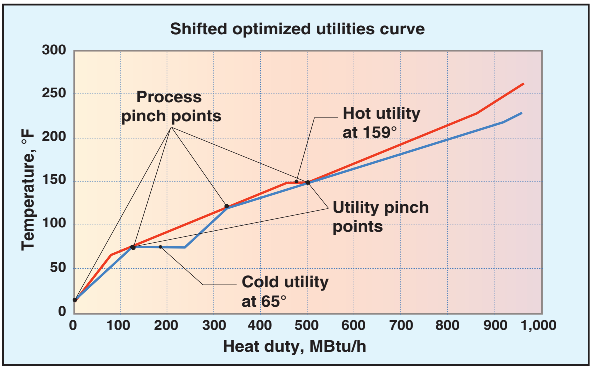

FIGURE 7. Adding the utility streams into the shifted composite curve shows how the optimum energy solution can create additional pinch points

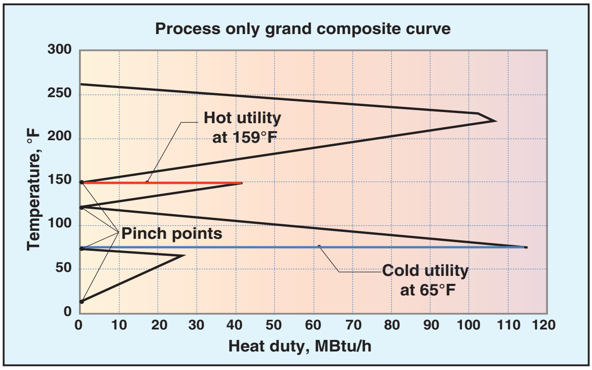

FIGURE 8. Replotting the grand composite curve shows the utilities' impact on the curve

articles and resources available that go into detail on creating the heat exchanger networks themselves [*1–3*].

Pinch analysis example

Figure 3 shows two composite curves that depict the hot and cold utility requirements as 42 MBtu/h and 114 MBtu/h, respectively. It has a 20°F pinch temperature. One thing to note is that only the process streams are plotted. The reasoning is that we want to make adjustments to the process, by adding or rearranging heat exchangers, in order to exploit the energy inventory in the process streams before adding energy (hot or cold) via utilities.

There are two features of this example process worth noting. The hot stream enters warmer than the desired cold stream outlet, and the cold stream enters colder than the desired hot stream outlet. The implication of this is that it is not necessary to have the hot utility above the desired cold-stream-outlet temperature and conversely, the cold utility does not need to be below the desired hot-stream-outlet temperature.

Pinch temperature selection

A rarely addressed point that needs to be discussed is how the pinch temperature was determined. Where does that number come from? In the training materials I have read, the choice of pinch temperature is usually rather vague. Materials often mention that it is the best temperature that the heat exchanger network can obtain for this type of process. In order to help quantify the pinch temperature, it is useful to take the following relationships into account. The basis of the pinch

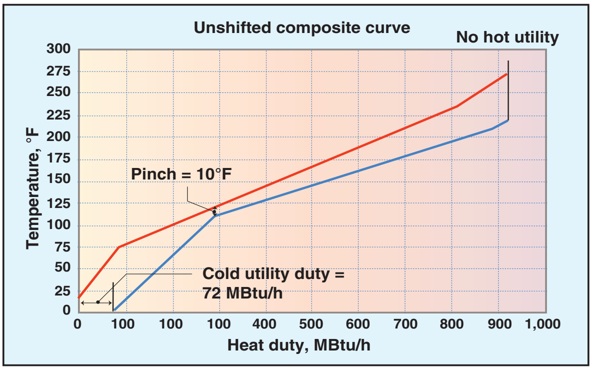

FIGURE 9. Optimizing the pinch temperature can sometimes eliminate the need for a utility

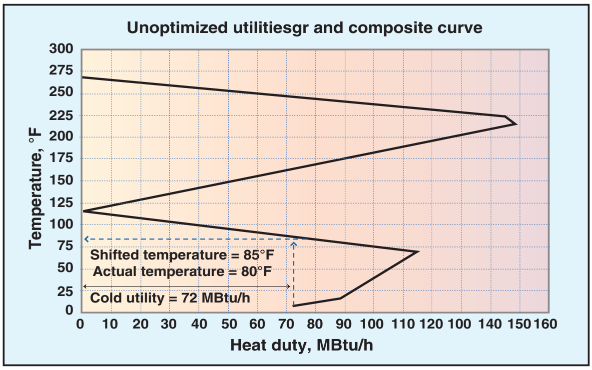

FIGURE 10. Optimizing the pinch temperature can sometimes even change the type of utility required

temperature is the following heat transfer equation:

$$Q = U_0 \times A \times LMTD \qquad (1)$$

Where:
Q = the duty of the heat exchanger
U_0 = the overall heat transfer coefficient
A = the heat-exchanger heat-transfer surface area
$LMTD$ = the log mean temperature difference

In this equation, minimizing the pinch temperature increases the heat recovery (Q) from the process. Minimizing the pinch temperature will decrease the $LMTD$, so in order to increase the duty (Q) we need to provide additional surface area (A). In this example, it is assumed that the overall heat-transfer coefficient stays relatively constant, because trying to increase the overall heat-transfer coefficient usually requires increasing the fluid velocities, which increases the pressure drop. Often this pressure drop is not available due to compressor or pump limitations. It is the overall heat transfer coefficient that is used to determine whether to use a small or large pinch temperature. Therefore, it is necessary to have a good knowledge of the process. If the process heat exchangers have small overall heat transfer coefficients near the pinch point (such as for vapor-vapor heat exchangers), then it will require a lot of extra surface area per extra Btu desired, thereby increasing the capital requirements significantly.

However, if the overall heat transfer coefficients are large near the pinch point, then a smaller pinch temperature can be used, requiring less surface area per Btu than in the case of the low overall heat transfer coefficient. The above overall heat-transfer-coefficient relationship must be used in conjunction with the size of the potential utility-duty savings. If the potential utility savings are small, there typically isn't enough savings to justify much capital expenditure for heat exchangers and piping.

Returning to the example, someone not familiar with pinch analysis would be tempted to add the utilities at the end of the hot and cold curves in order to match the end point temperatures. Their solution might look similar to Figure 4. A novice at pinch analysis would know that the utilities could be added at a lower temperature, but might not know how to determine the optimum temperatures.

Shifted composite curve. In order to find the optimum solution, you need to re-plot the composite curve as a "shifted composite curve." This is accomplished by subtracting one half of the pinch temperature from the hot composite curve temperatures and adding one half of the pinch temperature to the cold composite curve temperatures. The resulting plot is shown in Figure 5. This plot shows that the hot and cold utility requirements have not changed, but at the pinch point, the curves now touch. This is mainly done to allow the curves to be re-plotted in a different form, to create a "grand composite curve."

Grand composite curve. The grand composite curve is created by subtracting the hot curve duties from the cold curve duties at each temperature. Where there is no cold line to subtract the hot duty from, use the duty at the end point of the cold curve. Re-plotting the curve in this manner produces a plot as shown in Figure 6. As pointed out earlier, the hot stream inlet is hotter than the required cold-stream outlet temperature and the cold stream inlet is colder than the required hot stream outlet. These traits produce a grand composite curve that doubles back toward the y-axis. This allows us to use the graph to easily find the optimum temperature needed for the utilities. This is accomplished by drawing a line from the endpoint of each branch of the curve back up or down to the adjacent leg of the curve and then over to the y-axis.

Utility temperatures. This gives the "shifted" temperature of the utility required to achieve the desired process-outlet temperature. The actual temperature required would be the shifted temperature plus one half of the pinch temperature for the hot utility, and minus one half of the pinch temperature for the cold utility. This shows that the heat source for this example only needs to be ~159°F versus 275°F. The cold utility should be ~65°F versus 4°F. A utility at 65°F is usually much cheaper to obtain than one at 4°F, which requires a refrigeration system. If you choose a colder hot utility or a warmer cold utility, you would find that the process would pinch before enough heat or cold could be added to obtain the desired temperatures at the stream outlets.

Inserting the utilities into the shifted composite curve yields the curve shown in Figure 7. Shown on the curve

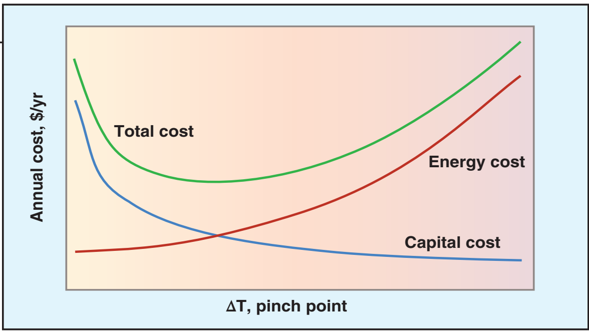

FIGURE 11. A graph of total, energy and capital costs for a typical process

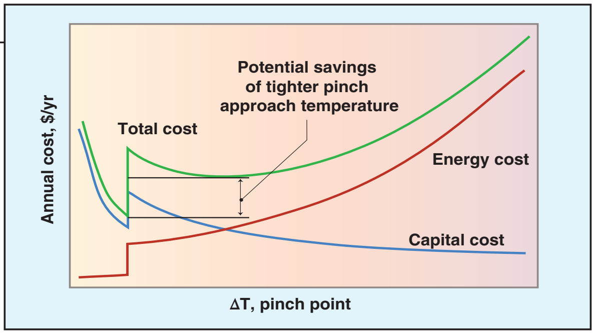

FIGURE 12. Sometimes when optimizing the pinch temperature, as utilities are eliminated or the type changed, discontinuities in the cost curves are created that may save costs

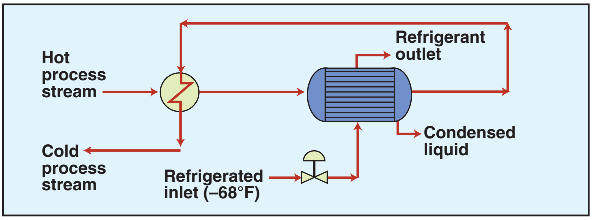

FIGURE 13. A typical "actual" stream cooling-process diagram

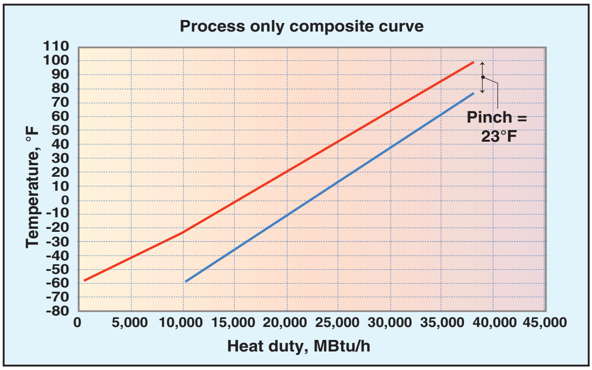

FIGURE 14. A composite curve for a "typical" threshold-cooling process

are the original process-pinch point, three new process-pinch points, and two utility-pinch points. The addition of the new process-pinch point at the very cold end of the composite curves is the result of both optimizing the utility temperatures and having the shifted cold-end temperatures being equal (the required hot-outlet and the cold-inlet temperatures were only different by the pinch temperature). The other two, new pinch points are created by the procedure used with the grand composite curve, shown in Figure 6. In other words, the procedure minimizes the utility temperatures by creating additional pinch points.

Utility pinch temperatures. The above procedure assumes that the utility would use the same pinch temperature as the process pinch temperature. Often this would be the case. However, as mentioned earlier, having a good working knowledge of the process may allow the utility to use a different pinch temperature. For example, if the process pinches at a vapor/vapor portion of the process, where the overall heat transfer coefficient would be relatively small, and you have a utility where a high overall heat-transfer coefficient could be obtained (that is, a steam heater or cooling water utility), then you could use a smaller utility pinch temperature. This would shift the utility curve up (for a cold utility) or down (for a hot utility) and when plotted on a shifted composite curve, would actually cross the other stream. Plotting the unshifted composite curve would show that we are not creating a real temperature cross in the heat exchanger. This will be illustrated in a later example.

For illustrative purposes, the grand composite curve can be re-plotted with the utilities to show the impact of adding the utilities at the minimum temperature levels. This step does not need to be done as part of the pinch analysis.

Additional optimization step

In Figure 3, we used a 20°F pinch temperature, which is a fairly easy target to hit. If we were to change the pinch temperature and perform a sensitivity analysis to determine how the utility duties vary as a function of the pinch temperature, an interesting result would appear. When the pinch temperature drops to 10°F, the hot utility duty drops to zero. This is shown in Figure 9.

In this case, because there is no longer a hot utility requirement, we do not need to add the hot utility heat exchanger nor the associated equipment (steam traps), piping and control systems. This could save a significant amount of capital, which could be used to pay for the additional heat-transfer surface area required for a tighter pinch point. In addition, you would no longer be required to pay for the energy costs for this heat.

If we re-plot the grand composite curve, and plot the line from the cold tail of the curve up to the warmer part of the curve and over to the shifter temperature axis, we find that the minimum shifted temperature (temperature of the cold utility) has risen from 75°F to 85°F. After adjusting the shifted temperature back to unshifted temperatures, the cold utility requirement has gone from 65°F to 80°F, which takes us from a refrigerated cooling source to cooling tower water. This would save the cost of a refrigeration system at the cost of a cooling tower for a significant capital savings. In addition, the cost of operating a cooling tower is significantly less than operating a chiller system.

To illustrate the effect of this shift from 20°F to 10°F in pinch temperature, we would typically see a cost versus pinch temperature relationship similar to Figure 11. This shows that as the pinch temperature decreases and the energy costs decrease, the capital cost and total cost increase, usually rising sharply as the pinch temperature decreases toward very small values. However, in the case being examined here, there is a discontinuity (or two). When the hot utility disappears, there is a sharp drop in the capital costs required. And, when the cold utility

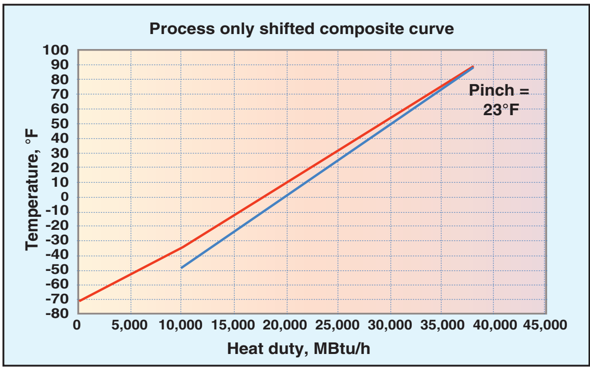

FIGURE 15. The shifted composite curve for a "typical" threshold-cooling process

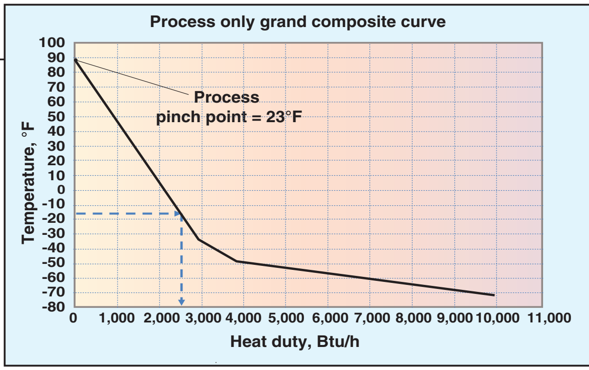

FIGURE 16. The amount of –68°F refrigerant duty that can be shifted to the –28°F refrigerant system with a 23°F pinch temperature is approximately 2,500 Btu/h

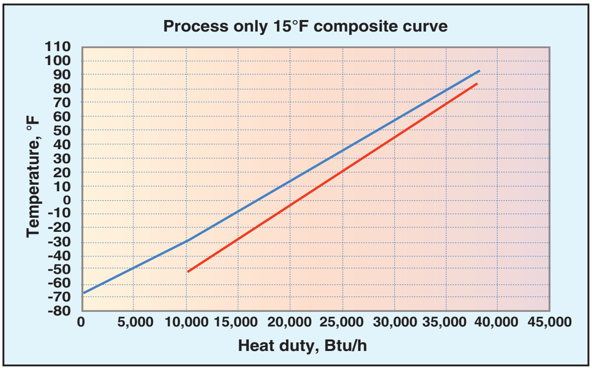

FIGURE 17. The shifted composite curve for a 15°F pinch temperature

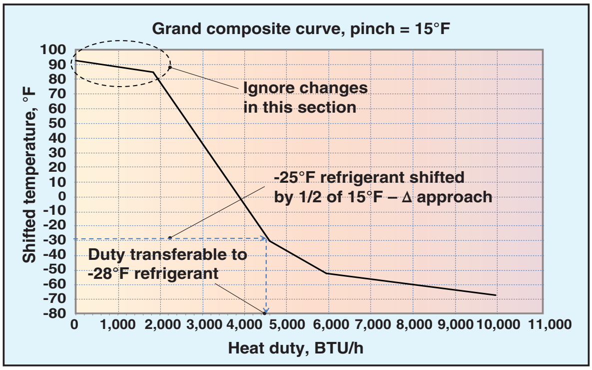

FIGURE 18. The grand composite curve for the 15°F process pinch temperature and 8°F utility pinch temperature will save approximately 4,500 Btu/h of of –68°F refrigerant duty

switches from a refrigerated system to cooling water, both the capital cost and the energy costs drop sharply. This is illustrated in Figure 12. As can be seen, the total savings can potentially be more than enough to pay for the cost of additional surface area that would be required for the tighter 10°F pinch temperature. Therefore, it can be very useful to analyze the system to see if a utility can be eliminated or switched to a cheaper utility.

Real world example

As is probably obvious, the preceding example was contrived to illustrate some very useful techniques developed as part of pinch analysis. Figure 13 depicts an actual process in which pinch analysis can be applied. The process is a simple condensation of a liquid from a non-condensable gas stream. The vapor inlet is above the dew point until about three quarters of the way through the feed/product interchanger. The condenser is cooled by –68°F refrigerant (low temperature), and the condensed liquid is used in a different cooling application and is therefore not available to pre-cool the vapor inlet stream. The desired hot stream outlet temperature is –60°F.

The composite curve is shown in Figure 14. It has a 23°F pinch point at the warm vapor inlet and requires ~10,000 MBtu/h refrigerant duty at –68°F. This is known as a threshold problem because the pinch is at the end of the composite curves, instead of the middle as is typical.

If we now plot the shifted composite curve (Figure 15) and then re-plot it as a grand composite curve (Figure 16), we see that the curves are quite different from the previous examples. The grand composite curve is different in that the curve does not turn back on itself, so we cannot find a utility temperature that eliminates the refrigerant at –68°F. However, there are some things we can do. In this particular process, there is also a refrigeration system operating at –28°F (high temperature). This is useful because the –68°F refrigeration system uses 6 hp per ton of refrigeration and the –28°F system uses only 4 hp per ton of refrigeration. So, we can plot the shifted refrigerant temperature on the grand composite curve and determine how much low-temperature refrigeration duty we can save (Figure 16, dotted line). As the graph shows, by following the –16.5°F shifted temperature line (–28°F + 1/2 of the shift temperature = –16.5°F) to the grand composite curve, we see that we can save approximately 2,500 MBtu/h of the low-temperature refrigeration duty by using some high temperature refrigeration duty.

However, since we know that the dew point is about 4°F, and we can split the cold stream into two parts at the high-temperature refrigerant's temperature, we can use a different pinch temperature. This is because we know that below the dew point, we will be condensing liquids out of the gas and we will usually have a higher overall heat transfer coefficient. Therefore, we can try using a smaller pinch temperature, say 15°F. In addition, because we can get an even higher heat transfer coefficient in the refrigerant evaporator, due to the boiling refrigerant, we will use a utility pinch point of 8°F. In order to do this, we need to make an adjustment to the high temperature refrigerant shifted temperature. The shifted refrigerant line we will use on the 15°F grand composite curve will be: –28°F refrigerant temperature + ½ × process pinch – difference in pinch tem-

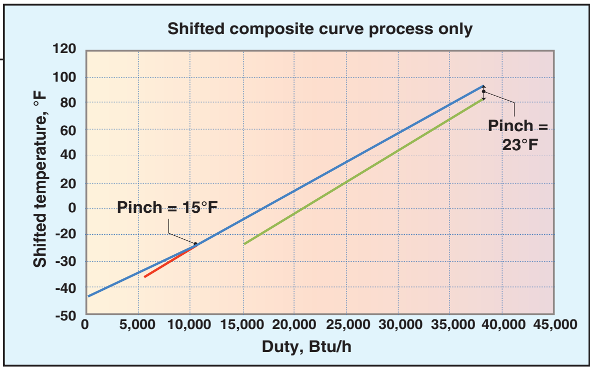

FIGURE 19. The new shifted composite curve for the 15°F process pinch temperature

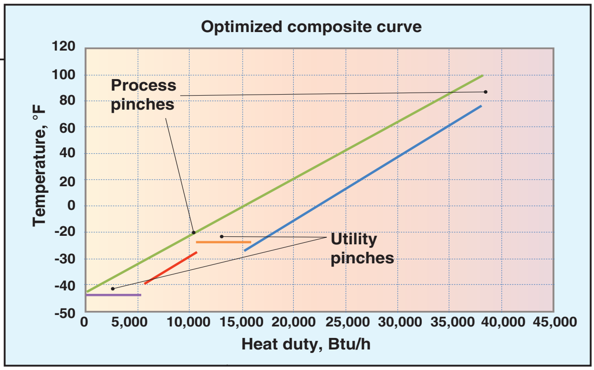

FIGURE 20. The new shifted composite curve for the 15°F process pinch temperature with the utilities curves added

peratures = –28°F + ½ × 15°F – (15°F – 8°F) = –27.5°F high-temperature refrigerant's shifted temperature

By re-plotting the shifted composite curve and the grand composite curve we get Figures 17 and 18.

We see that the hot and cold composite curves have separated and the grand composite curve now has a slightly different shape.

By adjusting the pinch temperature from 23°F to 15°F and using a tighter utility pinch temperature, we have increased the shift of duty from ~2,500 MBtu/h to ~4,500 MBtu/h for an 80% increase in duty shifted to the high temperature refrigerant. The re-plotted, shifted composite curve with this new pinch point is shown in Figure 19.

By adding the refrigerant lines to the composite curve, we get the curve shown in Figure 20. This curve shows that we have our original 23°F process pinch point at the warm end of the curves, where we are exchanging heat between two vapor streams, a new 15°F process pinch point in the condensing region, and two 8°F utility pinch points, one at each refrigerant temperature level. It also shows that we have shifted about 45% of the low-temperature refrigerant duty to the high-temperature refrigeration system.

In addition, if this were a retrofit of an existing process, we would reuse the feed/product interchanger, which would now have a smaller duty. This would result in obtaining a smaller pinch temperature at the warm end of the composite curve, because the exchanger would now have excess surface area.

The resulting process would look like Figure 21, where a new refrigerant evaporator and a new, small feed/product heat exchanger have been added.

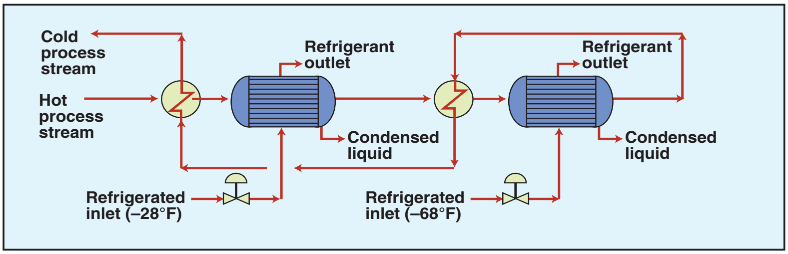

FIGURE 21. The "optimized" stream cooling process diagram

Final remarks

The following points will help you further minimize your utility usage:

- Perform a full pinch analysis and develop your heat-exchanger network on your process streams. Then perform a localized pinch analysis on each stream that requires utilities in order to achieve the desired outlet temperatures
- Know your process, so that you have an idea of what the heat transfer coefficients (*Uo*) are and the order of magnitude of the possible duty reductions, in order to pick a proper pinch temperature(s)
- Know your utilities' temperatures and available loads
- Plot and perform the pinch analysis on the composite curves, shifted composite curves, and the grand composite curves for the process streams only, to maximize process stream energy utilization
- Look for opportunities to eliminate utilities by adjusting the pinch temperature
- Look for opportunities to use lower energy utilities (cooler hot utilities and warmer cold utilities) ■

Edited by Gerald Ondrey

References

1. Rossiter, A. P., Improve Energy Efficiency via Heat Integration, *Chem. Eng.Progress*, pp. 33–42, December 2010.

2. Red Vector; Online Education, Chemical Engineering: Pinch Technology.

3. Rossiter, A. P.,"Introduction to Pinch Analysis; Including a Retrofit Case Study", AIChE Webinar,, 2011.

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Control Valve Diagnostics

The proof is in the process, as exemplified in this former HART Plant of the Year winner. This process economic evaluation helps frame the business case

Gyula Ötvös
and **József Bartók**
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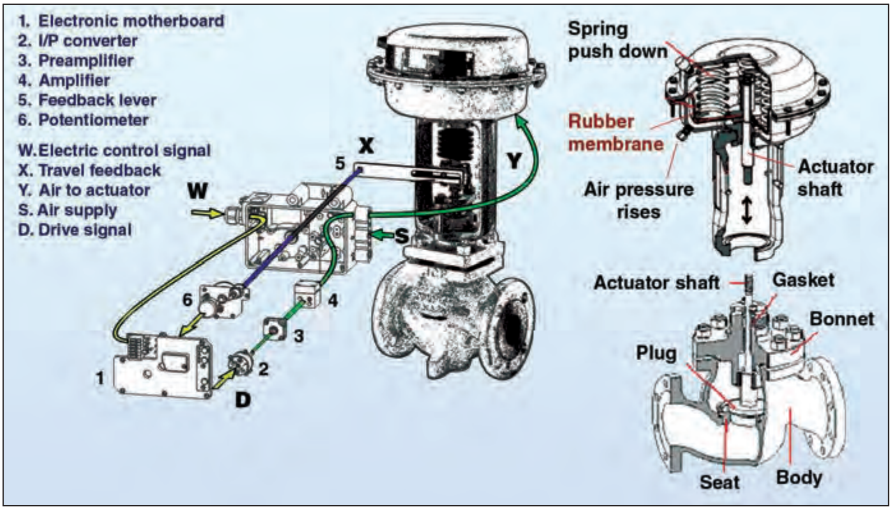

FIGURE 1. Contaminated instrument air affects the I/P converter

The benefits of field-device diagnostics are often acclaimed in qualitative terms, but on a much lower frequency in quantitative ones. Yet, an attractive cost-benefit analysis is necessary for almost any initiative to make it off the drawing board and into a plant. Even more rare are economic figures that come directly from the process plant engineers (as opposed to a vendor with vested interest in selling diagnostic equipment or systems).

Perhaps that state of affairs was on the judges' minds when they selected the MOL petroleum refinery near Budapest, Hungary to receive the 2010 HART Plant of the Year Award. The application, which is the basis for the analysis here, highlights two areas where control-valve diagnostics benefit the bottom line substantially: Contamination of control-valve instrument air and inaccurate control-valve settings.

In the first part of this article, the operation and significance of control valve diagnostics is explained, using an existing problem of contaminated instrument air. The newly developed, diagnostics-based method that solved the problem, is also briefly described. Based on the success of the new method, it was eventually ordered across the entire operating area of the Danube refinery.

The second part of the article investigates the product loss caused by the inaccuracy of control valve settings and the economic impact that diagnostics and preventive maintenance can have in reducing lost product.

For the purpose of both studies, we used technical data from the debutanizer equipment of the fluid catalytic cracking (FCC) units in the Danube refinery and in the Bratislava refinery of Slovnaft, MOL Group.

EFFECTS OF POLLUTED INSTRUMENT AIR

In many process plants, such as petroleum refineries, pneumatic control valves are most often used as intervention devices. The intervention device is part of the automatic control loop; in other words it is the element executing the command issued by the control unit. Control valves are incorporated in pipe armatures or fittings to regulate the quantity of the flowing media. This way the control loop can directly or indirectly influence the defined parameters of the technology. The term ”pneumatic” refers to the auxiliary drive (energy) of the intervention device, that is, where a concerned device applies energy drawn from air pressure to move mechanical elements. To drive these pneumatic valves, so-called instrument air at 5 bars pressure is used.

Control valve operation

In the Danube refinery described here, intellegent, electro-pneumatic positioners are used to operate control valves (Figure 1). The phrase electro-pneumatic means that the device generates a pressure value from an electrical signal. Meanwhile, the word intelligent describes the information available through microcontroller based devices, which have arisen in the digital age. In fact, the positioners manufactured in the past 10–15 years all possess intelligent electronics. This observation will be important later on.

One of the most important elements of the positioner is the device converting the electrical signal into a pressure signal; in what follows, this element will be called the I/P converter.

The signals received from the travel sensor attached to the valve shaft — a potentiometer in most cases — and the distributed control system (DCS) are compared by the electronics of the positioner, which then sends out the electrical signal with the proper magnitude (typically in the 1–2-mA

SAVINGS FOR REPAIR VERSUS REPLACEMENT

- The repair cost of an I/P converter is just one-third of the price of a new device
- The devices cleaned and reset in the workshop are immediately available. There is no longer any weeks-long delivery time
- The defective part is not treated as hazardous waste, it can be reused

According to the newest financial statement, the savings with this maintenance-method is around €14,000/yr per 23 pieces at the Danube Refinery (according to SAP PM). ❑

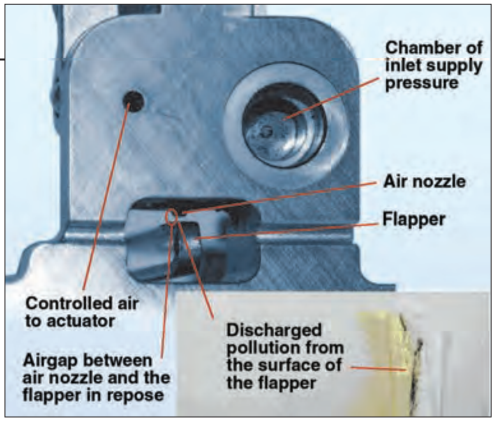

FIGURE 2. I/P converters are prone to blockage

range) to the I/P converter. This feature, called the drive signal by most manufacturers, is displayed by the positioner in units of percentage (%).

Depending on the signal received, the I/P converter pushes a sufficient amount (pressure) of instrument air into the valve actuator, moving the valve shaft as necessary.

The main parts of the I/P converter are as follows: a coil body and a connected flapper, plus a threaded chamber nozzle, located in the I/P converter housing.

Polluted instrument air

The 5-bars pressure instrument air that a control valve uses is produced by a central compressor from the surrounding environmental atmosphere. Subsequent to pressure boosting, the air goes through filtering and drying processes, prior to being sent to the central backbone line. However, in spite of the cleaning processes, instrument air is susceptible to being polluted by trace amounts of contaminants.

The micron-sized pollutants migrating into instrument air first move through the filters. Eventually (1–2 years), these contaminants block the air nozzles and ducts of the I/P converter that is functioning as a part of the positioner (Figure 2).

Symptoms of gradual clogging. The following symptoms of gradual clogging are slow but certain to appear for pneumatic valves:

1. The dynamic characteristics of the valve deteriorate in a spectacular way, specifically as follows:
   - Slow valve operation, especially for air takeout
   - More and more control errors (travel deviation) are produced by the positioner
2. The steady-state operation of the control loop is perturbed, making the automated operation of the technology impossible
3. The valve does not close (or open) in the terminal stage, as the positioner is unable to blow down the air from the actuator. This failure equates to operational breakdown

Past experience shows that the "symptoms" listed above are more pronounced in the winter season.

The reason for the seasonal challenges is probably the contraction (shrinking) of materials due to cold weather. One must keep in mind that here we are dealing with air gaps, air ducts, or chambers with dimensions of several hundred microns, so even a minimum amount of contamination may cause problems, especially in the long run.

This is where the intelligent electronics play a role, because the positioner device is capable of performing self-diagnostics. By measuring certain parameters, it is possible to identify and manage (or even cure) the above mentioned symptoms in their early stage.

By using maintenance systems, we can collect and monitor the signals and parameters sent or shown by intelligent devices, which enables us to perform state-of-the-art preventive maintenance based on diagnostics.

Repairing or replacing parts?

In units where intelligent valve positioners and a maintenance system collecting the signals from these are available, the contamination phases can be tracked by observing the processes described in the second section of this article "Slow and innacurate valve operation". This way, the diagnostics system can aid the planning of the intervention.

In traditional practice, clogged and defective I/P converters were invariably replaced by new items. But, to perform proper parts cleaning, disassembly is required, whereupon the factory's precision-mechanics settings are destroyed. For the correct operation of the I/P converter, the recovery of the manufacturing-plant working position is required — in an extremely narrow range, and with ultimately high precision. In our case, the relevant work instructions were lacking; therefore, the manufacturer had proposed replacement.

Prompted by the growing number of blockages, however, and observing more and more replacement requests, we initiated an in-depth study of the operation of this actually very simple part. Given that disassembly and cleaning does not inflict any mechanical damage on the device, there is no reason whatsoever why the I/P converter should not continue to operate in full vigor.

To restore the factory settings, we must first understand the operation of the I/P converter, which is not complicated at all. Proper functioning requires the air gap between the flapper and the threaded blow-down nozzle to be set in the appropriate range (see Figure 2).

Settings can be checked through the value of the "drive signal" representing the modulation of the I/P converter; as a reminder, its factory value falls between 55 and 80%. While continuously monitoring the drive signal, the threaded nozzle can be carefully driven in or out, thereby restoring the original air gap size.

If the drive signal value of the I/P converter is set between 55 and 80%, then it is suitable for operating use.

So far, the I/P converters were repaired using the above method in three units, in a total of 29 valve positioners, the first item in March, 2009. The refurbished pieces are under focused supervision with the aid of online diagnostics, their test operation extending to March 31, 2010. Up to now, the incorporated parts manifested no sign of failure, and we have realized a number of benefits, including shorter lead time for repair and projected savings of €14,000/yr at a single refinery (see box, above).

SLOW AND INACCURATE VALVE OPERATION

In the second part of this article, we proceed to investigating the detrimen-

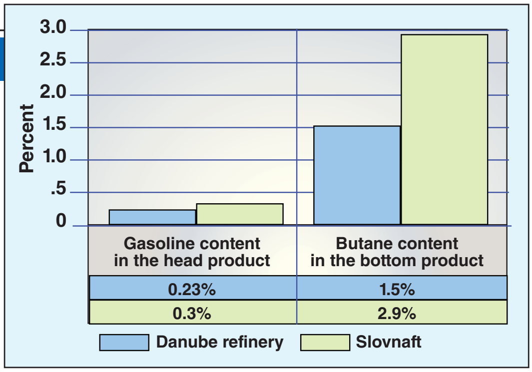

FIGURE 3. In the FCC unit of the Danube Refinery, the C_5 content of the top was 0.23%, and the C_4 content of the bottom was 1.5%. The same data for the Slovnaft refinery were 0.3%, and 2.9%, respectively

tal effects caused by slow and inaccurate valve operation, via an example taken from everyday practice.

The scope of our study was limited to the debutanizer equipment of the FCC units of the Danube refinery of MOL Plc. and that of the Bratislava refinery of Slovnaft, MOL Group. In the study, we observed the instability of certain control loops, and the effect thereof on production.

Impact on yield and quality

The main investigation areas considered were the debutanizer towers of these FCC plants. The two main control loops of each debutanizer tower were examined. Namely, these were the reflux control loop and the reboiler control loop. The study involved two time periods concerning the above two subjects: first, the whole year of 2009, and then a one-week period of the same year. The main point of the full year study was to define the calculation method, and it was also necessary to determine the average losses as accurately as possible. Of course control loop investigations cannot be performed precisely on annual scales, due to the length of the sampling period. Therefore, for these loops, weekly and daily measurements were also made in order to show the operation of the control loop as precisely as possible.

The main objective of the investigations was to consider the effect of control valve operation (in this case two) on control loops. In terms of operation, the debutanizer tower is a distillation tower. In our case, the binary fluid mixture is separated into gasoline and C_4 components. Gasoline is a liquid obtained from crude petroleum by way of distillation. It is not a homogeneous compound, but rather a mixture of hydrocarbons of the paraffin sequence, including mainly hexane (C_6H_{14}) and heptane (C_7H_{16}). These are open chain, saturated hydrocarbons, but motor gasoline contains more than 400 constituents (including olefins, cyclohexane, benzene, toluene, xylenes and other compounds).

The most valued output of distillation is gasoline. In our case, the main point is to maximize the yield of gasoline. The quality of produced gasoline is fundamentally influenced by the quantity of the remaining C_4 components. If the rate of the remaining C_4 components is too high, it spoils the end boiling point and the octane number. The degradation of quality can be remedied later in the blending process, by increasing the rate of more valuable gasoline derivatives, such as alkylates and ethyl *tert*-butyl ether (ETBE). The C_4 products extracted at the tower top (head) will be used as feedstock during later processing in the ETBE and hydrofluoric-acid alkylation (HFA) units, where high-quality motor-gasoline blending components are manufactured. Due to these reasons, the main indicator number of tower operation quality is the C_4 content of gasoline taken from the tower bottom, and the C_4, C_5+ content taken at the top.

In our investigations, in the FCC unit of the Danube refinery (based on 2009 data) the C_5 content of the top was 0.23 %, and the C_4 content of the bottom was 1.5%. The same data for Slovnaft were 0.3 and 2.9%, respectively (Figure 3.)

As the above results show, separation is not perfect. Certainly, at present it is not possible to apply settings and use devices that would guarantee perfect separation. However, the quality (degree) of separation could be significantly enhanced by using the appropriate tools and applying the suitable maintenance processes. Material compositions are essentially influenced by the operation of the tower reflux-quantity control valve, and the operation of the reboiler control valve. The control loop's proportional-inte-

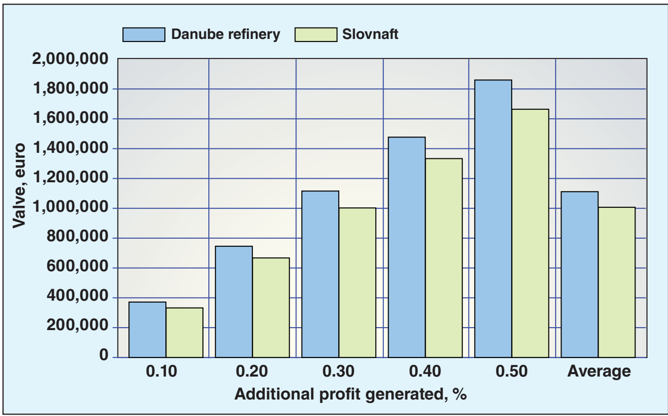

FIGURE 4. According to the calculations, the average amount of profit lost from inaccurate control valve settings is €1 million per year

gral-derivative (PID) control output operates the control valve built in the loop. The DCS does not display the true opening value of the control valve, only what the PID controller needs. Due to the contamination of the I/P converter described above, the actual opening value does not always coincide with the requested opening value. This failure can only be identified by operating a diagnostics system.

If the difference between the true opening and the requested opening values is large, it has a fundamental impact on the operation of the control loop, too: it will cause control loop oscillation. Initially, this does not cause a major problem, as the control algorithm is capable of compensating this swaying for a while, but as time passes, the disturbance in the loop will grow, thus the amplitude of oscillation may increase. At present, it is impossible to exactly screen out every control-valve defect or disturbance. This process becomes traceable once maintenance systems and intelligent field devices are used. This oscillation in the control loop then has a profound influence on the quality of the manufactured product, too.

The economic impact of diagnostics on this problem was determined as follows here:

- Bottom C_4 content was taken at 1.5% on the average
- The above quantity could have been reduced by an average of 0.5%, if a diagnostics and preventive maintenance system had been used
- The yield of useful products grows by the difference in these two amounts in linear progression
- Considering the mean sales price of gasoline, the amount of lost profit can be determined

If diagnostics and preventive maintenance systems are used, the defects of control valves can be detected in the initial period. Thus the control loop in question remains accurate.

In our case, no diagnostics were placed at all on the two control loops considered. The valves, both in Slovnaft and in the Danube refinery, were older than 25 years. Even in the case of one modern control valve equipped with advanced diagnostics, it is possible to report some savings, due to the improved precision of the control valve. This effect was also included when we determined the amount of lost profit (Figure 4).

According to the calculations, the amount of average lost profit is obtained as: €1,000,000/yr.

In this exercise we have proven the usefulness of field-diagnostic-based preventive maintenance with historical data, and we have already realized the cost savings of diagnostics and preventive maintenance and have validated our study. ■

Edited by Rebekkah Marshall

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Piping: Minimizing the Risk of 'Pre-buys'

FIGURE 1. Large, capital-intensive projects throughout the CPI typically require complex piping arrays. Thoughtful planning is required to maximize efficiency and minimize risk during the acquisition, supply, fabrication and erection stages required for such piping arrays, especially in the face of changes elsewhere in the project design

Buying too early may risk a surplus; buying too late may impact the schedule and budget

Stephen Wyss
Bechtel Oil, Gas and Chemicals

To stay on budget, major capital projects often call for aggressive schedules. Engineering, procurement and construction (EPC) contractors often end up using work processes that are not part of an established or standard work procedure. This is especially true when it comes to acquiring materials to support the schedule, particularly for critical paths related to the piping design, supply, fabricate and erect processes.

However, the risks associated with such an approach, given the complexity of materials required for large-scale piping configurations (Figure 1), can be significant. When additional costs are incurred in the range of tens of millions of dollars, profitable project execution may be imperiled. EPC contractors must acknowledge this risk, take steps to address it in order to minimize exposure, and be able to mitigate the inevitable surplus that will result.

The major piping processes

Phase complexity. Before we can appreciate why the risk is necessary, we need to understand the complexity of the process. The simple Level 1 schedule shown in Figure 2 demonstrates how the four major phases of the project — piping design, supply, fabricate and erect — overlap.

Criticality of the design phase. The piping design phase drives the overall process and it always evolves over time. For instance, the design phase involves a series of successive approximations, and must adapt to changing process requirements, since these will affect line sizes and pressure and temperature considerations. Piping design also requires close coordination with other disciplines that are involved in the process design, such as the mechanical, civil, structural and electrical engineering and instrumentation.

Further complicating the design phase is the fact that, all too often, the construction dept. wants to build the facility in a way that differs from the way in which the design process has already been evolving. For instance, whereas the piping design typically evolves from outlying areas of a unit, from pieces of equipment to pieces of equipment, and through the interconnecting piperacks, construction personnel often prefer to begin construction in the pipe-rack areas.

This places pressure on the Engineering Dept. to issue incomplete drawings earlier than might be ideal, for example, when only part of the design has been finalized, with "holds" in place to denote portions of the design that are not yet complete. This allows construction to proceed on a limited — often inefficient — basis, and increases the risk that aspects of the drawings designated "on hold" might change in a way that will later impact the portions of the drawing that were initially said to be firm. This inevitably leads to revisions that impact all the subsequent phases of the project — the supply, fabricate and erect stages.

In the simple example above, the first eight to twelve months will entail developing and finalizing the design. Engineering will not start to provide issued for construction (IFC) documents (such as isometric drawings, orthographic drawings, and so on) until some time around the ninth or tenth month. Hopefully, all IFC documents will be issued by the end of the twelfth month. In a perfect world, the engineering departments's work would be complete at this point, but in reality, design changes along the way call for the IFC drawings to be revised and reissued, either as a result of upstream process changes (such as line size changes, material changes, and others) or related detail design changes (such as equipment, foundation and steel changes). This uncertainty can be chaotic during the design phase and cascades to subsequent phases of the project.

The supply phase. Working backwards from the erect phase to the supply phase, the former cannot proceed until a critical mass of pipe spools have been fabricated and delivered to the site. Meanwhile, pipe spool fabrication cannot proceed until there is a critical mass of pipe spool components on hand for the fabricator. And the supply phase itself consists of several sub-phases. These include the requisition, bidding and awarding

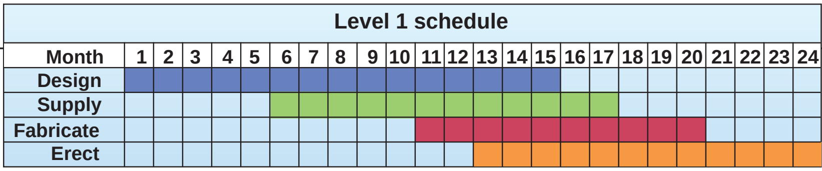

FIGURE 2. Shown here are the necessary overlaps that occur between the key stages that must be carried out when executing any complex piping project

phases of the project (which typically requires 4–8 weeks), manufacturing (which may entail from 2–52 weeks on an individual component basis) and delivery (which can take from 2–10 weeks, depending on logistical issues). All of these supply phase steps must begin a minimum of 5–6 months before the pipe spool fabrication in order to enable the delivery of an adequate number of pipe spool components to the pipe spool fabricator, so that production can be scheduled in the most efficient mode.

Most EPC contractors have standard procedures for requisitioning materials, such as complex piping bulks (since these typically require that requisitions for purchase be based on IFC documents). To put this activity in perspective, a single new process unit may entail piping materials consisting of 300,000 lineal feet (LF) of pipe, encompassing more than 200 size/material combinations, 50,000 fittings (encompassing more than 5,000 component/size/materials combinations, and 5,000 valves involving more than 500 type/size/material combinations).

Figure 2 shows the dilemma facing the EPC contractor, relative to the disconnect between when the supply phase must commence to support the fabricate and erect phases, relative to the maturity of the design phase. When the supply phase is initiated before the design has been adequately confirmed, a significant portion of these tens of thousands of items purchased will — as the design matures — potentially not be required, incurring potentially tens of millions of dollars of surplus. However, waiting until the design phase is sufficiently mature to support a more-efficient supply phase often pushes the entire schedule four to six months to the right on Figure 2. Since schedule delay is not acceptable, the only solution left is to establish a "pre-buy" process in which materials are requisitioned out-of-process (for instance, not as a function to IFC documents), in a manner that minimizes the risks while still supporting the schedule.

A successful 'pre-buy' process

While any process that commits resources to a less-than-firm design basis will always impose some risk, a well-thought-out application will minimize that risk. Key elements of a successful "pre-buy" program include:

- A comprehensive materials-management plan
- The use of robust materials-management software
- Assignment of design-related risk
- Assignment of materials-related risk
- Acquisition-related provisions to mitigate risk (described below)
- Quantification of risk
- A risk-related requisition plan
- Ongoing risk assessment

A materials-management plan

First and foremost, the project must have a sound, fundamental, and comprehensive materials-management plan (MMP) based on an equally sound, fundamental and comprehensive project-execution plan. It must be based on critically coordinated engineering and construction planning that breaks the project into areas that facilitate both manageable construction and manageable design. The construction and engineering departments must agree on construction sequences, by area, that reasonably dovetail with the engineering department's ability to advance the design in a way that supports the planned construction sequence.

These construction sequences then serve to establish required on site (ROS) dates for all materials according to their respective areas. As the design progresses, the continued feasibility of the planned construction sequences must be reviewed frequently for viability, and where necessary, adjustments must be made to the ROS dates.

Using robust software

The use of robust, integrated materials-management software — which integrates design (for instance, 3D models) with requirements, component attributes, requisitions, need dates, purchases, and material statuses — is essential. The software must be able to quickly communicate design changes to the downstream modules, to sum up requirements and generate requisitions. It must also be able to manage and maintain leadtime data (for instance, time to purchase, manufacture and deliver each individual component to the various destinations) and convert individual component ROS dates into latest materials requisition (LMR) dates. It must be capable of assigning risk attributes to individual components.

The ability of the materials-management software to establish LMR dates does more to allow the EPC contractor to establish risk exposure than all other factors combined. This functionality establishes exactly when individual components must be requisitioned to support the construction schedule. In short, it gives the project management team the ability to choose the least damaging action: (1) "no materials action," which may compromise schedule, or (2) "purchasing non-IFC materials," which may never be utilized. When assessed in light of the design-based risk and materials-based risk (discussed below), the project management team is able to make intelligent, risk-related decisions to either move forward and purchase the materials or delay and impact construction.

Design-related risk

Design-related risk is dynamic, is related to the specific application, and typically falls into three categories:

1. Metallurgical
2. Pressure/temperature
3. Detailed design

Design-related risk from metallurgical changes is the highest of the three and thus impacts the other types of design-related risks. For instance, any underlying metallurgy changes — such as the decision to move from Type 304 stainless steel to Type 316 stainless steel — will require that every component in the line changes. How high the risk is from a given change is a combination of the high (or low) nature of the specific risk (such as metallurgical change) combined with the likelihood that a given line will be subject to a metallurgical change. For example, a situation for which there is a slight likelihood that a common material will change imparts a relatively low risk. By comparison, a situation for which there is a high likelihood that changes will be made related to an exotic material grade imparts a high risk.

Meanwhile, design-related risk resulting from pressure or temperature changes is lower than metallurgical change. By definition, piping material classes use standard pipewall thicknesses. If a pressure or temperature change increases the theoretical wall thickness, it might not impact all components in a line, as the standard wall thickness selected previously may still suffice for the new conditions.

As with metallurgical changes during the design development, the level of the risk associated with pressure- or temperature-related changes will reflect the nature of the risk (that is, how likely it is that an individual component will change) and the likelihood that a given line will be subject to a pressure or temperature change. For example, components in "standardized" piping classes, where higher-than-required pipewall thickness has been specified, carry a lower risk than components in higher-pressure "calc wall" piping classes, where pipewall thicknesses are specifically calculated for the intended use.

Design-related risk from detailed design changes poses the lowest risk, in terms of potential financial exposure. Consider the type of risk that is associated with the piping that runs in congested areas in which other lines may still be at a state of design that is "soft" (that is, not yet finalized). Such piping may be subject to re-routing or change, or a piece of equipment might be subject to relocation. Individual component changes of this type would only occur if a re-route were mandated to accommodate changes in the already designed components (for instance, where a direction change using 90-deg elbows was replaced with a direction change using 45-deg elbows). In general, components not subject to a re-route change (for instance, pipe, caps, and so on) have almost no risk, while those with a function that is related to direction (elbows, reducers and so on) have a higher risk.

Design-related risk can be managed or mitigated at the component level by assigning a risk factor to each component. The risk factor reflects the nature of the three articulated risks, along with the likelihood that the underlying piping line will be subject to that change. Each component is assigned a risk factor (a numeric value), which is a product of the three related categories. The end product relates directly to a projected likelihood, quantified as a percentage, that the component will end up as surplus.These risks are discussed below.

Assignment of materials-related risk. Materials-related risk is different than design-related risk in that it is static and thus is not associated with any specific application. Rather, materials-related risk is tied to the likelihood that the project can recover its investment if an individual component ends up as surplus.

When it comes to piping, materials-related risk generally results from two attributes: wall thickness and component function. The wall thickness risk is directly related to the commonality of the specified wall thickness, metallurgy and size (meaning, how widely used is that component, as this will impact whether it can be reused elsewhere or deemed surplus). For example: 2-in. Schedule-40 carbon-steel pipe is so common that any surplus can often be offloaded at only minimal cost. By contrast, a 16-in. Schedule 140 duplex stainless steel alloy is likely to be so unique that finding a buyer who is willing to pay more than scrap value is doubtful.

The risk factor associated with component function is directly related to the core function of the component, which in turn relates to the likelihood that a change that would make the item surplus might be able to be absorbed elsewhere. For instance, pipe itself (as opposed to, for instance piping components that are used for direction changes or piping size changes) has no risk factor in this category, as it performs a function that cannot be replaced by any other component. By comparison, components used to carry out simple direction changes, such as 90-deg elbows, carry a relatively low risk factor, as they tend to be used universally and widely. Components such as reducers, which tend to be size-specific, tend to carry a higher risk factor. And other two-size components — particularly items such as reducing flanges — carry a high risk factor.

As with design-related risk, materials-related risk is imparted at the component level by assigning a risk factor to each component that is a combination of the two attributers. These risks are multiplied, as noted later in the section entitled risk-related requisition plan.

Acquisition-related provisions to mitigate risk. Proper procurement procedures can do much to mitigate or remove the risks associated with change by negotiating provisions into the purchase orders that allow for cancellation or return to the supplier. Such provisions aim to define a timeframe early in the delivery sequence during which the material can still be cancelled without penalty, and specifies buy-back provisions at a nominal restocking fee for components that may have already been manufactured or even delivered. The ability to establish the most advantageous contract terms — to mitigate risk in this way — is highly dependent on the uniqueness of the underlying components and market conditions when the purchase order is negotiated. Again, as with design- and materials-related risks, acquisition-related risk mitigation is imparted at the component level and summed as noted below.

Quantifying risk

Before we get to the requisition plan, we need to first discuss risk quantification. Using the static materials-related risk factors discussed above, each component is assigned a risk category — low, medium or high, as well as a risk percentage. The noted percentage relates to the value of exposure for the underlying component, should it end up as surplus. A low risk designation relates to value recovery in the range of 10–40%; medium risk denotes value recovery in the 40–70% range; high risk relates to 70–100% risk recovery.

The other factors — for instance, risk factors associated with dynamic design, and efforts to mitigate acquisition-related risks — relate not to the percentage value of exposure, but to the percentage of quantity exposed. These need to be quantified at the time of the purchase-order commitment.

Risk-related requisition plan. The requisition plan is the heart of any sound pre-buy planning. It must support the delivery of materials to all destinations (for instance, to pipespool fabricators, module facilities and construction locations, as applicable). This plan, which is an offshoot of the MMP, must articulate what requisitions need to be prepared and when, and describe how the desired quantities will be requisitioned over time.

Using the appropriate software to establish the quantities that must be requisitioned no later than the LMR dates, the plan must specify when major component groups need to be requisitioned, by percentage blocks. For example, in our scenario above, the planning process might show that 40% of all stainless steel pipe needs to requisitioned at the start of Month 6, another 30% at the start of Month 9, another 20% at the start of Month 12, and the final 10% at the start of Month 13. The plan needs to address all other major component groups — all pipe, fittings, valves and so on, by major metallurgy group.

As each requisition milestone approaches, a review determines the risk categories discussed above, on a component basis. When the requisition is prepared, if the total quantity requisitioned exceeds the total quantity derived from the IFC documents, materials-management personnel review and quantify the risk (for instance, multiplying the quantified dollar figure of risk by the appropriate percentages by risk category), and assess the potential impact of deferring requisition activities with respect to schedule, taking into account when the design will firm up.

Again using our example above, if, at Month 9, the cumulative 70% of stainless steel pipe (40% already requisitioned at Month 6, plus 30% now required) equated to 70,000 LF, and only 40,000 LF was IFC at the time, a dollar value of risk would be associated to the 30,000 LF not yet IFC by multiplying the estimated value of the 30,000 LF of pipe by the associated risk factor percentage, taking into account static risk, the dynamic design-related risk, and any mitigating procurement-related risk. For example, if the 30,000 LF of pipe above was estimated at $300,000, and the risk percentage was 15% with no procurement-related mitigation, the exposure would be quantified at $45,000. If however, the project expected to place the order with a provision for cancellation within 60 days with zero penalty, the risk exposure would be quantified at $0, at least for the first 60 days. So at the time that project management is asked to approve a dollar figure of commitment in the form of a purchase order, the team has a quantified value of risk related to that commitment.

The requisition plan is a "living" plan and must evolve as the design proceeds and details related to timing and percentages evolve. The dynamic nature of the plan also applies to requisitions that are already completed, as quantities may change to increase or decrease risk with respect to processed requisitions. As the design proceeds, the quantified risk exposure will either be reduced (when IFC documents are issued as anticipated) or solidified (when design changes cause exposed materials to become surplus). This allows the materials-management personnel to address the firm surplus at the earliest possible time, giving the project maximum time to dispose of surplus to yield the highest return. ■

Edited by Suzanne Shelley

Author

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Oil-Mist Systems


Colfax

FIGURE 1. Shown here is a closed-loop oil-mist system that provides lubrication for bearings in process pumps and their drivers. If desired, the small, blue collection containers that are shown in this image can be furnished with automated or manual means of pumping the coalesced oil into the spent mist-return header

This primer discusses the pros and cons of open- versus closed-loop designs for lubricating pump and motor bearings

Heinz P. Bloch
Process Machinery Consultant

For decades, plant-wide oil-mist systems have been used to lubricate rolling-element bearings in high-speed applications throughout the petrochemicals, textiles, pharmaceuticals, mining and other chemical process industries (CPI). Applications range from small motors to large rotating cylinders and a variety of fluid movers. Plant-wide oil-mist systems provide a centralized way to supply lubricating oil to all such components, and often eliminate the need for frequent maintenance and corrective action.

Closed-loop oil-mist systems (Figure 1) have been widely used in these industries for decades. In fact, the CPI have been leaders in the use of plant-wide oil-mist systems since the 1960s.

Due to their lower initial cost, open-loop oil-mist systems have traditionally been more popular in the U.S. While they may be less costly up front, open-loop systems consume oil in a once-through fashion (Figure 2) and they can discharge spent or "stray" oil mist to the atmosphere, which creates environmental issues.

By comparison, closed-loop systems (as shown in Figures 1 and 3) allow the oil mist that has passed through the equipment bearings to be collected, filtered and reused. As a result, the lifecycle cost of a well-designed closed-loop system is often less than that of a comparably sized, plant-wide open-loop system.

As noted above, one particular downside of open-loop systems is that they allow a considerable amount of stray mist to escape from the pump bearing housings (Figure 2). In the face of strict, plant-specific environmental requirements, many facilities now prefer to implement closed-loop technology, whereby the mist is routed in compliance with API 610.

API 610 is a widely used and strongly recommended — although not compulsory — industry specification, which calls for oil-mist introduction between a modern face-type or rotating labyrinth-style bearing-housing protector seal and the adjacent rolling-element bearing. This is shown in Figure 3. The introduction of an oil mist into this open space prevents process vapors or contaminated atmospheric air from accumulating there. Similarly, the existence of oil mist in those spaces at slightly over atmospheric pressures precludes the ingress of moist or dirt-laden atmospheric air.

It is worth noting that lip seals — which are widely used in inexpensive pumps — are not considered to be acceptable, per the API standard. It is generally assumed that elastomeric lip seals start leaking after about 2,000 operating hours. In contrast, some API-recommended face and rotating labyrinth seals run well in excess of 50,000 hours. In the modern face-type bearing-protector seal (as shown in Figure 3), a closing force is applied by a series of magnets. These magnets are equally spaced around the circumference of the stationary element of the seal.

In API 610-compliant systems, the oil mist must flow through the bearing (or bearings) on its way to the central outlet port. Central outlet ports — usually located at the 6 o'clock position of the bearing housing, as shown in Figure 3 — can be connected to a common return header, which operates at a pressure below that of the oil-mist supply line. This application of a slight vacuum will increase the flowrate through the system.

The spent mist in the drain header can then be sent through a final coalescer element, which will capture residual oil droplets that are still entrained in the carrier gas. Instrument air is generally used as the carrier gas. While other carrier gases are entirely feasible, instrument air is fully satisfactory in virtually all plant-wide oil-mist installations.

A closed-loop system that applies oil mist to the bearing housings creates

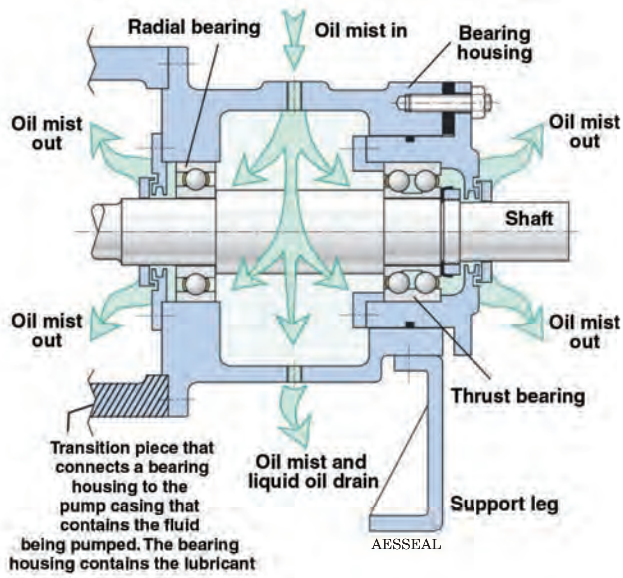

FIGURE 2. Old-style, open-loop oil-mist systems can result in considerable mist escaping to the environment. Bearing protector seals are purposely left off here so as to promote through-flow. As one knows from basic laws of physics, a pressure difference is needed for gas to flow from one location to another

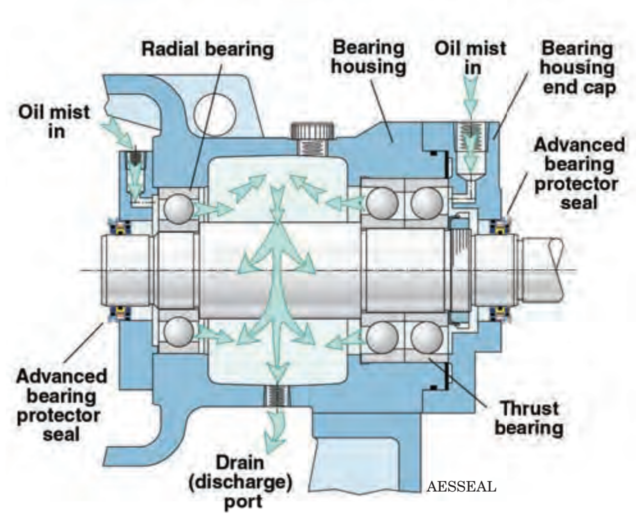

FIGURE 3. This pump bearing housing has face seals that allow for appropriate oil mist flow, per the API-610 standard. The task of manually emptying a 2-quart container once or twice per year is considered to be more cost-effective by many than automating the means of returning oil from the bottom of a bearing housing to a more-remote collection point. Modern magnet-closed bearing protector seals are shown; these will prevent atmospheric air from being drawn into the bearing housing. During operation, oil mist or carrier air arriving at the bearing housing drain will have traveled through one of the bearings

virtually oil-free carrier air, which can ultimately be discharged to atmosphere, or be recompressed for use as motive air elsewhere in the facility. However, the volume of this spent air is typically only about 1% the typical suction-air requirement of a facility's instrument air compressor. Thus, the economics typically do not favor either recompression, or the piping that would be necessary to return the spent carrier air to the facility's instrument-air inlet system.

The choice of the most appropriate coalesced-oil collector (from either the drain or the outlet port) is left to the user, and many different collector bottle configurations are available. In general, the average pump-bearing housing produces less than two quarts (about two liters) of coalesced lube oil per year.

Only closed-loop systems are suitable for locations where the use of best available lubricant application technology is preferred from a failure-risk-reduction point of view. In some cases, open oil-mist systems are simply disallowed because they discharge excess oil into the surroundings and because protecting the environment takes precedence. Moreover, open systems consume significantly more oil than properly managed, closed-loop systems.

Regarding the ability to reuse the collected oil, any potential concern that this oil may have been overheated — and thus might have lost some of its required properties — is not supported by field experience. From a practical perspective, the temperature rise that is encountered in the rolling-element bearing of many process pumps causes no measurable degradation of the premium-grade synthetic lubrication oils that are widely used by today's reliability-focused plants in their closed-loop oil-mist systems.

In general, the initial as-installed cost of closed-loop, oil-mist systems will be higher than that of open systems. However, the ability to both eliminate the unwanted discharge of stray oil mist (and thus protect the environment) and to recover lube oil for reuse helps to lower the overall lifecycle costs of the system, compared to open-loop designs. In fact, for many facilities, the benefits of closed oil-mist systems clearly outweigh the disadvantages of less costly, but messy and inefficient open systems. Close adherence to the configuration shown in Figure 3 has been shown to result in increased profitability and significant reductions in the numbers of pump failures in many facilities worldwide. ■

Edited by Suzanne Shelley

References

1. Bloch, H.P. and Budris, Allan, "Pump User's Handbook: Life Extension," 3rd Ed., Fairmont Press, Lilburn, Georgia, ISBN 0-88173-627-9, 2010.
2. Bloch, Heinz P., "Pump Wisdom: Problem Solving for Operators and Specialists," John Wiley & Sons, Hoboken, NJ; ISBN 9-781118-041239, 2011.

Author

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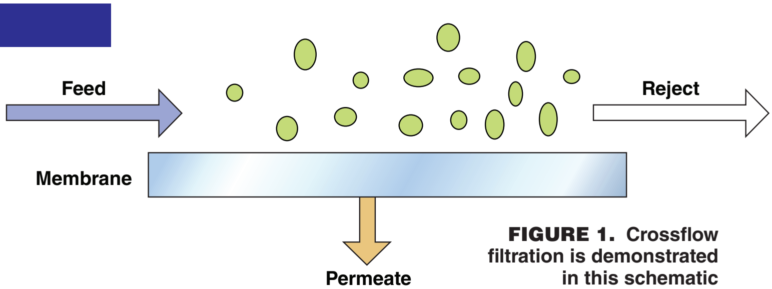


FIGURE 1. Crossflow filtration is demonstrated in this schematic

Modern Concepts in Makeup Water Treatment

Technologies offer new alternatives for water treatment

Brad Buecker
Kiewit Power Engineers

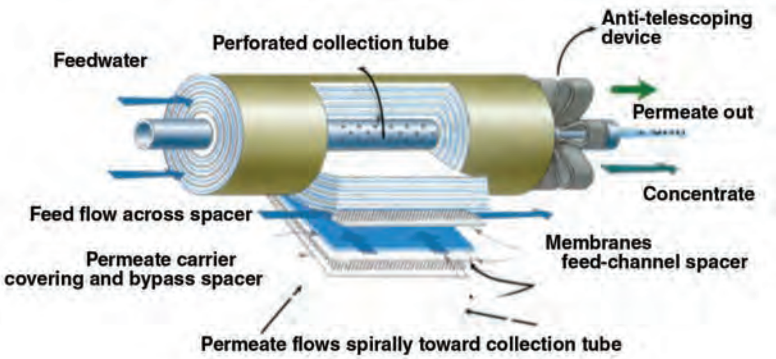


FIGURE 2. The spiral-wound membrane is the most common configuration for RO membranes

Water and steam are vital components of virtually all plants in the chemical process industries (CPI). And, a very important operation is the treatment of makeup water to produce the purity required for certain applications, most notably for use in heat exchangers and steam turbines. An important consideration in water treatment is that many industrial facilities are, or will soon be, dealing with tightening restrictions on wastewater discharges. These may include cooling tower blowdown, rainwater runoff and other aqueous discharges.

As with other technologies, the processes utilized to produce high-purity water have been greatly improved over the last decades. This article examines several of the most modern techniques for makeup water production. These technologies are also being employed to reduce wastewater volume and to recover pure water for reuse in the plant. (For more on reuse strategies, see Strategies for Water Reuse, *Chem. Eng.* September 2009, pp. 34–39.)

Think twice about a clarifier

Typically, the general makeup-treatment process involves: 1) large solids removal by screens or settling basins; 2) suspended solids removal; and 3) dissolved solids removal to produce the water needed for the process. We will focus on the last two process steps.

Clarification and media filtration were commonly used in the past for suspended solids removal. Where lime softening is needed to reduce raw water hardness, clarification is still a viable process. However, when the primary focus is removal of suspended solids only, micro- or ultra-filtration offers a very reliable alternative. My own personal experience is with microfiltration as a clarifier/filter replacement for makeup water pretreatment to an 800-MW supercritical utility boiler [*1*].

All major microfilter designs utilize hollow-fiber membranes. A very common design uses pressurized systems, where thousands of spaghetti-like membranes are packed into pressure vessels. The number of pressure vessels then determines system production capabilities.

This microfiltration process, like others of its type, operates in what can be thought of as a combination of crossflow and dead-end modes. Raw water flows parallel to the membrane surface in a crossflow pattern (Figure 1), but unlike reverse osmosis (RO) where most impurities are carried away with the concentrated stream (called the reject or concentrate), suspended solids collect on the membrane. Water that passes through the membranes and is purified is known as permeate and, of course, is sent onward, while in many designs the reject returns to the unit inlet.

So, this begs the question of how suspended solids are purged from the system. Typically, a regular backwash with an accompanying air scrub dislodges particulates and discharges them to a waste stream.

One microfiltration system has, in five years of operation, consistently produced water with turbidity levels below 0.04 nephelometric turbidity units (NTU). The results on downstream RO operation have been predictable in the best sense of the word, where the frequency of cartridge filter replacements went from weeks to months; and where microfiltration combined with an improved chemical-treatment program corrected a microbiological fouling problem that once plagued the RO

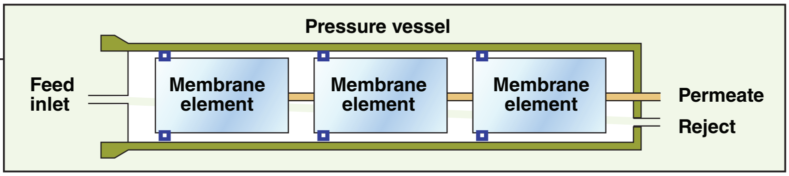


FIGURE 3. This schematic shows a generic outline of an RO pressure vessel

membranes. An aspect to note is that this microfilter treats lake water in which turbidity rarely, if ever, exceeds 15 or 20 NTU. This is certainly not a highly demanding application, but microfiltration technology has advanced to the point that systems are now in place to treat river water where the turbidity sometimes exceeds 2,000 NTU. For applications like this, close monitoring is imperative. For applications where high suspended-solids loading is frequent, it may be necessary to employ clarification ahead of the microfilter to prevent excessive membrane fouling.

For even finer particulate-matter control, ultrafiltration (UF) is an option. The minimum particle size screened by microfiltration (MF) is in the range of 0.05–5 microns, whereas for UF the range is 0.005–0.1 microns. UF will even remove viruses from water, and thus can serve in potable water applications.

The common material of construction for MF and UF membranes is polyvinylidene fluoride (PVDF), which is quite chemically resistant. Accordingly, the membranes are very tolerant of oxidizing biocides, and can be aggressively cleaned for removal of fouling and scaling impurities.

Reverse osmosis: The first step in demineralization

Before the development of reliable RO systems, the common makeup-water-treatment process utilized ion exchange immediately after the clarification/filtration step. Thus, the lead ion-exchange resins were subjected to water that contained roughly the original concentration of dissolved solids. The end result was restricted ion-exchanger run times and frequent regenerations with sulfuric acid and sodium hydroxide. Then RO came into the picture.

Reverse osmosis is a filtration technique, but unlike conventional filtration, RO has the ability to remove dissolved solids down to the smallest ions. As the name RO indicates, the process utilizes pressure to force water through membrane materials, producing high-purity permeate on one side of the membrane and a concentrated reject on the other. Although the passages within RO membranes are often referred to as pores, they more resemble very tiny maze-like tunnels. The passages range from one Angstrom (10^{-8} cm) to ten Angstroms in diameter. Because the pathways are so narrow, the molecular layer of water that attaches to the membrane surface inhibits ions from passing through the pores. Even so, some ions and molecules may still find their way through the RO membrane. These include monovalent ions, such as sodium and chloride, and small organic molecules.

By far the most-common RO membrane design is the spiral-wound configuration (Figure 2). These membranes are manufactured in flat sheets, which are wound around a central core to produce a membrane element. Several elements are placed in series and are sealed in a pressure vessel (Figure 3). Within the vessel, the feed enters the forward end of each element and flows to the opposite end. Permeate passes to the central core of the element, while the concentrate is collected and discharged at the element end cap.

The feature of spiral-wound membranes that makes them most practical is the multiple wrap within an element. This allows an element to process much more water than would be possible through a flat sheet. The once-common standard element surface area was 365 ft^2, but advances in membrane technology now allow a larger surface area of perhaps 400 ft^2. However, larger surface area requires a smaller spacer size, which makes the element more susceptible to suspended solids fouling. Proper pretreatment becomes even more important in these applications. Regarding element loading in pressure vessels, a very common configuration for the large units at power plants and other industrial complexes is five or six elements per pressure vessel.

An RO unit has been called nothing more than a high-pressure pump, some pressure vessels and pipe. In truth, the operation is a bit more complex than this description. Spiral-wound-membrane elements can come in several different sizes, but the most popular size by far is 8-in. dia. by 40-in. length. The rate at which water passes through the membrane is known as the flux, and is measured in gallons per square foot per day (GFD). The general purity of the water in large part dictates the flux rate. A general guideline suggests the following flux rates:

- Surface water: 8 to 14 GFD
- Well water: 14 to 18 GFD

For normal surface and ground waters, each pressure vessel will produce about 50% purified water and 50% concentrated reject. This may not seem very efficient, but the concentrate is normally still pure enough to be treated again at another 50/50 split to produce 75% permeate. This design is the very common single-pass, two-stage configuration (Figure 4).

Membrane technology has developed such that 99% or greater dissolved-solids removal is practical. Even higher purity can be obtained if the first-pass permeate is treated in a second pass, and, as we shall examine shortly, two-pass RO followed by a single ion-exchange polishing stage is becoming increasingly popular. By far the most common material utilized for RO membrane construction is polyamide, which is always layered with other materials for structural support. These membranes are most often known by the name of thin film composite (TFC).

Pretreatment. Proper pretreatment ahead of an RO membrane is vital to ensure reliable operation. Excessive concentrations of suspended solids will quickly foul RO membranes, and for this reason RO units are almost always equipped with inlet pre-filters. The installation of a micro- or ultra-filter ahead of an RO element can greatly improve RO run times between membrane cleanings. Polyamide is quite intolerant toward oxidizing biocides, including chlorine and bromine, so these compounds must be removed with a reducing agent prior to membrane contact. The most common reducing agent is liquid sodium bisulfite ($NaHSO_3$), injected via a basic chemical-feed system.

Pretreatment chemicals, such as those used in clarifiers, can negatively impact RO membranes. Coagulating agents of the cationic variety are particularly troublesome to RO membranes, especially to polyamide membranes whose surface is negatively charged. Aluminum gels that carry over from alum treatment in clarifiers can also cause problems. Such fouling is often overlooked until it occurs.

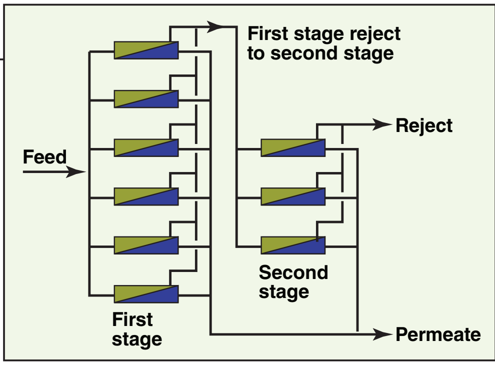


FIGURE 4. The two-stage RO system is a common configuration

For those who may eventually be tasked with specifying, purchasing, or installing an RO system, the importance of obtaining accurate influent water-quality data cannot be overemphasized. Ideally, historical data would be available. If not, then analyses should be collected as far in advance as possible of the decision to purchase an RO unit.

Scale formation. Prevention of scale deposits is very important for RO operation. As permeate is produced by the successive membranes, the reject ion concentration continually increases as the water passes from element to element. This increases the scaling potential. Calcium carbonate, calcium sulfate and other compounds can build up to a point where precipitation begins to occur. Additional potential scales include silica and alkaline metal silicates, strontium sulfate, barium sulfate and calcium fluoride. While pretreatment will reduce the concentrations of many scale-forming compounds, the remainder may still cause problems. Barium- and strontium-sulfate scales are especially difficult to remove. Reputable membrane manufacturers have developed programs that will calculate the solubility limits for scale-forming compounds. The program warns the user if any solubility limit is exceeded.

Because scale formation can quickly, and often irreversibly degrade membrane performance, anti-scalant feed is commonly used for industrial RO units. Common anti-scalant chemicals include polyacrylates and phosphonates. The correct anti-scalant or blend can control calcium sulfate at up to 230% above the saturation limit, strontium sulfate at 800% above the saturation limit, and barium sulfate at 6,000% above the saturation limit. The chemicals function by sequestering cations or modifying crystal growth, such that adherent scales do not form. Just a few parts per million of the treatment is usually sufficient to prevent abnormal scaling. (For more on scale inhibitors, see Biodegradation and Testing of Scale Inhibitors, *Chem. Eng.* April 2011, pp. 49–53.)

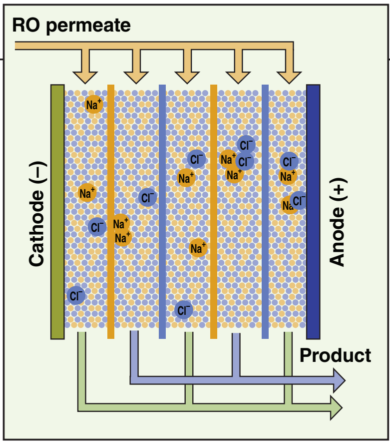
Polishing the water

While single-pass, and especially two-pass RO permeate will perform satisfactorily in low-pressure steam generators and many heat exchangers, an extra treatment step is necessary if the water serves as feed to high-pressure boilers or highly refined applications, such as those in the pharmaceutical or electronic industries. Single-pass RO plus a downstream cation-anion, mixed-bed ion-exchange unit is one such scenario. However, a technique whose popularity is increasing is two-pass RO followed by portable mixed-bed ion-exchange polishers. A primary motivating factor for this choice is that expensive and hazardous regeneration chemicals, such as sulfuric acid and caustic, may be eliminated from the plant site by having the mixed-bed "bottles" regenerated off-site by a contract supplier.

Another polishing option that is gaining popularity due to technology improvements is electrodionization (EDI) for polishing. EDI is one of the newest developments in water purification. It is based on ion exchange principles (Figure 5), but there are two significant differences:

1. Membranes are used, but they are actually ion exchange materials in very thin, flat-sheet form
2. Regular mixed-bed resins are also utilized, but they are regenerated by electricity, not by acid and caustic

EDI is based on an older technology called electrodialysis (ED). With EDI, water is introduced into compartments that have a cation-exchange membrane on one side and an anion-exchange membrane on the other. Under the influence of an applied direct-cur-



Source: Siemens Water Technologies

FIGURE 5. Electrodeionization is gaining popularity for water treatment

rent voltage, cations migrate through the cation-exchange membrane and anions migrate through the anion-exchange membrane. As the water flows down the chambers, the columns from which the ions migrate become progressively demineralized, while water in the remaining columns becomes increasingly concentrated. The product is delivered to the process, while the concentrate discharges to waste.

One of the initial shortcomings of the old ED technology was its limitation in removing silica and CO_2, even though the anion membrane is a strong base exchanger. This deficiency is overcome in EDI by the mixed-bed resins within the compartments.

Another ion-exchange option — especially useful when space is limited for equipment installation — is known generically as short-bed demineralization. In this option, compact exchangers use very fine mixed-bed resin for high-purity water production.

These units typically operate on short run times of perhaps 20 minutes or so, and then are automatically regenerated. Because the resin bed completely fills the compartment, thus prohibiting backwash for solids removal, the feed to these ion exchangers must be quite free of suspended solids. A number of my colleagues in the power industry have installed or operated these systems, some with limited success and some with excellent results. Good pretreatment is a key issue. ■

Edited by Dorothy Lozowski

Reference

1. Buecker, B., Microfiltration: An Up and Coming Approach to Pre-Treatment for the Power Industry, presented at the 26th Annual Electric Utility Chemistry Workshop, Champaign, Illinois, May 9–11, 2006.

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Brad Buecker is a process specialist with Kiewit Power Engineers (9401 Renner Boulevard, Lenexa, KS 66219; Phone: 913-928-7000; Fax: 913-689-4000; Email: brad.buecker@kiewit.com). He has 30 years of experience in, or affiliated with, the power industry, much of it in steam generation chemistry, water treatment, air quality control and results engineering. He has held positions with City Water, Light & Power (Springfield, Illinois) and Kansas City Power & Light Co.'s La Cygne, Kansas station. He also spent two years at a CPI manufacturing plant. Buecker has an A.A. in pre-engineering from Springfield College in Illinois and a B.S. in chemistry from Iowa State University. He is a member of the ACS, AIChE, ASME, and NACE. He is also a member of the ASME Research Committee on Power Plant & Environmental Chemistry, the Electric Utility Workshop planning committee, and the Coal-Gen planning committee.

WHO'S WHO

Potter

Clement

Wendell

Veselka

Zimmer

Aaron Potter becomes engineering manager for **Innovative Processing Solutions** (Aurora, Ind.), an affiliate of Stedman Machine Co.

Codexis, Inc. (Redwood City, Calif.) appoints *Achilles Antonio Clement* to head Codexis do Brasil Participacoes Ltda., the company's newly formed operations in Brazil.

Pascal Villemagne becomes vice president, commercial, for **Carbogen Amcis** (Bubendorf, Switzerland), a developer of pharmaceutical and biopharmaceutical processes and active pharmaceutical ingredients.

George Prest becomes CEO of **Material Handling Industry of America** (Charlotte, N.C.), an international trade assn. representing the material-handling and logistics industry.

Middough, Inc. (Cleveland, Ohio), an engineering, architectural and management-services company, welcomes *Carl Wendell* and *Joseph Veselka* to its Major Projects Group. Wendell becomes senior vice president and general manager; Veselka becomes regional manager.

Synagro Technologies, Inc. (Houston), a service company specializing in waste capture and conversion, appoints *Eric Zimmer* executive vice president, services division.

Global chemical company **Oxea GmbH** (Oberhausen, Germany) appoints *Bernhard Spetsmann* managing director. He succeeds *Neil Robertson*, who is retiring. ■

Suzanne Shelley

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

JOB FUNCTION

20 Corporate Management
21 Plant Operations incl. Maintenance
22 Engineering
23 Research & Development
24 Safety & Environmental
26 Other____________

EMPLOYEE SIZE

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

YOU RECOMMEND, SPECIFY, PURCHASE

(please circle all that apply)

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

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

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BUSINESS NEWS

PLANT WATCH

ColBiocel selects Chemtex technology for ethanol production in Colombia

September 26, 2011 — Chemtex (Wilmington, N.C.; www.chemtex.com) has entered into a term sheet agreement with Colombiana de Biocombustibles Celulósicos (ColBiocel) for the supply of a license and associated engineering and technical services for an 85,000 metric ton per year (m.t./yr) cellulosic ethanol plant using Chemtex's Proesa process. The project will be implemented in Chitaraque, Colombia using sugarcane bagasse as the feedstock.

PPG to increase global production capacity for precipitated silica

September 22, 2011 — PPG Industries (Pittsburgh, Pa.; www.ppg.com) is increasing its global precipitated-silica production capacity by more than 18,000 ton/yr. The capacity expansion includes projects at PPG's Lake Charles, La., and Delfzijl, the Netherlands, manufacturing locations. Some of the capacity will begin to come online during the 4th Q 2011, and the expansion projects will be completed by the end of 2012.

Lanxess to produce first bio-based EPDM rubber in the world

September 21, 2011 — Lanxess AG (Leverkusen, Germany; www.lanxess.com) aims to commercially produce ethylene-propylene-diene monomer (EPDM) from bio-based ethylene by the end of the year. It will be the first form of bio-based EPDM rubber in the world. This bio-based form of ethylene is produced by dehydrating ethanol from Brazilian sugar cane. Braskem S.A. (São Paulo, Brazil; www.braskem.com.br) will supply the bio-based ethylene to Lanxess' existing EPDM plant in Triunfo, Brazil.

Evonik builds new catalyst plant for biodiesel production in Argentina

September 16, 2011 — Evonik Industries AG (Essen, Germany; www.evonik.com) is building a new plant for manufacturing catalysts for biodiesel fuel production in Argentina. The plant, which is expected to be operational by the end of 2012 at the latest, will supply ready-to-use alcoholates as catalysts for the production of biodiesel fuel from renewable resources. It will primarily serve markets in Argentina and Brazil, with an annual capacity of over 60,000 m.t.

Technip wins FEED contract for ammonia-urea fertilizer facility in Gabon

September 15, 2011 — Gabon Fertilizers Co. has awarded an engineering contract to Technip (Paris, France; www.technip.com) for a grassroots ammonia-urea fertilizer project to be developed at Port Gentil, Gabon. The proposed project includes a 2,200-m.t./d ammonia plant and a 3,850-m.t./d granulated-urea plant. Under this contract, Technip will perform the front-end engineering design (FEED) for the project as well as the detailed cost estimate for the engineering, procurement and construction phases.

UOP technology selected for petrochemical production in China

September 8, 2011 — Fujian Meide Petrochemical Co. has selected UOP LLC (Des Plaines, Ill.; www.uop.com), a Honeywell company, to provide key technology to help meet the growing Chinese demand for propylene. The new propane dehydrogenation unit will use UOP's C3 Oleflex technology to produce 660,000 m.t./yr of propylene. The unit at Fujian Meide's facility in Fujian City, Fujian Province, China is expected to start up in 2014. It is said to be the largest propane dehydrogenation unit in the world to date.

Evonik to double its L-lysine capacities in the U.S.

September 6, 2011 — Evonik Industries AG is doubling its North American capacities for producing the feed amino acid L-lysine. The two-phase expansion of the Blair, Nebraska plant to an annual capacity of 280,000 m.t. is on track and is expected to be completed by August 2012.

MERGERS AND ACQUISITIONS

Dow and Argonne National Laboratory collaborate on new battery materials

October 4, 2011 — The Dow Chemical Company (Midland, Mich.; www.dow.com) and the U.S. Dept. of Energy's (DOE) Argonne National Laboratory (Argonne, Ill.; www.anl.gov) have signed a memorandum of understanding (MOU) for a multi-year research collaboration to jointly develop the next generation of materials for advanced battery technologies. Dow and Argonne will be collaborating on several new materials with the intent to improve the performance, cost competitiveness and adoption of these advanced materials in the energy storage industry.

Braskem completes its acquisition of Dow's polypropylene business

October 4, 2011 — The Dow Chemical Company has closed the sale of its global polypropylene business to Braskem S.A. The two U.S. polypropylene manufacturing plants in Freeport and Seadrift, Tex. will be fully integrated into Braskem America, Inc. The two German plants at Schkopau and Wesseling will operate under Braskem Europe GmbH.

BASF to sell fertilizer activities to EuroChem

September 27, 2011 — BASF SE (Ludwigshafen, Germany; www.basf.com) plans to sell its fertilizer activities in Antwerp, Belgium as well as its 50% share of the joint-venture (JV) PEC-Rhin (Ottmarsheim, France) to EuroChem (Moscow, Russia; www.eurochem.ru). The transaction, expected to be completed by the end of the 1st Q of 2012, is valued at approximately €700 million and is subject to approval by the appropriate authorities.

Codexis and Raizen to improve first-generation ethanol process in Brazil

September 27, 2011 — Codexis, Inc. (Redwood City, Calif.; www.codexis.com) and Raizen Energia S.A. (São Paulo, Brazil; www.raizen.com) have signed a joint development agreement to develop an improved first-generation ethanol process with enhanced performance economics. Raizen is a JV between Shell and Cosan, and is Brazil's largest sugar and ethanol producer. The parties anticipate pilot production at Raizen's Bonfim mill. Codexis will retain commercialization rights and Raizen will receive preferential commercial terms.

BASF Qtech formed as a new corporation to commercialize surface coatings

September 13, 2011 – BASF Corp. (Iselin, N.J.; www.basf.com) has announced that its affiliate, BASF Canada Inc., has joined Quantiam Technologies Inc. (Edmonton, Alberta, Canada; www.quantiam.com), as co-shareholders in a newly formed corporation named BASF Qtech Inc. This start-up business will focus on commercializing catalytic surface coatings for steam-cracker furnace tubes. Manufacturing, R&D and technical services will be provided by the Quantiam team, while marketing and sales support will be led by BASF's Catalysts Div. ■

Dorothy Lozowski

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

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

Economic Indicators

2009 — 2010 — 2011

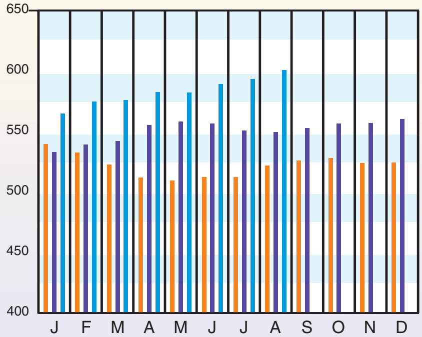
DOWNLOAD THE *CEPCI* TWO WEEKS SOONER AT *WWW.CHE.COM/PCI*

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Aug. '11 Prelim.	July '11 Final	Aug '10 Final
***CE* Index**	600.6	593.2	549.5
Equipment	734.4	724.1	657.3
Heat exchangers & tanks	691.9	681.8	605.8
Process machinery	674.5	675.8	621.7
Pipe, valves & fittings	909.6	915.3	827.1
Process instruments	501.9	446.9	416.9
Pumps & compressors	909.9	909.5	902.5
Electrical equipment	512.6	512.5	482.7
Structural supports & misc	775.7	764.7	675.6
Construction labor	330.6	326.9	330.0
Buildings	521.0	520.5	503.0
Engineering & supervision	331.9	332.1	337.9

Annual Index:

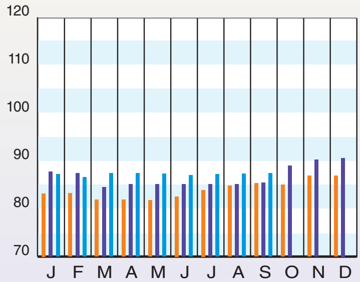
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8



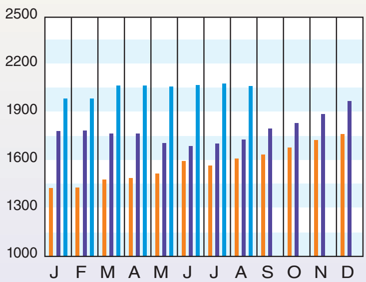
CURRENT BUSINESS INDICATORS

	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2007 = 100)	Sep. '11	=	87.4	Aug. '11	=	87.3	Jul. '11	=	87.2	Sep. '10	=	85.4
CPI value of output, $ billions	Aug. '11	=	2,068.1	Jul. '11	=	2,083.1	Jun. '11	=	2,073.4	Aug. '10	=	1,732.7
CPI operating rate, %	Sep. '11	=	75.4	Aug. '11	=	75.3	Jul. '11	=	75.2	Sep. '10	=	73.3
Producer prices, industrial chemicals (1982 = 100)	Sep. '11	=	338.7	Aug. '11	=	336.5	Jul. '11	=	338.0	Sep. '10	=	264.0
Industrial Production in Manufacturing (2007=100)	Sep. '11	=	90.9	Aug. '11	=	90.6	Jul. '11	=	90.3	Sep. '10	=	87.5
Hourly earnings index, chemical & allied products (1992 = 100)	Sep. '11	=	158.0	Aug. '11	=	158.0	Jul. '11	=	159.4	Sep. '10	=	159.1
Productivity index, chemicals & allied products (1992 = 100)	Sep. '11	=	109.2	Aug. '11	=	109.6	Jul. '11	=	110.7	Sep. '10	=	111.8

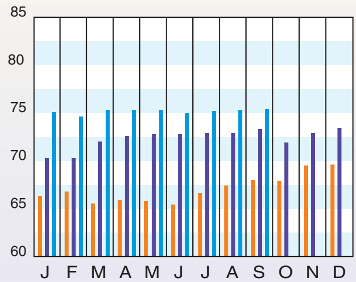
CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



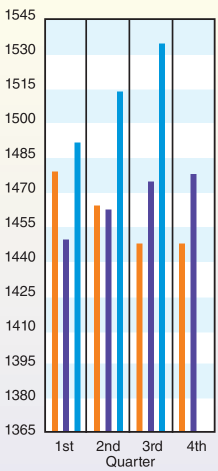
Current Business Indicators provided by Global Insight, Inc., Lexington, Mass.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	3rd Q 2011	2nd Q 2011	1st Q 2011	4th Q 2010	3rd Q 2010
M & S INDEX	1,533.3	1,512.5	1,490.2	1,476.7	1,473.3
Process industries, average	1,592.5	1,569.0	1,549.8	1,537.0	1,534.4
Cement	1,589.3	1,568.0	1,546.6	1,532.5	1,530.0
Chemicals	1,559.8	1,537.4	1,519.8	1,507.3	1,505.2
Clay products	1,579.2	1,557.5	1,534.9	1,521.4	1,518.3
Glass	1,491.1	1,469.2	1,447.2	1,432.7	1,428.5
Paint	1,608.7	1,584.1	1,560.7	1,545.8	1,542.1
Paper	1,502.4	1,480.7	1,459.4	1,447.6	1,444.5
Petroleum products	1,698.7	1,672.0	1,652.5	1,640.4	1,637.0
Rubber	1,641.4	1,617.4	1,596.2	1,581.5	1,579.3
Related industries					
Electrical power	1,517.6	1,494.9	1,461.2	1,434.9	1,419.2
Mining, milling	1,648.6	1,623.5	1,599.7	1,579.4	1,576.7
Refrigeration	1,884.4	1,856.4	1,827.8	1,809.3	1,804.8
Steam power	1,572.2	1,546.5	1,523.0	1,506.4	1,502.3

Annual Index:

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



CURRENT TRENDS

Capital equipment prices, as reflected in the *CE* Plant Cost Index (CEPCI), increased approximately 1.3% on average from June to July, after increasing approximately 0.73% from June to July.

Meanwhile, according to the Current Business Indicators (see middle table) from Global Insight, Inc. (Lexington, Mass.), September saw increases in the CPI output index and the CPI operating rate.

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

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