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January 2009

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Controlling Emissions With Ceramic Filters

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Coal-to-Liquids

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Mixing and Blending

Predictive and Preventive Maintenance

Mechanical Carbon

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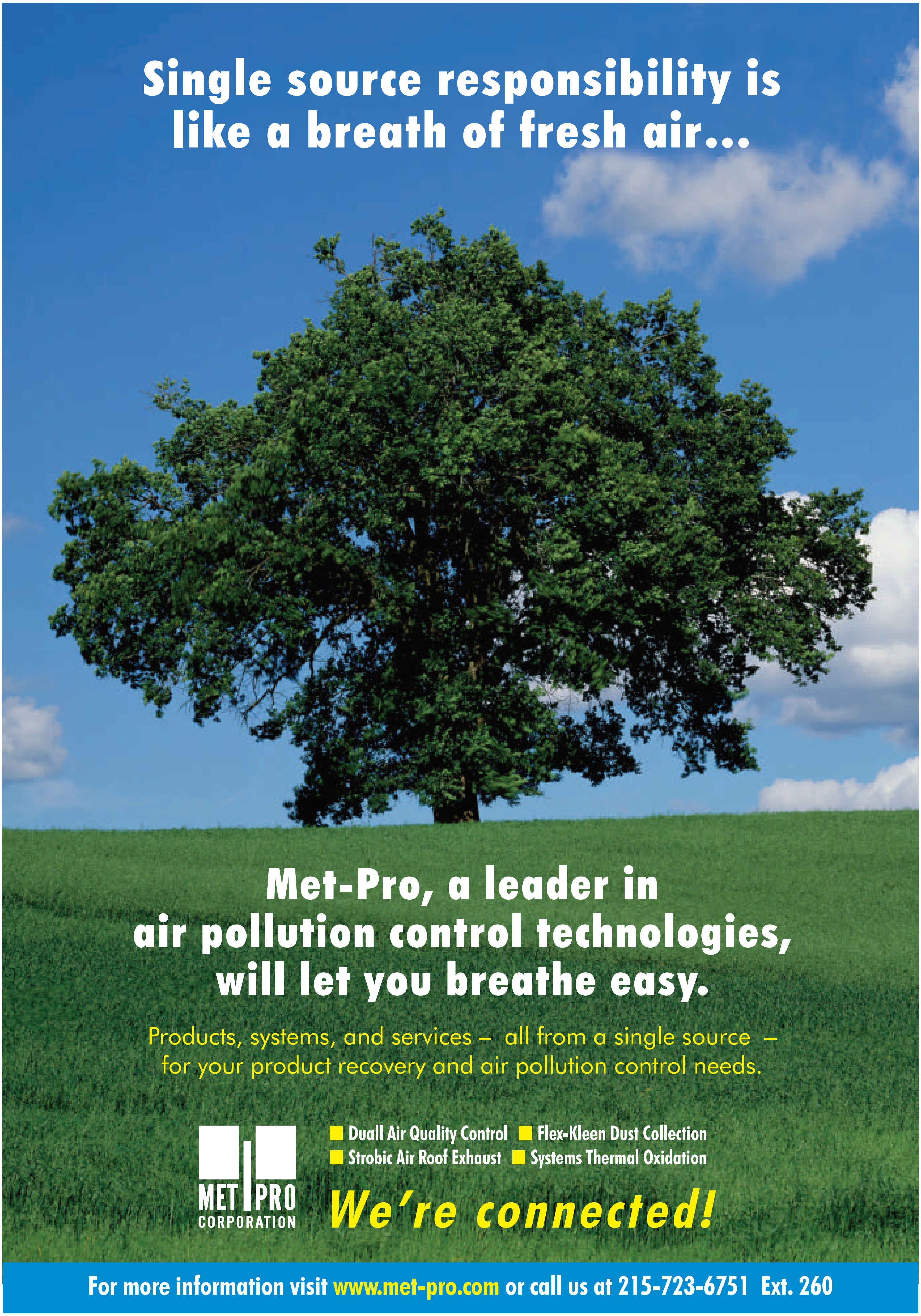
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COVER STORY

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28I-1 New Products & Services (International Edition) This new paddle design simplifies installation and removal; This little data logger stores a lot of measurements; HART communication is now possible with this gas monitor; Size-up protein molecules without sacrificing samples; Temperature monitoring for trace-heating applications; and more

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COMMENTARY

5 Editor's Page **Our 2009 lemonade recipe** The chemical process industries (CPI) are in a deep recession, marked by plant closings and layoffs. There is a sweet side, though, for those who take advantage of smart investments and for projects that require a shutdown

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CHEMICAL ENGINEERING

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Editor's Page

Our 2009 lemonade recipe

First, you'll need a lot of lemons. As 2009 kicks off, sour fruit happens to be in great supply. To be blunt, the chemical process industries (CPI) are in the middle of what appears to be the worst recession since World War II (WWII).

There are many signs that point to such a conclusion, but a particularly clear picture can be drawn from the November 2008 CPI operating rate (see p. 60), which is the industry's most recent figure available on capacity utilization. At 72.7%, the operating rate hasn't been this low since the end of the 2001 recession. "But that data point is of cold comfort," says Mike Montgomery, analyst at Global Insight, Inc., (Lexington, Mass.), "Since the low of the last recession will be passed (going down) with ease [in the December number]." In the release of January data, Montgomery expects the operating rate to fall — again, "with ease" — below any other post-WWII recession except for that of 1981–1982. "The recession is spreading fast, and all the cutbacks in car and truck production announced recently will make January dismal, with slim chance of improvement in February or March," he says.

What is reflected in the declining operating rate is a sharp drop in demand for nearly everything. In response, CPI companies have idled production and are implementing other cost-cutting measures. Last month, Dow Chemical Co. (Midland, Mich.), the U.S.'s largest chemical company in terms of revenue, eliminated 5,000 jobs (or 11% of its workforce) and closed 20 facilities while also announcing plans to temporarily idle approximately 180 plants and reduce its contractor workforce by approximately 6,000 worldwide. Only weeks before, BASF (Ludwigshafen, Germany), the world's largest chemical company, announced plans to temporarily idle 80 plants and to reduce capacity at 100 other facilities. (For more on both, see p. 59.)

The comprehensive list of CPI companies with similar moves is long and includes Arkema, DSM, Eastman, DuPont, Lanxess, Air Products and Merck KGaA. While their cost cutting measures certainly help to dilute the sour effects of the current economic recession, our recipe also calls for something sweet: strategic capital improvements, particularly those that improve performance while also reducing costs.

For instance, the newsfront on predictive and preventive maintenance, p. 20, outlines a number of ways in which substantial returns can be achieved in the short-term with minimal costs. The article also touches on the virtues of industrial wireless technology, yet another powerful tool that brings otherwise-expensive process improvements within reach.

Even some longer-term investments make sense now, for several reasons. The virtual elimination of demand pressures is one; a more opportune time you will not find for projects that require shutdown. Meanwhile, the cost of capital equipment, itself, is decreasing. *Chemical Engineering's* Plant Cost Index (also see p. 60) has been on a steady decline since August. The only categories showing a mild increase at all this month are pumps/compressors and electrical equipment. Categories experiencing the most dramatic decline are tanks and general equipment, due to their high copper and steel makeup. Excess supplies of these raw materials are likely to persist in the form of price breaks for awhile, says Montgomery. As an example, copper hit its low price in 2003, even though the U.S. recession ended in late 2001.

Of course, nearly everyone is pointing out that there is a practical limit on how far consumer spending will retreat. No one knows for sure, however, where the limit is. Most agree with Montgomery that the recovery will be strong as the inventory cycle reverses itself, and job cuts turn to payroll gains. In the meantime, the rest of us will continue squeezing. ■

Rebekkah Marshall

Discussions on pressure relief

I would like to draw your attention to a few points on the November 2008 article, Pressure Relief System Design (pp. 40–45):

1. Pressure drop and pressure loss: The inlet pressure "drop" that the author refers to under Relief system piping is non-recoverable pressure loss, and does not include a "drop" in pressure due to elevation increase. It should be labeled as a pressure loss rather than a pressure drop as the author has specified elsewhere. It may sound trivial, but such errors are not uncommon. The 3% rule is code-mandated and should be followed. However, any excess above this can still be defended in some circumstances in the court of law, but only by an expert analysis.

2a. Bursting of rupture disk: In the penultimate paragraph, when a rupture disk is used in series with a relief valve, the author writes: "... the disk would never burst". The rupture disk (as well as a conventional relief valve) is a differential pressure device. So the disk will burst when the difference between the upstream pressure and the downstream pressure of the disk equals the burst pressure of the disk (or the set pressure of a conventional relief valve).*

2b. Pressure indicator between a rupture disk and relief valve: The second point in this subject is the illustration of Figure 5 which is backed by the author's recommendation: "whenever a rupture disk is installed upstream of a relief valve, it is important to have a pressure indicator in the section between the two." If the author is following the ASME VIII, Div. 1, the paragraph UG-127 stipulates the following: "the space between a rupture disk device and a pressure relief valve shall be provided with a *pressure gage, a try cock, free vent, or suitable telltale indicator*. This arrangement permits detection of disk rupture or leakage." Because of the presence of a serial comma in the phrase in italic letters, a grammatical parsing of the phrase accepts the author's recommendation to include just a pressure gage to be in technical compliance with the code. However, the spirit of intent of the code will not be followed by such design. In fact just the installation of a pressure gage is not enough and it is unsafe to do so.*

3. K.O. drum: By showing the K.O. drum in strategic position, the author implies two-phase flow possibilities. The DIERS (Design Institute for Emergency Relief Systems) does not recommend the use of conventional relief valves for applications with potential two-phase flows. The pressure drop calculations for two-phase flows are more complex than the methods used by the author.*

Dilip K. Das, P. E.
Bayer CropScience, Kansas City, Mo.

Author replies

1. Pressure drop and pressure loss: Having worked in various projects worldwide, I had a look at process data sheets for the terminology used for permanent pressure loss. In many cases, I found that the term "pressure drop" has been used to denote permanent pressure loss, such as in flow-orifice data sheets. The following books also use the

* This letter has been abbreviated to fit here. The full letter and response can be found at www.che.com by searching for the title of the article.

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Thanks,

Brent Boudreaux
KBR Project Engineer

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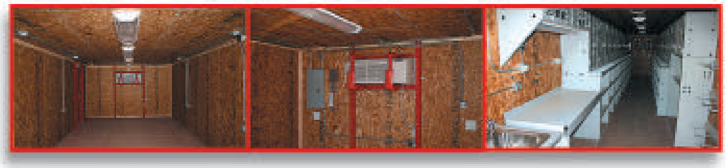

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Letters

term "pressure drop" instead of "pressure loss":

- "Control Valve Handbook", 4th edition, by Emerson
- "Applied Instrumentation in the Process Industries" Vol III (Andrew WG/Williams HB) and Vol IV, (Leslie M Zoss)
- "Perry's Chemical Engineers' Handbook" uses the term frictional losses in some cases. However, at many places, it also uses the term "pressure drop" for two-phase flow, single-phase flow, flow in spirals, annular flow, flow through beds of solids and so on
- Even the API 521 (5th Ed, January 2007) uses the term "pressure drop" at many places

The term "pressure drop" may be interpreted by some as a drop in pressure due to elevation increase. However, references show that in several cases, the term "pressure drop" has been used to denote frictional losses.

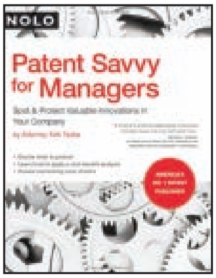
2a. Bursting of rupture disk: When I mentioned "rupture disk would never burst", what I meant was "rupture disk would never burst at its burst pressure". An example is illustrated in a rupture disk with a burst pressure of 90 psig. The protected equipment design pressure is 100 psig. A pinhole develops and the space between the rupture disk and the relief valve reaches a pressure of 60 psig. Now the contingency develops. The protected equipment reaches 90 psig (the burst pressure of the disk). Downstream of the rupture disk, the pressure is 60 psig. At this stage, we would expect the rupture disk to burst, but it will not, because the differential pressure is only 30 psig (90 – 60). Now the protected equipment reaches 100 psig (its design pressure). Even now the disk will not burst. This is what I meant by my statement in the article. The pressure in the protected equipment now further develops until it reaches 160 psig. Downstream of the rupture disk, the pressure has reached 70 psig. Only at this stage will the rupture disk burst. But the damage to equipment may have been done. It may be argued that there is a margin of safety in the vessel. However, this is not what the design was intended for. The disk should burst at its burst pressure.

2b. Pressure indicator between a rupture disk and relief valve: The pressure indicator between the rupture disk and the relief valve, of course, needs monitoring. We have detailed designs of combinations of rupture disks and relief valves with a pressure switch on the line and an on/off valve, which depressurizes the system once the pressure reaches a certain set value. Detailed schemes such as these could be the subject of another article.

3. K.O. drum: Yes there are two-phase flow possibilities. But two-phase flow will not necessarily occur all the time. Single phase flows are also possible. Please note that Figure 1, where the K.O. Drum is shown has no direct relation with the illustrated example. The example illustrates a single-phase flow calculation to show how discharge-side piping headers and branch lines are sized. The basic theory and equations for single phase flow will not change, whether it is the more recent API 521 (January 2007) or the relatively older API standard cited in the article. For two-phase flow, there are several references in the literature. But it was not the intent here to illustrate a two-phase flow calculation.

Siddhartha Mukherjee
Lurgi India Co., Ltd.

Bookshelf



Patent Savvy for Managers. By Kirk Teska. Nolo, 950 Parker St., Berkeley, CA 94710-2524. Web: nolo.com. 2007. 278 pages, $29.99

Reviewed by Charles R. Richard, Patent Attorney, Washington, D.C. crobrich@yahoo.com

The book I am reviewing here is one in a series of Nolo guides geared toward non-lawyers on various legal topics and their aspects. I must caution readers that although this book provides some good background into the world of patenting, it is no substitute for consultation with a competent patent attorney or agent when appropriate. Although I did not notice problems with it, I cannot guarantee that this book is "complete" for any reader's purpose and/or error free, nor do I necessarily agree with all the author's opinions/advice. (Sorry for the disclaimer, but that is the world we live in.)

Mr. Teska takes readers through various practical and important patenting topics using easy-to-understand language and provides as illustration interesting (sometimes even humorous) stories, many based on actual patent cases. I am pleased to see the inclusion in Chapter 3 of one of my favorites, the Dembiczak case (also known as the "Pumpkin Case"), as an illustration of non-obviousness; after reading about it, readers should agree that patents can be fun! Unfortunately, there were few if any chemical case examples, but this is to be expected from a book that is aimed at a general technical audience; examples focus on technology that is generally familiar.

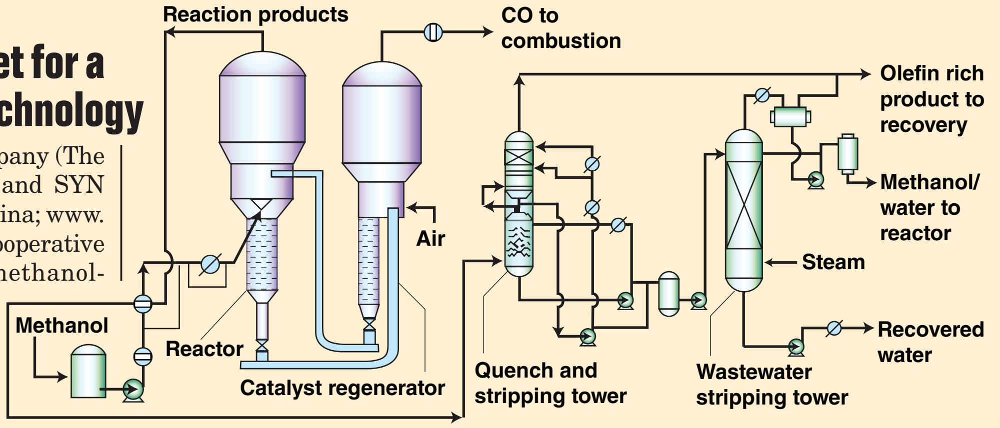
The book contains an introduction that is worth reading, ten chapters, an extensive glossary and an index. Chapters 1–4 cover important background patent principles and myths (this book might well be worth reading to see these alone), case studies, patentable subject matter and patentability standards, and understanding claims and how to read a patent — all very useful to know.

Chapters 5–8 take up "capturing" patentable inventions, getting to patent pending, patent prosecution and going international; some very practical information/advice on costs, timing and how the patenting process should work, as well as perspective on what many activities relating to patenting actually provide and may be worth are included. I recommend taking a good look at the discussion on searching in Chapter 6, even though the author may be a bit more negative than warranted. The comments on patent examiners in Chapter 7 should be very revealing for those with little experience with the U.S. Patent Office.

Any reader who thought that patent litigation might be desirable would be advised to take the discussion in Chapter 9 into account before making any decision in an actual case. The comments on licensing in Chapter 10 will probably be illuminating for neophytes as well as for many who have had experience here.

(Continues on p. 28)

Commercialization is set for a methanol-to-olefins technology



Lummus Technology, a CB&I company (The Woodlands, Tex.; www.cbi.com) and SYN Energy Technology Co. (Dalian, China; www.syn.ac.cn) have signed a global, cooperative market agreement to license a methanol-to-olefins (MTO) process. The technology, called DMTO, was developed by the Dalian Institute of Chemical Physics, Chinese Academy of Sciences (Dalian, China), which has a controlling interest in SYN.

The first application of the technology will be in a coal-gasification-MTO complex that is being built by Shenhua Baotou Coal Chemicals Co. in Baotou, China. The olefins plant will convert 1.8-million metric tons (m.t.) per year of methanol into 600,000 m.t./yr of ethylene and propylene. Startup is scheduled for 2010.

In the DMTO process (flowsheet), methanol is fed to a fluidized-bed reactor and converted by a molecular sieve catalyst to ethylene, propylene, some butene, and 1–2% coke and light ends, plus 55% water. Conversion takes place at slightly above atmospheric pressure and 400–550°C, depending on the amount of propylene desired. The ratio of propylene to ethylene can range from 0.8 to 1.2:1, depending on the reaction conditions, says Helion Sardina, vice president and general manager of Lummus Technology.

Currently, the economics of the process are roughly equal to those of naphtha-based plants, with naphtha priced at around \$375/m.t. and methanol at roughly \$140/m.t., says Sardina. He expects the process will find a ready market in regions where there is an abundant supply of coal, such as China, or where there is stranded natural gas that can be converted to methanol. He also sees a large market potential in the addition of capacity at existing steam crackers.

More efforts to capture CO_2 from power plants

Aiming at bringing down the barriers to the commercial deployment of post-combustion capture (PCC) of CO_2, an Australian team from CSIRO Energy Technology (Newcastle, New South Wales; www.csiro.au), CSIRO Energy Technology (Clayton South, Victoria), and several other research organizations has developed an integrated PCC R&D and pilot plant program. The program includes four pilot plants:

- The Latrobe Valley PCC pilot plant at the Loy Yang power station in Victoria started operating in March 2008. It is based on amines as the CO_2 solvent. It will be tested on flue gases from Victorian brown coal. The capture plant capacities range from 100 to 500 kg/h of CO_2
- The second pilot plant, based at Delta Electricity's Lake Munmorah black-coal-fired power station in NSW, is undergoing commissioning. The plant is based on aqueous ammonia for CO_2 capture
- A third plant, to be located at the Tarong power station in Queensland will focus on the determination of an optimum solvent for flue gases. The plant will be constructed in the first half of 2009 and will be ready for operation in the second half of 2009
- CSIRO has also partnered with the Xi'an Thermal Power Research Institute and China HuaNeng Group for the development and operation of an amine based pilot plant at the HuaNeng Beijing Co-generation Power Plant. This power station has fluegas desulfurization (FGD) and deNOx. (The Australian power plants do not have FGD and deNOx.) The Chinese plant will help CSIRO understand the tradeoffs between an integrated pollution control system and separate control technologies for each pollutant. It has been operating since June

PCC science leader Paul Feron, of CSIRO Energy Technology, says further development of the capture technology and the power plant technology can lead to power-plant-generation efficiencies with 90% CO_2 capture, which are equivalent to the current efficiencies without CO_2 capture (For more on CO_2 capture, see *CE*, December 2008, pp. 16–20).

Bioethanol

Last month, an energy-saving plant for producing bioethanol started up in Norrköping, Sweden, for Lantmännen Agroetanol AB. When operating at full capacity, the plant will produce 470,000 L/d of bioethanol from grain (mostly wheat), making it the largest bioethanol facility in Northern Europe. The plant is based on the Multipressure system of Vogelbusch GmbH (Vienna, Austria; www.vogelbusch.com). The Multipressure system uses several distillation columns operating at different steam pressures, which results in a "significant" reduction in steam consumption — over 50% less than conventional technology, says Vogelbusch. Additional energy savings are achieved through optimal thermal integration of the distillation and dehydration processes.

Photolithography

Last month, Sumitomo Chemical Co. Ltd. (Tokyo, Japan; www.sumitomo-chem.co.jp) started up a \$120-million plant for producing argon-fluoride (ArF) liquid immersion (LI) semiconductor resist at its Osaka factory. The facility has a production capacity of 100,000 gal/yr, which the company says will give it one third of the global market share — two thirds of which is in Asia — for ArF LI resists, which are use in ArF excimer-laser (λ = 193 nm) photolithogtaphy.

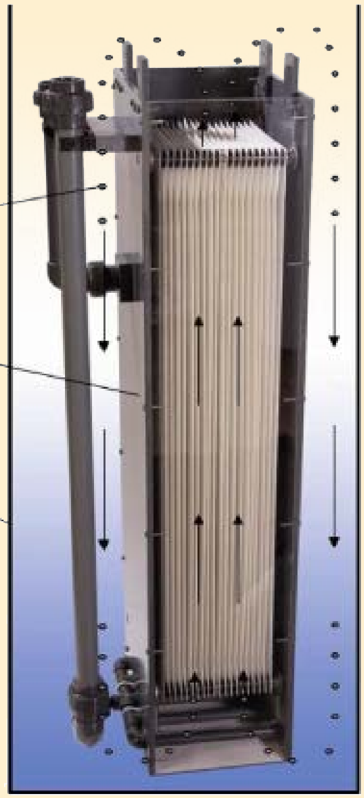
(*Continues on p. 14*)

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

This mechanical cleaning process reduces fouling in MBRs without chemicals

For wastewater treatment, membrane bioreactors (MBRs) provide superior effluent quality in a small footprint compared to alternative activated-sludge treatment methods. However, MBRs are prone to fouling, and thus may require frequent membrane cleaning with the associated manpower and chemical costs. Microdyn-Nadir GmbH (Wiesbaden; www.microdyn-nadir.de), in cooperation with Darmstadt University (both Germany), has developed a unique fouling-control process, called Bio-Cel-MCP, which does not require chemicals. Tests conducted on two pilot plants operating continuously for more than 400 days have demonstrated that the process leads to a 40% increase in flux compared to a standard MBR operating without MCP, says Stefan Krause, head of water-treatment technology & applications at Microdyn-Nadir.

The MPC process is based on the principles of fluidized-bed technology. Small (3-mm dia.) plastic granules are added into the filtration basin (inside the activated sludge), and are forced to flow upward alongside the membranes by an air-induced crossflow — mechanically cleaning the membrane as they rise — and then settle back down by gravity after leaving the module (diagram). In the pilot plants, back-washable, flat-sheet membranes (Bio-Cel) are used. The hydraulic flow conditions of this module allow the addition of particles for fouling control. Also, the mechanically strong and permanent hydrophilic flat sheet PES (polyethersulfone) membranes (Nadir UP150) have been shown to withstand the cleaning action of the granules as demonstrated by the continuous operation of the MBR module at high flux rates (23.6 gallons per square foot of membrane per day) without significant decrease of permeability, says Krause. After more than one year of operating the two pilot plants, the average COD (chemical oxygen demand) removal was about 95%, and online measurement of the turbidity of the effluent showed no disturbance, indicating a constantly high removal of suspended solids and hence an intact membrane, he says. Krause estimates the the return-on-investment for an MPC system at about six months.



Pretreatment helps recover more coal from primary flotation step

Coal is typically cleaned by gravity separation to reduce ash and pyrite content, with flotation used to recover fines. Various methods have been applied to disperse fine clay particles from the surface of coal particles and thus improve coal flotation performance. A team of researchers from the Ian Wark Research Institute, University of South Australia (Adelaide; www.unisa.edu.au), has studied the effect of fine clay on the flotation of several coal samples. It found that the removal of fine particles either from the primary tailings or the feed sample by sieving (38 µm) or de-sliming with a Mozley hydrocyclone gave vastly improved flotation performance of the coarse coal particles. Team member Keith Quast says this process recovers coal that did not float in the primary flotation stage, and would otherwise be lost to the process. In both cases, he said, the removal of slimes from the circuit stage gave a better overall combustible recovery than processing a feed that had received no pretreatment.

The team has found that the removal of fine particles leads to an increase in coal recovery from 28% (after 20 minutes flotation using 64 g of diesel per ton of coal) to 79% with screening at 75 µm, and 97% with screening at 38 µm (after 12 min flotation; 40 g diesel/ton coal). It says that the process' downside is that it leads to a fine product that cannot be discarded since it contains significant amounts of coal that would be difficult to recover by flotation. The losses of coal in the screened fines represent 26% (screening at 75 µm) and 22% (screening at 38 µm).

However, the team also conducted experiments to compare the effects of fine-particle removal by either wet screening the feed or the primary flotation tailing at 38 µm and de-sliming the feed or tailing using the Mozley cyclone. The results showed that the removal of fines from the primary tailing by sieving or de-sliming allows a high proportion of the coal to float using a smaller addition of diesel (20 g/ton instead of 54 g/ton).

(*Continued from p. 13*)

The company has begun mass production of Sumiresist PAR, a specific photo acid generator (PAG) for the manufacture of 50-nm-node memory, which performs well without a top coating. Another product being produced is for 40-nm-node logic device applications. The company is also in the final stages of developing an LI resist for 40-nm-node DRAM (dynamic random access memory) and Flash memory, and preparing for the development of 30-nm-node processes.

Tough ceramic

Scientists at the DOE's Lawrence Berkeley National Laboratory (Calif.; www.lbl.gov) have synthesized a ceramic that imitates the structure of Nacre (mother of pearl). Nacre is 95% aragonite, a hard, brittle calcium-carbonate mineral, and 5% "soft" organic molecules, and yet can be 3,000 times more resistant to fracture (toughness)than aragonite. By emulating the microstructure of Nacre, the scientists have created large, porous ceramic scaffolds and "brick-and-mortar" structures.

The hybrid ceramics are

(*Continues on p. 16*)

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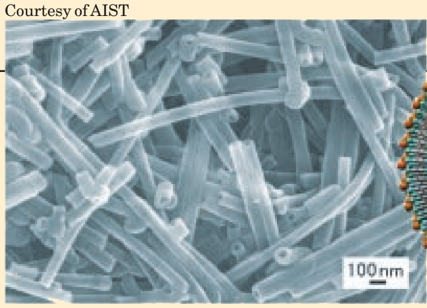
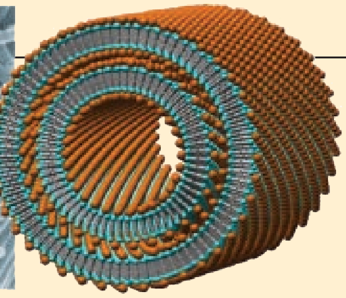




orange ball	=	metal ions
light blue ball	=	hydrophyllic part of the peptide lipids
gray stick	=	hydrophobic part of the peptide lipids

Mass-production technology for making functionalized organic nanotubes

Researchers at the Nanotube Research Center of the National Institute of Advanced Industrial Science and Technology (AIST; Tokyo; www.aist.go.jp) have developed a process for making organic nanotubes of metal complexes (photo, left). The scientists have produced organic nanotubes with metal ions (Zn^{+2}, Cu^{+2}, Co^{+2}, Ni^{+2}, Fe^{+2} and Mg^{+2}) complexed at the inner and outer surfaces of organic nanotubes (diagram, right), and believe such materials will find applications as: new catalysts with transient metal coordinated spatially on the inside; low-molecular-weight compounds with coordinated functional groups; DNA and protein inclusion, adsorption, and separation for biotechnology; and new electronic, magnetic and optical materials. For example, a Cu-complexed organic nanotube has been shown to selectively adsorb gold nanoparticles that have an amino group on their surface.

The new nanomaterials are made by adding aqueous solutions of metal salts to a suspension of peptide lipids in methanol or ethanol. Nanotubes form after 10 minutes, producing about 2–20 g/mL of suspension — a production rate about 200 times higher than alternative methods. The simple procedure consumes little energy and is easy to scale up, says AIST.

This is the third mass-production process for making organic nanotubes that has been developed by AIST. The previous processes produce organic nanotubes with hydroxyl and carboxyl groups on the surface.

Continued commercial success for a new MEG process

When completed in early 2010, Shell Chemicals' B.V. (The Hague, Netherlands; www.shell.com) 750,000-m.t./yr facility at the Shell Eastern Petrochemicals Complex in Singapore will be the world's largest plant to produce mono-ethylene glycol (MEG) using Shell's Omega process. This plant marks the fifth license of the Omega technology since the first commercial application came on stream last May — a 400,000 m.t./yr facility for Lotte Daesan Petrochemical Corp. (Daesan, Korea).

Omega (short for Only MEG Advanced) integrates two complementary and highly selective processes: Shell's Master EO (ethylene oxide) process and a catalytic MEG conversion process originally developed by Mitsubishi Chemical Corp. (MCC; Tokyo; www.m-kagku.co.jp), and acquired exclusively by Shell in 2002 (for more process details, see *CE*, July 2002, p. 19). The process achieves a selectivity of EO to MEG of 99.3–99.5%, compared to about 90% for conventional processes, and produces up to 1.95 ton of MEG per ton of ethylene, compared to 1.53–1.70 ton, depending on the catalyst used, says Shell.

According to Shell, capital costs for a new Omega plant are about 10% less, at equal MEG yield, compared to alternative technologies. Omega also generates 30% less wastewater, has 20% lower steam consumption at equal EO reaction selectivity, and produces negligible amounts of byproducts, such as diethylene glycol and tri-ethylene glycol derivatives, thereby eliminating the need for the infrastructure and resources needed to handle and market these products.

A new PFSA polymer for membrane and other applications

Solvay Solexis S.p.A. (Bollate, Italy; www.solvaysolexis.com) has commercialized a new perfluorosulfinic acid (PFSA) polymer, tradenamed Aquivion, which was specifically designed for polymer electrolyte membrane (PEM) fuel cells. Aquivion ionomer membranes are melt-extruded products based on the Short Side Chain (SSC) copolymer of tetrafluoroethylene and a sulfonyl fluoride vinyl ether of low molecular weight. The membranes enable PEM cells to operate over a broad temperature range with improved ion conductivity.

The membranes are also suitable for applications in water electrolyzers, H_2 separators, and pervaporization or gas humidification systems. The polymer is also available as a dispersion that can be used for making electrodes, super-acid catalysts or for surface treatment of membrane-filtration devices.

(*Continued from p. 14*)

made through the controlled freezing of aqueous suspensions of an aluminum oxide (alumina) and the addition of polymethylmethacrylate (PMMA), producing materials that are 300 times tougher than their constituents. To make even tougher materials, the researchers are working to increase the proportion of ceramic to PMMA (presently 85 wt.% alumina), and by replacing PMMA with a different polymer or, eventually, metal.

Self-healing coatings

Researchers at the University of Illinois (Champaign; www.illinois.edu) have developed coatings that automatically repair themselves and prevent corrosion of the underlying substrate. The coating is made by encapsulating in separate, 100-µm-dia. beads, a catalyst and a healing agent. The beads are then dispersed within the desired coating material to be applied to the substrate. When the coating is scratched, the contents of the damaged beads is released, causing the catalyst and healing agent to mix. The subsequent reaction is said to repair the damage within minutes or hours, depending on the environmental conditions.

New engineered polymers

Kraton Polymers LLC (Houston, Tex; www.kraton.com) has introduced two new sulfonated copolymers, MD9150 and MD9200, for ion-exchange and high-water-transport applications. The new polymers are selectively mid-block sulfonated copolymers and are available in both membranes and solution form.

A hard coating promises to reduce wear and power use in rotating equipment

Researchers at the U.S. Dept. of Energy's (DOE; Washington, D.C.) Ames Laboratory (www.ameslab.gov) and Iowa State University (both of Ames, Iowa) have developed a hard, smooth coating that can be applied to industrial equipment, such as pumps, gears and cutting tools, to reduce friction and extend the life of the equipment. Ames has been working with various companies, including Eaton Corp. (Cleveland, Ohio; www.eaton.com), whose products include hydraulic pumps.

The coating material is a ceramic alloy that combines boron, aluminum, magnesium and titanium boride, says Alan Russell, a professor of materials science and engineering at the university. These ingredients are milled to a particle size of 0.5–1 µm, thoroughly mixed, then compressed in a graphite die at about 1,400°C and 14,000 psi to form a solid, dense block.

The researchers have been using a technique called pulsed laser deposition to dislodge atoms from these blocks and deposit 1-µm coatings on adjacent targets, such as pump vanes. However, this method is not practical for commercial use, says Russell, so Eaton is using magnetron sputtering, a commercial-scale process. This is done in a vacuum chamber and uses radio frequency energy to ionize argon. The ions dislodge atoms for deposition on the target.

In laboratory tests the coating has proved to have only about 5% the wear rate of tungsten carbide, says Russell. He adds that in tests of rotating parts, performed by Eaton, the coatings have reduced power requirements by up to 8%, due to less friction.

Filtering oil from water

Material engineers at Perdue University (West Lafayette, Ind.; www.purdue.edu) have developed a new type of membrane for separating oil from water. The membrane consists of a layer of perflourinated end-capped polyethylene glycol, which is covalently bonded to fritted glass membranes. When an oil-in-water emulsion is passed through the membrane, the oil beads up on the Teflon-like surface, while the water passes through. A 98% separation efficiency has been observed in the labortatory, using hexadecane as a model oil.

OLEDs

BASF SE (Ludwigshafen, Germany; www.basf.com) and Osram Opto Semiconductors GmbH (Regensburg, Germany; www.osram-os.com) have developed a highly efficient white organic light-emitting diode (OLED) that achieves a light yield of over 60 lumens per Watt, while also meeting the international Energy Star SSL Standard with regard to color requirements. The new OLEDs contain phosphorescent metal complexes as emitter materials and customized complementary materials; this

(*Continues on p. 18*)

(Continued from p. 17)

combination enables the diodes to be "color-stable" even when there are variations in luminous intensity.

EPA proposal on HCFCs

The U.S. Environmental Protection Agency (EPA; Washington, D.C.; www.epa.gov) has proposed a new rule to decrease the consumption and production of hydrochlorofluorocarbons (HCFCs) for the years 2010 (by at least 75%) to 2014. HCFCs are ozone-depleting substances and potential greenhouse gases, and as a party to the Montreal Protocol on Substances that Deplete the Ozone Layer, the U.S. will completely phase out HCFCs in 2030.

This action will also amend provisions concerning HCFC production for developing countries' basic domestic needs and would clarify a ban on the sale and distribution of HCFCs through interstate commerce under the Clkean Air Act. EPA will accept comments on the proposed rule for 60 days after publication in the Federal Register. ❏

This LNG vaporization process will reduce air emissions

A new method for vaporizing liquefied natural gas (LNG) that is more environmentally friendly than the traditional submerged combustion vaporization (SCV) process is being offered by Black & Veatch (B&V; Overland Park, Kan.; www.bv.com).

In an SCV process, LNG is passed through stainless steel tubes in a water bath that is warmed by sparging combustion gases from a submerged, gas-fired burner. The thermal efficiency is close to 100%, says Brian Price, vice-president of LNG technology for B&V. However, he points out, the downside is that the combustion gases create nitrous, nitric, carbonic and other acids in the water bath and the stack gas emissions contain oxides of nitrogen (NOx) and carbon monoxide. Also, the bath has to be neutralized to maintain a pH above 6 and the bath water has to be treated for disposal.

B&V calls its method fired heater vaporization technology (FHVT). The process uses a conventional fired heater with a low-NOx burner and fluegas recirculation. The combustion gases are used to heat a closed-loop circulating fluid (usually water) to 100–200°F. This loop vaporizes the LNG via a shell-and-tube heat exchanger.

The company has obtained a configuration patent on the technology, but has not piloted it, says Price, who notes that it uses conventional components. He points out that the process avoids the disposal of large volumes of wastewater and is calculated to reduce NOx emissions to close to those of an SCV system that is equipped with selective catalytic reduction. CO emissions are expected to be less than 20% of those from an SCV. Preliminary calculations indicate that the process has an overall efficiency comparable to that of SCV, says the firm. ■

KIRKPATRICK CHEMICAL ENGINEERING ACHIEVEMENT AWARD

Nominations for the 2009 round are now open

Many of you know of a company — perhaps your own employer — that has recently commercialized an innovative process, product, or other chemical-engineering development. If so, we would like to hear from you. Nominations are open for this magazine's 2009 Kirkpatrick Chemical Engineering Achievement Award. We aim to honor the most-noteworthy chemical engineering technology commercialized anywhere in the world during 2007 or 2008.

Chemical Engineering has awarded this biennial prize continuously since 1933. The 2009 winner will join a long and distinguished roster, studded with such milestones as BOC Group's low-temperature NOx absorption out of fluegases (2001), Amoco Chemical's anaerobic treatment of process wastewater (1991), Tennessee Eastman Co.'s coal-based acetic anhydride (1985), E.I du Pont Nemours & Co.'s hollow-fiber reverse osmosis (1971), Dow Corning Corp.'s silicone products (1955), The Dow Chemical Co.'s magnesium from seawater (1941) and Carbide & Carbon Chemical's petrochemical syntheses (1933). The most-recent achievements appear in the table.

How to nominate

Nominations may be submitted by any person or company, worldwide. The procedure consists simply of sending, by March 15, an unillustrated nominating brief of up to 500 words to:

Rebekkah Marshall, Secretary
Kirkpatrick Award Committee
c/o Chemical Engineering Magazine
110 William St., 11th floor
New York, NY 10038

Email: kirkpatrick@che.com

The nomination should summarize the achievement and point out its novelty, as well as the difficulty of the chemical-engineering problems solved. It must specify how, where and when the development first became commercial in 2007 or 2008.

If you know of an achievement but do not have information to write a brief, contact the firm involved, either to get the information or to propose that the company itself submit a nomination. Firms are also welcome to nominate achievements of their own.

THE MOST-RECENT WINNERS

2007 — Axens. For its Esterfip-H process for making biodiesel fuel

2005 — Chevron Phillips Chemical. For significant advances in alpha-olefins technology

2003—Cargill Dow LLC. For producing a thermoplastic resin based on corn as the starting material

2001— BOC Group, Inc. For low-temperature NOx absorption out of fluegases

1999 — CK Witco Inc. For a streamlined process to manufacture organofunctional alkoxysilanes

1997— Membrane Technology & Research, Inc. For a system to recover monomer from polyolefin-plant purge streams

1995–Air Products and Chemicals, Inc. For oxygen-based technology enabling efficient recycle of office wastepaper

For earlier winners, see *CE*, Feb. 16, 1987, p. 41, and Feb. 5, 1973, p. 40.

The path to the winner

After March 15, the Secretary will review the nominations to make sure they are valid — for instance, that the first commercialization did in fact take place during 2007–2008. Then she will submit copies to more than 100 senior professors who head accredited university chemical engineering departments and, accordingly, constitute the Committee of Award. Working independently of each other, each professor will vote for what he or she considers to be the five best achievements, without trying to rank them.

The five entries that collectively receive the most votes become the finalists in the competition. Each finalist company will then be asked to submit more-detailed information — for instance, a fuller description of the technology, performance data, exhibits of press coverage, and/or a description of the teamwork that generated the achievement.

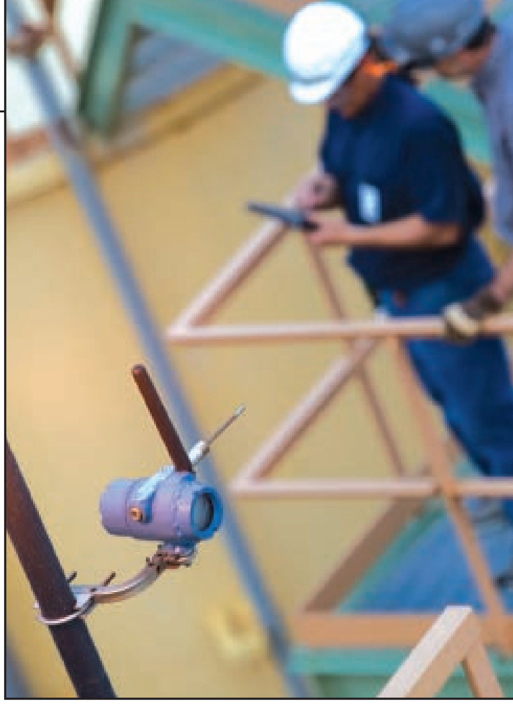
The Secretary will send copies of these more-detailed packages to a Board of Judges, which, meanwhile, will have been chosen from within, and by, the Committee of Award. In late summer, the Board will inform the Secretary as to which one of the five finalist achievements it has judged the most noteworthy. The company that developed that achievement will be named the winner of the 2009 Kirkpatrick Chemical Engineering Achievement Award. The four other finalist companies will be designated to receive Honor Awards. Sculptures saluting the five achievements will be bestowed with appropriate ceremony in the fall. ■

Rebekkah Marshall

PM AND PDM: CRUCIAL GEAR IN THE CPI TOOLBOX

Given that predictive and preventive maintenance programs save money and increase uptime, the capital expenditure is relatively easy to justify

Emerson Process Management



Emerson's wireless field network at PPG installs easily and is up and running in five minutes

With the challenging global marketplace and these unstable financial times, the chemical process Industries (CPI) must do everything possible to economically maintain production while providing innovative and high quality products for their customers. To achieve both these goals, predictive and preventive maintenance programs are possibly the most important gear in any processors toolbox.

Not only will performing predictive and preventive maintenance tasks on at least critical process equipment help extend the life of those assets and reduce capital spending, but it will also reduce downtime, which leads to greater production rates, and keep machinery running to specification, which helps ensure product quality. However, while all industrial facilities require maintenance in order to keep on running, the CPI have a few unique challenges, including a complex and diverse set of operations in any one facility.

"There may be differences of complex chemical synthesis with very specialized equipment and significant variations of scale from small bioreactor systems up to enormous ethylene manufacturing units, all with different unit operations in a single facility," explains Michael McAtee, senior vice president of engineering and maintenance for BASF Corp. (Florham Park, N.J.). "Other industries, such as [petroleum] refineries tend to have a fairly small slate of unit operations they perform, and it's just a question of what scale they operate those in."

McAtee adds that because of the variations from site to site, each chemical processing plant will have a different set of tools and techniques in place. "I'm not aware of any facility that has applied every type of maintenance tool to every plant or the same tools in every plant and successfully kept it in place. This isn't necessary to yield efficient results."

What is necessary, however, is a strong foundation for predictive and preventive maintenance. "No matter what discipline of the chemical processing industry, the maintenance team has to have a solid framework to build upon," McAtee says. Most start with a Computerized Maintenance Management System (CMMS) that serves as the base for data capture, work planning and scheduling, materials management and repair history. "From our perspective, the CMMS is the foundation that leverages any of the other more sophisticated predictive and preventive maintenance tools," notes McAtee.

The CMMS should be combined with tools and field devices that monitor and analyze the health of critical equipment, such as instrumentation, rotating equipment and fixed or large assets. The data from these tools, he says, should be tied into a centralized database that allows all the field conditions and information to be analyzed more effectively and provides trend analysis, as well as suggestions back to the maintenance staff or operations regarding whether a piece of equipment needs attention.

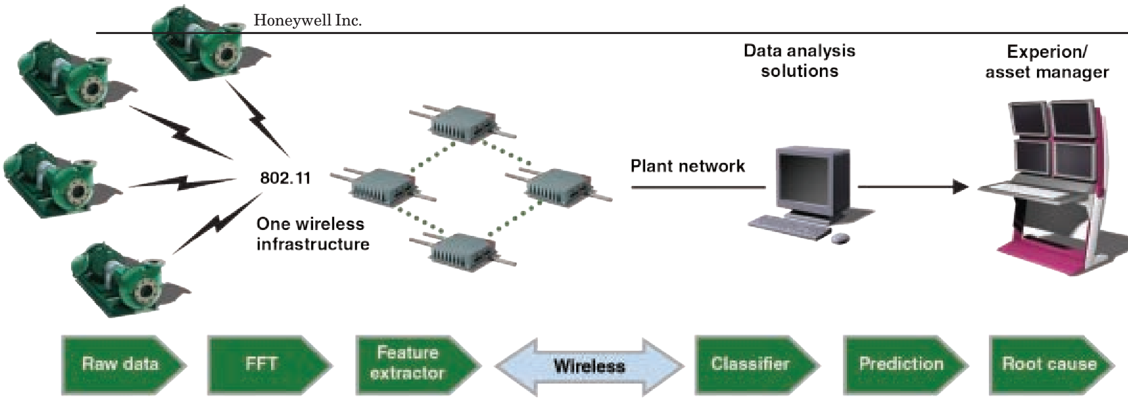
"A setup that provides early identification of potential performance problems usually results in a successful maintenance practice," says McAtee.

Early identification of problems is key to predictive and preventive maintenance practices, which are crucial in today's economy because they turn maintenance from a reactive effort into a more proactive one where problems are spotted early and corrected during planned maintenance intervals during slow production times.

"It's important for chemical processors to operate their equipment without any surprises and with minimal possible maintenance costs. Unplanned and unscheduled work tends to be two to four times as expensive as planned maintenance work," explains Bart Winters, reliability solution manager with Honeywell Process Solutions (Morristown, N.J.) "For this reason, the goal of most chemical processors is to operate from planned shutdown to planned shutdown without any unplanned downtime in between."

This goal is especially important during a time when raw material costs are still on the rise and energy prices are fluctuating, according to Scott Hokeness, business development manager of the Asset Optimization Division of Emerson Process Management (Austin, Texas). For this reason, now is the time chemical processors should be looking into leveraging new tech-

Honeywell Inc.



The XYR 6000 SmartCET wireless corrosion monitoring transmitter is part of Honeywell's OneWireless Solution, which allows processors to reap the benefits of equipment monitoring without the expense of installing wires. Without wires these transmitters can be installed and operating in minutes to quickly provide information back to a system

PREDICTIVE AND PREVENTIVE MAINTENANCE SERVICE PROVIDERS

ABB	www.abb.com
Emerson Process Management	www.emersonprocess.com
Honeywell	www.honeywell.com
Invensys Process Systems	www.ips.invensys.com
Rockwell Automation	www.rockwellautomation.com
Siemens Energy & Automation	www.siemens.com/process
Yokogawa	www.yokogawa.com

nologies. "New technologies can make a huge difference," says Hokeness. "What we typically see is that for optimized plants, customers are doing approximately 10% reactive maintenance and 90% planned maintenance. In plants that don't embrace technology, we see typically up to 50% reactive maintenance. Using technology to plan for maintenance can save a lot of money during hard economic times."

Going wireless

New wireless solution technologies are one area where processors can benefit, says Hokeness. Many facilities have started installation, implementation and utilization of wired devices and sensors that gauge the health of critical assets, but stopped short of going all the way due to the associated costs. "But with the advent of more advanced wireless technologies, it is very inexpensive to finish the process," he says. "The installed cost savings is up to 90% over wired technologies because you don't have to pull wires to different pieces of equipment. This allows you to reap the benefits of monitoring without the price tag."

Emerson's Smart Wireless solution is an extension of its PlantWeb digital plant architecture, combining highly reliable, smart monitoring devices with wireless transmitters in a self-organizing mesh network that automatically adapts as device points are added or removed, or obstructions encountered.

PPG Industries installed the Smart Wireless solution at its facility in Lake Charles, La. The plant's wireless network uses ten Rosemount transmitters for measurement of pipeline and steam header temperature, thereby enabling operators to watch for cold spots and adjust steam throughput. PPG also plans to use the Smart Wireless solution to do temperature profiling of the entire expansive plant, enabling load sharing and balancing to maintain superheated steam, plant wide. The processor has also commissioned eight wireless transmitters on the self-organizing mesh for tank level measurements to provide back up of primary radar-level measurements, helping ensure level control.

Wireless transmitters allow PPG to install instrumentation that would normally be cost-prohibitive in the plant, which covers approximately 765 acres and is dense with pipes, buildings and equipment. PPG estimates installation costs for wired instruments at nearly $20/ft for wiring and conduit. These wireless measurements have the potential to increase process reliability and provide low-cost, redundant measurement.

Smart Wireless technology from Emerson was also applied to the problem of monitoring rising temperatures in railcars containing chemicals at Croda Inc., an international specialty chemical manufacturer. No matter where the rail cars are positioned at the Mill Hall, Pa., plant, a wireless temperature transmitter on each car sends minute-by-minute temperature readings to a central host. Croda uses this information to improve the performance and safety of its facility. In this way, Emerson's wireless system contributes to overall plant safety, making operators aware of any unexpected temperature rise, while saving the company about $15,000/yr in reduced maintenance.

In order to offset some of the reduced labor issues many chemical facilities face, which often leads to ignored alarms and neglected corrective actions, Invensys Process Systems (London, U.K.) offers Mobile Operator, a wireless solution that allows operators to keep in touch with process alarms and conditions while conducting shift operations. The solution not only allows mobile operators to view and acknowledge control room alerts from the field, but also to exact a shutdown from the hand-held device in case of an emergency. The wireless network also has a number of hot spots across the facility, providing operators with continuous access and allowing the connection of any network or device.

A new master alarm database has also been developed to allow process engineers to share their knowledge on why the alarm was set, how long the operator has to respond and what corrective action is required when the alarm is acknowledged. Combined, the solutions should result in enhanced plant safety, better utilization of manpower and increased productivity.

Monitoring for corrosion, too, is going wireless with the introduction of Honeywell's realtime corrosion sensor, the XYR 6000 SmartCET wireless corrosion monitoring transmitter. As part of Honeywell's OneWireless Solution, these wireless transmitters enable customers to obtain critical data and create information from remote and hazardous measurement locations without running wires, where running wires is cost-prohibitive and where the measurement target is in

PRACTICAL ADVICE FOR PREDICTIVE AND PREVENTIVE MAINTENANCE

With shrinking budgets and fewer resources, plant management must find ways to improve equipment reliability while optimizing cost efficiencies, says Bart Winters, senior marketing manager, Reliability Solutions, Honeywell Process Solutions. A key factor to ensuring equipment reliability is to focus on predictive and preventive maintenance, he says. Following, according to Winters, are crucial things to consider for predictive and preventive maintenance:

- ***Start at the beginning.*** Develop overall condition/performance assessment of plant wide assets
- ***Know your assets.*** Understand the current state of each asset and its condition
- ***Develop collaboration.*** Create a partnership between operations, maintenance and suppliers for quicker resolution of issues
- ***Prevent surprises.*** Reduce equipment damage by operating in the design envelope
- ***Performance and condition monitoring.*** Monitor instruments and the control system, rotating equipment and fixed equipment to predict behavior and detect conditions before failure
- ***Early event detection.*** Use performance-to-failure model to detect issues early
- ***Ongoing maintenance.*** Implement a continuous improvement process to ensure optimum asset performance

"Consider that just one percent improvement of overall equipment effectiveness at a plant can equal roughly $1 million in savings, and it's easy to see that sites embracing proactive and predictive maintenance, including best-in-class work practices and technology, can improve operational performance, asset reliability, manage costs and minimize downtime," says Winters. ❑

a hazardous location. Without wires the transmitters can be installed and operational in minutes, quickly providing information back to a system.

The XYR 6000 SmartCET transmitter uses algorithms and data analysis techniques to accurately measure corrosion rate and pitting. It provides four outputs, which include general corrosion rate, an indicator for localized corrosion (pitting), Stern-Geary constant (B-value) and a fourth variable to help diagnose the corrosion mechanism. The transmitter connects to the process environment through a process specific probe and electrode combination.

"What's unique about this product is that we are able to use it as a process variable and to control the process," says Winters. "When we reach a corrosion rate that is not acceptable, we can look at the process and then make necessary adjustments to minimize corrosion."

Get real (time)

It's also important for chemical processors to be able to monitor the health of an asset, diagnose problems and create alerts in realtime, according to Som Chakraborti, process system manager with Rockwell Automation (Milwaukee, Wis.).

Many of Rockwell's offerings allow plant operators to see how an asset is operating in realtime. Parameters of concern might include temperature, vibration, excessive electrical draw, excessive energy peaks and so on. "These areas of information are important for critical areas of equipment because these data points often signal when equipment requires maintenance or is likely to fail," says Chakraborti.

One of the latest products in the company's portfolio, Plant PAx, has a significant asset management suite that allows such parameters to be seen in realtime and make decisions on when to plan a shutdown, how long certain batches can be extended before shutdown is planned or, on a shorter term basis, what types of maintenance tasks are needed to extend the life of the asset.

In addition, the suite includes new data delivery capabilities, tools and procedures that track assets and their performance, maximizing productivity and the bottom line while optimizing system use and fulfilling external reporting requirements. Version management of control assets, calibration management of process instrumentation and diagnostics for HART and process fieldbus devices are included in the offering, as well.

Likewise, ABB (Norwalk, Conn.) also offers a realtime asset optimization solution. The 800xA Asset Optimization tool presents realtime information seamlessly and in the proper context to operations, maintenance, engineering and management. The Real-TPI, ABB's realtime performance measurement and analysis software solution, improves plant productivity by identifying ways to increase Overall Equipment Effectiveness, a key performance indicator. The software automates data collection and analysis and provides reports tailored to plant management's needs.

"This provides, in realtime, a condition-based monitoring solution for all the equipment in the whole plant, including electrical, rotating and instrumentation, as well for the quality of the process itself," explains Jeffrey Vasel, marketing manager, Asset Optimization for System 800xA.

Energy matters

As energy prices continue to fluctuate, many processors are looking to integrate energy information to their production information so that the operations team can understand the cost of production decisions as it relates to the lifecycle of the assets and time to failure, says Rich Chmielewski, chemical and biofuels marketing manager with Siemens Energy & Automation (Alpharetta, Ga.).

"As a matter of fact, monitoring the operating condition is an essential aspect of both energy conservation and maintenance programs because motors, along with drives and pumps, consume approximately 64% of the energy in a plant," says Chmielewski. "It is estimated that up to 40% of the manufacturing revenue is applied to maintenance, and up to 60% of scheduled maintenance checks on valves and motors proves to be unnecessary."

To help align energy conservation with predictive and preventive maintenance, Siemens offers several products, including power monitors, which can help pinpoint the energy consumers in a plant to determine if there are changes in the quality of the power supplied that may negatively affect the fed devices. "Increased power consumption/current can be an indicator of a failing device, and looking for ways to add a variable frequency drive to low-speed, low-inertia applications like pumps and fans can save energy and assets," says Chmielewski.

"Saving energy has two significant paybacks," he says. "It lowers plant energy costs and improves overall asset utilization. Technology, including smart electrical instrumentation, exists today to make process control more efficient. By adopting these smarter technologies, CPI manufacturers will not only save energy and help the environment, but will also decrease the cost of production and help with maintenance strategies." ■

Joy LePree

Technology Showcase

A PRIMER ON COAL-TO-LIQUIDS

Converting coal to liquid fuels is one option China and the U.S. are persuing

TABLE 1. COAL-TO-LIQUIDS PROJECTS		
Pilot plants (U.S.)		
Location	**Developers**	**Capacity, bbl/d**
Colorado	Rentech	10–15
New Jersey	Headwaters	Up to 30
Oklahoma	ConocoPhillips	300–400
Oklahoma	Syntroleum	70
Plants under consideration (U.S.)		
Arizona	Hopi Tribe, Headwaters	10,000–50,000
Montana	State of Montana, Bull Mt. Land Co., DKRW Energy	22,000
Montana	State of Montana	10,000–150,000
North Dakota	GRE, NACC, Falkirk, Headwaters	10,000–50,000
Ohio	Rentech, Baard Energy	2 X 35,000
Wyoming	DKRW Energy	33.000
Wyoming	Rentech	10,000–50,000
Illinois	Rentech	2,000
Illinois	American Clean Coal Fuels	25,000
Pennsylvania	WMPI	5,000
West Virginia	Mingo County	10,000
Mississippi	Rentech	10,000
Alaska	State of Alaska, AIDEA, Chinese Petroleum Corp. of Taiwan	80,000
Louisiana	Synfuel	n.a.

International plants and projects			
Country	**Owner/developer**	**Capacity, bbl/d**	**Status**
South Africa	Sasol	150,000	Operating
China	Shenhua	20,000 (initially)	Under Construction
China	Lu'an Group	≈3,000–4,000	Under construction
China	Yankuang	40,000 (initially) 180,000 (planned)	Under construction
China	Sasol JV (2 studies)	80,000 (each plant)	Planned
China	Shell/Shenhua	70,000–80,000	Planned
China	Headwaters/U.K. Race Investment	2 X 700 (demonstration plants)	Planned
Indonesia	Pertamina/Accelon	≈76,000	Under construction
Australia	Anglo American/ Shell	60,000	Planned
Philippines	Headwaters	50,000	Planned
New Zealand	L&M Group	50,000	Planned

As an energy resource, global coal reserves represent 2,000 billion barrels of oil equivalent. In 2007, global oil reserves were about 1,300 billion barrels of oil. World wide, oil demand will grow 40 to 50% by 2030. But coal offers an opportunity to diversify worldwide liquid-fuel supplies and coal utilization to produce fuels that can extend the lifetime of world oil reserves. This is a strategic long-term option for the U.S., which currently controls only 3% of world oil reserves at 22 billion barrels. China is already pursuing this option in earnest.

Given the gradual depletion of oil resources around the world, at some stage in the not-to-distant future, major alternative sources of liquid fuels will be required to avoid a major global recession. Coal liquefaction is one possible source, backed by large recoverable coal reserves globally.

There are two pathways to convert coal to fuel: direct or indirect liquefaction. Table 1 lists the projects underway or being planned for these two routes.

Direct liquefaction

In direct coal liquefaction, coal is pulverized and mixed with oil and hydrogen in a pressurized environment. This process converts the coals into a synthetic crude oil that can then be refined into a variety of fuel products.

In the direct process shown in Figure 1, coal is ground and slurried with a process derived solvent, mixed with a H_2-rich gas stream, preheated and sent to a two-stage liquefaction reactor system. In the reactors, the organic fraction of the coal dissolves in the solvent and reacts with H_2 to form liquid and gaseous products. Sulfur in the coal is converted to H_2S, N_2 is converted to NH_3, and O_2 is converted to H_2O.

The reactor products go to vapor-liquid separation. The gas is cleaned and, after removal or a purge stream, is mixed with fresh H_2 and recycled. Heavy gasoil is recycled and process solvent and vacuum bottoms are gasified for H_2 production.

Direct liquefaction processes aim to add H_2 to the organic structure of coal, breaking it down only as far as necessary to produce distillable liquids. Many different processes have been developed, but most are closely related in terms of underlying reaction chemistry. Common features are the dissolution of a high proportion of coal in a solvent at elevated temperature and pressure, followed by the hydrocracking of the dissolved coal with H_2. The liquid products from direct liquefaction processes are of much higher quality than those from pyrolysis processes, and can be used unblended for stationary fuel applications. They do, however, require further upgrading before they can be used directly as transportation fuels. This upgrading uses standard petroleum-industry

For more detailed information, see: "Technology Intelligence for Coal-to-Liquids Strategies," a 550-page report recently published by SRI Consulting (Menlo Park, Calif.; see box on p. 27).

Technology Showcase

processing techniques, allowing products from a direct liquefaction plant to be blended into intermediate feedstock streams of a petroleum refinery or a standalone integrated plant section.

Direct liquefaction processes are theoretically the most efficient routes to fuels currently available. Liquid yields in excess of 70 wt.% of dry, mineral-matter-free coal have been demonstrated in process development or pilot scale units.

No direct commercial scale liquefaction fuels plant has yet been built. However, China's Shenhua 1 first-phase construction project of a three-phase plan to build a major coal refinery in Inner Mongolia, based on direct liquefaction technology, is scheduled for startup early this year.

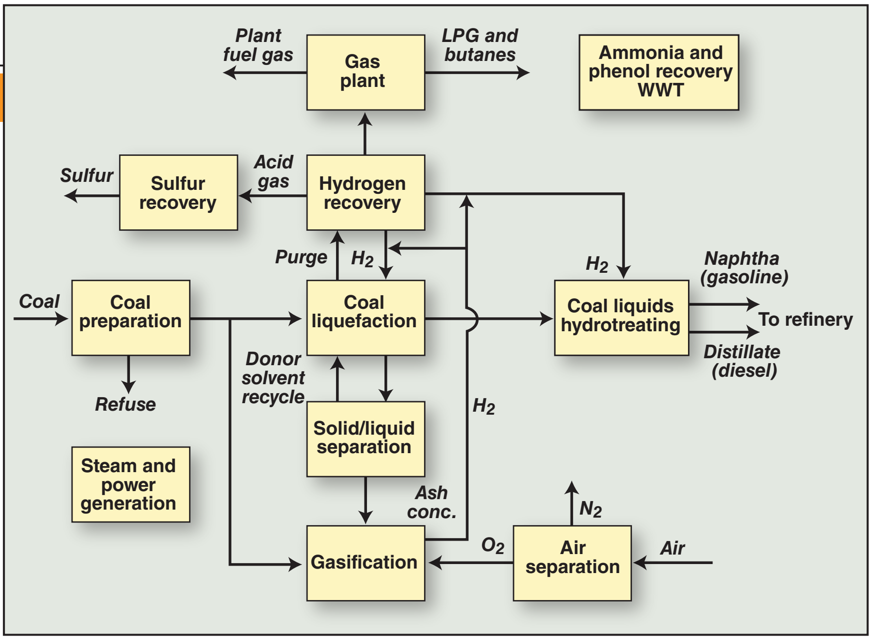


FIGURE 1. In direct coal liquefaction, coal is pulverized and mixed with oil and hydrogen in a pressurized environment. This process converts the coal into synthetic crude oil that can then be refined into a variety of fuel products

Indirect liquefaction

Indirect liquefaction (Figure 2) involves as a first step, the complete breakdown of coal structure by gasification with steam and O_2. The composition of the gasification products is then adjusted, following cleanup to remove sulfur and other contaminants, to the required mixture of H_2 and CO in synthesis gas (syngas). The syngas is reacted over a catalyst at relatively low pressure and temperature to produce paraffins, olefinic hydrocarbons, or alcohols, depending on the catalyst selected, the type of synthesis reactor chosen, and the synthesis reaction conditions used.

In a coal-to-liquids (CTL) complex with Fischer-Tropsch (F-T) synthesis, coal feed is prepared in the milling and drying section and then sent to the gasifier where it is fully converted to raw syngas. (A coal-slurry gasifier may also be employed instead). Both solid and slurry fed gasifiers are entrained-bed gasification systems. The newer entrained-bed gasifiers, while being considerably more efficient, produce a gas that has a higher syngas content of H_2 and CO, but a lower H_2 to CO ratio. Oxygen for the gasification is supplied by an air separation unit (ASU). A part of the raw syngas is treated in the CO water-gas-shift unit to convert the steam and CO to H_2 and CO_2, after which this treated gas is remixed with the untreated portion. Split between the portions is controlled such that the required H_2 to CO ratio of the F-T synthesis is always met. The shifted syngas is then submitted to an acid-gas-removal (AGR) step, where COS, H_2S, and CO_2 are removed to produce clean syngas feed for the F-T synthesis unit. To sufficiently protect the F-T catalyst from contaminants, a Rectisol adsorption process is typically deployed for acid gas removal as this process is commercially proven in CTL applications. However, a more energy efficient Selexol AGR system may also be used. A small fraction of the clean syngas is sent to a pressure-swing-adsorption (PSA) unit for the production of pure H_2, which is required in the product work-up section, and the major part of the syngas is routed to the F-T plant.

In the F-T synthesis step, the syngas is converted to raw F-T product. The lighter ends of the raw F-T product are partially recycled internally and the remainder sent to the heavy ends recovery unit. The tail gas from the heavy-ends recovery unit is sent to a combined cycle plant to produce sufficient power for the entire CTL complex. The F-T products, namely F-T waxes and F-T condensate, are sent to the product upgrade section, where they are hydroprocessed with H_2 from the PSA to produce primarily diesel product. Not only hydrocarbons, but also a significant amount of water is produced during F-T synthesis. This water fraction contains impurities such as oxygenates, which have to be removed in a water treatment step.

Sour gas (H_2S, COS) removed in the AGR unit is sent to a sulfur recovery unit (Claus plant), where it is converted into elementary sulfur. The tail gas from the Claus plant is hydrogenated and recycled to the AGR unit.

The yield of F-T products in a fully self-sufficient, free-standing, CTL plant, based on hard coal gasification, is approximately 0.25 tons of F-T product per ton of coal. The sulfur produced depends on the sulfur concentration in the coal.

F-T synthesis

The basic reactions in the F-T synthesis are the following:

Paraffins formation
$(2n+1)H_2 + nCO = C_nH_{(2n+2)} + nH_2O$

Olefins formation
$2nH_2 + nCO = C_nH_{2n} + nH_2O$

Alcohols formation
$2nH_2 + nCO = C_nH_{(2n+1)}OH + (n-1)H_2O$

Other reactions may also occur during the F-T synthesis depending on the catalyst employed and the conditions used.

Water gas shift
$CO + H_2O = CO_2 + H_2$

Boudouard disproportionation
$2CO = C + CO_2$

The production of hydrocarbons using traditional F-T catalysts (iron or cobalt) is governed by chain growth or polymerization kinetics.

The most important aspects for development of commercial F-T reactors

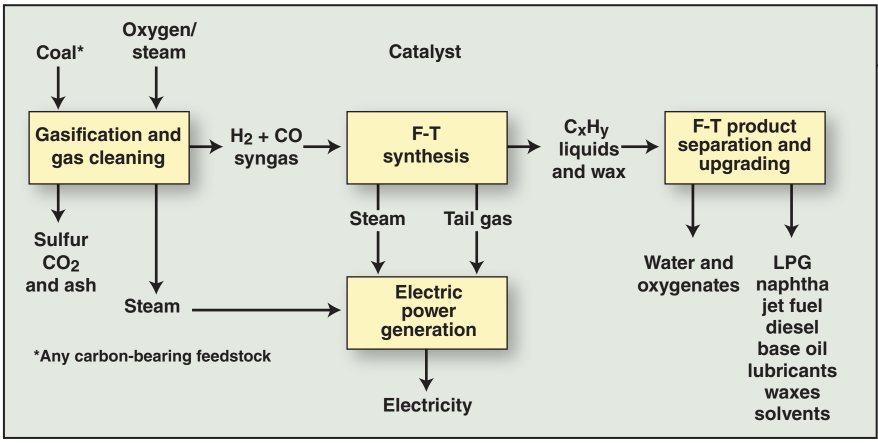


FIGURE 2. With Indirect coal liquefaction, coal is subjected to intense heat and pressure to create synthesis gas (H_2 + CO). After the syngas is cleaned, it is converted to liquid fuels by F-T synthesis

are the high reaction heats and the large number of products produced with varying vapor pressures (gas, liquid, and solid hydrocarbons). The main reactor types, which have been proposed and developed since 1950, are the following:

- Slurry bubble-column reactors with internal cooling tubes (Sasol SSPD)
- Multitubular fixed-bed reactor with internal cooling (Arge, Sasol, Shell)
- Circulating fluidized-bed reactor with circulating solids, gas recycle, and cooling in the gas/solid recirculation loop (Synthol, Sasol)
- Fluidized-bed reactors with internal cooling (Advanced Synthol, Sasol)

Fischer-Tropsch reactor operation can be classified as either high temperature, (HTFT; 340°C), or low temperature (LTFT; 220–240°C).

F-T products, CTL upgrading

The LTFT primary-reaction products are ideally suited for upgrading wax to middle distillates with naphtha as the main coproduct. The most suitable, middle distillate product is diesel. Lighter and heavier fractions are usually less desirable due to limited markets or lower prices, or both.

For middle distillate production, two types of upgrading processes are used, including hydrocracking of heavy F-T wax, and catalytic oligomerization of light (C_3–C_5) olefins.

The latter is especially applicable to the product from a high-temperature (HTFT) process, where the bulk of the product consists of these olefins. However, this report is focused on the maximum production of diesel fuels, so hydrocracking is the most relevant process. The hydrocracking of heavy paraffins serves two purposes, namely to lower the boiling range of wax to middle distillates and to improve the cold flow properties of F-T diesel with hydrocracked products that are mostly branched molecules. Currently the production of a high-quality diesel fuel is preferred to the production of gasoline. This is because the very factors that count against F-T gasoline, such as product linearity and low

aromatic content, are very positive factors in favor of high-quality, high-cetane-number diesel fuel. For maximum production of high quality diesel, the slurry bed reaction operating in the high wax-selectivity mode with cobalt based catalyst, or the high diesel-selectivity mode with iron based catalyst, is the recommended route.

Straight-run F-T diesel makes up about 20% of the total F-T product and because it is predominantly linear, it has a cetane number of about 75. Note that this compares with refinery naphtha cetane numbers varying from 40 to 50. The F-T slurry reactors are operated for maximum fuels production because subsequent downstream hydrocracking of the wax under relatively mild conditions makes the largest contribution of the final diesel fuel pool. There are two reasons for operating the F-T process at high pressures, namely the wax selectivity increases with pressure, and secondly, the degree of branching decreases. There is therefore a big incentive to improve the selectivity of the wax hydrocracking operation in order to increase the diesel cut yield. Some chain branching does occur during the wax hydrocracking operation, so the cetane number of the diesel fuel produced is somewhat lower than that of straight run F-T diesel. The final diesel pool, however, has a cetane number above 70.

The diesel produced in the wax hydrocracking process consists only of alkanes. The naphtha produced in the F-T process also consists predominantly of linear alkanes. To convert these two naphtha cuts into on-specification gasoline would require a considerable amount of further octane number upgrading. However, since these naphthas consist essentially of linear alkanes, they make an excellent feedstock for the production of ethylene by steam cracking, yielding a much higher selectivity of ethylene than would be obtained from steam cracking normal, crude-oil naphtha. ■

Edited by Gerald Ondrey

Acknowledgement

This article has been derived from a 550-page report, issued last July, entitled "Fuels of the Future: Technology Intelligence for Coal-to-Liquids Strategies," and prepared by Ron Smith, Marianna Asaro and Syed Naqvi of SRI Consulting (Menlo Park, Calif.). The full report covers a wealth of quanitative and other information on coal-to-liquids technology. Although both direct and indirect liquefaction are covered, the economic focus of the report is on indirect liquefaction. Economic analyses are provided for production of middle distillates from coal in order to maximize diesel fuel production using conventional iron or cobalt catalysts. In addition, the report profiles, in detail, different types of coal gasification, syngas cleaning and processing options and coal/biomass cogeneration technology.

Other alternative CTL fuels technologies covered in the report include coal to methanol and coal to dimethyl ether (DME). The report investigates the latest developments in synthesis catalysis for F-T diesel, and direct DME sysnthesis, including parameters and features of CTL catalysts and an overview of recent R&D catalysis for F-T, methanol and DME. The report also reviews recent patents related to CTL technology. Environmental considerations, including the emission of CO_2 and its process-configuration requirements for capture as it relates to CTL technology, is included. To learn how to buy the full report, contact the key author: rsmith@sriconsulting.com.

WHO'S WHO

Tully

Allred

Waring

Boss

Murphy

The American Institute of Chemical Engineers (New York, N.Y.) names *June Wispelwey* executive director.

Richard L. Killion becomes president and COO of **Babcock & Wilcox Power Generation Group, Inc.** (Baberton, Ohio).

Bio-Chem Fluidics (Boonton, N.J.) appoints *John Tully* distribution sales and marketing manager.

Peter Allred joins **ESR Technology** (Warrington, U.K.) as CFO.

Marcus A. Pignataro is elected president and general manager — Asia/Pacific of **Excel Polymers, LLC** (Solon, Ohio).

Garner Industries (Lincoln, Nebr.) promotes *Todd Peterson* to vice-president of sales.

Honeywell Specialty Products (Morris Township, N.J.) names *Jack Boss* vice-president and general manager.

Range Fuels, Inc. (Broomfield, Colo.) elects *David C. Aldous* CEO.

Dover Fluid Management (Chicago, Ill.) announces the appointment of *Tim Waring* to president of the OPW Fluid Transfer Group.

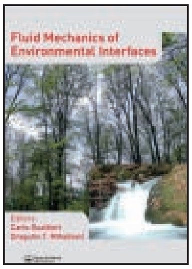
Starfire Systems (Malta, N.Y.) names *Patrick J. Murphy* chief commercial officer.

Tom Larson of Trek, Inc. (Medina, N.Y.) is elected to the board of directors of the **Electrostatic Discharge Association (ESDA)** (Rome, N.Y.) by its members. ■

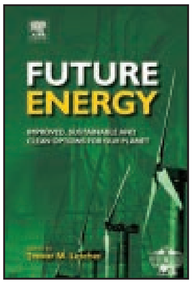
Kate Torzewski

Bookshelf *(Continued from p. 9)*

All in all, I would recommend this book to managers, but also to most non-managers, in the chemical process industries (CPI) and related industries and academia, even if they have little or no direct contact with patenting. The CPI is highly dependent on patents, so it is worthwhile for chemical engineers to understand what this book explains. The book is easy to read and understand, not overly long and provides a good, no-nonsense foundation in vital areas of patenting.

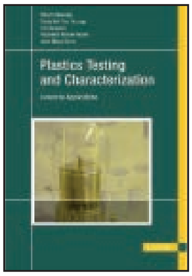


Fluid Mechanics of Environmental Interfaces. By Carlo Gualtieri and Draguntin T. Mihailovic. CRC Press, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL 33487. Web: crcpress.com. 2008. 348 pages. $169.00.

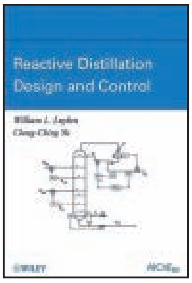


Future Energy: Improved, Sustainable and Clean Options for our Planet. By Trevor Letcher. Elsevier, 30 Corporate Drive, Suite 400, Burlington, MA 01803. Web: elsevierdirect.com. 2008. 400 pages. $80.95.

Selection of Polymeric Materials. By E. A. Campo. ASM International, 9639 Kinsman Road, Materials Park, OH 44073. Web: asminternational.org. 2008. 253 pages. $230.00.



Plastics Testing and Characterization: Industrial Applications. By A. Naranjo, M. Noriega, T. Osswald, J. Sierra M., and A. Roldan. Hanser Gardner, 6915 Valley Ave., Cincinnati, OH 45244. Web: hansergardner.org. 2008. 375 pages. $99.95.



Reactive Distillation Design and Control. By William L. Luyben and Chen-Ching Yu. John Wiley & Sons, Inc. 111 River St., MS 8-01, Hoboken, NJ 07030-5774. Web: wiley.com. 2008. 574 pages. $104.00.

Guidelines for Chemical Transportation Safety, Security, and Risk Management. By the Center for Chemical Process Safety (CCPS). Wiley-AIChE. 111 River St., MS 8-01, Hoboken, NJ 07030-5774. Web: wiley.com. 2008. 166 pages. $125.00.

Ionic Transport Processes In Electrochemistry and Membrane Science. By Kyosti Kontturi, Lasse Murtomaki, and Jose A. Manzanares. Oxford University Press, 198 Madison Ave., New York, N.Y. Web: uop.com. 2008. 320 pages. $110.00. ■

Kate Torzewski

Fluke

JANUARY New Products

Krohne

MV Products

KNF Neuberger

ITT

Vacuum degassing chamber connects directly to vacuum pump

This off-the-shelf, portable degassing chamber is ideal for removing entrapped air and water vapor from urethanes, epoxies, resins and other liquids. The MV Portable Degassing Chamber (photo) is constructed of stainless steel with a 1.5-in.-thick clear-acrylic top for viewing contents, includes a 0–30-in.-Hg gauge, and vent and isolation valves. It connects directly to a vacuum pump and has a VisiTrap vacuum pump inlet trap to protect the unit from harmful vapors. Available in 15- and 4-gal sizes, the MV Portable Degassing Chamber offers users a standard product for small batch processing and laboratory research applications. Options include shelves, trays, feed-thrus for stirring the contents, and a variety of different ports and fittings. — *MV Products, No. Billerica, Mass.*
www.massvac.com

Simplify Fieldbus testing with this product's bus health test

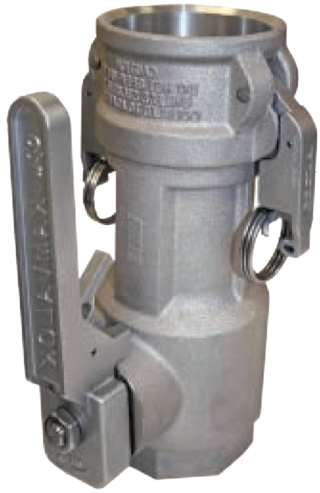
Two models have been added to this firm's range of Color ScopeMeter Test Tools (photo) with automated test capability for Fieldbus, ProfiBus and other industrial communication protocols. The new models, the ScopeMeter 225C (200 MHz, 2.5 GS/s) and 215C (100 MHz, 1 GS/s), are designed for maintenance specialists who keep automation and process-plant equipment operational. These systems often operate in harsh environments requiring special techniques and tools for maintenance and troubleshooting, including verification of electrical signal quality on industrial buses such as Fieldbus Foundation, CAN-bus (or DeviceNet), Profibus, RS-485, ModBus, ASI and more. The new instruments feature easy signal validation of all critical signal parameters and have floating and fully isolated inputs for true differential signal measurements on 2-wire differential bus systems. — *Fluke Corp., Everett, Wash.*
www.fluke.com

Cut costs when operating with this vertical pump

The Goulds VRS vertical rubber-lined canteliver sump pump (photo) is said to set new standards for energy efficiency and other costs. The VRS liners, impellers and casing halves are all interchangeable with the firm's SRL horizontal pumps, resulting in reduced parts inventory and maintenance costs. The VRS vertical pump also allows for liner replacement without requiring a change of the entire pump casing. The impellers are built with tighter tolerances than other vertical pumps, which improves the operating efficiency and saves up to 40% in energy costs, says the manufacturer. The VRS pumps are available in 2-, 3-, 5- and 6-in. dia. with 4 and 6-ft lengths. They can handle duties with up to 120 ft head, solids up to 1/4 in., and 75 psi working pressure. — *ITT Corp., White Plains, N.Y.*
www.itt.com

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

New Products



OPW Engineered Systems

Satortius Mechatronics

Rockwell Automation

Achieve high flowrates with these customizable pumps

This process pump is engineered to deliver the highest flowrate of any electrically operated diaphragm pump. These pumps offer oil-free operation without risk of medium contamination and can be equipped with a double diaphragm system for increased safety critical when handling valuable or dangerous gases. All Type N0150 process pumps (photo, p. 28D-1) can be customized to meet application requirements, including explosion-proof motors, corrosion-resistance, leak-tight capabilities, and a choice of pump materials. Depending on model, these pumps can achieve flowrates up to 300 L/min (10 SCFM), maximum vacuums up to 29.3 in. Hg, and maximum pressure up to 30 psig. They are designed to exhibit significantly low leak rates ranging from 6 x 10^{-3} mbar l/s (standard models) to 6 x 10^{-6} mbar l/s (double-diaphragm versions). — *KNF Neuberger, Inc., Trenton, N.J.*
www.knf.com

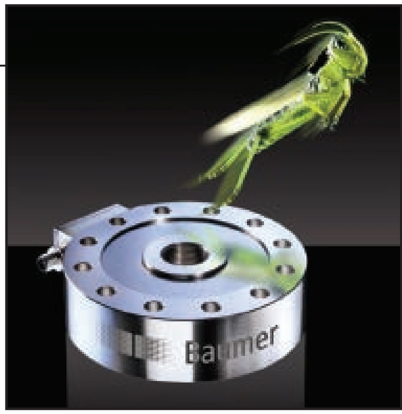
Use this ultrasonic level transmitter in wastewater applications

The Optisound VU3X Series Continuous Ultrasonic Level transmitter (photo, p. 28D-1) provides a reliable, repeatable and highly accurate (0.15%) continuous level measurement of liquids. It is capable of liquid level measurement to ranges up to 30 ft. with a 2-wire 4–20 mA, HART output signal. The Optisound VU30 sensor is constructed of CPVC for use in environments that are classified hazardous (Class I, Div. 1) with Intrinsically Safe or Explosion Proof installation requirements, temperature range from –0°C to 70°C and process pressures up to 50 psig. The compact electronics comes standard with an integral display and keypad for local configuration ,and precludes the need for hand-held communicators or PC software. Internal software features support over 80 standard flume and weir characterizations with totalization display in a resettable and a non-resettable format. — *Krohne, Inc., Peabody, Mass.*
www.krohne.com

Prevent spillage at liquid transfer points

Kamvalok Dry Disconnect Couplings (photo) are used at liquid transfer points where product loss could occur, providing a reliable solution to prevent spillage during the connection or disconnection process. It features stainless-steel Autolok locking arms, and a stainless-steel locking handle that secures both


Turck



Baumer

the opened and closed positions to prevent accidental release or uncoupling. The Autolok locking arms provide added protection with an automatic locking mechanism signaled by a positive click; uncoupling requires only an easy tug on the lock release. The poppeted-seal cylinder design, equipped with an easily replaceable snap-on nose seal, offers dual protection and automatic closure from both the coupler and adaptor. The Kamvalok coupler is available in aluminum and stainless steel in sizes 1 ½, 2 and 3 in. — *OPW Engineered Systems, Lebanon, Ohio*
www.opw-es.com

Checkweighing and metal detection in one unit
This firm has extended its Synus series of dynamic checkweighers with a new series of weighing products called CoSynus (photo, p. 28D-2), a combination of a metal detector and a checkweigher in one unit. With its modular design and wide range of accessories offered, from conveyor systems to diverse evaluation electronics as well as a choice of dimensions, CoSynus models can be seamlessly integrated into any production process. In addition, in a facility that already has a Synus, it can be changed in just a few simple steps into a CoSynus. The metal detector is operated utilizing Synus dynamic checkweigher electronics. A single interface can be used to configure the two functions quickly and easily, which saves time, especially when there is no floor space. — *Satortius Mechatronics Corp., Edgewood, N.Y.*
www.satorius-usa.com

These motor control centers offer a variety of product solutions
This firm has released the Allen-Bradley OneGear product line (photo) providing a full range of motor control center and power control center options. The OneGear product line is the next generation of medium-voltage motor control specifically designed for use with full voltage and solid-state, reduced voltage applications, supporting operating voltages up to 15 kV and utilizing both vacuum-contactor and circuit-breaker switching technology. All OneGear products will be available with optional arc-resistant cabinets, which meet IEEE

Pentair Industrial

C37.20.7 and IEC Type 2 protection. The OneGear product line offers remote monitoring, diagnostic capability and in-depth motor protection for maximum motor utilization while avoiding damage and downtime. — *Rockwell Automation, Milwaukee, Wis.*
www.rockwellautomation.com

This quick-connect wiring system provides up to 18-amp of power

The M16 powerfast wiring system (photo) is designed for machine power distribution and motor control. The quick-connect system provides a time- and cost-saving replacement for traditional hardwiring installations and complies with NFPA 79 (National Fire Protection Assn. Electrical Standard for Industrial Machinery). These 2-, 3- and 4-pin connectors and tees provide up to 18 A in a compact form factor. All connectors deliver IEC IP 67 protection and are rated for 600 V and up to 18 A. Tees are available with simple connectors or with branches. The line offers male or female options, straight connectors, standard and custom lengths, and pigtails or extensions. To complete the system, fully encapsulated mating receptacles with nickel-plated brass housing and 1/2–14-in. NPT, 3/8–18-in. NPT, M18 and M20 mounting threads are available. — *Turck Inc., Minneapolis, Minn.*
www.turck.com

These load cells monitor static or dynamic forces

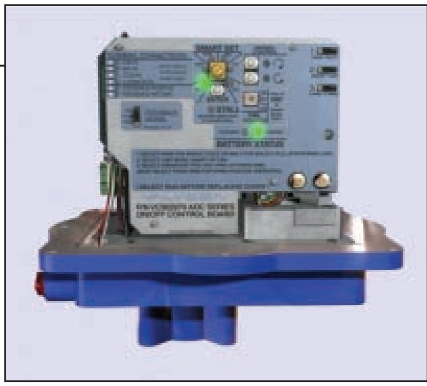
DLRx Load Cells (photo, p. 28D-4) are sensors designed to measure force in a range of harsh industrial environments. Featuring IP65/IP67 protection and stainless-steel housings, this new load cell line delivers extremely fast dynamic signal processing and accuracy to 0.3%. Designed to offer excellent transverse sensitivity by compensating for non-centrally applied forces, DLRx Load Cells offer highly accurate force absorption and precise, low-noise, dynamic signal processing during all measuring applications. These sensors can be used to measure both compression and tension/compression over the entire conventional force range of 0.5–100 kN. These compact load cells start at just 32-mm dia., making them ideal for installation in limited-space environments. They can be used in static or highly dynamic applications and are well suited for force

measurement, weight measurement and force monitoring. — *Baumer, Ltd., Southington, Conn.*
www.baumerelectric.com/usa

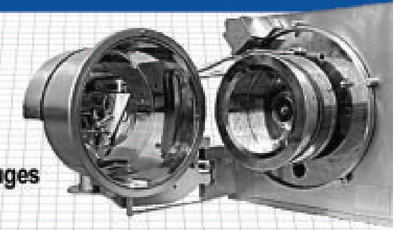
Achieve filtration up to 4,100 gal/min with these housings
Designed for use in commercial and industrial filtration applications, Multi-Round Liquid Cartridge Housings (photo, p. 28D-5) offer an exceptional 11 to 205 cartridge capacity, and accept 20-, 30- or 40-in. filter cartridges, delivering 120–4,100 gal/min flowrates. These cartridge housings are pressure rated at 150 psi and accept double open-end cartridges or 222-style cartridges with closed top caps. They also provide several housing options, including a duplexing housing for continual flow during maintenance, as well as housings with higher pressure ratings and different connection sizes and types. Users can add ASME Code U stamp as an option. The housings feature carbon and stainless-steel construction options, paired with 316-stainless-steel center guide posts, cup-and-spring assemblies, as well as heavy-duty support legs. — *Pentair Industrial, Sheboygan, Wis.*
www.pentairindustrial.com

A wireless product sends complete maintenance information
This company, in collaboration with SKF, has introduced OneWireless Equipment Health Monitoring (EHM), which will wirelessly transmit complete spectral information — including vibration amplitude and operating parameter information — from the field to the plant room. OneWireless EHM is a compact, eight-channel monitoring device that collects acceleration, velocity, temperature and bearing condition data and delivers them to process operators and maintenance personnel to alert them of equipment problems. The device is a cost-effective and efficient alternative to the manual inspections that many industrial facilities employ to monitor the health of rotating equipment, such as pumps, compressors and motors. — *Honeywell Process Solutions, Phoenix, Arizona*
www.honeywell.com/ps

Metso Automation



A membrane that improves salt rejection and flowrate
This firm announces two new FilmTec 8-in. saltwater reverse osmosis (SWRO) membrane elements for improved performance and energy efficiency in desalination applications. At 99.80%, the FilmTec SW30XHR-400i has the highest salt rejection consistently demonstrated in the industry,



FilterSense

according to the firm. It features a guaranteed active area of 400 ft^2 and flowrate of 6,000 gal/d. FilmTec SW30ULE-400i elements have a flowrate of 11,000 gal/d with 99.70% salt rejection. Both FilmTec SW30XHR-400i and SW30ULE-400i are offered with iLEC interlocking caps that reduce pressure drop within the permeate tube and help eliminate the O-ring damage that can be a cause of major leakage in traditional desalination membrane systems. — *Dow Water Solutions, Edina, Minn.*
www.dow.com/liquidseps

This actuator supports torque up to 3,000 in.-lb

Valvcon ADC RS-485 addressable quarter-turn electric actuators offer the torque and reliability of the Valvcon ADC platform combined with sophisticated data communications and control capabilities. They are well suited for on/off duty and proportional applications in multi-actuator network installations where continuous duty and high starts per minute are a must. The ADC Series RS-485 offers high data transmission speeds (35 Mbits/s up to 10 m and 100 Kbits/s at 1,200 m) and the ability to query and command multiple units on a single network. They are available for torque requirements up to 3,000 in.-lb. Standard Valvcon ADC RS-485 capable actuator features include all hardened steel gears, standard ISO5211 mounting interfaces, stall protection, and a sleep/wake mode to preserve battery power. They are available in NEMA 4, 4X, 7, and 9 enclosures. — *Metso Automation, Northborough, Mass.*
www.metsoautomation.com

Loop-powered particulate matter transmitter for dust collectors

This loop-powered particulate matter transmitter (photo, p. 28D-7) provides simple two-wire installation and interface with the company's B-PAC baghouse optimization controllers or existing plant control systems. The transmitter exceeds the EPA MACT standard for baghouse and dust collector leak detection. Employing field-proven induction-sensing and protected-probe technologies, these particulate matter transmitters are said to offer increased reliability over traditional triboelectric and opacity products. The combination of induction sensing and a protected probe provide high reliability even in difficult applications such as fly ash from coal, carbon black, chemicals, smelters and spray dryers. General benefits include detecting emissions before they are visible, eliminating cleanup costs, preventing the escape of valuable powders and protecting downstream equipment. — *FilterSense, Beverley, Mass.*
www.filtersense.com

This diamond coating is durable and long lasting

A a new diamond coating for mechanical seals has been introduced that offers excellent protection against wear during dry running, in applications with mixed friction and under exposure to abrasive media. DiamondFaces, a specially developed crystalline diamond coating on the seal

face, is extremely hard, exceptionally long wearing, and features outstanding heat conductivity, excellent chemical resistance and low friction, thus enabling considerable savings in terms of energy, says the manufacturer. Purchasers of this product say that the additional financial outlay pays for itself in a short period of time, since the diamond coated mechanical seals make for minimized wear and significantly longer service life. — *EagleBurgmann Group, Houston, Tex.*
www.eagleburgmann.com

Measure turbidity, suspended solids, and sludge blanket level

Hach

The TSS Portable hand-held meter (photo) offers turbidity, suspended solids and sludge-blanket level measurement in one instrument. The TSS is ideal for remote monitoring of rivers and applications involving municipal and industrial wastewater, and drinking water. Additionally, this instrument can be used as an optimization tool or as an easy way to calibrate or validate on-line sensors. The TSS Portable uses a multibeam alternating light method with an infrared (IR) diode system, allowing a broad measuring range for both turbidity and suspended solids. It stores up to four different calibration curves for suspended solids and one for turbidity. The meter's internal memory stores up to 290 measuring values, including time, date, measurement, location, and homogeneity. — *Hach Co., Loveland, Colo.*
www.hach.com/tssportable

This fiber-optic transmission probe eliminates fouling

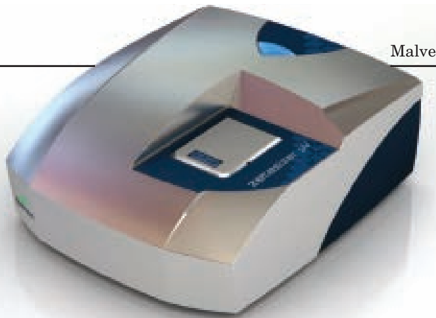
The FPT-855 Near-IR Transmission Probe features an integral heating jacket that virtually eliminates the occurrence of fouling due to condensation of product on the probe surfaces. FPT-850 near-IR, visible and ultraviolet transmission probes were developed to provide long-term reliability under the extreme conditions of high temperature, thermal shock, and aggressive chemistries. One key design element is a proprietary sealing technique involving a direct sapphire-to-nickel-alloy welded pressure seal, which eliminates fatigue and stress failures common with brazed seals, as well as the limited lifetime characteristic of elastomeric seals. Another key element is the elimination of optical fibers within the probe, providing for reliable, long-term operation at temperatures as high as to 400°C. — *Axiom Analytical Inc., Tustin, Calif.* ■
www.goaxiom.com

Kate Torzewski

Circle 31 on p. 58 or go to adlinks.che.com/23010-31

JANUARY

New Products


Malvern Instruments


CiK Solutions


Garner Industries

Bartec

MSA in Europe

This paddle design simplifies installation and removal

A new option for the BMRX and Maxima+ rotary level indicators is a collapsible paddle. This paddle design simplifies installation and removal of the rotary by allowing the stainless-steel paddle to be collapsed to fit through a standard 1-1/4-in. opening common to powder and bulk agricultural and industrial storage bins. The paddle is available on new level indicators and can be retrofit onto existing devices. The paddle is offered as either a one- or two-paddle design. The two-paddle design (photo) is said to be best suited for light- to medium-weight materials, such as feeds, seeds and grains, or where more surface area is needed to apply resistance to the paddle and activate alerts. — *Garner Industries, Lincoln, Neb.*
www.garnerindustries.com

This little data logger stores a lot of measurements

The MSR145 Analog (photo) is said to be the world's first Mini-datalogger with four integrated sensors. The tiny (52-mm long; 32-g weight) device can store up to 2-million measured values from up to four analog inputs (0–3 V, 12 bit). Integrated sensors measure temperature, moisture, pressure and acceleration along three axes, while the analog inputs can be used for monitoring conventional sensors, such as pH, flowrate and conductivity. — *CiK Solutions GmbH, Karlsruhe, Germany*
www.cik-solutions.com

HART communication is now possible with this gas monitor

The Ultima XE gas monitors with display (photo) are now available with HART field communications protocol. HART provides two-way digital communication between intelligent field instruments and host systems. Increased sensor data as well as convenient setup, calibration and diagnostics can be offered for better management of plant assets. Ultima XE gas monitors with HART protocol offer an affordable choice in continuous gas detection and monitoring, while retaining key features and sensors of the Ultima X Series. — *MSA in Europe, Berlin, Germany*
www.msa-europe.com

Size-up protein molecules without sacrificing samples

The new Zetasizer µV (photo) is an advanced light-scattering system for the characterization of proteins, other biomolecules and nanoparticles. The system is designed and optimized for maximum sensitivity and minimum sample volumes; just 2 µL of sample are required, allowing measurement of as little as 40 picograms of bovine serum albumin, for example. Sample is recoverable, ensuring no loss of valuable material, says the firm. Both dynamic- and static-light scattering are used for measuring diffusion speeds, particle size and particle-size distributions, absolute molecular weight and second viral coefficient — a parameter used to assess protein solubility and suitable conditions for crystallization. — *Malvern Instruments Ltd., Malvern, U.K.*
www.malvern.com

Temperature monitoring for trace-heating applications

The new digital temperature controller DPC III (photo) is optimally matched to trace-heating applications. It monitors measuring circuits on breaks, interruptions and short

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

Spectro Analytical

Siemens

Samson Controls

Krohne

SIKA Dr. Siebert & Kühn

circuits of the sensor as well as on under- and over-range in order to guarantee process safety. The DPC III is integrated in a lock-in casing for TS 35 hat-profile rail. At the measuring input, a Pt 100 resistance thermometer and thermal elements can be connected. The controller is equipped with a load relay (16 A), for the two-position control; an alarm relay (8 A); a logical voltage output for the PID control; and two digital inputs. The device can be used as an on/off (two-position controller) or as a PID controller. — *Bartec GmbH, Bad Mergentheim, Germany*
www.bartec.de

Distributed I/Os that communicate wirelessly

Simatic ET 200pro IWLAN (photo) is the first distributed I/O system from this firm that communicates via Industrial Wireless LAN (IWLAN). For this purpose, the new 154-6 PN HF IWLAN interface module was developed for the Simatic ET 200pro system. The interface module wirelessly integrates the distributed I/O system into the automation network, and is designed for harsh industrial environments with a high degree of protection (IP65/66/67). Typical applications include overhead monorail conveyors, automatic guided vehicles and warehouse logistics. The interface module works according to the WLAN standards IEEE 802.11 a/b/g/h, and therefore operates in the 2.4 and 5 GHz frequency bands. — *Siemens Industry Automation Division, Nuremberg, Germany*
www.siemens.com/automation

Crevice-free valves for critical aseptic control

Eliminating areas that might increase the potential for bacterial growth, such as traps and crevices, is important in the design requirement for control valves used in aseptic applications. This firm offers a range of valves (photo) that incorporate these features. The Type 3347 control valve, for example, has polished steel parts to ensure the highest purity for the process medium, special PTFE bushing and an additional steam line construction that prevents bacteria from spreading at the actuator stem guide. The Type 3249 is equipped with an EPDM diaphragm and a backup safety packing box. Finally, the Type 3345 cavity-free valve body features a diaphragm made of either rubber, nitrile, butyl or PTFE, which acts both as a seal and a valve plug. — *Samson Controls Ltd., Redhill, U.K.*
www.samsoncontrols.co.uk

Measure the flow without contacting the fluid

The VUS is a solid-state flow sensor incorporated into the SoniQ ultrasonic flow sensor (photo). The medium simply flows through a straight stainless-steel tube, and ultrasonic transducers positioned on the outer surface of the pipe measure the fluid flowrate. The fluid does not make contact with the transducers, and the device has no moving parts, making it suitable for applications where paddle wheel sensors cannot be used. Three output signals are provided: frequency, analog (4–20 mA) and alarm. The device covers the flow range from 1.5 to 30 L/min, and is suitable for water and non-conductive aqueous solutions. — *SIKA Dr. Siebert & Kühn GmbH & Co. KG, Kaufungen, Germany*
www.sika.net

The advantages of tantalum more affordable in a Coriolis flowmeter

A new tantalum version of the Optimass 7300 Coriolis mass flowmeter (photo) has recently been introduced for applications involving highly aggressive and corrosive fluids. Generally, the wall thicknesses of Coriolis measuring tubes are significantly less than those of the process piping, which tolerate a higher rate of corrosion before failing. Although tantalum has been used in the past by other firms, the twin, bent-tube designs made these devices very expensive. With the advent of the straight-tube design, the costs are more reasonable, because only the measuring tube and the raised face of the process flange need to be made of tantalum. This firm uses an alloy called Tantalum Ta10W, which consists of 10% tungsten and 90% tantalum. — *Krohne Ltd., Wellingborough, U.K.*
www.krohne.co.uk

Perform X-ray analysis in the field with one hand

The new xSORT hand-held, energy-dispersive XRF (photo) offers precise laboratory-like analysis in engineering, PMI or scrap-sorting applications by non-laboratory-trained staff. A special silicon drift detector (SDD) with up to ten times the counting speed of conventional systems not only gives faster analysis and better detection limits for 41 elements from magnesium to thorium, but also allows measurement of light elements such as aluminum, silicon and phosphorous without complicated helium purging or vacuum techniques. Typically, the full range of elements can be measured in a single run of 2 s, or up to 10 s if light elements are included. — *Spectro Analytical UK Ltd., Halesowen, U.K.*
www.spectro.co.uk ■

Gerald Ondrey


ITALY
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Access Intelligence

A promising outlook for Italy's chemical industry

Italian pharmaceutical manufacturers and equipment vendors are optimistic about the US market, writes Guido Furetta of the Italian Trade Commission in Los Angeles

In this global economy, so drastically — and probably permanently — altered over the last few months, the worldwide chemical industry as a whole is doing well, despite the crisis in the financial markets. This continues the positive trend set in 2007 and 2008. In fact, industry experts are predicting steady growth, in spite of the fact that oil and natural gas prices will continue to be volatile and demand could slow down in some areas. This relatively good financial performance has led global chemical players, both European and American, to increase investment in R&D as well as capacity.

Both European and US manufacturers have held back on price increases, especially for petrochemicals. As a consequence, higher sales have not created big profits. The largest price increases were reserved for agricultural chemicals and inedible oils and fats.

The falling dollar has definitely had an impact on exports from Europe, making them more expensive. Despite this, China is increasing its imports from Europe.

The European chemical industry as a whole remains the world's largest producer of chemicals, with 30% of global *Continued on p. 28I-6*

Italian innovation

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Petrochemicals: no big profits, but sales figures are relatively buoyant

These high-head pumps are simple and robust

Thanks to their low operating speeds and generous clearances, Finder Pompe's PEP pumps give dependable service at heads up to 300 m, with low cost of ownership

The PEP range of pumps has been specifically designed by **Finder Pompe SpA** for low-flow, medium-to-high head, low-NPSHa duties to API 610 requirements without the use of increased speeds.

Their hydraulic design is described in the literature as a "partial-emission" or Barske-type pump, that is, an open impeller with full radial vanes, 90-deg. exit angle, and a concentric volute, transferring energy to the fluid in a forced vortex regime and using a diverging diffuser to convert this into pressure.

The unusual feature of the PEP range is that the required output velocity is obtained by increasing the impeller diameter in the range 7–13 in. The rotational speed is always that of the driving motor: 3,000 or 3,600 rpm.

Low rotational speeds ensure that NPSHr is always less than 1 m @ 3,000 rpm without the need for inducers, which often restrict the operating region of the pump. The concentric volute keeps radial loads to a minimum, while axial loads are limited by the scalloped impeller design. The stuffing boxes are designed to carry API 682 cartridge mechanical seals.

The result is a simple, robust, maintenance-friendly pump able to meet extreme service conditions and convey any kind of hazardous or flammable fluid. Flowrates range from less than 1 m^3/h up to 19 m^3/h, heads up to 300 m, casing pressures above 50 bar, and temperatures up to 400°C.

The single-stage PEP is an API 610 OH2 horizontal overhung design

The open-impeller design and generous clearances allow fluids with moderate solid contents to be handled.

The advantages of PEP pumps in low-flow applications compared to conventional volute, closed-impeller pumps are:

- eliminates impeller backflow, reducing erosion, noise, and vibration;
- lower radial loads prevent shaft deflection and high vibration levels;
- low and stable NPSHr characteristic across the whole pump curve.

In low-flow, high-head applications, compared to OH6 increased speed pumps, PEP pumps show:

- low and stable NPSHr with no need for an inducer;
- less sensitive to off-design conditions;
- maintenance friendly: no gearbox, simple to work on, cartridge seals.
- cheaper to buy and maintain.

PEP pumps are also available in a two-stage version called Dual PEP (D-PEP). These share all the advantages of the single-stage pumps, but provide twice the head. **www.finderpompe.com**

Continued from p. 28I-4

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Italy has a strong export position in pharmaceutical intermediates and APIs

sales (€1,476 billion in total), ahead of the US (22%) and Japan (11%). Within Europe, Italy ranks fourth, with about 12% of production, after Germany, France and the UK.

The US chemicals market, meanwhile, is projected to grow by nearly 9% over the next five years, and should reach over $530 billion by 2012.

Pharmaceuticals changes

Experts agree that "big pharma" is ready for significant change, reducing investment in big plants and focusing on the generics market. For the US in particular, the next five years will see significant changes as patents expire, leading to an increasing number of products facing competition from generics.

The custom pharmaceutical sector in Europe and the US is recovering well after the slump of the last few years. In the face of competition from Asia, the industry as a whole is now shifting toward the high-tech end. Some companies that have lost their technology advantage, however, are now diversifying their operations through partners and suppliers in China and India.

According to a recent analysis by PricewaterhouseCoopers, the center of gravity of the global pharmaceutical industry will soon shift from Europe and US to the Asia-Pacific region, with China, India and Singapore as the world's largest markets for drugs.

US pharmaceutical imports have risen rapidly in recent years, especially from European countries including Ireland, Germany and the UK.

Italian strengths

The North American market is the natural and most important outlet for Italian chemical companies. This applies especially to active pharmaceutical ingredients (APIs) and intermediates, and also to custom manufacturing; in these sectors, Italy exports 85% of its total production.

The priority for Italian companies is therefore to promote their products in this market — not the world's most difficult task, given that Italian manufacturers are already recognized as among the world's best in quality, high technology, reliability and advanced production methods.

The "Made in Italy" label is a *Continued on p. 28I-8*

A famous name in heat transfer

FBM Hudson Italiana is a leader in the manufacture of heat exchangers and high-pressure equipment

FBM Hudson Italiana specializes in the manufacture of heat exchangers and high-pressure equipment. The company is one of the world's largest suppliers of complete air-cooled heat exchangers units for refineries, gas, petrochemical and chemical plants, and is also very well known as a skilled manufacturer of shell and tube heat exchangers, process gas boilers, and fully welded plate heat exchangers; specialist exchanger types include HP closures, high-efficiency (HE) exchangers, and special metallurgy exchangers.

Founded in Italy in 1941, FBM Hudson Italiana has always had a strong position in equipment for demanding services. The company has developed innovative design and fabrication methods for high-pressure equipment, and in the use of corrosion-resistant materials such as titanium, zirconium, Hastelloy, Incoloy, duplex and super-duplex steels, Monel, nickel and tantalum.

FBM Hudson Italiana has two manufacturing bases. The larger, at Terno d'Isola, near Bergamo in northern Italy, was built in the mid-1960s and expanded in 1975 and 1992. The smaller workshop, at Jebel Ali in the UAE, was set up in 1991 and expanded in 2006; it has easy access to Abu Dhabi and Dubai international airports, and a deep-water quay.

Both workshops are authorized to use the ASME "U","U2", "R", and "S" stamps, and hold a China Manufacturing License. They both operate ISO 9001–2000 quality systems.

In 2006 FBM Hudson Italiana became part of the Malaysian group KNM Process Systems, a world-class process equipment manufacturer for the oil, gas, petrochemical, minerals processing and power industries, which provides valuable financial support for large contracts, as well as cost savings through centralized global purchasing.

FBM Hudson Italiana remains the group's centre of excellence for the design and manufacture of heat exchangers. The company's technical and quality know-how, and much of its manufacturing, remain firmly rooted at Terno d'Isola.

Research activities include new techniques for welding and stress analysis, leading to equipment that is lighter, stronger and more corrosion-resistant. Other

FBM Hudson Italiana is an expert in the supply of high-pressure equipment

successful research includes new design codes and manufacturing techniques for multi-layer equipment operating at very high pressures, thermodynamics, noise and vibration analysis.

www.fbmhudson.com

You don't need to look for the future. The future has been with you for eighty years.

The Pompetravaini pump ethic was born in a far distant 1929.
For Pompetravaini, eighty years are not simply a great achievement, but also a starting point for the future. Long experience, many years of history, technology, strategy, and marketing have consolidated the Pompetravaini brand - not only in our national territory, but with our continued leadership, with more than eighty presences worldwide, also in the international market. Seven new Pompetravaini operations have been opened throughout the world: U.S.A., Canada, France, The Netherlands, Germany, United Kingdom, Poland and these, together with more than twenty exclusive distributors, complete our current international presence.

pompetravaini

Our commitment is always to stay ahead

pompetravaini spa
I-20022 Castano Primo (Mi) • Via per Turbigo, 44 • Ph. +39.0331.889000 • Fax +39.0331.889057 • sales@pompetravaini.it • www.pompetravaini.it

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The Italian pavilion at Informex showcases Italy's fine-chemical manufacturers and equipment vendors

reliable indicator of several important selling points, including:

- high levels of production know-how that stem from the Italian chemical industry's decades of experience in world markets;
- high product quality resulting from Italy's tradition of hard work, pride in their jobs, and attention to detail;
- consistent product quality, thanks to sophisticated production methods backed up by careful quality control;
- flexibility production that allows manufacturers to adapt to changing market requirements.
- continuous technological innovation through R&D; and
- high levels of professionalism among technical and sales staff.

Italy traditionally takes a leading position amongst suppliers of APIs to the US market, where Italian manufacturers have earned well-deserved recognition as high-tech suppliers offering global service to their customers.

The Italian Trade Commission in Rome supports Italian companies with promotional activities. These include participation at **Informex** (www.informex.com), the annual custom chemical manufacturing trade convention organized by the US **Synthetic Organic Chemical Manufacturers Association** (SOCMA; www.socma.com). Informex 2009 takes place January 27–30 in San Fracisco, Calif.

With the help of its Los Angeles office, the Italian Trade Commission has taken part at every Informex since 1995. Since 1997, this participation has been in the form of an Italian Pavilion that brings together 20 or more Italian exhibitors and their trade associations.

In subsequent years, other countries including the UK, France, Germany and latterly China have all followed Italy's lead by creating national pavilions of their own at Informex. Recently, however, only the Italian and Chinese pavilions have remained active — perhaps an indication of Italian tenacity. **www.ice.com**

The leader in surfactants and detergents

From its strong base in surfactants and detergents, Desmet Ballestra has branched out into sulfuric acid, LAB, fertilizers, and chemicals for detergent applications

Desmet Ballestra SpA, since its foundation in 1960, has been a world leader in the design and supply of plants for the production of surfactants and detergents.

The company has provided technology to every major surfactant and detergent manufacturer worldwide. During its 47 years in business it has supplied no fewer than 1,600 plants in over 120 countries, as well as what are possibly the world's largest sulfonation plants (24 t/h as 100% active surfactant). Desmet Ballestra's film sulfonation technology has many advantages over competing processes:

- outstanding performances in terms of product quality, especially when processing sensitive raw materials;
- exceptionally good conversion rate and color, with maximum absorption of SO_3;
- simpler construction, which ensures easier maintenance;
- lower operating pressures;
- no need for extra coolers or chilled water systems; and
- extra-low energy consumption.

Desmet Ballestra operates an R&D center dedicated to the optimization of its processes. Of special note are proprietary processes for upgrading surfactants downstream of the sulfonation unit, with dioxane stripping and drying to produce pure dry surfactant.

The company's detergent powder plants are well-known worldwide for their outstanding performance, flexibility, reliability and ease of operation. They have been optimized over the years to give customers improved performance with reduced energy demand.

Desmet Ballestra offers standard plant designs for capacities of 1–25 t/h, plus custom design for larger capacities.

Desmet Ballestra 450 t/d sulfuric acid plant in Egypt

Beside its core business in detergents and surfactants, the company is also increasingly active in several other fields of the chemical industry, using either its own proprietary know-how or technology licensed from leading companies including UOP, MECS, and Akzo Nobel. These activities include:

- sulfuric acid plants with capacities of 100–1,500 t/d;
- LAB projects based on the advanced Detal process from UOP;
- fertilizer plants for potassium sulfate, single superphosphates, and triple superphosphates;
- chemicals for detergent applications: sodium silicate, sodium sulfate, zeolites, and sodium tripolyphosphate.

The recent integration of Ballestra into the Desmet group has substantially enhanced both the company's presence in the world markets and its ability to offer cost-competitive plants with strong local backup. Resources and capabilities include:

- 150 employees and full-time consultants;
- ISO 9000 certification;
- R&D center with laboratories and full-scale pilot plants;
- up to 250,000 engineering hours per year;
- 3-D computer design;
- a full range of services from feasibility studies to turnkey projects;
- global sourcing of equipment and materials; and
- project financing.

www.desmetballestra.com

Celebrating an 80th anniversary in style

A new president, a new company in Poland, new sizes of liquid-ring vacuum pump and an innovative vacuum package are keeping pump specialist Pompetravaini busy

Pompetravaini Group is celebrating its 80th anniversary with several exciting projects under the direction of its new president. After 55 years, Mario Travaini has passed the position of president on to his son Carlo, though he remains active in the company. The new president is himself a veteran, having been with the company for nearly 20 years.

In such a landmark year, Pompetravaini has invest a lot of effort in expanding its worldwide presence and developing new products. 2008 saw the startup of a new branch in Poland, Travaini Pompy Polska, alongside Travaini's existing affiliates in France, Germany, the Netherlands, the UK, Canada and the US.

2009 will see the launch of two new sizes of the TRVX, Travaini's new-generation liquid-ring vacuum pump series. The new models build on the success of the patented TRVX 1007.

This year the company will launch a new engineered vacuum package named the HYDROTWIN, a two-stage system based on a Roots blower followed by a liquid-ring vacuum pump. A dedicated control system adjusts the motor speed to maintain vacuum performance, ensure safety, and optimize power usage. Developed in partnership with Roots blower manufacturer Bora Blower of Modena, the HYDROTWIN is available in eight sizes, with a maximum capacity of 2,500 m^3/h, and provides vacuum down to 5 mbar a.

No power vacuum here: Mario Travaini (l) hands over control to son Carlo (r)

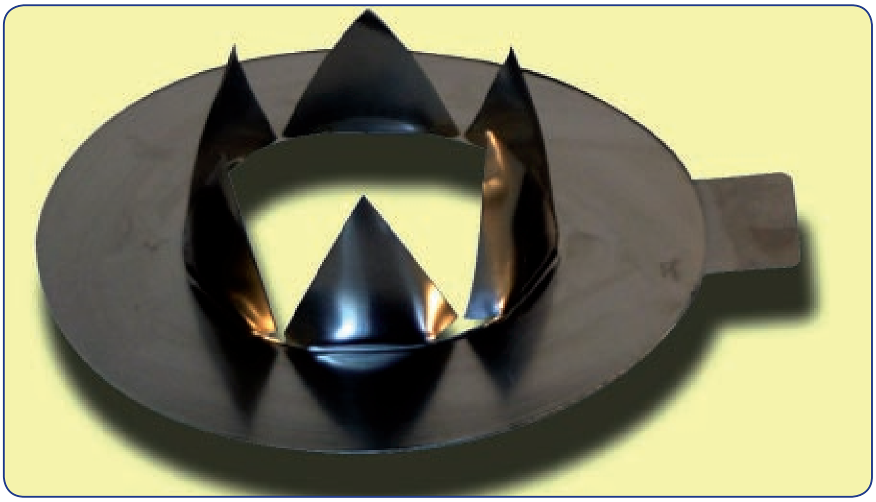
Pompetravaini has supplied liquid-ring vacuum pumps, centrifugal pumps and side-channel centrifugal pumps for 80 years. The company has three factories, seven subsidiaries, and distributors in over 80 countries. **www.pompetravaini.it**

A specialist in safety devices for pressure relief

Rupture discs and explosion vent panels are the main products of Donadon SDD, a specialist with more than 50 years' experience in manufacturing rupture discs

Rupture discs (bursting discs) are used to protect tanks, reactors, silos and other equipment from the consequences of excessive pressure or vacuum.

Donadon SDD manufactures rupture discs to customers' specifications, covering a wide range of diameters and burst pressures. High-precision, computer-controlled techniques ensure zero manufacturing range and low tolerance, even at low bursting pressures. Standard delivery is two to three weeks, but rush orders can be shipped in a few days. Delivery is worldwide, and prices are competitive.



With its six "petals" instead of the conventional four, this Donadon SCD reverse-acting rupture disc reduces the risk of metal fragments being carried downstream

Rupture discs may be used either alone, or in combination with relief valves. A rupture disc in parallel with a relief valve, for instance, offers a second level of protection and increases design flexibility—a typical application is in protecting liquefied gas tanks. When corrosive materials are present in the relief header, a downstream bursting disc with a lower pressure rating protects the relief valve. If the process fluid itself can cause corrosion, scaling or polymerization, an upstream bursting disc isolates the relief valve, reducing maintenance costs and avoiding corrosion-induced leaks.

Explosion vent panels are similar to rupture discs in their general philosophy, but are designed to limit the maximum overpressure that occurs during an explosion. They protect against subsonic deflagrations, not high-velocity detonations, and are used where there is a likelihood that flammable vapors or dust will mix with air. Typical applications are dust manifolds, dryers, troughs, silos, separators, mixers, boosters, air filters and sieves.

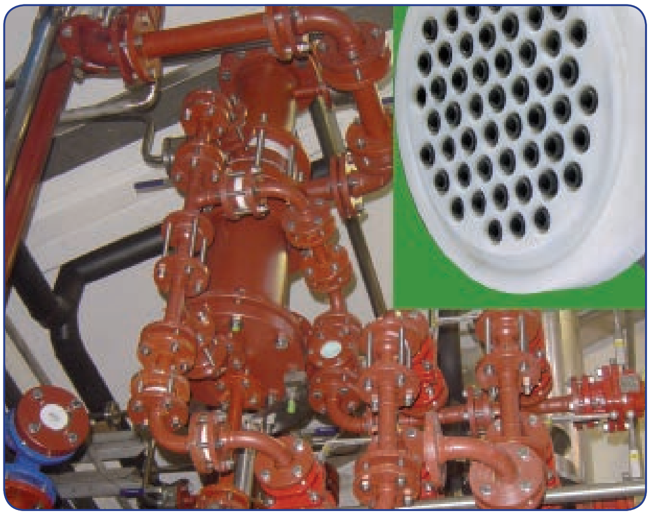
Even after an explosion vent panel has opened, the pressure inside the equipment will continue to rise, though its peak value will be lower than if the vent panel were not present. To avoid exceeding the maximum allowable pressure inside the equipment, explosion vent panels must open rapidly and fully, and be correctly sized.

Unlike most rupture discs, explosion vent panels do not require special holders. Instead, they can be fitted to simple supports such as welded steel frames.

Explosion vent panels do not typically come in a wide range of bursting pressures. To protect equipment operating at atmospheric pressure, they are typically manufactured with an activation pressure of 0.1 bar g. **www.donadonsdd.com**

PTFE and stainless steel for the best of both worlds

IT TECH's SiC/PTFE heat exchanger is leak-free even at elevated temperatures



Backing the PFTE tubesheet with a perforated stainless steel plate has allowed IT TECH to design a silicon carbide heat exchanger that resists leakage as well as corrosive fluids

Heat exchangers with silicon carbide (SiC) tubes benefit from the very high heat transfer coefficient typical of this material, points out corrosion-resistant materials specialist **IT TECH**. The weak points of a conventional SiC shell-and-tube heat exchanger, however, are the seals between the tubesheets and the tubes.

The problem is that these seals are normally made from PTFE. At temperatures around 100°C, PTFE loses much of its tensile strength. This hinders good sealing between the tubesheets and the tubes, and leaks often result.

Over the last three years, the Research & Development department at IT TECH has worked to create a new technology for the assembly of heat exchangers with PTFE tubesheets and tubes made from SiC or other corrosion-resistant materials. The result is the GUARDIAN "armored" PTFE exchanger.

The new heat exchanger has PTFE tubesheets supported on one side by a layer of stainless steel in the form of a perforated plate. While the PTFE lining provides complete chemical resistance, the stainless steel armor ensures that the tubesheet remains absolutely rigid; thus supported, the PTFE seals remain intact at temperatures that would cause them to fail in a conventional exchanger. Splitting the tasks of providing structural rigidity and resisting chemical attack makes for a reliable heat exchanger with a long working life.

Guardian heat exchangers use a sealing system based on threaded bushings made from Guaflon, a modified PTFE. These bushings screw into corresponding threads on the PTFE tubesheet, gripping the tubes and compressing O-ring seals made from perfluoroelastomer. The material of choice for the seals is Kaflon 72B, which the company says possesses the highest possible elasticity, softness and thermal resistance. These properties allow the tubes to expand and contract without compromising the integrity of the seals. **www.ptfe.ch**

Filters and dryers with pharmaceuticals in mind

Comber is a leading manufacturer of batch equipment for solid-liquid separation and vacuum drying that needs to be carried out under hygienic conditions

COMBER filtration and drying equipment is widely used to produce pharmaceutical ingredients, fine chemicals, dyes and food additives.

The product range includes filters, filter/dryers, horizontal vacuum paddle dryers, and agitated vacuum pan dryers. COMBER supplies individual machines as well as complete installations, including auxiliary equipment and extensive engineering services. Laboratory and pilot-scale tests are also offered.

Established in 1960, the company has its headquarters in Milan and a manufacturing site at Colzate (Bergamo). COMBER machines operate on every continent, and the company's agencies worldwide handle installation, commissioning, spares, repairs, and maintenance contracts.

COMBER engineers work with a wide range of construction materials, including Hastelloy and glass-lined steel. Pressure vessels are certified to ASME ("U" stamp), BS 5500, TÜV, and many other authorities, while the complete machines are approved by a similarly wide range of insurers. The company is certified to ISO 9001.

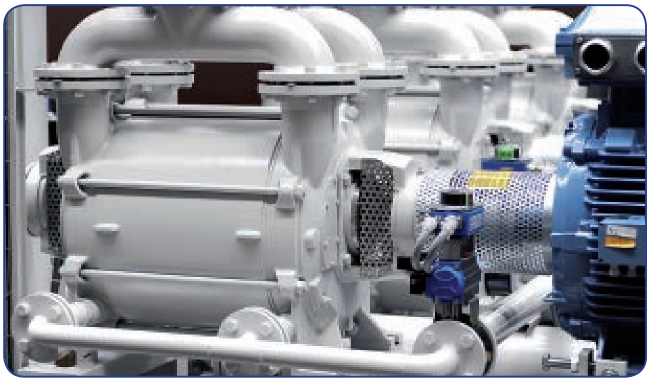
All COMBER's equipment is designed for simple validation, easy cleaning, and good heat and mass transfer even with difficult products. The product range comprises versatile Pressofiltro agitated nutsche filters and filter/dryers, Turbodry vacuum pan dryers, Condry conical-bottom agitated vacuum pan dryers, Pharmadry vacuum paddle dryers, and Termomix vacuum paddle dryer/reactors. The Termomix is intended for one-off or serial production, as a combination of mixer, reactor, precipitator and dryer.

www.comber.it

COMBER supplied this Pharmadry vacuum paddle dryer to Merck in Darmstadt, Germany

The vacuum power behind electricity generation

Robuschi liquid-ring vacuum pumps are ideal for removing air from condensers



Robuschi liquid-ring vacuum pumps ready for installation

Robuschi has successfully established a leading position in the world market, and has also gained an international reputation as an expert in blower and pump systems that specializes in customized solutions. The company can respond quickly to rapidly changing needs, and develops systems to satisfy both planned future demand and its customers' individual requirements at the lowest possible costs.

Recently Robuschi supplied an air removal system for a power plant, to remove air and gas from the steam side of the condenser. The system consists of three skid-mounted RVS 40 liquid-ring vacuum pumps, including piping, valves, non-condensibles separator tank, seal water cooler, controllers, and first-stage ejectors.

Each pump is driven by a 55 kW motor, giving a combined capacity of 51 kg/h of saturated air at a pressure of 40 mbar.

All the components are controlled and supervised from the control room, so it is possible to start and stop the pumps by remote control without the need for local checks. Instrumentation includes a monitoring system to ensure the correct flowrate and temperature of seal liquid to ensure safe and reliable operation.

Each pump is fitted with an ejector, allowing it to reach the required operating pressure even with seawater as the cooling liquid. Ejector bypass lines ensure excellent performance during initial pumpdown (hogging) of the condenser.

The service liquid is cooled indirectly against seawater, using a corrosion-resistant alloy heat exchanger. A Robuschi RNS series centrifugal pump is used to recirculate the service liquid.

The Robuschi RVS liquid-ring vacuum pump is a single-stage monobloc model with following features:

- vacuum down to 33 mbar a;
- suction capacity up to 4,200 m^3/h;
- able to pump both gases and vapors;
- able to handle liquid and gas together;
- nearly isothermal compression;
- no lubricant in contact with the process gas;
- safe operation and minimum maintenance;
- reduced noise and vibration;
- can be used for many different applications, with the proper choice of construction materials and service fluid.

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CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Kate Torzewski

Tray Column Design

Here, we present criteria needed for the intelligent, effective specification of trays for a distillation or stripping column.

Among the key parameters and accessories during specification are column diameter, tray spacing, number of trays, number of passes, type of downcomers, weir heights, provision of downcomer backups, tray pressure drops, design of bottom seal pan, column bottom arrangement, and nozzle location and orientation.

TRAY SPACING

The vertical distance between adjacent trays varies from 450 to 900 mm in the columns generally employed in the chemical process industries (CPI), as seen in Table 1.

Spacing involves a tradeoff between column height and column diameter; with greater tray spacing, the column height increases, while the required diameter decreases.

Height/diameter ratios greater than 25–30 are generally not recommended.

TABLE 1. Guidelines for Selection of Tray Spacing

Description	Tray Spacing, mm	Comments
Column diameters larger than 3,000 mm	> 600	The tray support beams restrict crawling space available; hence the large tray spacing
Column diameters between 1,200 and 3,000 mm	600	This spacing is sufficiently wide to allow a worker to freely crawl between trays
Column diameters between 750 and 1,200 mm	450	Crawling between the trays is seldom required, because the worker can reach the column wall from the tray manways
Fouling and corrosive service	> 600	Frequent maintenance is expected
Systems with a high foaming tendency	At least 450 mm, but preferably 600 mm or higher	Required to avoid premature flooding
Columns operating in spray regime	At least 450 mm, but preferably 600 mm or higher	Required to avoid excessive entrainment
Columns operating in froth regime	< 450	Lower tray spacing restricts allowable vapor velocity, thereby promoting froth-regime operation

TRAY PASSES

Set the number of passes such that liquid loads do not exceed 70 m^3/h per meter weir length.

After the number of passes has been selected, if necessary, adjust the column diameter in order to arrive at a minimum path length of 400 mm.

- For a column diameter of 1,200 to 2,100 mm: use two passes at maximum
- For a diameter of 2,100 to 3,000 mm: use three passes at maximum
- For a diameter above 3,000 mm: use four passes at maximum

DOWNCOMERS

Downcomers are conduits having circular, segmental or rectangular cross sections that convey liquid from a tray to the one immediately below.

Liquid velocities in downcomers:
- Minimally foaming liquids: 0.12–0.21 m/s
- Medium foaming liquids: 0.09–0.18 m/s
- Highly foaming liquids: 0.06–0.09 m/s

Downcomer areas and clearances: For the cross-sectional area of the downcomers, values less than 5–8% of the column cross-sectional area should not be specified. Also, the downcomer width should not be less than 10% of the column diameter.

Specify the downcomer clearance to be less than the outlet weir height; otherwise, vapor will flow up the downcomer rather than through the tray deck above.

Downcomer sealing: To achieve a proper downcomer seal, the bottom edge of the downcomer should be about 10 mm below the top edge of the outlet weir.

The downcomer clearance should be selected such that the liquid velocity under the downcomer does not exceed 0.45–0.50 m/s.

OUTLET WEIRs

- Weir heights in the froth regime are restricted to 50–80 mm
- Weir heights for columns operating in the spray regime should be 20–25 mm

Weir loadings should fall within the range of 15 to 70 m^3/h per meter weir length.

PRESSURE DROP

For trays to function reasonably close to their best efficiency point, the dry-tray pressure drop must be roughly equal to the hydraulic-tray pressure drop.

SEAL PANS

The clearance between the seal pan floor and the bottom downcomer should exceed the clearance normally employed under the tray downcomers. It should be at least 50 mm.

The distance that the downcomer extends downward within the seal pan should be about the same as the clearance between downcomer bottom and pan floor.

The distance between bottom tray floor and seal pan floor should be 150 mm greater than the normal tray spacing.

NOZZLE ORIENTATION

For nozzles that feed liquid into the top tray, the nozzle should be perpendicular to the downcomer of the top tray.

Nozzles feeding liquid at intermediate trays can be placed anywhere except in the downcomer segment. The space between the two trays should be at least 800 mm.

COLUMN BOTTOM

Inlets for the bottom feed and reboiler return lines should be at least 300 mm above the high liquid level.

The bottom feed and reboiler return should not impinge on the bottom seal pan, seal pan overflow, or the bottom downcomer.

The tops of both pipes should be at least 400–450 mm below the bottom tray.

References

1. Mukherjee, S., Tray Column Design: Keep Control of the Details, *Chem. Eng.*, September 2005, pp. 52–58.

CSTRs: Bound for Maximum Conversion

Here, a design approach for continuous stirred-tank reactors is outlined for both reversible and irreversible second-order reactions

Ralph Levine
Retired

Multiple CSTRs (continuous stirred-tank reactors) are advantageous in situations where the reaction is slow; two immiscible liquids are present and require higher agitation rates; or viscous liquids are present that require high agitation rates. Unlike in plug-flow reactors, agitation is easily available in CSTRs. In this article, analyses of batch and plug-flow reactors are calculated and compared to multiple CSTRs.

The number of reactors required in a CSTR system is based on the conversion for each stage. When the final stage obtains the fraction of unconverted reactant that is equal to the desired final value from the plug-flow case, the CSTR system is complete.

The volumetric efficiency of multiple CSTRs is expressed as a function of conversion per stage and gives the total conversion required. In this article, we will apply this to both irreversible and reversible second-order reactions.

2nd-order, irreversible reaction

For a two-component system reacting irreversibly, design of a CSTR series requires knowledge of the following: the volumetric efficiency of the reactor based on the order of the reaction, the number of stages, and the conversion in the first stage. The initial ratio of one component to the other may be greater than one.

The reactor design is developed by first selecting a conversion in the first stage. Then, the second-stage conversion is equal to that of the first stage, since it requires an equal volume. This procedure is continued until the fraction of reactant remaining equals the desired value. Reactors may be stacked, one above the other, to reduce the overall cost (Figure 1).

The kinetics of a bimolecular or second-order reaction, at constant volume and temperature, are represented by Equation (1). The reaction is illustrated below (nomenclature defined on p. 34).

$$B + D \longrightarrow P + \ldots$$

$$-r_B = kC_BC_D \quad (1)$$

$$C_{Bf} = C_{B0}(1 - X_f) \quad (2a)$$

$$C_{Df} = C_{B0}(1 - X_f) \quad (2b)$$

Here, $M = C_{D0}/C_{B0}$ for $M > 1.0$.

Conversion at the final desired concentrations is defined by Equations (2a) and (2b). Substituting these equations at any conversion level into Equation (1) gives the following expression.

$$-r_B = k(C_{B0})^2(1 - X)(M - X) \quad (3)$$

The ideal plug-flow case is given by Equation (4). The batch case may also be evaluated by this equation, because batch reaction time t is equal to (V/υ) for plug-flow.

$$\frac{V}{F_{B0}} = \frac{V}{\upsilon(C_{B0})} = \int_0^{X_f} \frac{dX}{-r_B} \quad (4)$$

$$\frac{V}{\upsilon} = \frac{1}{k(C_{B0})} \int_0^{X_f} \frac{dX}{(1 - X)(M - X)} \quad (4a)$$

Substituting Equation (3) into Equation (4), and integrating the resulting Equation (4a), gives Equation (5).

$$\frac{V}{\upsilon} = \frac{1}{kC_{B0}}\left[\frac{1}{(M - 1)}\right]\ln\frac{(M - X_f)}{(1 - X_f)M} \quad (5)$$

When M = 1.0, second-order kinetics as given in one of the author's earlier articles can be used [3].

Reactor volume. The case for CSTRs at constant volume and temperature is shown in Equation (6).

$$\frac{V_1}{F_{B0}} = \frac{V_1}{\upsilon C_{B0}} = \frac{X_1}{-r_{B1}} \quad (6)$$

$$-r_{B1} = kC_{B0}^{\ 2}(1 - X_1)(M - X_1) = C_{B1}^{\ 2} \quad (6a)$$

Substituting Equation (6a) into (6) and rearranging gives Equation (6b).

$$\frac{V_1}{\upsilon} = \frac{1}{k(C_{B0})}\left[\frac{X_1}{(1 - X_1)(M - X_1)}\right] \quad (6b)$$

Based on Equation (6a), we can find the reaction rate for any stage, as shown in Equations (7a)–(7c).

$$-r_{B2} = kC_{B1}^{\ 2}(1 - X_1)(M - X_1) \quad (7a)$$

$$-r_{B2} = kC_{B0}^{\ 2}\left[(1 - X_1)(M - X_1)\right]^2 \quad (7b)$$

$$-r_{B3} = kC_{B0}^{\ 2}\left[(1 - X_1)(M - X_1)\right]^3 \quad (7c)$$

The second reactor in a series of CSTRs is of equal volume to the first reactor. Therefore, the conversion is $X_1 = X_2$, as given in Equation (8).

$$\frac{V_1}{\upsilon} = \frac{X_1}{kC_{B0}\left[(1 - X_1)(M - X_1)\right]^2} \quad (8)$$

The third stage is also the same volume, so the conversion is $X_1 = X_3$ as given in Equation (9).

$$\frac{V_1}{\upsilon} = \frac{X_1}{kC_{B0}\left[(1 - X_1)(M - X_1)\right]^3} \quad (9)$$

It can be shown that the nth reaction

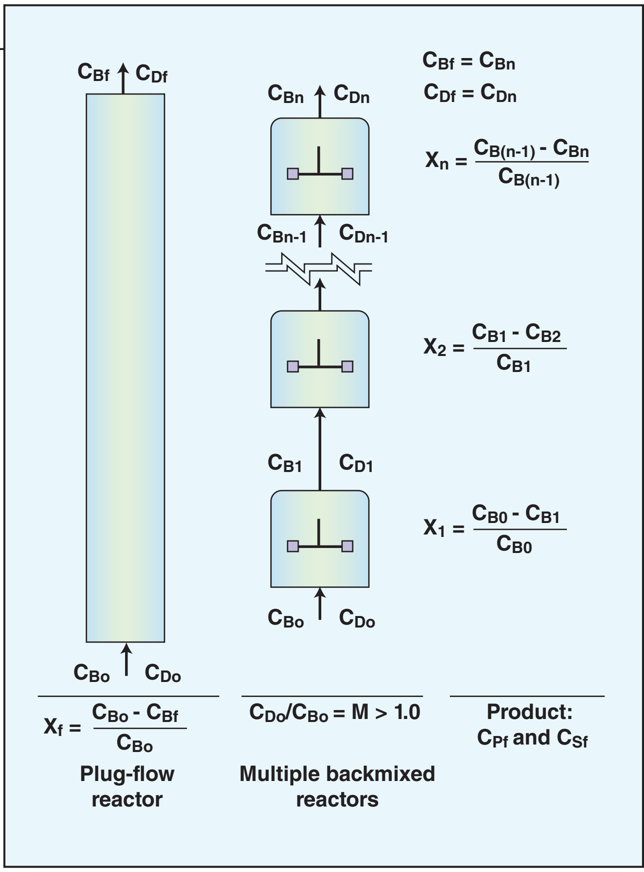

FIGURE 1. Conversion in plug-flow reactors and CSTRs for second order reactions is shown here, with conversion per stage shown for the CSTR case

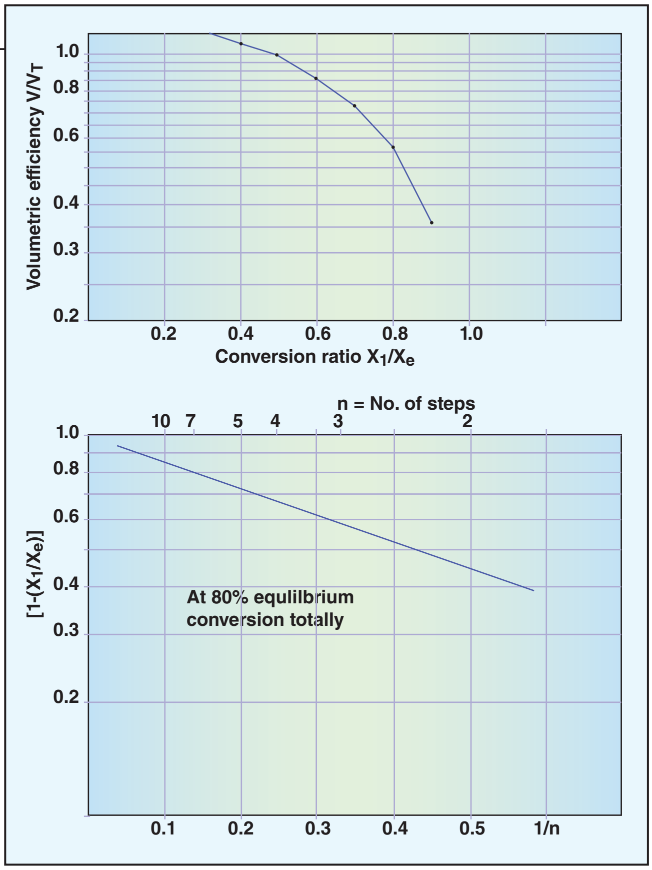

FIGURE 2. These graphs represent the calculations performed in Table 3. They illustrate the volumetric efficiency as a function of conversion ratio (top), and $[1-(X_1/X_e)]$ as a function of $1/n$ (bottom)

is given by Equation (10) and the final stage is given as (10a).

$$-r_{Bn} = kC_{B0}^{2}\left[(1-X_1)(M-X_1)\right]^n \quad (10)$$

$$\frac{V_T}{\upsilon} = \frac{X_1}{kC_{B0}\left[(1-X_1)(M-X_1)\right]^n} \quad (10a)$$

The volume of each stage is dependent on the conversion in the first stage, as in Equation (6a), for any value of υ, k, C_{B0}, and M.

Volumetric efficiency. The volumetric comparison for plug-flow or batch reactors to the series of CSTRs is called "volumetric efficiency," as shown below.

$$\frac{V}{V_T} = \frac{\textit{Volume in Plug Flow}}{\textit{Volume of } n \textit{ Backmixed}}$$

Divide Equation (5) by Equation (10a) to calculate the volumetric efficiency.

$$\frac{V/\upsilon}{V_T/\upsilon} = \frac{V}{V_T} = \frac{2.303\left(\frac{1}{M-1}\right)\log\left[\frac{(M-X_f)}{(1-X_f)M}\right]}{\frac{X_1}{\left[(1-X_1)(M-X_1)\right]^n}} \quad (11)$$

$$\frac{V}{V_T} = 2.303\left[(1-X_1)(M-X_1)\right]^n \times \frac{\log\left[\frac{(M-1)+(1-X_f)}{M(1-X_f)_1}\right]}{(M-1)X_1} \quad (11a)$$

Simplify Equation (11), noting that $(M-X_f) = (M-1)+(1-X_f)$.

$$\frac{V}{V_T} = \frac{2.303\left[(1-X_1)(M-X_1)\right]^n \times \log\left[\frac{(M-1)}{M(1-X_f)} + \frac{1}{M}\right]}{(M-1)X_1} \quad (11b)$$

Tables 1 and 2 for plug-flow reactors show the calculations involved in Equation (11b) for various values of final conversion. At high conversions, the volume of the reactor should be larger, assuming a constant flowrate for each case. The volume required is calculated using Equation (5).

For CSTRs in series, one of several cases of conversion for a series of reactor stages may be selected. Each stage must contain the same volume to obtain the same conversion (X_1) in each.

If we select a conversion of X_f = 0.8 (80%) and M = 2 mole ratio of D to B initially, then the plug-flow volume effect is 1.0988, as shown in theright-hand column of Table 1. Meanwhile, Table 2 shows the calculation progression for the CSTR volume effect (the bottom half of Equation [11]) with the complete term represented in the high-hand column. In order to find the volumetric efficiency, the final CSTR-volume term, $X_1/[(1-X_1)(M-X_1)]$ must be equal to or higher than the final value for the volume in plug-flow.

1. If we select X_1 = 0.5 (50%), three stages are required. The volumetric efficiency for this CSTR series is: V/V_T = 1.099/1.185 = 0.927
2. In the case where X_1 = 0.4 (40%) conversion, 6 stages are required. The volumetric efficiency is: V/V_T = 1.099/1.139 = 0.965
3. The next case, where X_1 = 0.35 (35%) conversion, 9 stages are required. The volumetric efficiency here is: V/V_T = 1.099/1.129 = 0.973
4. The last case to consider is where X_1 = 0.6 (60%) conversion. Here, 2 stages are required. The volumetric efficiency for this case is: V/V_T = 1.099/1.465 = 0.750

The preferred design is at X_1 = 0.5 (50%), where 3 stages are required.

The comparison for 3 stages (at 50% conversion) to 6 stages (at 40%

conversion) is:
0.927/0.965 = 96.1%

For 3 stages versus 9 stages at 35% conversion, volumetric efficiency is:
0.927/0.973 = 95.3%

This means that we lose less than 5% of the volumetric efficiency at the increase of more stages, making a three-stage CSTR series an efficient choice for this reaction.

2nd-order, reversible reaction

A kinetic process that depends on two components for a reversible reaction may be designed by calculating the conversion in the first stage; the number of stages of equal volume; and the volumetric efficiency of the reactor. The initial ratio for the two components may be any value greater than 1. However, a preferred ratio of 2 could simplify the reaction rates.

B+D is to be converted to P+S. The kinetic rate expression of a reversible bimolecular reaction is given as Equation (12) at constant temperature and volume for each stage.

$$-r = k_F C_B C_D - k_R C_P C_S \quad (12)$$

$$k_R = k_F / K \quad (12a)$$

$$C_{Bf} = C_{B0}(1 - X_f) \quad (13a)$$

$$C_{Df} = C_{B0}(M - X_f) \quad (13b)$$

Here, $M = C_{D0}/C_{B0} > 1$ mole ratio.

Equations (14a) and (14b) relate the initial concentration of B to the final concentrations of the P and S for a given final conversion, assuming that there is no initial concentration of P and S.

$$C_{B0}X_f = C_{B0} - C_{Bf} = (C_{P0} + C_{Pf}) + (C_{S0} + C_{Sf}) \quad (14a)$$

$$C_{B0}X_f = C_{B0} - C_{Bf} = C_{Pf} + C_{Sf} \quad (14b)$$

Assume that P and S compounds are not present in the feed components. Therefore, C_{P0} and C_{S0} are equal to zero, and the following expressions are true:

$$C_{Pf} = C_{B0}X_f \quad (14c)$$

$$C_{Sf} = C_{B0}X_f \quad (14d)$$

$$\left(C_{B0}X_f\right)^2 = C_{Pf} + C_{Sf} \quad (14e)$$

TABLE 1. PLUG-FLOW, M = 2

$M-X_f$	$1-X_f$	$(M-X_f)/(1-X_f)M$	$\log[(M-X_f)/(1-X_f)M]$	$2.303 \times \log[(M-X_f)/(1-X_f)M]$
1.2	0.2	3.000	0.477	1.099
1.25	0.25	2.400	0.398	0.917
1.3	0.3	2.167	0.336	0.773
1.35	0.35	1.928	0.285	0.657
1.4	0.4	1.750	0.243	0.560
1.5	0.5	1.500	0.176	0.406

TABLE 1. Here, calculations are performed to find the plug-flow volume effect, as determined using Equation (11). The 1/(M-1) term in this case is equal to 1

Expressing reaction rate. The rate equation is modified to include conversion and equilibrium constant terms. Substituting Equations (12a)–(14d) into (12) gives Equation (15a).

$$-r = k_F C_{B0}(1 - X_f)C_{B0} \times (M - X_f) - \frac{k_F}{K}(C_{B0}X_f)^2 \quad (15a)$$

$$-r = k_F C_{B0}^2\left[(1 - X_f)(M - X_f) - \frac{1}{K}X_f^2\right] \quad (15b)$$

At equilibrium, the reaction rate equals zero.

$$0 = (1 - X_e)(M - X_e) - \frac{1}{K}X_e^2 \quad (16a)$$

$$0 = M - X_e(M + 1) + \left[X_e^2 - \frac{1}{K}X_e^2\right] \quad (16b)$$

$$0 = \left(\frac{K - 1}{K}\right)X_e^2 - (M + 1)X_e + M \quad (16c)$$

Using the quadratic equation, Equation (16c) becomes (16d).

$$X_e = \frac{(M + 1) \pm \sqrt{(M + 1)^2 - 4M(K - 1)/K}}{2(K - 1)/K} \quad (16d)$$

Referring to Equation (15b), we can combine terms.

$$-r = k_F C_{B0}^2\left[\frac{(K - 1)}{K}X_f^2 - (M + 1)X_f + M\right] \quad (17a)$$

$$X_f = \frac{(M + 1) \pm \sqrt{(M + 1)^2 - 4M(K - 1)/K}}{2(K - 1)/K} \quad (17b)$$

$$-r = k_F C_{B0}^2\left[X_e - X_f\right] \quad (17c)$$

$$-r = k_F C_{B0}^2 X_e\left[1 - (X_f/X_e)\right] \quad (17d)$$

Stirred reactor in a batch or plug-flow reactor. The batch reactor case and the ideal continuous plug-flow case are given in Equation (18).

The reaction time is t for the batch case, or V/υ for plug-flow case.

$$\frac{V}{\upsilon C_{B0}} = \int_0^{X_f}\frac{dX}{-r} \quad (18)$$

Substituting Equation (17d) into (18) gives Equations (18a) and (18b).

$$\frac{V}{\upsilon C_{B0}}\left(k_F C_{B0}^2\right)X_e = \int_0^{X_f}\frac{dX}{\left[1 - \left(X_f/X_e\right)\right]} \quad (18a)$$

$$\frac{V}{\upsilon}\left(k_F C_{B0} X_e\right) = \ln\left[1 - \left(X_f/X_e\right)\right] \quad (18b)$$

Volume of each CSTR stage. An expression for the first stage of a CSTR is given in Equation (19). The first-stage conversion X_1 occurs in each of the successive stages (X_2, X_3, and so on), and each stage has the same volume.

$$\frac{V_1}{\upsilon C_{B0}} = \frac{X_1}{-r} \quad (19)$$

Substituting Equation (17d) into (19) and rearranging gives (19a).

$$\frac{V_1}{\upsilon C_{B0}} = \frac{1}{(k_F C_{B0}^2)}\left[\frac{(X_1/X_e)}{1 - (X_1/X_e)}\right] \quad (19a)$$

$$\frac{V_1}{\upsilon}(k_F C_{B0}) = \left[\frac{(X_1/X_e)}{1 - (X_1/X_e)}\right] \quad (19b)$$

Equation (19b) has only one independent variable (V). If each stirred reac-

TABLE 2. CSTR STAGES AT CONVERSION X_1

X_1	$1-X_1$	$(1-X_1)(M-X_1)$	n	$(1-X_1)(M-X_1)^n$	$X_1/[(1-X_1)(M-X_1)]^n$
0.80	**0.20**	**0.360**	**1**	**0.360**	**2.222**
0.70	0.30	0.510	1	0.510	1.373
0.60	0.40	0.640	1	0.640	0.938
0.60	**0.40**	**0.640**	**2**	**0.410**	**1.465**
0.50	0.50	0.750	1	0.750	0.667
0.50	0.50	0.750	2	0.563	0.889
0.50	**0.50**	**0.750**	**3**	**0.422**	**1.185**
0.40	0.60	0.840	1	0.840	0.476
0.40	0.60	0.840	2	0.706	0.567
0.40	0.60	0.840	3	0.593	0.675
0.40	**0.60**	**0.840**	**6**	**0.351**	**1.139**
0.35	0.65	0.878	1	0.878	0.399
0.35	0.65	0.878	2	0.771	0.454
0.35	0.65	0.878	3	0.677	0.517
0.35	0.65	0.878	4	0.594	0.589
0.35	0.65	0.878	5	0.522	0.671
0.35	**0.65**	**0.878**	**9**	**0.310**	**1.129**
0.30	0.70	0.910	1	0.910	0.330
0.30	0.70	0.910	2	0.828	0.362
0.30	0.70	0.910	5	0.624	0.481
0.30	0.70	0.910	7	0.517	0.581
0.30	0.70	0.910	10	0.389	0.770
0.30	**0.70**	**0.910**	**15**	**0.243**	**1.235**
0.25	0.75	0.938	1	0.938	0.267
0.25	0.75	0.938	4	0.774	0.323
0.25	0.75	0.938	8	0.599	0.417
0.25	0.75	0.938	16	0.359	0.696
0.25	0.75	0.938	20	0.278	0.899
0.25	**0.75**	**0.938**	**24**	**0.215**	**1.162**

TABLE 2. This table shows the calculations performed to find the CSTR volume effect, as determined using Equation (11). The last row for each value of X_1, which are shown in bold, give the required number of stages for particular reactor conversion

tor stage is to be of equal volume and at a constant volumetric flowrate, then the result is a constant conversion per stage. That is, each stage, when at a fixed set of conditions, has the same conversion resulting from each stage, expressed as:

$X_1 = X_2 = X_3 \dots = X_n$

Number of stages. Conversion for stage 1 is expressed by Equation (20).

$$X_1 = \frac{C_{B0} - C_{B1}}{C_{B0}} \qquad \textbf{(20)}$$

The equilibrium conversion is based on the time needed to reach a reaction rate of zero, which may be calculated by Equation (16d) or (21).

$$X_e = \frac{C_{B0} - C_{Be}}{C_{B0}} \qquad \textbf{(21)}$$

Subtract Equation (21) from (20) and divide by (21) to find Equation (22).

$$X_e - X_1 = \frac{C_{B1} - C_{Be}}{C_{B0}} \qquad \textbf{(22)}$$

$$\frac{X_e - X_1}{X_e} = \frac{(C_{B1} - C_{Be})/C_{B0}}{(C_{B0} - C_{Be})/C_{B0}} \qquad \textbf{(22a)}$$

$$1 - (X_1/X_e) = \frac{(C_{B1} - C_{Be})}{(C_{B0} - C_{Be})} \qquad \textbf{(22b)}$$

The exit concentration, $C_{B1,}$ can be calculated from Equation (22a). Also, the exit concentration from the second stage, C_{B2}, can be calculated from Equation (23a), based on each stage having the same volume and conditions.

$$1 - (X_1/X_e) = \frac{(C_{B2} - C_{Be})}{(C_{B1} - C_{Be})} \qquad \textbf{(23a)}$$

Substitute Equation (22b) into (23a) to obtain (23b).

$$\left[1 - (X_1/X_e)\right]^2 = \frac{(C_{B2} - C_{Be})}{(C_{B1} - C_{Be})} \times \frac{(C_{B1} - C_{Be})}{(C_{B0} - C_{Be})} \qquad \textbf{(23b)}$$

$$\left[1 - (X_1/X_e)\right]^2 = \frac{(C_{B2} - C_{Be})}{(C_{B0} - C_{Be})} \qquad \textbf{(23c)}$$

Continue this process for the nth stage to obtain the following equations.

$$\left[1 - (X_1/X_e)\right]^n = \frac{(C_{Bn} - C_{Be})}{(C_{B0} - C_{Be})} \qquad \textbf{(24)}$$

$$(n)\log\left[1 - (X_1/X_e)\right] = \log\frac{(C_{Bn} - C_{Be})}{(C_{B0} - C_{Be})} \qquad \textbf{(24a)}$$

$$\frac{(C_{Bn} - C_{Be})}{(C_{B0} - C_{Be})} = \left[1 - (X_f/X_e)\right] = \left[1 - \frac{X_1}{X_e}\right]^n \qquad \textbf{(24b)}$$

Total volume of all stages. Substitute Equation (19b) into (25).

$$V_T = nV_1 \qquad \textbf{(25)}$$

$$\frac{V_T}{\upsilon}k_F C_{B0} = n\frac{V_1}{\upsilon}k_F C_{B0} = n\frac{(X_1/X_e)}{\left[1 - (X_1/X_e)\right]} \qquad \textbf{(25a)}$$

Substitute Equation (24a) for n in (25a).

$$\frac{V_T}{\upsilon}k_F C_{B0} = \frac{\log\left(\dfrac{C_{Bn} - C_{Be}}{C_{B0} - C_{Be}}\right)}{\log\left[1 - (X_1/X_e)\right]} \times \frac{(X_1/X_e)}{\left[1 - (X_1/X_e)\right]} \qquad \textbf{(25b)}$$

By definition, $C_{Bn} = C_{Bo}(1 – X_f)$, where X_f is the overall or total conversion in the nth stage or the final desired conversion of the plug-flow reactor. By the method used to obtain Equation (22), the following equation is similarly derived. Substitution of Equation (24b) into (25b) gives Equation (25c).

$$\frac{V_T}{\upsilon}k_F C_{B0} = \frac{\log\left[1 - (X_f/X_e)\right]}{\log\left[1 - (X_1/X_e)\right]} \times \frac{(X_1/X_e)}{\left[1 - (X_1/X_e)\right]} \qquad \textbf{(25c)}$$

TABLE 3. VOLUMETRIC EFFICIENCY FOR EQUATION (26A)

$$\frac{V}{V_T}=\frac{-2.303\left[1-\left(X_1/X_e\right)\right]\times\log\left[1-\left(X_1/X_e\right)\right]}{X_e\left(X_1/X_e\right)} \quad \textbf{(26a)}$$

X_1/X_e	X_e	$1-(X_1/X_e)$	$\log[1-(X_1/X_e)]$	$(V/V_T)X_e$	V/V_T
0.1	0.7	0.9	-0.046	0.948	1.355
0.2	0.7	0.8	-0.097	0.893	1.275
0.3	0.7	0.7	-0.155	0.832	1.189
0.4	0.7	0.6	-0.222	0.766	1.095
0.5	0.7	0.5	-0.301	0.693	0.990
0.6	0.7	0.4	-0.398	0.611	0.873
0.7	0.7	0.3	-0.523	0.516	0.737
0.8	0.7	0.2	-0.699	0.402	0.575
0.9	0.7	0.1	-1.000	0.256	0.366

TABLE 3. For any ratio of conversion per stage to equilibrium conversion, this table provides the corresponding volumetric efficiency, based on Equation (26a).

NOMENCLATURE

C_B	Concentration of component B, moles/unit volume
C_D	Concentration of component D, moles/unit volume
F	Molar flowrate
k	Reaction velocity constant
K	Overall reaction velocity constant
M	Initial mole ratio of D/B
n	Number of stages
r	Reaction rate
t	Reaction time
V	Reactor volume
v	Volumetric flowrate
X	Conversion
	Subscripts
0	Refers to initial conditions
1,2,3	Refers to first, second and third stages
e	Refers to equilibrium conditions
j	Refers to any stage in the series of reactor stages
n	Refers to the *n*th stage
f	Refers to the overall or final conditions
F	Conditions for forward reaction
R	Conditions for reverse reaction
T	Refers to the total of all n stages

Volumetric efficiency. Since V_T/v in Equation (25c) is residence time, as is V/v in Equation (18b) for CSTRs, these terms are equivalent. The volumetric flowrate is the same in all cases (a batch operation for one complete reaction cycle). Thus, the ratio of comparison should be V for plug-flow or batch operation (reaction volume and time only) compared to V_T for multiple CSTRs. This ratio (V/V_T) is expressed as Equation (26), as derived from (18b) and (25c).

The variables needed to evaluate the volumetric efficiency are: the first stage conversion; the number of reactor stages n; and the initial mole ratio of the excess reagent to the limiting reagents, M.

$$\frac{\frac{V}{\upsilon}k_F C_{B0} X_e}{\frac{V_T}{\upsilon}k_F C_{B0}} = \frac{-\log\left[1-\left(X_f/X_e\right)\right]\times 2.303}{\frac{\log\left[1-\left(X_f/X_e\right)\right]}{\log\left[1-\left(X_1/X_e\right)\right]}\left[\frac{X_1/X_e}{1-\left(X_1/X_e\right)}\right]} \quad \textbf{(26)}$$

(See Table 3) **(26a)**

Equation (26a) is independent of initial or final concentrations and the velocity constant at constant temperature, as well as of overall conversion.

Examples: reversible reaction. The desired final conversion at a constant volumetric conversion is related to the number of stages required. The number of stages required can be obtained by solving Equation (24a).

With n stages in multiple reactors, the conversion per stage is calculated from Equation (24a). Assume an overall conversion of 80% of the equilibrium conversion. A plot of $(1–X_1/X_e)$ versus $1/n$ on semilog paper gives a straight line, as seen in Figure 2 [*3*].

Refer to the volumetric efficiencies in Table 3, which represents Equation (26a). If we select a volumetric efficiency of 0.893, a plug-flow reactor will have only 89.3% of the multiple CSTR volume. The conversion in Table 3 is about 20% conversion per stage. From Figure 2 or Equation (24b), and a ratio of conversion per stage compared to equilibrium conversion or $(1–X_1/X_e)$ = 0.80, 7.14 stages is required.

This calculation can be performed in reverse, if we would like to design the CSTR series in four stages. From Figure 2, we find that the term $(1–X_1/X_e)$ equals 0.67. Next, refer to Equation (26a) and Table 3 for the efficiency at (X_1/X_e), which equals 0.33, and finally shows the volumetric efficiency of 81%.

Summary of conclusions

The volumetric efficiency in a CSTR is independent of initial concentration, velocity and equilibrium constants at constant temperature and the final conversion desired. It is dependent on only the ratio of the first stage conversion to the equilibrium conversion. ■

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Controlling Emissions With Ceramic Filters

Ceramic filters are well suited for high-temperature processes that are subject to strict emissions limits, including those for dioxins

Andrew Startin and Gary Elliott
Clear Edge Filtration

Ceramic filters offer practical operating benefits and commercial competitiveness in pollution abatement applications where processes combine elevated-temperature off gases with the need for high levels of corrosion resistance and the ability to eliminate dust emissions. This article discusses the applicability of ceramic filtration technology, with focus on, and examples of its use in incineration processes.

The ability to deliver low emissions, even with fine particles that are 2.5 micrometers (μm) or smaller ($PM_{2.5}$), while operating at an elevated temperature is the primary driver for the application of ceramic elements to high temperature processes that are subject to strict emissions limits. Such processes include metal smelting, chemicals production and waste incineration. In the latter case, ceramic elements have been applied to a number of small- to medium-scale incineration duties including medical waste, soil cleaning, asphalt recycling, industrial waste, chemical waste and building waste.

Several new, high-temperature incineration installations have been set up to deal with waste that is of mixed composition from various sources. Ceramic elements have been selected as the filter medium for a number of these installations. Of particular interest are the emissions of dioxin chemicals and particulate matter that have been under close scrutiny since the 1990s. Official emissions reports commissioned for these plants indicate emissions well within regulated limits.

Ceramic filtration technology

The concept of using a refractory ceramic material to form a filter medium, predominantly for use at elevated temperature (generally in the region of 200–400°C, but can be up to 900°C) has been around for many years [*1*]. One of the earlier forms of ceramic filter was devised for advanced power-generation applications with the requirement for operation at high temperature and high pressure. In the form of flanged tubes, closed at one end, these "high density" media are still in widespread use across a broad range of applications.

Low-density ceramic filter elements (hereafter referred to as ceramic elements) were initially developed in the middle 1980s. One of the first applications for ceramic elements was in thermal soil remediation. This process involves driving off the volatiles from contaminated soil in a rotary furnace to decontaminate it and make it reusable. The first stage in the complex off-gas treatment train is high tem-

TABLE 1. CHARACTERISTICS OF HIGH- AND LOW-DENSITY CERAMIC-FILTER ELEMENTS

	High density	Low density
Structure	Granular	Fibrous
Density	High	Low
Filter drag	High	Low
Porosity, % (inverse of resistance to flow)	0.3 – 0.4	0.8 – 0.9
Tensile strength	High	Low
Fracture mechanism	Brittle	Ductile
Thermal shock resistance	Low	High
Cost	High	Low

ABOUT INCINERATION

Incineration processes are being widely used more and more to deal with the disposal of waste materials. In many countries, land filling of waste materials is not practical or desirable due to a lack of appropriate sites. Incineration has the benefit of reducing both the volume and mass of waste, thus reducing the amount of material to be disposed of.

Incineration is now applied to a wide range of waste streams from high-tonnage municipal solid waste (MSW) through to the lower-tonnage specialty wastes produced by industrial processes. However, whatever the application, the imperative for the incineration process is broadly the same — a reduction in mass and volume while rendering the remaining waste material as inert as possible and, of course, producing the absolute minimum of emissions.

Waste incineration, as with other industrial processes, has been the subject of ever tightening emissions legislation in recent years. Public disquiet over incineration processes and the generation of potentially dangerous emissions has subsequently, detrimentally affected the approval of many new installations. Consequently, the industry has sought effective post-incinerator processes for dealing with off gases in terms of reducing and eliminating emissions and where practical, recovering useful energy. Many techniques and combinations of techniques have been developed and are under development — a broad overview of which is beyond the scope of this paper. ❑

TABLE 2. CHARACTERISTICS OF (LOW-DENSITY) CERAMIC ELEMENTS	
Form	Monolithic rigid tube
Composition	Refractory fibers plus organic and inorganic binding agents
Porosity	about 80–90%
Density	about 0.3–0.4 g/cc
Support	Self supporting from integral flange
Geometry	Outer dia. up to 150 mm; Length up to 3 m

TABLE 3. MAXIMUM OPERATING TEMPERATURE OF FILTRATION MEDIA		
	Operating Temperature (°C)	
	Continuous	Surge
Sulfar ("Ryton")	180	200
Aramid ("Nomex")	200	240
Polyimide ("P84")	240	260
PTFE ("Teflon")	260	280
Glass	260	300
Ceramic elements	900	900

perature filtration, which removes particulates from the gas prior to further processing.

The ceramic elements manufactured in the middle 1980s were sectional, meaning they were built up from a series of inner- and outer-tube sections. The first monolithic elements were produced around the late 1980s and early 1990s. One of the early applications envisaged was advanced power generation, so the form of the first monolithic ceramic element was typical of the high-density elements being applied in the development of advanced power-generation technology — it was a 1-m-long tube, with a 60-mm outside dia., closed at one end and with an integral mounting flange at the other end.

Table 1 summarizes the main characteristics of the two types of elements referred to as low and high density. In addition to the characteristics outlined in the table, one major difference between high- and low-density ceramic filter elements is the forming method. Typically, high density elements are manufactured from refractory grains (such as alumina or silicon carbide) by pressing or tamping to form the basic shape. Low-density ceramic filter elements are vacuum formed from a slurry of refractory fibers to produce a blank, which is machined to shape, or in some cases to produce the final shape. It is also worth mentioning that ceramic filter elements are also produced in the form of plain tubes and can be applied to "inside out" filtration as well as "outside in". Normally, however, "outside in" filtration is employed.

Characteristics and benefits. The key characteristics of ceramic elements are summarized in Table 2. Ceramic elements are formed from refractory ceramic fibers with a fiber diameter of around 3 µm. Fiber diameter is crucial to promoting surface filtration and thereby good filtration characteristics.

TABLE 4. EFFICIENCY OF CERAMIC ELEMENTS IN VARIOUS APPLICATIONS

Process	Dust loading	Particle size	Emission level	Inferred efficiency
	mg/Nm^3	d_{50}[1], µm	mg/Nm^3	%
Zirconia production	Up to 8,000	1.2	0.8	99.99
Aluminum powder production	550	<50	<1	>99.8
Secondary aluminum	about 870	<1	0.5	99.9
Smokeless fuel production	1,000	4.8	1.5	99.85
Nickel refining	about 11,800	<10	<1	>99.99

1. Diameter of median size particle

TABLE 5. EUROPEAN WASTE INCINERATION DIRECTIVE ANNEX V: AIR EMISSION LIMIT VALUES (ELV)

	Directive Requirement		
	ELV mg/m^3	Averaging/Monitoring Period	Monitoring Frequency
Total Dust	10	Daily average	Continuous
VOCs (as TOC)	10	Daily average	Continuous
HCl	10	Daily average	Continuous
HF	1	Daily average	Continuous
SO_2	50	Daily average	Continuous
NOx (as NO_2)	200	Daily average	Continuous
CO	50	Daily average	Continuous
Cd and Tl	total 0.05	All average values over the sample period (30 min to 8 h) to be less than these limits	Periodic: 2 per year but every 3 months during first year of operation
Hg	0.05		
Sb, As, Pb, Cr, Co, Cu, Mn, Ni and V	total 0.5		
Dioxins and furans	0.1 ng/m^3 TEQ	CEN[2] method, sample period 6 to 8 h	As above

2. Conseil European pour la Normalisation

The structure and composition of ceramic elements confer three principal benefits for the technology:

- High-temperature filtration capability
- High collection efficiency
- Corrosion resistance

Although the maximum use temperature claimed by the various manufacturers for their ceramic elements varies, it is typically stated as 900°C (1,650°F). This temperature is well above that required by the majority of "end-of-pipe" air pollution control (APC) duties that utilize traditional fabric bags for particulate capture. The ceiling temperature for commonly used fabric-bag materials is shown in Table 3.

The elevated ceiling temperature of ceramic elements coupled with high filtration efficiency constitutes the basis for selection of the technology. Where the off gas to be filtered is consistently at a temperature below 250°C, then a needlefelt or coated needlefelt manufactured from a traditional polymeric material will often be adequate. However, stringent emissions regulations coupled with an elevated or variable off-gas temperature can be too tough for polymeric fabrics and favor the application of ceramic elements. Examples of the emissions

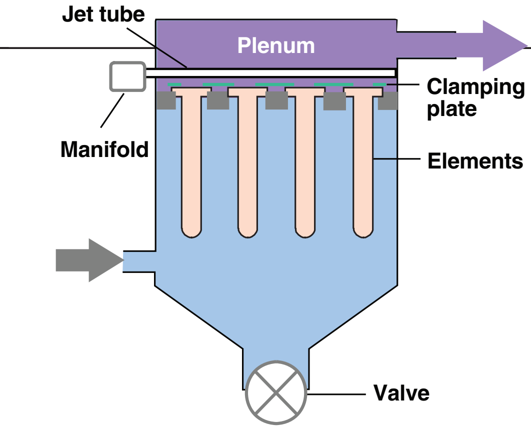

FIGURE 1. A ceramic filter plant is shown in this schematic diagram

TABLE 6. SOME APPLICATIONS OF CERAMIC ELEMENTS	
Air pollution control applications	**Product collection/recovery applications**
Waste incineration	Titanium dioxide production
Soil cleaning	Fumed silica production
Metals smelting	Carbon black production
Minerals processing	Catalyst manufacture
Foundry processes	Platinum smelting
Glass furnaces	Metal powder production
Cement production	Activated carbon production
Fluidized beds	
Boiler plant	

achieved by ceramic elements are presented in Table 4.

Application and duties. Many industrial processes, and in particular, high-temperature processes, emit off-gas streams of mixed gas laden with particulate matter that has a variable composition. Managing these off-gas streams is a necessary part of the industrial activity. Air emissions from an incineration plant can involve a broad range of species, including particulate matter, oxides of nitrogen (NOx), oxides of sulfur (SOx), hydrogen chloride, volatile organic compounds (VOCs), polychlorinated biphenyls/dibenzo furans (dioxins) and heavy metals. The abatement regime is required to reduce these pollutants to below the regulated limits. The European Waste Incineration Directive, currently being enacted in the U.K. and elsewhere, requires specified incineration processes to meet a series of defined emission limit values (ELVs). These are outlined in Table 5.

A number of established and emerging technologies have been developed to meet regulated emission limits. These include barrier filters, dry, semi-dry and wet scrubbing, cyclones, electrostatic precipitators and catalysis-conversion processes. These cleanup processes are used, often in combination, to achieve at least the regulated emission limits. Process choice is affected by many factors, apart from the regulations in force, not least of which are economics and reliability.

Ceramic elements can be employed in a filtration plant to meet the particulate (dust) emission target across a broad range of processes. In this article, the terms filter plant and filtration plant refer to a full filter assembly consisting of the housing and filter elements (Figure 1). The filtration plant can be a new build, or ceramic elements can be retrofitted into an existing bag-house filter. The filter plant, housing the array(s) of ceramic elements, is often used in combination with dry scrubbing and is placed downstream of cooling or heat recovery apparatus.

In principal, the operation of ceramic filter plants is similar to fabric bag houses. The gas to be cleaned is typically drawn into the plant by an induced-draft fan such that the particulate matter being collected builds up on the outside of the elements in the form of a cake. The cleaned gas passes through the wall of the elements and into the plenum, the cake being periodically removed from the elements by a reverse-pulse mechanism. The rigid nature of the elements promotes surface filtration, which in turn results in low emissions and extended media life.

Ceramic elements have been applied to a wide range of services where the benefits of the technology can be utilized, for example the need for efficient filtration at an elevated temperature. Some of these applications are listed in Table 6.

The waste incineration applications can be further sub-divided into a number of small- to medium-scale duties. These include clinical, chemical, petrochemical sludge, animal waste, laboratory waste, tires and building waste.

Japan's incineration example

With an area of 147,000 square miles, a population of 127,000,000, and around two thirds of the land area being mountainous and forested, Japan's relative lack of space has precluded dependence on landfilling for waste management. Japan has achieved creditable recycling rates for waste paper, tires, and aluminum and steel cans; and Japan has utilized incineration for many years.

Of the 51.6-million metric tons (m.t.) of municipal waste created in 1998, some 78% was incinerated in 1,800 incinerators. A further 400-million m.t. of industrial waste are handled by 3,300 privately owned industrial incinerators.

In the 1980s, the Japanese system for dealing with municipal waste, with its integrated recycling and incineration program, was looked upon as somewhat of a model for municipal waste management. However, in the 1990s the growth of incineration led to greater public and media awareness of the potential for pollution created by the many incineration facilities. Particular emphasis was placed on dioxin emissions with the dioxin family of chemicals being suspected of causing a range of health problems.

Tougher emissions regulations for municipal waste incinerators were introduced in 1997, which included a tighter standard for dioxins. The dioxin standard for waste incinerators in Japan is now in line with that specified in European regulations at 0.1 ng/Nm^3 TEQ (toxic equivalent). The standards for other pollutants, such as acid gases and particulates, are generally higher than those adopted in Europe. For instance, the particulate standard for municipal waste incinerators is 50 mg/Nm^3 while a higher figure is regulated for smaller incineration facilities, typically 100–150 mg/Nm^3.

Case study background. As with municipal waste, the incineration of building waste has been the subject of more stringent emissions legislation in recent years. Such waste is derived from the construction and upgrade of buildings. Due to the source of the waste, the composition is highly variable, and contains wood, paper, cardboard, plastics and metal. There are a number of building-waste incineration plants in Japan, most of which are new installations. The first of these plants, a new installation utilizing ceramic elements, was commissioned in May 2002.

During that project design stage the end user considered both PTFE on PTFE needlefelt as well as ceramic elements for the off-gas filtration medium. Given the similar price of the two types of media, ceramic elements were eventually selected due to their additional benefits over the PTFE medium, which include the following:

- Temperature capability giving process latitude and "insurance" against temperature surges
- Low emissions
- Effective acid-gas scrubbing in combination with a dry sorbent

To date, three plants have been commissioned that utilize ceramic elements in the gas cleaning train — two on Honshu and one on Shikoku island. The first plant to be commissioned (referred to hereafter as Honshu I) is in the Chugoku region, the second plant is on Shikoku (Shikoku I) and the third plant also on Honshu (Honshu II). This case study focuses on Honshu I, but emissions test data, also included, have been made available for Honshu II.

Installation details. A simplified schematic diagram of the Honshu I plant is shown as Figure 2. Bulk waste is delivered to the plant and pre-sorted prior to being fed by mechanical loader into a shredder. Metal objects are removed by hand from the shredded material on the conveyor line, which feeds a hydraulically operated charging ram that feeds the primary combustion chamber.

Primary and secondary combustion is carried out at in excess of 1,270 K with further ash treatment in a rotary kiln to reduce final discharge volume. Combustion off gases are cooled by indirect, followed by direct cooling to accurately control temperature prior to sorbent injection.

Principal filter parameters are the following:

- Element type: 3 m length × 0.15 m outer dia.
- Number of elements: 324
- Configuration: Vertically mounted 36 × 9 array
- Filtration area: 453.6 m^2
- Design gas volume: 20,000 Nm^3/h

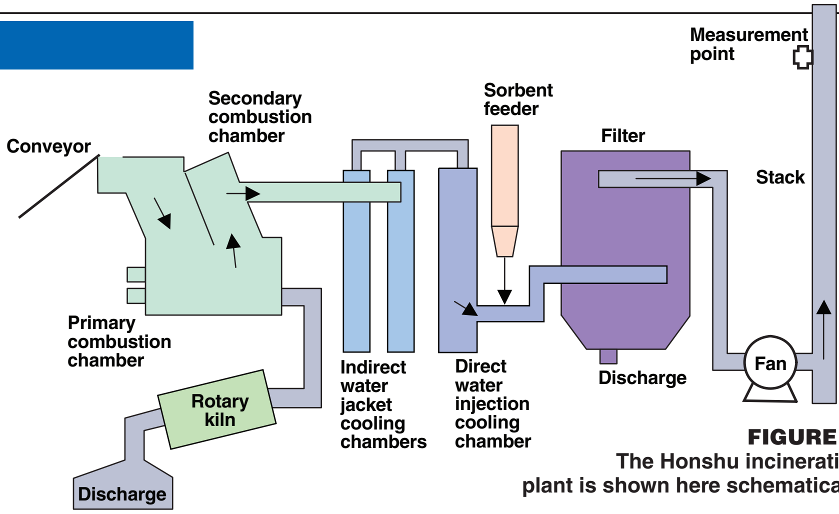

FIGURE 2. The Honshu incineration plant is shown here schematically

FIGURE 3. This is a general view of the filter plant and direct cooling chamber at Honshu I. The ceramic filter plant can be seen center left in the plant. To the right of the filter plant is the direct cooling chamber and to the left the exhaust stack

- Designed filtration velocity: 1.41 m/min at 523 K
- Sorbent: Slaked lime and activated carbon

Figure 3 shows a general view of the incineration facility and filter plant. The Shikoku I and Honshu II plants are similar in concept and operation to the Honshu I plant described above. Principal filter parameters for the Honshu II plant are as follows:

- Element type: 3 m length × 0.15 m outside dia.
- Number of elements: 216
- Configuration: Vertically mounted 24 × 9 array
- Filtration area: 302.4 m^2
- Design gas volume: 10,000 Nm^3/h
- Designed filtration velocity: 1.06 m/min at 523 K
- Sorbent: Slaked lime and activated carbon

The plant is designed somewhat more conservatively than the Honshu I plant to give a lower operational face velocity.

Operational results. In order to be granted an operating permit, all three of the incineration installations had to undergo an official emissions test, based on isokinetic sampling, soon after commissioning. Results from these tests are presented to the plant operators with actual readings being compared to the regulations in force. The official test results from the Honshu I and II plants are presented in Tables 7 and 8. The acid-gas emission figures are a function of the sorbent being employed and its application. Residence time of the sorbent in the gas stream is crucial to allow acid species to react.

TABLE 7. HONSHU I EMISSIONS MEASURED AT THE FILTER STACK ON MAY 31, 2002			
Item		Unit	Value
1) Dioxin		ng-TEQ/Nm^3	0.00032
2) Dibenzofuran		ng-TEQ/Nm^3	0.02296
3) PCB		ng-TEQ/Nm^3	0.0000326
4) 1) + 2) + 3)		ng-TEQ/Nm^3	0.023
5) Total particulate		mg/Nm^3	0.3
6) HCl		mg/Nm^3	2
7) SOx		ppm	<1
8) NOx		ppm	120
9) CO		ppm	0
10) O_2		%	10.6
11) Moisture		%	22.0
12) Actual gas volume	Wet	Nm^3/h	19,110
	Dry	Nm^3/h	14,910
13) Gas temperature		°C (K)	188 (461)

TABLE 8. HONSHU II EMISSIONS MEASURED AT THE FILTER STACK ON OCTOBER 25, 2002				
Item		Unit	Value[3]	Regulation[3]
1) Dioxin		ng-TEQ/Nm^3		
2) Dibenzofuran		ng-TEQ/Nm^3	0.010	
3) PCB		ng-TEQ/Nm^3	0.000010	
4) 1) + 2) + 3)		ng-TEQ/Nm^3	0.01	0.1
5) Total particulate		mg/Nm^3	0.1	250
6) HCl		mg/Nm^3	45	700
7) SOx	Concentration	ppm	28	
	Emission	Nm^3/h	0.34	10.44
8) NOx		ppm	100	
9) CO		ppm	0	
10) O_2		%	11.1	
11) Moisture		%	7.4	
12) Actual gas volume	Wet	Nm^3/h	13,000	
	Dry	Nm^3/h	12,000	
13) Gas temperature		°C (K)	134 (407)	

3. Empty cells mean either not measured or not regulated

Future developments

Ceramic elements are employed in filter plants, either new or retrofitted, in much the same way as traditional polymeric filter bags. It has been demonstrated that ceramic filters offer practical operating benefits and commercial competitiveness in high-temperature processes where corrosion resistance and the ability to eliminate dust emissions are needed.

A further important development of this technology has seen the introduction of ceramic filter elements that not only deliver the dual benefits of high particulate-removal efficiency and temperature resistance, but also treat gaseous pollutants. Fairly recently, these benefits have been enhanced by the addition of a catalyst to the filter systems [*2*]. The catalyst can reduce NOx with efficiency up to 95%, with the addition of ammonia or urea, and destroy VOCs as well as dioxins. This new technology has potential for application where particulate and NOx control are needed in tandem, and is competitive with electrostatic precipitators and standard selective catalytic reactors, particularly in the power generation, glass and cement industries. ■

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Active Management of Pipespool Fabricators

Contractors need to integrate and engage to improve deliveries and shorten project schedules

Stephen Wyss
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In today's fast track schedules for constructing new capital facilities, the process of designing, delivering and erecting piping often falls in the project's critical path. This is particularly true for facilities constructed in emerging economies, where the facility generally resides in a remote location, posing significant logistical challenges. Squarely positioned in the center of the piping design, deliver and erect (DDE) process sits the subprocess of fabricating piping components into erectable sections of piping, or pipespools. The engineering, procurement and construction (EPC) contractor's management approach to this fabrication is key because it impacts the project team's ability to manage the overall schedule. In fact, if handled properly, management of pipespool fabricators can get the piping DDE process off the project's critical path altogether.

Before we address how the EPC contractor's active spool management of the pipespool fabricator may positively affect schedule and, ultimately, the construction cost of the facility, we need to understand the challenging nature of the piping DDE process in today's fast-track-project environment; and we need to briefly address the level and nature of pipespool-fabricator services on a given project.

Evolving piping design process

In general, as a project unfolds, the overall facility piping design evolves as high-level process requirements translate into a physical design of equipment linked by piping systems. These piping systems are complex. A grassroots petroleum refinery, for instance, can require as many as 10,000 piping inventory codes identifying unique piping components, given metallurgical, mechanical, and configuration related factors. Ideally, the acquisition of piping materials would occur as the piping design becomes firm enough to confidently ascertain requirements. Practically, however, fast track schedules dictate that the material acquisition process be executed in parallel with the evolving piping design. This places the EPC contractor in the difficult position of attempting to balance the timing of piping materials acquisition between two scenarios: 1) waiting until the design is firm, risking schedule delays due to late arriving materials, or 2) purchasing early on poorly defined requirements, and risking purchase of the wrong materials. This latter scenario — purchasing the wrong materials — is a double edged sword. Not only does it require subsequent purchasing activity to replace the wrong materials, which often results in late deliveries, but it also incurs surplus of materials left over at the end of the project, in this case, the incorrectly purchased items.

Nevertheless, given that schedule delays and negative project economics are virtual certainties if the project follows the first scenario (waiting until materials requirements are firm), most EPC contractors choose to manage the parallel process of acquiring piping materials as the design evolves (commonly referred to as the "piping prebuy" process) to guide the project to a successful on-time completion. As we will see below, active management of a pipespool fabricator presents opportunities to recapture schedule time often lost in the piping prebuy effort, furthering successful project execution.

The piping prebuy process and the significant negative impact on the project's bottom line that surplus often incurs, are both subjects in and of themselves. They are addressed here only briefly to establish the schedule pressure they place into the overall piping DDE process and to emphasize the need for the EPC contractor to exercise every means possible to reduce the cycle time of the overall piping-DDE process.

Pipespool fabricators

Pipespool fabricators offer varying levels of services, most often influenced by the project setting and complexity, but for all practical purposes they fall into two broad categories: 1) those that supply the piping components and fabricate the pipespools, and 2) those that fabricate pipespools from spool components supplied to them by the EPC contractor.

Full-service pipespool fabricators (those that both supply the materials and fabricate the pipespools) are generally found in industrialized settings. These fabricators maintain on-hand inventory — at least for piping components of common metallurgy, wall schedules, and pressure ratings — and use their inventory to jumpstart fabrication. Full-service fabricators also are attractive to an EPC contractor because excess material can be carried over to future projects, at least for commonly used piping components. For an EPC contractor, who approaches each project as a unique cost center, and often ends up shedding surplus at a fraction of value, this approach offers a means to minimize surplus. Full-service pipespool fabricators become less attractive when the project entails a significant amount of piping compo-

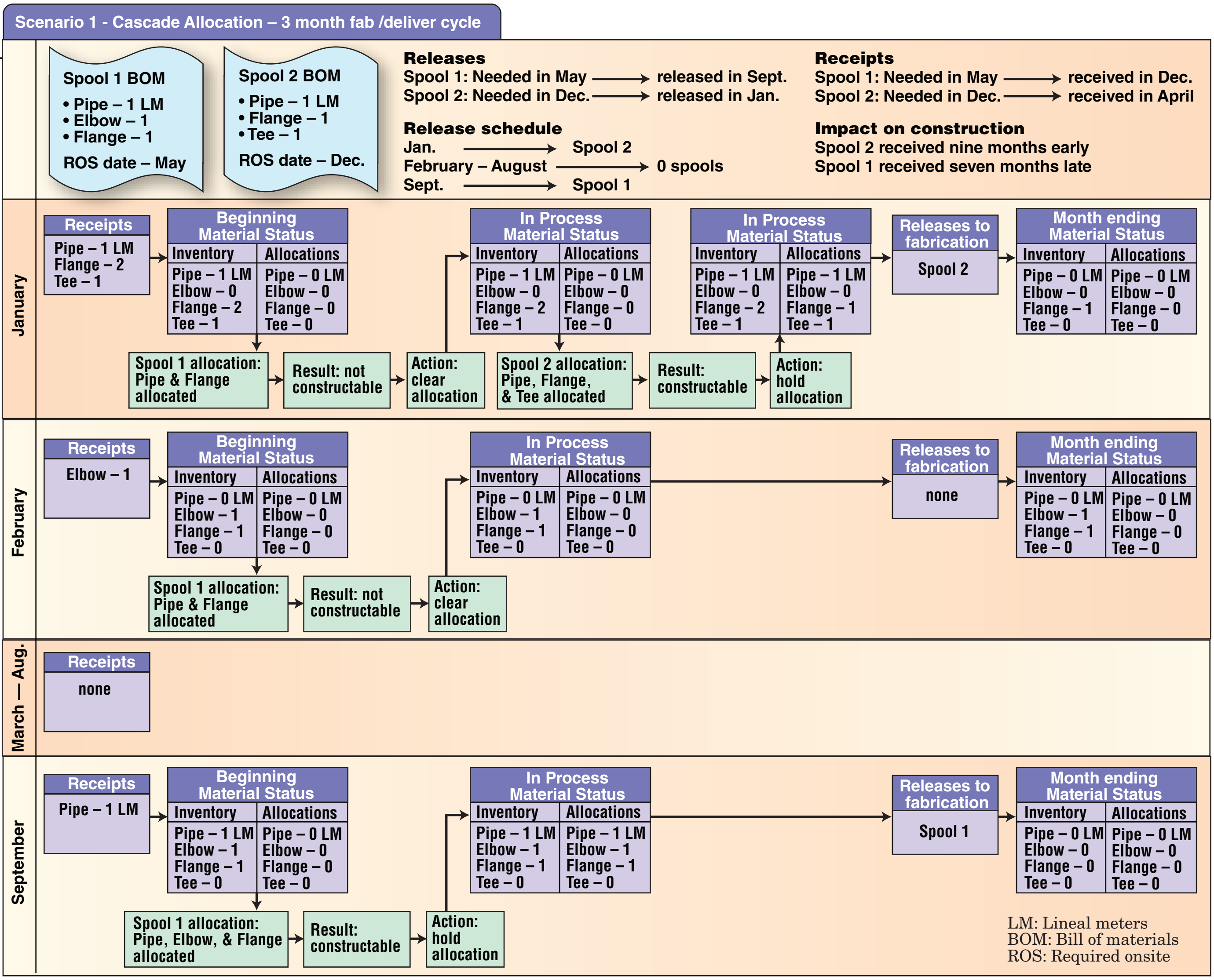

FIGURE 1. In January, this scenario returns Spool 1, which is required onsite in May, back to the pool of allocatable materials, resulting in Spool 2 being delivered nine months early, while Spool 1 (of higher-priority) is delivered seven months late

nents not stocked by the fabricator, and where the project is not geographically close to the fabricator, particularly where there are logistical challenges.

Pipespool fabricators that fabricate from materials supplied by the EPC contractor (a process referred to as free-issue) are commonly found in emerging economies. Most have limited procurement capacity, or tend to fabricate for projects where it is not economical to establish and maintain on-hand inventory, in particular for projects where there are unique requirements, or where a significant portion of the piping components are not easily usable on another project. Many operate in settings with limited infrastructure, sometimes setting up a project-specific facility adjacent to the project site. Many times these fabricators, due to their location or project set-up, are able to satisfy the all-too-common, emerging-economy project requirement for local content.

As such, for the projects that seem to have most challenges relative to the piping DDE process — such as those in emerging economies and those with remote locations and logistical challenges — the prevailing approach is to utilize a fabricator whose scope is limited to fabrication of free-issue materials supplied by the EPC contractor. Such projects, while offering the greatest challenge, also offer the greatest opportunity for an EPC contractor to actively manage the fabricator to deliver pipespools to favorably support the project schedule. The factors discussed below, while primarily directed toward positive, active management of a limited-scope pipespool fabricator, none the less apply to a lesser extent to a full-service pipespool fabricator.

KEY MANAGEMENT ISSUES

With this background of the piping DDE process and a perspective of pipespool fabricators, we'll now take a look at issues that present opportunities for an EPC contractor to actively manage the pipespool fabricator to facilitate delivery of spools, thereby optimizing piping erection, and overall construction of the facility. After reviewing the key issues, we'll look at the impact of these issues and the potential for positively affecting the project through proactive management.

Integration

First and foremost is the issue of integration. Both EPC contractors and pipespool fabricators operate these days in a highly automated mode. Virtually all EPC contractors design using a 3D model that is integrated with other design-related automation systems, particularly full spectrum (specify/design/purchase/receive/control/issue) materials management (MM) systems. In parallel, most pipespool fabricators engineer their spools using software that produces their fabrication drawings. Most fabricators will also have an MM system tailored to their needs and linked to the software that designs and details the spools. Fabricators that are not full service, but rely on free-issue materials, will generally have a limited spectrum (receive/control/issue) MM system.

Quite often, both the EPC contractor and the fabricator will be using software suites that are compatible, enabling the fabricator to upload data from the EPC contractor's 3D model to initiate the spool design and detailing processes. What is not as common is for the EPC contractor and the fabricator to link their MM systems such that each can see what the other sees, as it relates to spool component delivery. For the EPC contractor to effectively and actively manage the process, the first step is to be able to see what the fabricator sees relative to on-hand materials, issued materials, wastage, and constructability at the same increment as the fabricator. Conversely, as we will see below, the key to implementing a just-in-time fabrication program resides in the ability of the fabricator to see the EPC contractor's delivery data.

Speaking similar languages

EPC contractors generally erect piping using piping isometric (Iso) drawings extracted from the 3D model. An Iso will generally contain several pipespools and the related installing materials (valves, bolts, gaskets, and so on). The Iso will also possess a bill of materials (BOM), which generally identifies the materials required (commonly referred to as takeoff) and splits the BOM between field materials and shop materials, with the shop materials comprising the free-issue materials for the pipespools. The Iso has also historically been the increment by which the EPC contractor managed materials. For instance, the Iso BOM for shop materials generally shows the total requirements for all pipespools on that Iso without distinguishing what is needed for each individual pipespool. As such, Iso BOMs are the increment by which EPC contractors' MM systems generally operate.

On the other hand, the fabricator has no interest in the Iso other than as a reference and always manages materials at the increment of the spool. Fabricator's spool cut sheets (detailed spool drawings) possess a BOM just for the materials required for that spool, and the fabricator's MM systems will manage materials required for the spool at this level or increment.

So historically, there has been a disconnect between the EPC contractor MM system and the fabricator MM system, an "apples and oranges" comparison. In today's computing environment, where the EPC contractor's MM system is often not designed to extract BOM data at the spools level, the fabricator can easily pass spool BOM-level data to the EPC contractor, and a sufficiently robust EPC contractor MM system can then be configured to manage the free-issue materials at the same increment, for instance, the spool.

Priorities

For the EPC contractor to manage the fabricator such that spools are fabricated and delivered in the sequence at which the EPC contractor intends to erect them, the EPC contractor needs to communicate priorities, and must do so at a granularity that facilitates the allocation process, which is discussed below. Any good MM system will possess an allocation system, and generally, the finer the level of priority granularity, the better the system is able to allocate materials to support desired fabrication and erection sequencing. However, there needs to be a balance here, as specifying too many priorities can have its own downside.

Conflicting goals and processes

The goals of an EPC contractor on a given project and that of the pipespool fabricator are rarely in concert. The pipespool fabricator desires to operate his facility efficiently and at a constant level. This is best accomplished by scheduling groups of spools in a common metallurgy to be released for fabrication together, by scheduling together a group of spools in the same pipe diameter to simplify handling and optimize use of pipe "drops", and by releasing spools at a constant production rate by 1) building up and maintaining a backlog of constructable spools and 2) by releasing spools at a rate that does not deplete the backlog.

An EPC contractor, by contrast, generally wants spools delivered in sequence according to planned erection starts of piping in areas at the construction site, per the project schedule. In general, each area will contain a mix of metallurgies and a wide array of pipe diameters. The EPC contractor wants delivery of spools as soon as they are constructable in accordance with the priorities released into fabrication. The EPC contractor has no concern if this might cause a spike in production, and thus resources, at the fabricator, or if it depletes the fabricator's backlog. Given that the goals of the two parties are not aligned, it should not be surprising that the allocation process each prefers to utilize also conflicts.

Allocation processes are routines that form the core of the "control" aspect of an MM system. An allocation process takes the tens of thousands of pipe fittings and hundreds of thousands of feet of pipe — all spread over thousands of inventory codes as they are required on thousands of spools — and, according to the project priorities and control logic, determines which spools should be fabricated in what order.

Typical fabricator allocation

Most fabricators utilize what is commonly referred to as a cascade allocation. This process is designed to maximize current fabrication; for instance, identifying as many spools as possible that are constructable with the current on-hand inventory. Most will have the ability to interject EPC contractor priorities, so that spools are processed sequentially according to the priorities provided by the EPC contractor. But a cascade system is very different from a strict construction-priority allocation, which is commonly utilized by EPC contractors as noted below. Here is how the cascade allocation works.

Sequentially by priority, the MM system will look at the first spool BOM, and on an inventory code basis, ascertain if there is unallocated on-hand inventory for that inventory code. If there is, available stock will be allocated to this BOM and deducted from the available pool for following spools. The process then moves to the next inventory code for that spool and executes the

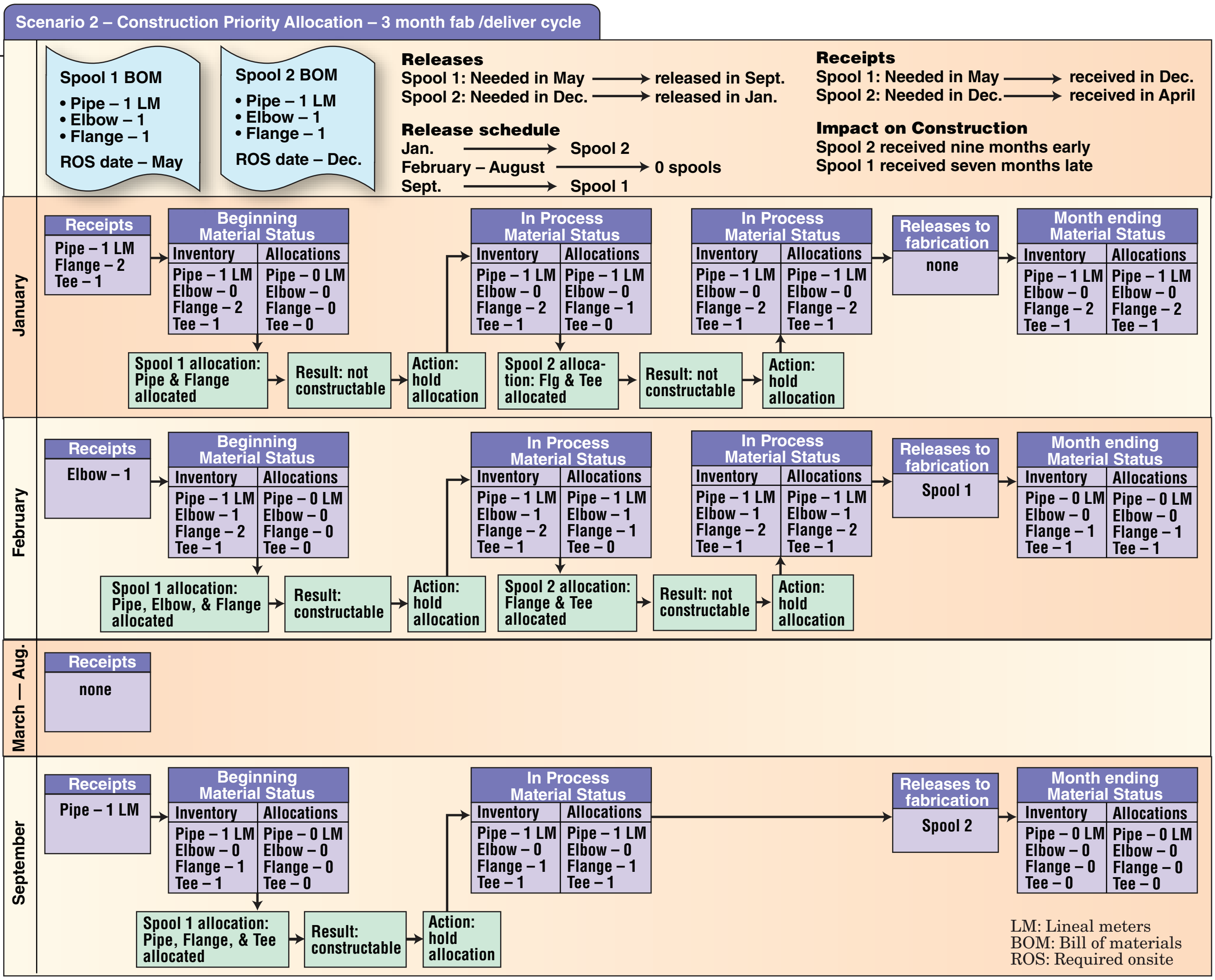

FIGURE 2. In the construction-priority allocation scenario, the fabrication of Spool 1 is held until materials are available, thereby keeping its materials from being allocated to a lesser-priority spool. As a result, both spools arrive on time

same evaluation. Once all inventory codes for that given spool have been evaluated, the system will look to see if all inventory codes for that spool have been satisfied, in other words if the spool is "constructable". If so, the allocations are retained. If not, the spool will be considered non-constructable if as little as a single inventory code has not been allocated to on-hand inventory. As a result, the allocations for each inventory code on that spool will be returned to the pool of allocatable material for the remaining spools.

The process will then move to the next spool BOM and perform the same analysis. This will continue until all spool BOMs have been assessed.

Typical EPC allocation

A strict, construction-priority-allocation process allocates on-hand inventory, as the name says, strictly by priority. As with the fabricator cascade system, the strict construction-priority allocation looks at the spool BOMs on an inventory code basis — doing so sequentially by priority — and allocates on-hand inventory if available, subtracting from the available pool accordingly. Contrary to the cascade process, however, the strict construction-priority process does not look to see if the spool is constructable before moving on to the next spool, nor does it return allocations to the allocatable pool if the spool is not constructable. Allocations once made, are retained, at least until the next run of the process.

This process is not intended to ascertain the maximum amount of constructable spools in the current timeframe, but instead is designed to see that priority spools are truly given priority. While this process might appear to be counter-productive when compared to the "cascade" process, as we will see below, the opposite is actually true.

Just-in-time fabrication

"Just-in-time" fabrication implies just what it says, fabrication just as the spool components arrive. This is similar to the just-in-time delivery concept used in manufacturing processes, but here the just-in-time concept applies to the end product, not the component.

As noted above, fabricators generally try to maintain a good backlog of constructable spools, usually four to eight weeks worth, so that they don't find their workers standing by idly with no spools to fabricate. For projects where fabrication proceeds from free-issue materials, the fabricator's MM system rarely has any knowledge of future deliveries and is limited to planning work according to on-hand inventory. This is another issue where integration with the EPC contractor, either by linking MM systems and downloading delivery data into a capable fabricator MM system, or by providing the fabricator access to the EPC contractor's MM system, or some melding of processes in between, allows the fabricator to use future deliveries as backlog. We will discuss this more in the sections below.

BENEFITS OF ACTIVE SPOOL MANAGEMENT

Now that we have highlighted key issues, let's look at how they facilitate active spool management and how active spool management increases the likelihood of spool deliveries to support the project's planned erection schedule.

Integration

Integration is the thread that runs through all of the key management issues. Without integration, the EPC contractor must rely on the pipespool fabricator to provide spool status and on-hand inventory of spool components at the fabricator's facility. Conversely, the fabricator only knows what he has, not what is coming.

By allowing each to see what the other sees, communication is much more open, and where either one desires information from the other, that information is often available by looking, instead of asking for it and waiting for a response.

Management at the spool level

Where an EPC contractor leaves his or her MM system incremented at the Iso BOM level, efforts to address why specific spools have not been released — for which the EPC contractor's MM system appears to show constructability — are often futile. Basically, unless the EPC contractor is managing at the same increment as the fabricator, and is actively reviewing constructability data at the spool level, the EPC contractor simply must rely on the fabricator to assess and ascertain constructability. This can often lead to significant frustration on the part of the EPC contractor, and unnecessary efforts expended by the fabricator to justify what has been released to fabrication. This is particularly true given the conflicting goals the two parties tend to work toward, which, without open communication, can cause unnecessary friction between the parties.

On some projects, an EPC contractor who has not integrated and does not have the means to manage at the spool level will attempt to direct the fabricator to release spools based on Iso constructability. By this, we mean the EPC contractor waits until all shop materials on an Iso are allocated. This, however, can significantly delay release of spools that would otherwise be constructable. An Iso will contain anywhere from one to five or six spools, averaging about three spools. When managing at the Iso level, it only takes one item — something as insignificant as a minor fitting — to make the Iso nonconstructable. Where a single item is holding up the Iso, it is unnecessarily holding up spools that are otherwise constructable. The solution here is, of course, to manage at the spool level.

Manageable priority granularity

Too few priorities tend to clog the allocation process, yielding a slug of pipespools being delivered all at once. Where EPC contractor construction resources for piping erection are limited and need to be spread out, this scenario delays erection commencement and causes unacceptable construction resource peaks. Conversely, a very high level of priority often leads to priority reshuffling, which tends to have a detrimental impact on planning.

The best scenario is where the EPC contractor has thoughtfully planned the work, breaking the project scope into manageable areas coinciding with schedule events (such as area access, equipment erection, system handover, and so on), and where this sequencing is translated into a set of priorities at a granularity level where the sequencing can be expected to hold.

Supporting project goals

In the case study in the box, we demonstrated the potential for detrimental impact of the cascade process on deliveries of spools to the construction site to support planned erection. A small project will have 5,000 or so spools; a large project may have 50,000 to 75,000. If we multiply the disconnect of deliveries relative to planned erection of the two spools in our example by 10,000 (to represent a medium size project with 20,000 spools) the impact becomes clear. Thousands of spools will arrive early, requiring unnecessary storage. Thousands will arrive late, causing construction delays. If the fabricator's system is limited to a cascade allocation, the only way to implement a strict construction-priority allocation is via the EPC contractor's MM system. And without both integration and management at the spool level, this will be very difficult.

Accelerated releases

As noted above, a fabricator that cannot see what his backlog includes, or who does not have the information to predict workload into the short-term (at least two to three months) can expect some unpleasant surprises, both due to pressure from production peaks, and from idle staff in an unforeseen production valley. Most fabricators try to avoid such surprises by scheduling

CASE STUDY: CASCADE VS. STRICT CONSTRUCTION PRIORITY

Figures 1 and 2 take us through a very simple set of examples of the two differing allocation processes. Here we have two spools with slightly different, but overlapping requirements. Scenario 1 shows the individual steps in the process for a cascade allocation; Scenario 2 does the same for the strict construction-priority allocation. The only substantive difference in the two scenarios occurs in the month of January where the cascade process returns the pipe for the higher-priority Spool 1 (with a required-onsite or ROS date in May) back to the pool of allocatable materials, because this spool is not constructable, and then allocates the pipe to lower priority Spool 2 (required-onsite or ROS date in December), because Spool 2 is constructable. The strict construction-priority process as shown holds this allocation for priority Spool 1.

Looking at the net result of these two processes from an aggregate delivery perspective, independent of priorities, the cascade process appears superior; it gets a spool into fabrication one month earlier also getting the spool onsite one month earlier.

Looking at the same net result from a priority focused aggregate perspective, however, the cascade allocation process has a devastating effect on planned erection. Scenario 2 gets one spool into fabrication, and thus onsite, one month later but gets both spools onsite when needed. Scenario 1 gets one spool onsite nine months early and one spool onsite seven months late.

This case study also demonstrates another negative effect of a lack of integration. Where the fabricator MM system is ignorant of future deliveries — generally the case in a free-issue scenario — it has no way of knowing that the elbow, which is restraining Spool 1 in January, is scheduled to arrive in February making priority Spool 1 not constructable until then. The EPC contractor MM system, which has this data, however, is not thusly impaired. ❐

production based on what they can see from on-hand inventory.

In a situation where the EPC contractor and the fabricator have integrated, and where the shop load can be predicted from both on-hand inventory and future deliveries, the fabricator can schedule production to release all constructable spools, up to his capacity level, in the current timeframe. Instead of establishing a backlog of spools from on-hand inventory alone, the fabricator can include spools that show to be constructable in the short-term based on both on-hand inventory and deliveries scheduled in the short-term.

In a situation where the fabricator would otherwise build up a four to eight week backlog of on-hand inventory, the production schedule could ideally be brought forward four to eight weeks. The net result would be to move the entire production schedule forward (sooner) four to eight weeks, yielding a net result to the project of all spools being delivered four to eight weeks earlier.

By itself, independent of allocation process issues, just-in-time fabrication can gain the project one to two months of schedule, that is, if the piping DDE process is on the critical path. Or it might get the piping DDE process off the critical path, allowing the EPC contractor to refocus resources elsewhere to improve schedule.

In any case, just-in-time fabrication cannot be achieved outside of an integrated relationship, and only if the EPC contractor is proactively engaged in management of the fabrication process, working to see that critical spool component deliveries are on track to support just-in-time fabrication.

Conclusion

EPC contractors, and pipespool fabricators who work with them, will continue to be challenged to meet the demanding fast track schedules presented by projects in emerging economies, particularly those with logistical challenges. By closing communication gaps and actively engaging pipespool fabricators, EPC contractors can be much better positioned to succeed. ■

Edited by Rebekkah Marshall

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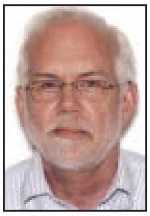

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Mechanical Carbon
In Chemical Processing Equipment

This self-lubricating material offers advantages when used for components that are running submerged in the process fluid

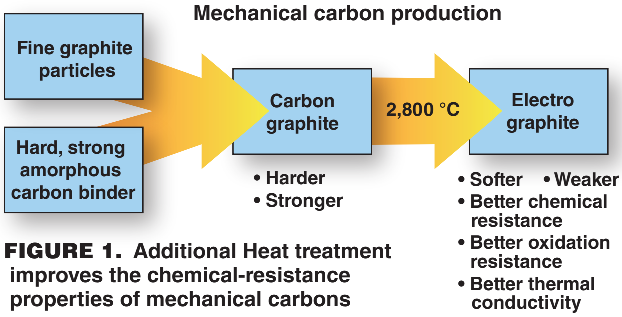

FIGURE 1. Additional Heat treatment improves the chemical-resistance properties of mechanical carbons

Glenn H. Phelps
Metallized Carbon Corp.

Frequently, in chemical processing equipment it is possible to place the shaft support bearings in the chemical that is being processed. In some cases, this precludes the use of oil- or grease-lubricated bearings because the operating conditions are not conducive to the use of such materials. For example, bearings that are lubricated with oil or grease can be problematic when submerged in liquids such as water or other solvents, liquefied gases, heat transfer oils and corrosive chemicals. For these operating conditions, self-lubricating, mechanical carbon bearings are often the best solution.

This article takes a close look at mechanical carbons, describing what they are and how they function when running submerged in chemical processing equipment.

Compositions

Mechanical carbons contain graphite, which they rely on for their self-lubricating characteristics. To make mechanical carbons, fine graphite particles are bonded with a hard, strong, amorphous-carbon binder to produce a mechanical carbon material that is called carbon-graphite. Further heat treating, to approximately 5,100°F (2,800°C), causes the amorphous-carbon binder to become graphitized, resulting in a material known as electrographite.

The electrographite is generally softer and weaker than the carbon-graphite material, but has superior chemical resistance, oxidation resistance and thermal conductivity compared to the carbon-graphite (Figure 1).

Impregnation

Both carbon-graphite and electrographite are normally produced so that they contain approximately 15% porosity by volume. To produce mechanical carbon grades with enhanced properties, the porosity in the carbon-graphite and electrographite materials can be impregnated — by vacuum or pressure processes — with thermal setting resins, metals or inorganic salts, as explained below:

Resins. The most common thermal setting resins used are phenolic, polyester, epoxy and furan resins. Resin impregnation produces materials that are impermeable (to 100 psi air) and have improved lubricating characteristics.

Metals. The most common metal impregnations are babbitt (an alloy of tin, antimony and copper that is used to make bearings), copper, antimony, bronze, nickel-chrome and silver. Metal impregnation produces materials that are harder, stronger and impermeable (to 100 psi air), with improved lubricating qualities and better thermal and electrical conductivity.

Inorganic salt. The inorganic salt impregnations are proprietary formulations that provide improved lubricating qualities. These salt impregnated materials also exhibit improved resistance to oxidation of the carbon-graphite or electrographite base material.

Running submerged

The coefficient of friction and wear rate of two rubbing metal parts is extremely low when they are separated by a hydrodynamic film of oil or grease. However, when metal parts are rubbed together in low viscosity liquids, such as water or gasoline, the hydrodynamic film is too thin and metal-to-metal contact can occur. When metal-to-metal contact occurs, the metal atoms in sliding contact have strong atomic attraction, which results in high friction, wear, galling, and seizing.

When carbon is rubbed against metal in a low viscosity liquid, the resulting thin, hydrodynamic film is normally adequate to provide lubrication. Since there is no strong atomic attraction between mechanical carbon and metal, a hydrodynamic film that is only a few microns thick is sufficient to prevent rubbing contact, even for high-speed and high-load applications. Since mechanical carbon is a self-polishing material, a polished finish on the counter material will quickly polish the mechanical carbon material. The thin hydrodynamic film that is created by low viscosity liquids can then separate the two polished surfaces.

Using the fluid being handled as the

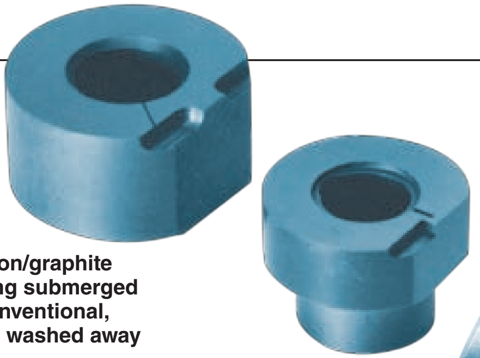

FIGURE 2. The photos to the right depict bearings made from two mechanical carbons. These babbitt-impregnated, carbon/graphite materials are designed for running submerged in low viscosity liquids where conventional, oil or grease lubricants would be washed away

FIGURE 3. Shown to the left is a mechanical carbon, steel encased bearing. This self-lubricating product is used for operating temperatures between 700 and 1,000° F, where conventional, oil or grease lubricants would breakdown and fail

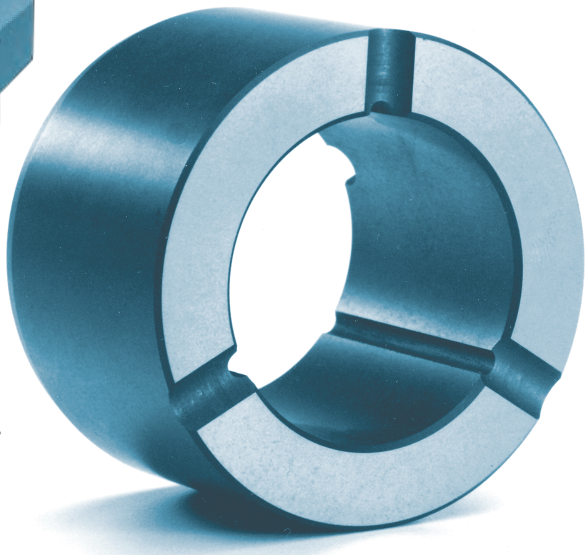

FIGURE 4. The photo above depicts another mechanical carbon — an antimony impregnated, carbon/graphite material — designed to run dry or submerged in environments where oil and grease lubrication cannot be used

working lubricant greatly simplifies the design of many rubbing mechanical parts. Carbon parts for these submerged applications include bearings and thrust washers for pumps and mixers that handle water, hot water, solvents, acids, alkalis, fuels, heat transfer fluids and liquefied gases. Mechanical carbon is also used extensively for mechanical-seal primary rings for sealing these same low viscosity liquids. Other applications include vanes, rotors, and endplates for rotary pumps; ball-valve seats handling hot oil; bearings for liquid meters; case wear rings for centrifugal pumps; and radial or axial seal rings for gear boxes and aircraft engines.

EXAMPLE 1

An example of a mechanical carbon bearing running submerged in strong chemicals is in the chemical pump industry. Nickel-chrome impregnated, carbon-graphite bearings are used in a stainless-steel, rotary vane pump for handling a broad range of chemicals. The nickel-chrome impregnated, carbon-graphite bearings carry a load of 830 psi (58.4 kg/cm^2) at a surface speed of up to 284 ft/min (1.44 m/sec). This gives a *PV* factor of 237,700 psi × ft/min (84.1 kg/cm^2 × m/sec). The pump is warranted for one year, but field experience indicates that these pumps normally give several years of continuous running service. ❑

Wear: Factors to consider

The wear rate of mechanical carbons running submerged is negligible under full fluid film, or hydrodynamic, lubricated conditions. To assure fully lubricated conditions, application engineers must consider the application load, speed, counter material, counter material surface finish, liquid viscosity, liquid flow and chemical resistance.

Load. The maximum load that is normally supported by mechanical carbons with full-fluid-film lubrication is approximately 1,000 psi (70 kg/cm^2). Application *PV* (pressure-times-velocity) factors of over 2,000,000 psi × ft/min (773 kg/cm^2 × m/sec) have been achieved with sliding speeds of over 3,600 ft/min (18.7 kg/cm^2 × m/sec).

Counter material. The counter material rubbing against the mechanical carbon must meet specifications of hardness, surface finish and corrosion resistance. The hardness should be greater than about Rc 45 (Rockwell C scale), but better results are achieved with even harder counter materials.

Surface finish. The surface finish on the counter material should be 16 micro-inch (0.4 micron) or better. Wear rate continues to improve with finer surface finish until an 8 micro-inch (0.2 micron) finish is reached. These high finishes are required because the hydrodynamic film with low viscosity liquids is extremely thin. With courser finishes on the counter material, the asperities (rough edges) on the counter material would break through the hydrodynamic film and "grind away" the mechanical carbon.

Viscosity. The liquid viscosity should be in the range from about 100 centipoise (cP) (light machine oil, for example) to 0.3 cP (acetone for example).

Liquid flow. A continuous flow of liquid to the rubbing surface is important to the performance of submerged mechanical carbon parts. If the flow of liquid is not sufficient, frictional heat will evaporate the liquid and the parts will revert to the dry running condition, where the wear rate is much higher.

An important benefit of mechanical carbon parts is that the parts can run dry without catastrophic failure if the flow of liquid is briefly interrupted.

Chemical attack. The chemical composition of the liquid must be considered because chemical attack of the counter material, or the mechanical carbon, will increase the wear rate. Chemical attack of the counter material is particularly harmful because

EXAMPLE 2

An example of mechanical carbon running at high *PV* with hydrodynamic film lubrication is in the mechanical seal industry. An antimony impregnated, carbon-graphite mechanical-seal primary ring, sealing low viscosity hydrocarbon liquids, runs against a polished, solid silicon-carbide counter face with a face loading of about 600 psi (42 kg/cm^2) and a rubbing speed of about 3,400 ft/min (18.7 m/sec). This gives a *PV* factor of about 2,000,000 psi × ft/sec (785 kg/cm^2 m/sec) and the seal rings normally last for about three years of continuous running. ❏

it causes pits and surface roughness that will disrupt the hydrodynamic film, resulting in a high wear rate. The most corrosion-resistant mechanical-carbon grades can withstand all liquid chemicals except for a few extremely strong oxidizing agents, such as hot, concentrated nitric acid.

Abrasion. Abrasive grit in the liquid being handled can also be extremely detrimental to mechanical carbon parts. The abrasive grit disrupts the hydrodynamic film, erodes the softer mechanical carbon material and can destroy the fine surface finish on the counter material.

Applications engineering

Any mechanical carbon manufacturer can determine if it has a material that can satisfy specific application requirements, and can also recommend its best mechanical-carbon grade for each specific application. They should also be able to recommend dimensions and dimensional tolerances for new mechanical carbon parts to assure proper press-fit or shrink-fit interference and shaft running clearance. It is also critically important to the success of mechanical carbon applications that correct mating material and mating-material surface finishes are specified.

Mechanical carbon materials have provided solutions to a wide variety of lubrication challenges for more than a century. For example, in recent years a growing concern for the environment and air quality has resulted in an increased use of mechanical seals that use carbon primary rings because they allow less leakage compared to other seal types. Today, new mechanical carbon materials are continually being developed to meet ever more demanding mechanical applications. ■

Edited by Gerald Ondrey

Author

Glenn H. Phelps is technical director at Metallized Carbon Corp. (19 South Water St., Ossining, NY 10562; Phone: 914-941-3738; Fax: 914-941-4050; Email: ghphelps@metcar.com), where he has worked for the past 34 years in the process and development of applications and products. His current responsibilities at the company are for the management of applications engineering. Prior to joining Metallized Carbon Corp., Phelps was employed as a process and product development engineer at Union Carbide National Division, Poco Graphite Inc. and Pure Carbon Corp. He holds a B.S. in ceramic engineering from the State University of New York at Alfred University, and is a member of STLE (Society of Tribologists and Lubrication Engineers) and ASTM.

FOCUS ON

Mixing & Blending


Sharpe Mixers


Neptune Mixer


Woodex Bearing

Munson Machinery


Philadelphia Mixing Solutions

Portable mixers for pilot plant and small-scale production processing

The PB Series pharmaceutical mixers (photo) feature a lightweight frame motor with a right-angle drive, 316 stainless-steel wetted parts, dry running mechanical shaft seal with CIP (clean in place) capabilities and vibration-free operation. Easily tailored to user requirements, the mixers can be configured with shafts up to 48-in. long and with various impellers for high flow, low shear, gas dispersion and solids suspension mixing. — *Sharpe Mixers, Seattle, Wash.*
www.sharpemixers.com

Routine maintenance is simplified with this mixer drive

The UniFirst 4040 mixer drive (photo) is designed to provide trouble-free operation while lowering maintenance costs. Routine maintenance is simplified with fewer parts, easy accessibility and standard components. Additional features include: rugged design withstands corrosive and caustic environments, high temperatures, harsh weather and fluctuating loads; unique drywell design and special end covers minimize leak paths and vibration from high motor output speeds, eliminating oil leaks; gears and bearings are designed specifically to handle overhung and fluctuation loads; available in double and triple reductions from 4:1 to 130:1 overall gear ratios; drive sleeve design allows for maximum output shaft and material configurations; tapered roller bearings are prelubricated. — *Philadelphia Mixing Solutions, Palmyra, Pa.*
www.philamixers.com

Blend, heat, cool and add liquids in this rotary batch mixer

This miniature rotary batch mixer blends bulk ingredients, adds liquids and achieves 100% batch uniformity in less than three minutes while heating or cooling the batch, according to the manufacturer. The model MX-1-SSJ mixer (photo) features an internal spray line for liquid additions, a discharge chute to direct the flow of discharged materials and an insulated, jacketed mixing drum that can be piped to an oil, steam or chiller system. Suitable for applications involving contamination-sensitive materials and frequent product changeovers, the 1-ft^3 (28 L) unit features 304 stainless-steel contact surfaces, wide spacing of internal flights for easy access, continuous polished welds and external removable seals. Construction with ex-

Charles Ross and Son

Chemineer

Silverson Machines

otic alloys as well as carbon steel is also offered, as are configurations with CIP vessel-cleaning nozzles. — *Munson Machinery Co., Utica, N.Y.*
www.munsonmachinery.com

These new laboratory mixers go digital

The new generation L5 Series laboratory mixers (photo) offer a high level of instrumentation and automation via a digital touchscreen. Functions include a programmable timer, infinitely variable speed control with "speedlock", an integral ammeter and digital tachometer. In addition to functional advantages, the touchscreen offers cleanliness and reliability. More than 40 interchangeable mixing units are available for use with the L5 range including tubular assemblies for narrow-necked or small containers. With a capacity range from 1 mL to 12 L, and inline flowrates of up to 20 L/min, this generation of laboratory mixers offers versatility in day-to-day laboratory and small-scale production duties. — *Silverson Machines, Inc., East Longmeadow, Mass.*
www.silverson.com

These top-entry agitators service a wide range of applications

Designed for a wide range of service in the chemical process industries (CPI) including pharmaceutical, ethanol and biofuels, water and wastewater and a variety of chemicals, the Model 20 HT/GT agitators (photo) are available in right-angle and parallel-shaft configurations to meet specific application requirements from critical chemical reactor systems to routine storage. The agitators incorporate a modular design package that reduces the number of replacement parts that need to be carried in inventory. Quick and easy seal-change capability saves time and reduces maintenance costs. A variety of seal options is available. A standard cast dry-well seal eliminates lubrication-oil leakage from the gearbox. An optimized gear design and lighter-weight shaft diameter requirements contribute to high energy efficiency, and a reversible rotation meets a variety of process requirements. — *Chemineer Inc., Dayton, Ohio*
www.chemineer.com

For high viscosity materials, consider these double planetary mixers

The double planetary mixer (DPM) is often used for the mixing of high viscosity materials up to approximately 6-million centipoise (cps). The DPM contains two mixing blades that revolve on their own axis, as well as on a common axis, within the mix vessel. The mix pattern ensures that all materials in the vessel are intermixed within a few minutes and that ingredients are not damaged during mixing. This company has recently completed three identical DPMs for the continuous processing of a specialty chemical product. The units shown (photo) include: vacuum construction; special addition ports; jacketed mix cans on casters for heating and cooling; thermocouples to monitor temperature; stainless-steel construction; manually operated flush discharge valves; and variable speed drives — *Charles Ross and Son Co., Hauppauge, N.Y.*
www.planetarymixers.com

Easily mount these mixers to IBCs or totes

Featuring a short shaft and a folding propeller that is constructed of 316 stainless steel and capable of fitting through a 2-in. opening, the HGL Mixer (photo, p. 49) allows easy integration with standard intermediate bulk containers (IBCs) or poly tote bins by use of an optional 2-in. bulkhead fitting. The propeller's operating diameter is nine inches, and a second folding propeller can be added as an accessory and bolted anywhere on the ¾-in. shaft. Available motors included electric motors (1/3 to 1 hp) and air motors (1/2 to 1 hp). Explosion-proof motors are also available. — *Neptune Mixer Co., Lansdale, Pa.*
www.neptune1.com

Split shaft seals for mixers and other rotating equipment

These seals (photo, p. 49) are available fully split to retrofit mixers, blenders and most other rotating bulk process equipment without the removal of bearings or drives. The seals work like a thrust bearing; there are no internal springs to loosen, corrode or break. A driving elastomer is the seal's only contact with the shaft protecting it from abrasion damage. Radial shaft misalignment and shock loads are accommodated, as well as thermal shaft growth in high-temperature processes. A minimum of 6 mm of total runout-misalignment capacity is built into the seals. — *MECO Shaft Seals, Div., Woodex Bearing Co., Georgetown, Maine*
www.woodex-meco.com ■

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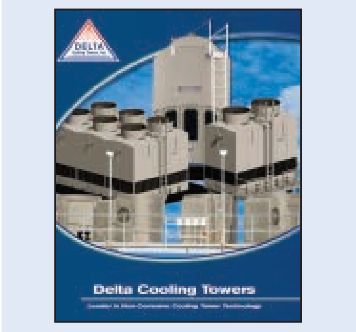

Delta Cooling Towers manufactures a complete line of corrosion-proof engineered plastic cooling towers. The towers incorporate a high efficiency counter-flow design and carry a 15-year warranty on the casing, which is molded into a unitary leak-proof structure of engineered plastic. All models are factory assembled, simple to install and nearly maintenance free.

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BUSINESS NEWS

PLANT WATCH

Construction of AkzoNobel's unit for ethylene amines in China progresses

December 17, 2008 — AkzoNobel Functional Chemicals (Amersfoort, The Netherlands) is installing production capacity for ethylene amines in Ningbo, China, including ethylene oxide and monoethanolamine (MEA). Startup of the plants is scheduled for the 3rd Q 2010. In conjunction with this and for the purpose of effectively carrying out the Chinese ethylene amines business, a new company, AkzoNobel Ethylene Amines China Ltd, has been established.

LyondellBasell grants 20th Lupotech T license since 2000

December 15, 2008 — Polimérica, the joint venture (JV) between Pequiven, Petroquímica de Venezuela, and Braskem S.A., has selected LyondellBasell's Lupotech T technology for a new 300,000 ton/yr low-density polyethylene plant to be built in the Bolivarian Republic of Venezuela. Startup is expected in 2013.

Dow streamlines its operating model to reflect current economic realities

December 8, 2008 — The Dow Chemical Co. (Midland, Mich.) has announced a series of aggressive actions to accelerate its strategy in light of current economic realities. Dow's transformation to a lean corporate center, a shared business services group and three business operating models, effective January 2009, will accelerate the company's ability to shed high-cost assets and centralized functional structures. As part of the actions, Dow will eliminate approximately 5,000 jobs, representing approximately 11% of the company's global workforce, close 20 facilities in high-cost locations and divest several businesses. Once fully implemented, these actions are expected to result in $700 million in annual operating cost savings by 2010 and are additional to the previously announced cost synergies of $800 million in the same timeframe for the anticipated Rohm and Haas acquisition. In addition, Dow will temporarily idle approximately 180 plants and reduce its contractor workforce by about 6,000.

Wacker Schott Solar presses ahead with solar-wafer capacity expansion

November 19, 2008 — Wacker Schott Solar GmbH, a JV between Wacker Chemie AG (Munich) and Schott Solar AG (Mainz, both Germany), have announced that they are expanding polycrystalline-silicon solar-wafer production capacity. Their new plant in Jena, Thuringia is on target to reach a nominal capacity of 50 megawatts (MW) per year, thus increasing Wacker Schott Solar's total capacity to 120 MW/yr by the end of 2008. Construction is underway to expand the Jena site's crystal-growing capacities to grow multicrystalline silicon ingots, which are then sawn into solar wafers. The company also announced that it has begun initial work for a further wafer production facility at Jena and intends to boost its annual capacity to 275 MW by late 2009 and to one gigawatt by 2012.

BASF responds to decline in demand by reducing production worldwide

November 19, 2008 — BASF (Ludwigshafen, Germany) is taking measures to avoid the creation of overcapacities as a result of a massive decline in demand. The company is temporarily shutting down around 80 plants worldwide. In addition, BASF is reducing production at approximately 100 plants. Worldwide, approximately 20,000 employees will be affected by the production cuts. The adjustments are primarily being carried out in units that supply the automotive, construction and textile industries. Value chains affected include ammonia, styrene and polyamide, which manufacture precursors for engineering plastics, coatings and fibers. Implementation of most of the measures has already started; reduced capacities are expected to last until January 2009 for individual plants. BASF will continue to follow market developments very closely and will adjust production planning accordingly.

N.A. Water Systems breaks ground on Peruvian mine-water-cleanup project

November 21, 2008 — N.A. Water Systems, a Veolia Water Solutions & Technologies company, has announced the start of a $25-million project to design and build a water treatment plant at the Minera Chinalco Peru S.A. Kingsmill Tunnel Water Treatment Plant site. N.A. Water Systems is partnered with Cosapi S.A. Ingenieria Y Construccion, a Peruvian engineering and construction company. Historical mining practices in the area fill the 11.2-km Kingsmill Tunnel continuously with acidic mine drainage containing metal contaminants. High-density sludge technology is being used to create a crystalline sludge that minimizes waste volume, lowers disposal costs, and reduces environmental impacts. Startup of the water-treatment system is scheduled for September 2009.

MERGERS AND ACQUISITIONS

Evonik and Daimler establish alliance for advances in lithium-ion batteries

December 15, 2008 — Evonik Industries AG (Essen) and Daimler AG (Stuttgart, both Germany), are combining their lithium-ion technology and automotive expertise to drive forward the research, development and production of battery cells and battery systems. The companies will establish a JV with a clear focus on the development and production of battery systems for automotive applications. Daimler will hold 90% and Evonik 10% of this JV.

BASF acquires Sorex pest control business

December 4, 2008 — BASF announced that it has signed an agreement to acquire Sorex Holdings Ltd., a manufacturer of chemical and non-chemical products for professional pest management. The financial details of the transaction, which includes U.S.-based Whitmire Micro-Gen and U.K.-based Sorex Ltd., have not been disclosed. The closing of the transaction will proceed after final regulatory approval.

Dow and PIC of Kuwait sign agreement to launch K-Dow Petrochemicals

December 1, 2008 — The Dow Chemical Co. (Dow) and Petrochemical Industries Co. (PIC), a wholly owned subsidiary of Kuwait Petroleum Corporation (KPC), have announced that they signed the Joint Venture Formation Agreement and other key definitive agreements regarding the formation of K-Dow Petrochemicals, a 50:50 JV that will be a global supplier of essential petrochemicals and plastics and will manufacture and market polyethylene, ethyleneamines, ethanolamines, polypropylene and polycarbonate, and will also license polypropylene technology and market related catalysts. ■

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

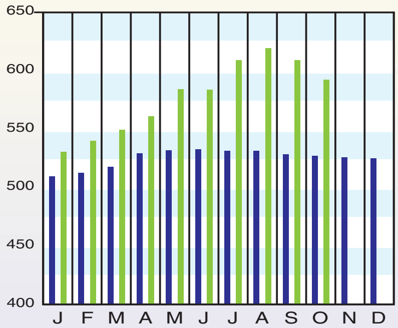
2008 2007

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

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Oct.'08 Prelim.	Sep.'08 Final	Oct.'07 Final
***CE* INDEX**	592.2	608.9	527.1
Equipment	720.0	744.4	626.2
Heat exchangers & tanks	711.7	758.4	593.3
Process machinery	664.7	674.3	594.9
Pipe, valves & fittings	864.0	865.6	740.2
Process instruments	439.0	446.8	422.1
Pumps & compressors	893.0	886.3	843.2
Electrical equipment	471.9	468.5	437.2
Structural supports & misc	771.8	817.8	660.8
Construction labor	326.3	328.2	318.3
Buildings	522.7	529.9	476.8
Engineering & supervision	351.3	351.7	355.0

Annual Index:
2000 = 394.1
2001 = 394.3
2002 = 395.6
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4

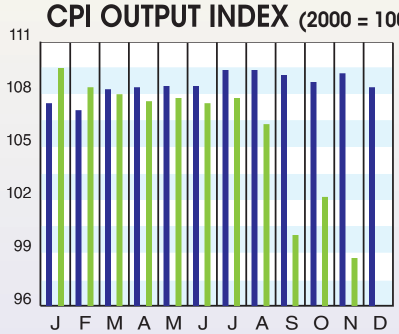


Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics

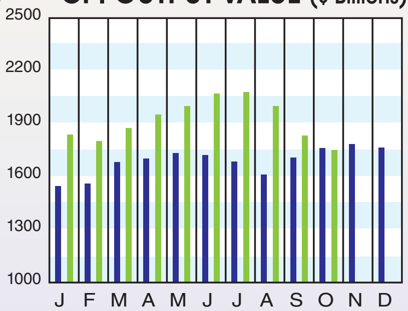
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS				YEAR AGO	
CPI output index (2000 = 100)	Nov.'08	= 98.7	Oct.'08	= 102.2	Sep.'08	= 100.0	Nov.'07	= 109.2
CPI value of output, $ billions	Oct.'08	= 1,752.4	Sep.'08	= 1,835.2	Aug.'08	= 2,000.6	Oct.'07	= 1,764.0
CPI operating rate, %	Nov.'08	= 72.7	Oct.'08	= 75.4	Sep.'08	= 74.1	Nov.'07	= 81.6
Construction cost index (1967 = 100)	Dec.'08	= 796.1	Nov.'08	= 800.9	Oct.'08	= 802.8	Dec.'07	= 753.1
Producer prices, industrial chemicals (1982 = 100)	Nov.'08	= 260.6	Oct.'08	= 286.9	Sep.'08	= 314.6	Nov.'07	= 248.2
Industrial Production in Manufacturing (2002=100)*	Nov.'08	= 105.5	Oct.'08	= 107.0	Sep.'08	= 106.3	Nov.'07	= 113.8
Hourly earnings index, chemical & allied products (1992 = 100)	Nov.'08	= 145.0	Oct.'08	= 143.4	Sep.'08	= 144.6	Nov.'07	= 142.5
Productivity index, chemicals & allied products (1992 = 100)	Nov.'08	= 126.3	Oct.'08	= 129.9	Sep.'08	= 122.6	Nov.'07	= 135.9

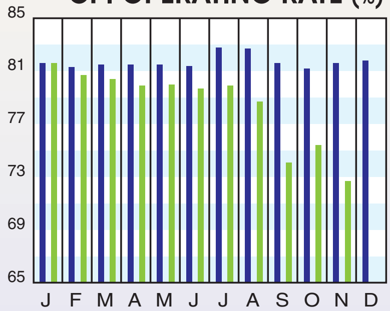
CPI OUTPUT INDEX (2000 = 100)



CPI OUTPUT VALUE ($ Billions)



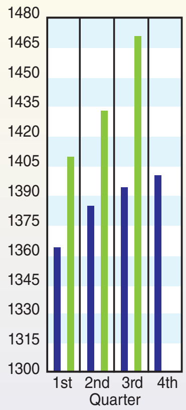
CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
Current business indicators provided by Global insight, Inc., Lexington, Mass.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	3rd Q 2008	2nd Q 2008	1st Q 2008	4th Q 2007	3rd Q 2007
M & S INDEX	1,469.5	1,431.7	1,408.6	1,399.2	1,393.0
Process industries, average	1,538.2	1,491.7	1,463.2	1,452.3	1,445.6
Cement	1,522.2	1,473.5	1,448.1	1,435.3	1,427.5
Chemicals	1,511.5	1,464.8	1,438.5	1,427.9	1,421.0
Clay products	1,495.6	1,453.5	1,429.1	1,415.0	1,408.8
Glass	1,432.4	1,385.1	1,359.7	1,348.8	1,341.8
Paint	1,543.9	1,494.8	1,467.6	1,457.1	1,451.2
Paper	1,443.1	1,400.0	1,377.7	1,369.2	1,364.0
Petroleum products	1,644.4	1,594.4	1,555.8	1,543.7	1,536.2
Rubber	1,575.6	1,537.5	1,512.3	1,500.1	1,494.8
Related industries					
Electrical power	1,454.4	1,412.8	1,380.4	1,374.9	1,359.0
Mining, milling	1,546.2	1,498.9	1,473.3	1,460.8	1,453.2
Refrigeration	1,793.1	1,741.4	1,711.9	1,698.8	1,691.7
Steam power	1,499.3	1,453.2	1,426.8	1,416.4	1,407.4



Annual Index:

2000 = 1,089.0	**2002 = 1,104.2**	**2004 = 1,178.5**	**2006 = 1,302.3**
2001 = 1,093.9	**2003 = 1,123.6**	**2005 = 1,244.5**	**2007 = 1,373.3**

CURRENT TRENDS

The CEPCI continues its decline in the October preliminary numbers (top). It reflects a substantial decrease in copper and steel prices caused by a slowing building boom in China and an overall economic slowdown worldwide. Meanwhile, the CPI Operating rate (middle) has hit its lowest point since the 2001 recession. For analysis, see p. 5.

CE's Online CEPCI provides access to the entire historical CEPCI database and earlier delivery of new data. Visit www.che.com/pci for more. ■