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July 2009

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Cover Photo: The classic rotor/stator mixer – the basis of the advanced rotor/stator mixing and dispersion technology available today. Courtesy of Charles Ross & Son Company

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CHEMICAL ENGINEERING

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Editor's Page

Keep one foot in your own yard

In offering up strategies for the chemical process industries (CPI), many business experts turn to the virtues of a global stage. For decades now, CPI companies in developed countries have eagerly followed the urge to expand into emerging regions. Likewise, geographical expansion is becoming attractive for companies in developing areas as they look to catalyze their own growth. A new analysis, however, shows that the grass is not necessarily much greener on the other side and instead advocates more of a straddle-the-fence approach.

The Accenture Research (New York; www.accenture.com) study of approximately 100 chemical companies and business units aims to understand how chemical companies most effectively manage the cyclical nature of the industry. Perhaps surprisingly, the results show that while many companies only consider foreign markets for growth, "home teams perform best," says Paul Bjacek, Accenture Research global chemicals and natural resources lead, and coauthor of the study findings. In fact, the research shows that high-performance chemical companies have no more than 45% of sales outside of their home markets.

This phenomenon can be explained, Bjacek says, by the fact that producers with a stronger emphasis on their home markets adjust to cycles better than those more geographically diversified. Domestic companies (in any particular region) have an advantage because they know how to manage their countries' inherent risks and excel within their own business environments, he adds. Consider, for instance, that North American and Western European companies' divisional operations in regions such as Asia, Latin America, Africa and the Middle East experience more volatility than the domestic producers in those regions, he says. Meanwhile, companies that perform best in foreign markets do so through joint ventures with local companies.

Contrary to popular perception, the CPI in developed economies such as Europe, Japan and the U.S., continue to grow, maintain margins and experience fewer swings in profitability, the study reveals. Therefore, Bjacek warns that chemical companies in developed economies should not abandon their home markets. He admits that competition is fierce in these regions, requiring unique innovation to serve customers that are themselves growing, inventive and internationally competitive. Still, with this complementary edge on developing new and better products, developed regional markets continue to maintain the world's highest overall margins (except for large-volume chemicals in the Middle East), he says.

Ironically, these so-called market makers attain the highest margins with the lowest productivity in terms of revenue per employee. They require more high-skilled labor, such as engineers and chemists for technical service, technology support and R&D, to address customers' increasingly intense technology needs. Market makers are not focused on scale or production. Instead, they focus on increasing margin through better ideas and revenue growth.

Of course, none of this is to say that geographic expansion should be avoided altogether, or that such a trend should be expected. In fact, Bjacek says that more investment capacity is headed into "risky territory" — risk in this case being defined by either political risk, political terror or corruption. For the study's projected period of 2008–2020, less than 10% is going to be invested in "low-risk" regions such as Canada, Australia, Japan and New Zealand, while more than 80% is destined for "high-risk" regions such as China and Russia.

In any case, the overall message is encouraging for chemical engineers in developed and developing countries alike. Each group still has an edge, especially at home. ■

Rebekkah Marshall

Letters

Passionate GHG arguments

I must applaud you on your May Editor's Page comments in "Keep the GHG debate on point".

I believe there are three distinct aspects to the issue that should not be commingled. First is "global warming", which is a natural phenomena that has occurred about every 1,500 years for the last million or so years that we can track it. It's happening, and there is nothing we can do about it. The second is the role that CO_2 plays in this, which is little to nothing, certainly nothing that puts responsibility on human factors. The third aspect is improving energy efficiency, and reducing dependency on fossil fuels.

Certainly it is necessary to reduce greenhouse gases that clearly have an impact on the world, basically pollution and health. But CO_2 isn't one of them. I have seen people use the numbers you quote in the reverse, by making them into "CO_2 equivalents", to emphasize a reduction in CO_2, not the GHG itself.

To move to a so-called cap-and-trade approach to reducing CO_2 emissions, which could mean severe limitations (taxes) on coal energy production or exhaust emissions, is a big mistake. Making efforts to increase fuel efficiency to either make our fossil fuels last longer or reduce dependence on foreign oil, is probably a good thing, and if that can be done by mandating better fuel efficiency for vehicles, well maybe that's a better idea.

Tom Rolfes
Rolfes International LLC, Wyoming, Ohio

I just finished reading your editor's page comment on anthropogenic global warming. I would recommend the following areas of study for you or your magazine in order for you to have a more rounded opinion on anthropogenic global warming.

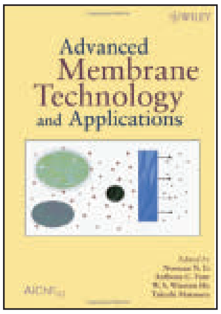
- Ice core data and CO_2
- Leaf stomata and CO_2 atmospheric levels
- CO_2 atmospheric sampling pre and post 1957
- ^{13}C isotopic concentration of the atmosphere
- Ocean currents and their effects on weather patterns
- CO_2 concentrations of seawater and their variations due to locale

This is just a small list of topics that when researched would give any scientist doubt as to the validity of CO_2 induced global warming. I will not go on and make any negative remarks about your insulting comment that any belief against anthropogenic [CO_2] induced global warming is nonsensical and likening those who fight this belief as being akin to possessing elementary-school-like minds as it pertains to science.

John Benkovic
Plant manager, CIL Isotope Separations

The editorial does not make any arguments for or against the premise of anthropogenic global warming. It merely argues that life-giving characteristics ALONE do not form the basis for a pollution exemption. Nor does it suggest that those who fight this belief possess elementary-school-like minds. Instead, it calls for deeper scientific education on the issue than that related to CO_2's life giving characteristics. — Ed.

Bookshelf



Advanced Membrane Technologies and Applications.

Edited by Norman N. Li. Wiley. 111 River St., Hoboken, NJ 07030. Web: wiley.com. 2008. 994 pages. $150.00.

Reviewed by Peter S. Cartwright, Cartwright Consulting Co., Minneapolis, Minn.

The crossflow-pressure-driven membrane separation technologies of microfiltration, ultrafiltration, nanofiltration and reverse osmosis have been commercially available for less than 50 years, yet critical shortages of water of acceptable quality for drinking, commercial, industrial and agricultural uses, as well as the opportunities for innovative chemical processing and manufacturing are fueling exceptional research and development activities in these technologies, with no end in sight.These seemingly frenetic activities in membranes have produced a number of technology offshoots utilized either in non-water applications or to meet specialized separation requirements.

This book is comprised of six categories with 35 chapters, addressing applications from traditional and relatively mature water and wastewater treatment and gas separations, to membrane contactors, reactors and fuel cells. This book offers something for every reader: what's new in water purification and wastewater treatment, membrane polymer chemistry, biomedical membrane applications and numerous specialized membranes still under development. There is almost no membrane application, whether commercially developed or still a laboratory curiosity, that is not addressed in this book.

With well over 35 authors, there is some redundancy, and with those for whom English is not their first language, spelling, grammar and punctuation were sometimes a problem.

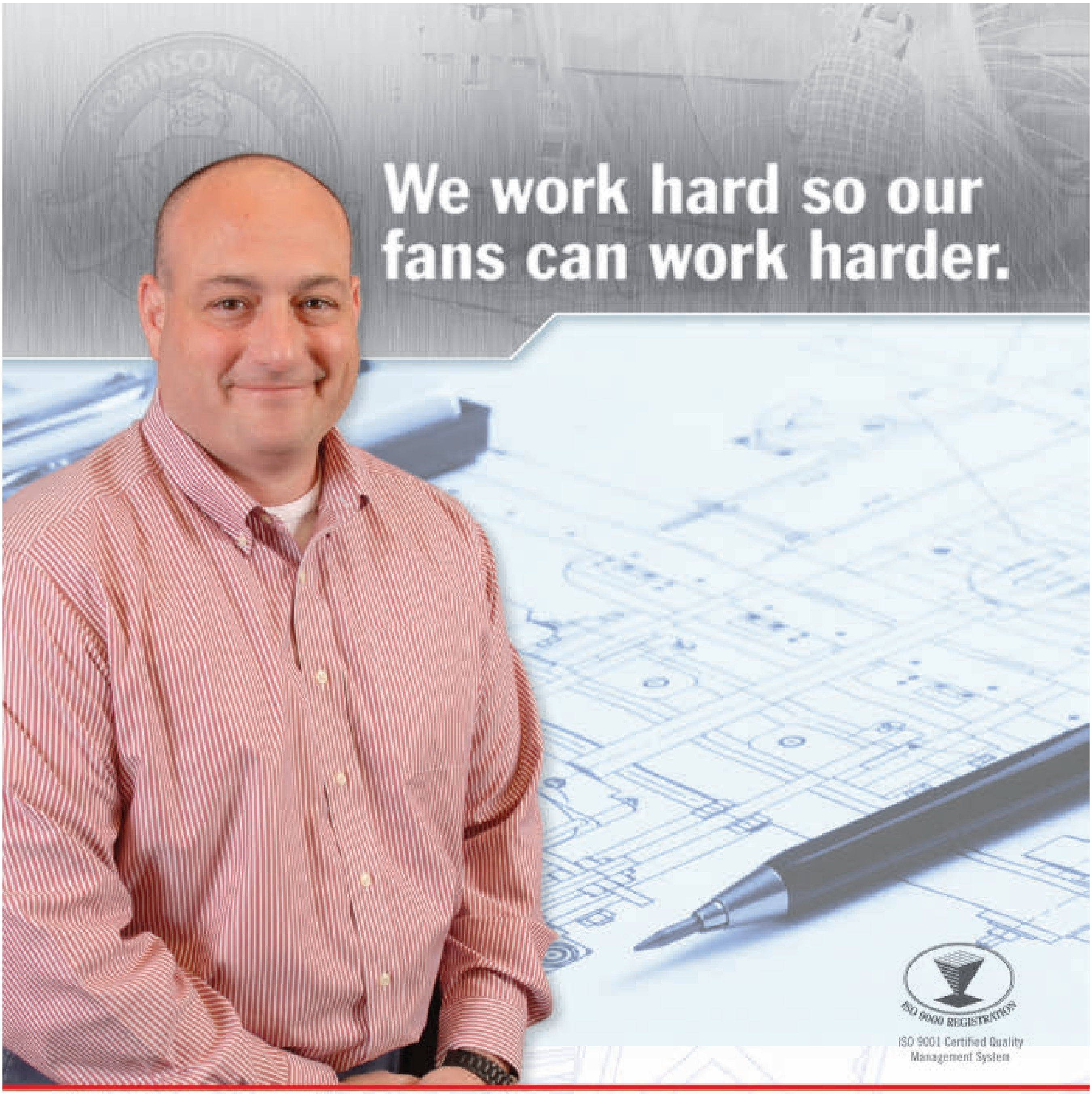
Some chapters have glossaries; however, it would have been beneficial to have had one for the entire work, and for all of the authors to have used the same acronyms throughout. Units of measurement should have included both metric and English in every chapter.

It was a relief to note that the figures and tables are virtually on the same pages where they are addressed; however, using different numbering systems for figures and tables would have been less confusing.

It would have been helpful to have had one chapter devoted to the history of membrane development, as it was repeated by a number of authors.

The mix of authors from membrane manufacturing companies and academia is refreshing, as the book is neither too commercial nor too theoretical.

The six categories comprised of water and wastewater, biotechnology, gas separation, contactors/reactors, environmental/energy and materials/characterization enable the reader to quickly focus on the chapter of interest.



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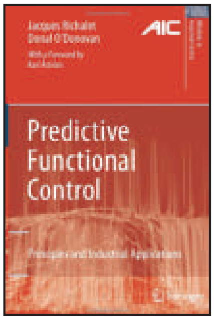
Circle 12 on p. 54 or go to adlinks.che.com/23016-12

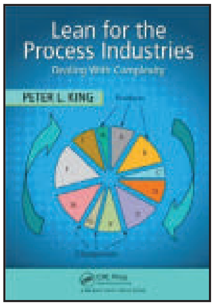
Bookshelf

This book captures the current “state of the art” for membranes on a global scale, encompassing today’s extremely diverse membrane climate and provides the reader with a vision of some of the interesting membrane developments that may be tomorrow’s commercial applications.

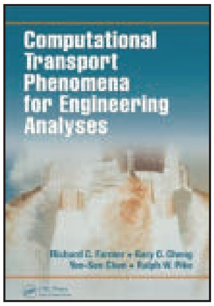


Magnetic Nanoparticles. Edited by Sergey P. Gublin. Wiley. 111 River St., Hoboken, NJ 07030. Web: wiley.com. 2009. 484 pages. $200.00.

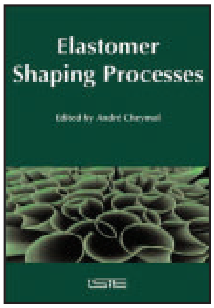
Predictive Functional Control: Principles and Industrial Applications. By Jacques Richalet and Donal O’Donovan. Springer. 233 Spring St., New York, NY 10013. Web: springer.com. 2009. 244 pages. $149.00.



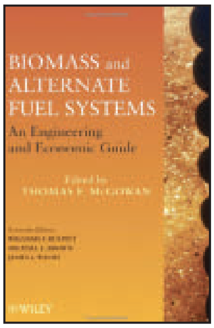
Lean For the Process Industries: Dealing with Complexity. By Peter L. King. Productivity Press. 7625 Empire Dr., Florence, KY 41042. Web: productivitypress.com. 2009. 358 pages. $49.95.



Computational Transport Phenomena for Engineering Analyses. By Richard C. Farmer, Ralph W. Pike, Gary C. Cheng and Yen-Sen Chen. CRC Press, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL 33487. Web: crcpress.com. 2009. 530 pages. $139.95.



Elastomer Shaping Processes. By Andre Cheymol. ISTE Publishing Company. 3rd Floor, Tuition House, 27/37 St George’s Road, London SW19 4EU, UK. Web: iste.co.uk. 2009. 576 pages. $289.95.



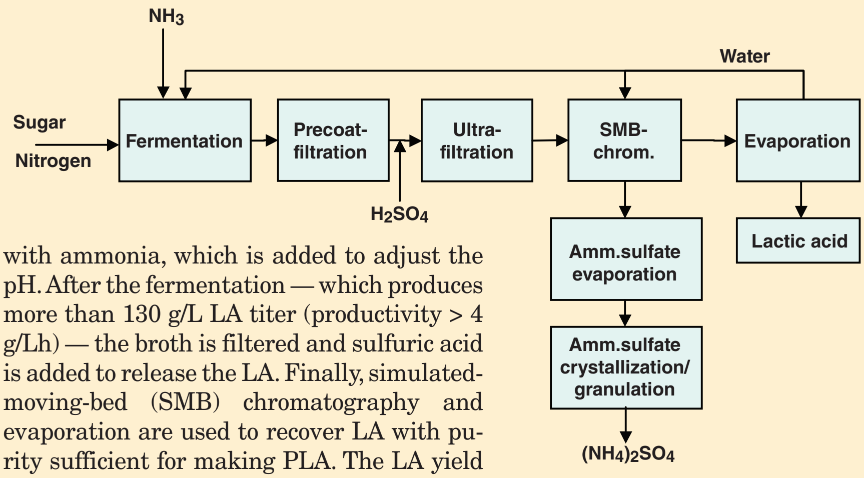
Biomass and Alternate Fuel Systems. By Thomas McGowan. Wiley-AIChE. 3 Park Ave., New York, NY 10016-5991. Web: iste.co.uk. 2009. 264 pages. $89.95.

Pipeline Rules of Thumb Handbook, Seventh Edition: A Manual of Quick, Accurate Solutions to Everyday Pipeline Engineering Problems. By E. W. McAllister. Gulf Publishing Company, P.O. Box 2608, Houston, TX 77252. Web: gulfpub.com. 2008. 800 pages. $125.00. ■

Kate Torzewski

Edited by Gerald Ondrey July 2009

A gypsum-free, energy-saving route to lactic acid



Uhde GmbH (Dortmund, Germany; www.uhde.biz) is developing a new process for producing lactic acid (LA) — a monomer for making the biodegradable plastic polylactic acid (PLA) — that does not require a distillation step. As a result, savings in steam and electrical power are calculated to be up to €100/ton of LA, says Joachim Schulze, head of Uhde's biotechnology division.

In conventional routes, lactic acid is made by the fermentation of sugar using bacteria, such as *lactobacillus*, *streptococcus* or *pediococcus*. As LA is produced, lime milk [saturated aqueous $Ca(OH)_2$] is added to keep the pH from becoming too acidic for the bacteria to survive. After fermentation, sulfuric acid is added to convert the calcium lactate into free acid, producing gypsum ($CaSO_4$) as a byproduct. The crude LA is separated by filtration and clarification of the broth and evaporation of the water, and then purified by distillation.

The new process (flowsheet) uses a thermophyllic bacteria strain that is also compatible with ammonia, which is added to adjust the pH. After the fermentation — which produces more than 130 g/L LA titer (productivity > 4 g/Lh) — the broth is filtered and sulfuric acid is added to release the LA. Finally, simulated-moving-bed (SMB) chromatography and evaporation are used to recover LA with purity sufficient for making PLA. The LA yield is better than 90%, says Schulze. Instead of producing low-value gypsum, the new route generates ammonium sulfate, which can be made into fertilizer granulate.

Uhde has been developing the new process at a test facility in Leipzig since 2007, and recently performed a toll operation (50 m^3 fermenter) in the Czech Republic. Plans are underway to build a pilot plant, and ultimately integrate the LA process into the PLA process of Uhde Inventa-Fischer GmbH (Berlin).

New catalyst boosts liquid-fuel yield from heavy hydrocarbons

A new zeolite catalyst that increases yields of light cycle oil (LCO) from high molecular weight "bottoms" hydrocarbons in petroleum fluid catalytic cracking (FCC) units was commercialized last month by Grace-Davison, an operating segment of W.R. Grace & Co. (Columbia, Md.; www.grace.com). Observed gains in LCO (boiling point 430–650°F) yields of up to 6% are significant to petroleum refiners seeking to improve production of valuable liquid products, such as transportation fuels and chemical feedstocks, from heavy hydrocarbons (HCs), says product manager Rosann Schiller.

Known as Midas 300, the USY- (ultra-stable Y-type) zeolite-containing catalyst derives its enhanced activity from an increase in mesoporosity of the catalyst matrix. Mesoporosity refers to pore sizes in the range of 100 to 600 Å — critical for allowing free diffusion of heavy HCs into the catalyst. Greater mesoporosity improves overall selectivity by converting coke precursors into liquid product, explains Schiller.

Enhanced catalyst mesoporosity, coupled with more acidic-active sites and pore structures that blunt the poisoning effects of contaminant metals (Fe, Ca, Ni, V), improves the selectivity of the catalyst in gasoline- and LCO-forming reactions compared to conventional FCC catalysts, says Schiller. Midas 300 "selectively cracks naptheneoaromatic compounds without a coke or gas penalty."

Midas 300 optimizes catalysis of three bottoms-cracking mechanisms, including pre-cracking of large molecules on the catalyst matrix, zeolite-catalyzed dealkylation of aromatics and long-chain breakage, as well as the destruction of napthene rings.

Midas 300 catalyst has been in commercial use at two FCC units in North America and an additional plant in the Asia-Pacific region since late 2008. The facilities include a small gas-oil refinery and a large, residual fuel-oil processor. Schiller notes that the economic value of a 6% yield increase in liquid products varies depending on the size of the FCC unit, the type of feed and the operating conditions, but benefits in the range of \$0.75–1.50/bbl have been reported.

FutureGen

The U.S. Dept. of Energy (DOE; Washington D.C.; www.doe.gov) has revived a program for a commercial-scale demonstration of a fully integrated plant that would combine coal gasification, H_2 production, electricity generation, and CO_2 capture and underground storage. The program, called FutureGen, had been dropped by the Bush Administration in 2008 because of the cost.

DOE has signed an agreement with the FutureGen Alliance (Washington, D.C.; www.futuregenalliance.org), an industrial sponsorship group, with the goal of building a plant in Mattoon, Ill. The agreement calls for \$1.073 billion to be contributed by DOE and \$400–600 million by the Alliance, a group of international companies that includes electric utilities and coal companies. A final decision either to move forward or discontinue the project will be made in early 2010, following a detailed cost study.

Li-ion cathode

Last month, BASF Corp. (Florham, N.J.; www.basf.com) signed a global license agreement with DOE's Argonne National Laboratory (ANL; Argonne, Ill.; www.anl.gov) to mass-produce and

(*Continues on p. 14*)

Note: For more information, circle the 3-digit number on p. 54, or use the website designation.

Direct conversion of cellulose to HMF demonstrated

Researchers at Pacific Northwest National Laboratory (PNNL; Richland, Wash.; www.pln.gov) have published the first direct route for converting plant cellulose to 5-hydroxymethylfurfural (HMF), a valuable platform chemical for the production of both plastics and biofuels. Appearing in the June issue of *Appl. Cat. A*, the research could mark a pathway to less expensive, large-scale production of HMF.

Although a two-step process of HMF formation from plant biomass via simple sugars has been demonstrated previously, a mild-temperature, single-step process to convert cellulose directly to HMF has remained elusive.

PNNL's conversion process relies on the use of twin metal chlorides ($CuCl_2$ and $CrCl_2$) dissolved in an ionic liquid (1-ethyl-3-methylimidazolium chloride) at temperatures of 80 to 120°C to catalyze the single-step conversion of cellulose to HMF. In the laboratory, the process achieves an unrefined purity of 96% among recoverable products, and an overall HMF yield of about 55%.

Principal investigator Conrad Zhang, who has since left PNNL, says that cellulose depolymerization occurs at a rate one order of magnitude faster than conventional acid-catalyzed hydrolysis. The research group evaluated a wide range of metal chlorides and found that a combination of $CuCl_2$ and $CrCl_2$ at a catalyst load of 37 µg/mol generated the highest HMF yields. Experiments are underway to elucidate the reaction mechanism, which is not yet understood.

A new support for biofilters

Researchers from the Environmental Biotechnology Cooperative Research Center (Sydney and Perth, Australia; www.ebcrc.com.au) have developed a new way to harness bacteria to biodegrade odor-causing substances. Traditional biofilters typically employ compost supported on wood chips to trap the odor-producing substances, and rely on micro-organisms in the compost to break down those substances. The center's executive director, David Garman, says that "while bacteria can deal with a wide range of odors, their unreliability, poor viability and poor performance in normal biofilter systems mean that often operators prefer to use simpler chemical systems. Some of these systems are effective at masking the odors but do not remove or break them down."

The center's new technology replaces the compost and wood chips by a non-biodegradable matrix that also acts as an adsorbent. A naturally occurring zeolite is used for that purpose. The electrically charged surface of the zeolite and the internally porous crystalline structure of regularly spaced cavities provide large surface area and molecular sieve properties. According to the researchers, those properties make zeolite a filter bed material capable of adsorbing odors, as well as provide surfaces for micro-organisms to form a biofilm to biodegrade the adsorbed odors. Since zeolite is inert, there is no need to replace it. Backflush or backwash should be enough to reduce blockage caused by biofilms.

A fully automated laboratory-scale (1-L) plant, with two separate filter reactors, has been constructed. Using ammonia as a model compound to understand the mechanism of odor removal, experiments have demonstrated that the adsorption capacity of the zeolite bed is comparable to that of conventional biofilters. The next step will be to demonstrate the system using odor-degrading micro-organisms. A full pilot plant will be set up shortly in Perth, Western Australia.

Using gold to catalyze oxidation reactions

Polymer-supported nanoclusters of gold have recently been shown to catalyze the oxidation of alcohols to ketones at room temperature in air by the research group of chemistry professor Shu Kobayashi, University of Tokyo (www.chem.s.u-tokyo.ac.jp), in a project supported by Japan Science and Technology Agency (JST). Now, the researchers have developed a procedure to deposit the gold catalyst onto the inside walls of glass capillary tubes, which can then be used as tubular reactors for performing oxidation reactions continuously. The catalyst strongly binds to the 0.25-µm-thick polysiloxane coating of a commercially available gas-chromatography capillary tube [Inert-Cap 225 from GL Science Co. (Tokyo)]. As a test of the system, 1-phenyl ethanol was oxidized to the corresponding ketone with high yield. After four days of continuous operation, no loss of catalyst or catalyst activity was observed. Improved yields and selectivity have also been observed by oxidation in a palladium-gold-supported capillary system.

(*Continued from p. 13*)

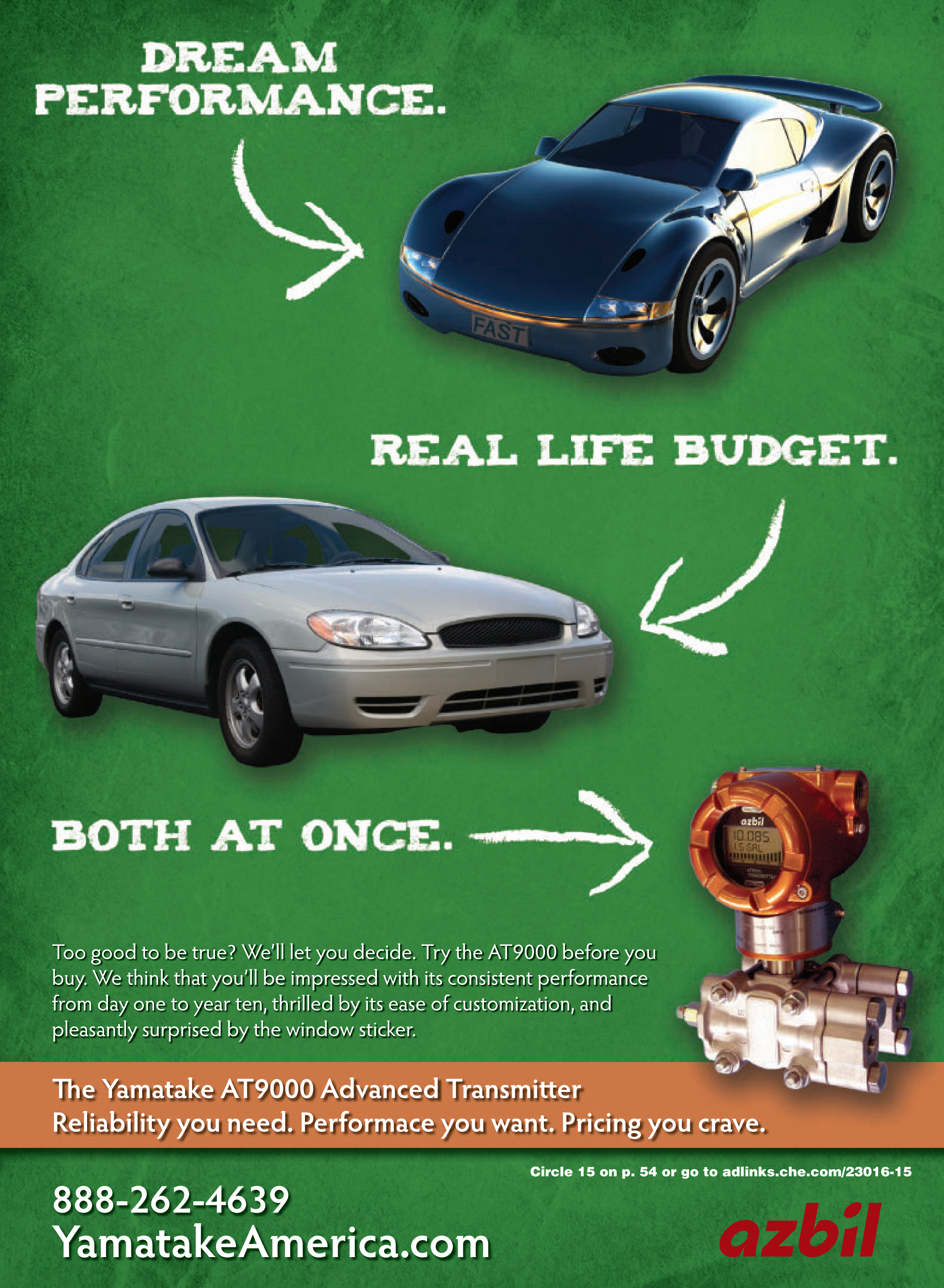
market ANL's patented composite cathode materials for advanced lithium-ion batteries. BASF will further develop the technology at its Beachwood, Ohio facility.

ANL's cathode is a combination of lithium- and maganese-rich, mixed-metal oxides designed to extend operating time between charges, increase the lifetime and improve the inherent safety of Li-ion cells. Enhanced stability of the composite material permits batteries to charge to higher voltages, which leads to a "substantially" higher energy-storage capacity, says ANL.

BASF plans to commercialize these cathode materials for transportation and other applications. Contingent upon winning a DOE grant under the Recovery Act (Electric Drive Vehicle Battery and Component Manufacturing Initiative), the company plans to build a cathode-material production plant in Elyria, Ohio.

CO_2 capture

Last month, Alstom (Paris,; www.alstom.com) signed an engineering, procurement and construction (EPC) contract with StatoilHydro ASA (Stavanger, Norway; www.statoilhydro.com) on behalf of the partners of the European CO_2 Technology Center Mongstad (TCM; Norway) for a chilled-ammonia, CO_2-capture plant. The demonstration plant will be the first one of its kind to treat fluegas (FG) from a gas-fired power plant, says Alstom. Alstom will supply and install the demonstration plant — scheduled to start up in November 2011, which will use the company's chilled ammonia, post-combustion technology (for process details, see *CE*, April 2008, p. 13) to capture CO_2 from FG of a combined heat and power plant at Mongstad. It will also treat FG from a petroleum processing plant at the nearby Mongstad refinery, which has a CO_2 output equal to that of a coal-fired power plant. The TCM facility will capture up to 100,000 metric tons (m.t.) per year, of which chilled NH_3 will capture 80,000 m.t./yr — the equivalent of a 40-MW_{th} power plant.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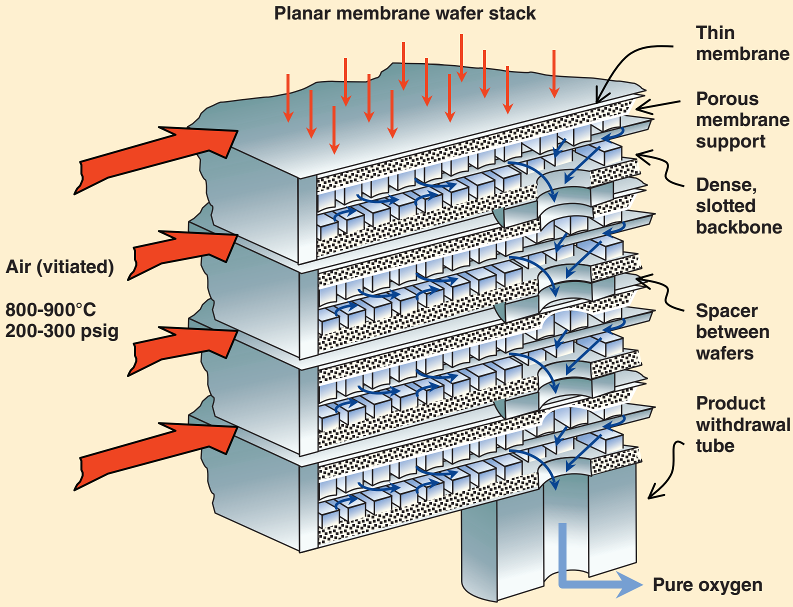


Scaleup is set for an air-separation membrane

The Electric Power Research Institute (EPRI, Palo Alto, Calif.; www.epri.com) has signed an agreement with Air Products (Allentown, Penn.; www.airproducts.com) to support the company's development of a ceramic ion transport membrane (ITM) for air separation. The membrane is being tested and scaled up under a cooperative agreement with the U.S. Dept. of Energy (DOE, Washington D.C.; www.doe.gov).

The goal is to substitute the membrane for cryogenic air separation for integrated gasification combined cycle (IGCC) and oxycombustion systems. In oxycombustion, oxygen replaces combustion air, thus producing a fluegas that is nitrogen-free, but rich in carbon dioxide, which can be readily captured. ITM technology is expected to reduce power consumption for air separation by up to 30% and capital costs by about 30%, says Ted Foster, director of business development for advanced gas separation with Air Products.

Air Products' ITM consists of a stack of wafers made of doped, complex metal oxides. Air is heated to above 700°C at 280 psi, and O_2 is ionized, passes through the membrane, then reforms into molecules (*CE*, December 2008, p. 19). Under the agreement with DOE, Air Products has been testing the membrane at a scale of 5 ton/d of O_2 and has achieved an O_2 purity of 99%. Starting in 2010, the company plans to test a 150-ton/d system and integrate it with a gas turbine. Several of EPRI's utility members are cooperating in the project.

A less-expensive way to make platinum catalysts

The cost of producing platinum catalysts could be reduced by up to 90% by a process being developed jointly by Lawrence Livermore National Laboratory (LLNL, Livermore, Calif.; www.llnl.gov) and Stanford University (Stanford, Calif.; www.stanford.edu). The process involves the deposition of minute amounts of platinum onto disks of carbon aerogel by a technique called atomic layer deposition (ALD), which permits atomic-level control of film thickness.

The catalyst structure has been tested for conversion of CO to CO_2 and achieved nearly 100% conversion efficiency with a platinum content of as little as 0.05 mg/cm^2. "We get a very fine dispersion, so a small amount of catalyst can do a lot," says Juergen Biener, a materials scientist with LLNL.

The carbon aerogels, made by sol-gel chemistry, are strong, yet highly porous, with surface areas of up to 3,000 m^2/g. The high surface area allows more of the catalyst to be exposed, notes Biener. In the ALD process, an organic platinum precursor in the vapor phase is deposited on aerogel disks at around 300°C in a nitrogen atmosphere. Biener points out that the process differs from chemical vapor deposition in that the deposition is surface-catalyzed and self-limiting, so that only one atomic layer is deposited at a time.

Extracting drinking water from humidity

An energy-autonomous process for capturing air humidity for drinking water has been developed by scientists at the Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB; Stuttgart; www.fraunhofer.de) and Logos-Innovationen GmbH (Bodnegg, both Germany; www.logos-innovationen.com). The concept is suitable for supplying water to single households or hotels in regions where there is no electricity infrastructure.

In the process, water from the atmosphere is absorbed by hygroscopic brine, which runs down a tower-shaped unit. The brine is then sucked up to an elevated tank, which is under vacuum, and heated by solar collectors thereby evaporating the water. Water vapor is then condensed and runs through a completely filled column, creating the vacuum needed for the brine tank. Reconcentrated brine then repeats the cycle. Prototypes for both system components — absorption and vacuum evaporation — have been built, and the combination tested on a laboratory scale. A demonstration facility is the next step.

This photocatalyst works with visible light

A photocatalyst that uses visible light to deodorize and disinfect air has been developed by Hiroshi Taoda at the Materials Research Institute for Sustainable Development, National Institute of Advanced Industrial Science and Technology, Chubu, Nagoya, (AIST; Chubu, Nagoya, Japan; www.aist.go.jp). The catalyst is made from inexpensive components, such as titanium dioxide, apatite mineral and iron, without using more costly noble and rare-earth metals, thus making it suitable for use in consumer applications, such as car interiors, bathrooms and smoking rooms.

An optimized composition of TiO_2, apatite and iron has been shown to be nearly six times more effective at decomposing formaldehyde than existing photocatalysts, which also do not respond to visible light, says Taoda. Also, acetaldehyde is completely broken down to CO_2 and water after 3-h irradiation. Furthermore, the photocatalyst showed enhanced performance for the decomposition of acetaldehyde under ultraviolet (UV) irradiation. For disinfection, the catalyst was shown to reduce the number of *Staphylococcus aureus* by nearly five orders of magnitude to below 10 after 8 h irradiation with white fluorescent light — an efficiency of 99%. The catalyst also eliminates 90% of oxides of nitrogen (NOx) by UV irradiation of a gasflow containing 1 part-per-million (ppm) NOx. The researchers estimate that the cost for producing a catalyst slurry would be a few thousand Yen (around $10) per kilogram.

Making solar panels even greener

Last month, Malibu GmbH & Co, KG (Bielefeld, Germany; www.malibu-solar.de) started up a thin-film photovoltaic-module fabrication facility that is claimed to be the world's first to eliminate the use of nitrogen trifluoride (NF_3) — a greenhouse gas with a significant global warming potential — from the manufacturing process. The facility uses an improved cleaning process based on fluorine (F_2), which is generated onsite by a patented technology from Linde Gases (Munich, Germany; www.linde.com). As a result, the carbon payback time — the time it takes the use of photovoltaic panels to offset the environmental impact of their manufacture — is reduced by one year, says the firm. The process is being used in Malibu's new, 40-MW production facility in Osterweddingen, Germany.

The missing piece for wireless process control

Last month, Honeywell Process Solutions (HPS; Phoenix, Ariz.; www.honeywell.com/ps) unveiled the process industry's first redundant wireless system gateway (WSG), connecting the last major gap in the path to wireless process control. WSGs manage data between wireless field instrumentation and a plant's process control network. Redundancy between the wireless instruments themselves and their assigned gateway was already a reality since the introduction of so-called wireless mesh networks. Prior to this latest release, however, anyone using wireless networking still had a reliability risk: that if a gateway failed, so would the signals being routed through it, explains Jeff Becker, global wireless business director at HPS. "We would not expect our customers to run [process] control over wires without full redundancy, so why should we expect them to do that wirelessly?" says Becker.

The redundant WSG overcomes important programming hurdles, such as the avoidance of signal confusion from dual gateways without more than a 2-s delay. Meanwhile, unique failure-recovery features help prevent data loss, Becker says.

The release is especially timely for the vast number of aging facilities with control networks and instrumentation that are nearing the end of their lifecycle, Becker says. To illustrate the cost advantage, he points to one of the first commercial installations planned for the new system, a 35-tank, monitoring and control system in Houston where the quote to install a wired system was 50% higher than for the wireless setup. Depending on location, the savings could be closer to 70%, he says. And, that completes the upfront capital for a full wireless network in which subsequent wireless devices can be added for "hardly anything". ■

A new way to make BDO from sugars

Genomatica (San Diego, Calif.; www.genomatica.com) has developed a process for the production of commercial-grade 1,4-butanediol (BDO) from renewable feedstocks, announcing last month that it can produce BDO at greater than 99% purity. In addition to glucose and sucrose, the ability to use xylose has also been demonstrated, which may lead to the development of second-generation processes that consume the carbohydrates of lignocellulosic biomass.

In the cost-efficient, scalable process, BDO is produced directly in a fermentation broth from sugars by strains of bacteria that are tolerant of the commercial target concentrations. The yield and rate of BDO production needed on a commercial scale are achieved.

Operations at a demonstration plant will be underway by 2010 with an expected capacity of approximately 1 ton/d. When the demonstration plant validation is complete, Genomatica plans to commercialize the process through partnerships. ❑

SEPARATION: MORE, MORE, MORE

FIGURE 1. The CDS StatoilHydro Bulk Deboiler is a compact cyclone designed to separate oil from water for a wide range of water cuts

Chemical processors are asking for more efficiency and higher purity from their separation equipment in an effort to produce higher-quality product at the lowest cost possible

Chemical processors want more from their separation processes these days. Whether their technology choice is distillation, membrane or magnetic, processors are asking for more energy efficiency, more process efficiency and more purity in an effort to make their companies more competitive.

"When you improve the efficiency or capacity of a product, it almost always can be used to improve the process economics with respect to investment costs or operating costs," says Mark Pilling, manager of technology with Sulzer Chemtech (Tulsa, Okla.). To help processors do this, separation-technology providers strive to maintain a strong base of engineering expertise to assist customers in making sure the separation design ultimately provided is the proper solution with respect to the whole process. "This is especially important when new processes are arising from the efforts for greener and more energy-efficient technologies," notes Pilling.

More efficiency

Energy efficiency certainly plays a starring role in what chemical processors are demanding from their separations, especially when it comes to distillation. "Distillation processes that make separations for chemical and oils are one of the biggest consumers of energy in the country," explains Frank Rukovena, vice president of marketing with Fractionation Research Inc. (Stillwater, Calif.). For this reason, finding a technology that can provide even a half-percentage change in efficiency across the industry would present a significant energy savings.

One promising area is a new "unconventional" tray design, according to Rukovena, whose non-profit research consortium includes 69 members in the chemical, petroleum, engineering and equipment supplier industries with an interest in separation technologies.

Typically, packing and trays in distillation towers are used to mix liquid and vapor. The liquid and vapor move counter-current to each other and, as they do that under normal gravity, the capacity can only get so high before vapor blows the liquid backwards up the tower. "We are always trying to figure out how to develop something that will let more capacity through and make the separation between the liquid and vapor without the back mixing that ruins the efficiency," says Rukovena.

These new, unconventional trays might be the ticket. Instead of just counting on gravity for separation of liquid and vapor, the new trays use centrifugal forces and impingement devices to accomplish separation, which lets processors go beyond the separation that would normally be achieved using gravity alone.

"For existing towers, this means you can get more through at the same separation or you can get the same amount through with better separation," explains Rukovena. "In new construction, the technology permits building of smaller towers. Some distillation towers can get as large as 40 ft. in dia., so any foot you can take off when working at higher pressure equals a big cost savings in material and energy." He notes that in either case, by increasing the efficiency of the separation, less energy is used in the process.

GEA Process Engineering (Columbia, Md.) is also working to improve energy efficiency of separation processes, such as evaporation and distillation, by integrating process steps.

"There are major trends to highly integrate the columns in the overall plant design, which allows us to offer combination units where the columns can heat each other, as well as to use hybrid units in combination with evaporators," explains Matthias Loewenberg, application engineer with GEA Process Engineering.

These integrated technologies provide energy savings by recycling heated steam. "In the case of integrated columns, you can reuse steam from the first column in the second column," says Loewenberg. In very basic terms, one column heats the other so processors only have to put energy into the first column and can conserve energy down the line in the next column.

The most common duos for this energy efficient technology, according to Loewenberg, include hybrid columns, such as combination units of falling-film evaporators in conjunction with distillation columns or rectification columns.

With compression systems, says

Loewenberg, GEA provides mechanical vapor recompression, where instead of using steam, boiled-off vapor is compressed and used again as a heating source.

Membrane technology, too, is another application for reducing energy use in separations, according to Kevin Donahue, business manager for industrial processes with Koch Membrane Systems (KMS; Wilmington, Mass.). For example, if a plant is processing at full capacity but wants to boost production further, debottlenecking the evaporator could help. “In these cases, the companies should consider the use of a membrane to remove water from the fluid ahead of the evaporator to preconcentrate the liquids or solids,” explains Donahue. “The membrane could provide a factor of five or ten times more energy efficiency compared to an evaporator [alone].”

While he says the exact savings are plant specific, using membranes in this way will most always provide payback without higher capital costs.

Process efficiency is also on many processors’ wish lists, especially when it comes to substance separation. “We see a lot of interest from operators in subsea oil processing in doing their separations in a more compact and efficient way,” says Rune Fantost, technology director of CDS Separation Technology (Houston), which is part of FMC Technologies’ Separation’s Group. “In this field they have been seeking a technology that will permit inland separation using pipe segments instead of large vessels.”

The quest for this technology is driven by bottlenecks and operating problems offshore on the platforms, which creates the need to find a simple way to retrofit. “They have a certain number of separation vessels and they don’t want to replace those vessels, so we can offer them solutions upstream or downstream from the existing vessels that can increase capacity and performance,” says Fantost.

CDS

FIGURE 2. The CDS StatoilHydro Inline deliquidizer has been applied at a number of fields, de-bottlenecking or replacing large, conventional gas scrubbers with ultra-compact separation in pipe segments

CDS has worked with a variety of operators to develop compact, inline separation technology. “We’ve spent a lot of time qualifying this technology to come up with operating envelopes and how it will perform in different applications with the major oil companies,” says Fantost. The result is a line of inline separators based on com-

MULTI-PASS TRAYS: CALCULATING CORRECTIONS

Recently, economics in many processes have favored very large-diameter (greater than 20–30 ft) distillation towers, according to Henry Kister, a well-known distillation expert with Fluor Corp. (Aliso Viejo, Calif.). While the current economy may mandate these large towers, the size often presents a problem: as the columns get bigger, the liquid load grows a lot faster than the vapor rate and the columns and trays begin having difficulty handling the flow of liquid, which restricts column capacity.

To remedy this problem, the common practice has been to move from single-pass trays to multi-pass trays that split the load. This allows half the liquid to go one way and half to move the other, which reduces the liquid load. If the load is still too big, the trays can be split again into a four-pass tray, but "the technology has been troublesome," says Kister. "This is because in one or two passes, there's perfect symmetry, but in four or more, there is not perfect symmetry."

This lack of symmetry causes "maldistribution," which occurs when the liquid-to-vapor ratio on one pass significantly differs from that of another and causes the separation process to suffer and efficiency to be reduced, sometimes by a large magnitude.

Tools for reliably predicting the nature and magnitude of multi-pass tray maldistribution are scarce, according to Kister. And, the available tools are proprietary. "Our experience has been that the hydraulics calculated by these generally fail to reliably predict maldistribution. All these render poor performance due to maldistribution common on multi-pass trays," says Kister.

In the absence of an adequate predictive tool, achieving adequate pass distribution and keeping the distribution within the recommended distribution-ratio criterion is elusive and often unreachable. "We are seeing far too many recent designs in which the distribution ratios were much worse than the recommended. We have seen this maldistribution causing major loss of efficiency, capacity, or both in four-pass trays," he says.

There is, therefore, a great incentive to develop a tool that will reliably predict and quantify this maldistribution in existing towers and prevent it on newly designed ones. As a result, Fluor worked to develop the Multi-pass Maldistribution Model, which is a step in the right direction. Using this formula, Fluor has had successful applications of multi-pass technology in very challenging applications, says Kister.

He says any progress made in this area is important as people begin to prepare for carbon capture technology. "Carbon capture is a big thing and people haven't figured it out yet, but it will most likely be done with big columns and tray towers," explains Kister. "There will be a lot of applications in the future that will require multi-pass technology, so it's important that we figure this out now as the large plants are being built, and older plants are being revamped, and they are all in need of carbon capture technology." ❑

pact cyclonic technology. Five types of inline separators are currently available, including a degasser that separates gas from a liquid stream, a deliquidizer that separates liquid from a gas stream, a desander that separates sand from a process stream, a bulk deoiler that separates oil from water and a flow splitter that improves the downstream flow regime.

Purer product

In addition to more efficiency, processors want to improve product purity. And, magnetic separators are one way to achieve this. "Processors are looking

Separation Technology Providers

CDS Separation Technology	www.fmctechnologies.com/CDSSeparationTechnologies.aspx
Eriez Magnetics	www.eriez.com
Fluor Corp.	www.fluor.com
Fractionation Research Inc.	www.fri.org
GEA Process Engineering	www.niroinc.com
Koch Membrane Systems	www.kochmembrane.com
Sulzer Chemtech	www.sulzerchemtech.com

for stronger magnets in magnetic separators so they can remove more ferrous contamination from their product and ultimately achieve purer product, which is important in the chemical industry," says Bill Dudenhoefer, manager of separation products with Eriez Magnetics (Erie, Pa.).

In answer, Eriez offers Rare Earth Drum Separators that feature Erium 3000, a high-quality rare earth permanent magnetic power source. The drum separators are able to purify large quantities of materials such as foods, plastics, abrasives, metal powders, ceramic material, paper, glass cullet, soda ash, kaolin clay, chemicals, gypsum and quartz powder. They remove very fine ferrous particles, locked particles and strongly paramagnetic particles.

"Our customers want more bang for their buck," notes Dudenhoefer. "And with stronger magnets, they get purer product, as well as other benefits." For instance, magnetic separators with increased strength can help protect processing equipment such as mills, crushers and grinders that don't react well to metal in the product. So by removing ferrous contamination, such as tramp metal, these separators improve product purity and protect equipment. Another added benefit is ease of cleaning. By nature, rare-earth drum magnets are self-cleaning, which saves time and labor, and increases safety in the facility, says Dudenhoefer.

Users of membrane technology are also seeking higher purity, says Donahue. "People are fractionating solids in the submicron area, and ultrafiltration or cross-flow microfiltration technology can be applied to meet these new requirements," he says.

Rather than developing new products to fit this emerging niche, Donahue says KMS is turning to established products, such as Romicon hollow-fiber ultrafiltration membranes and the FEG tube line. Romicon hollow-fiber ultrafiltration membranes are very energy-efficient cartridges that contain high packing density, which can be useful for separations in the submicron particle range. FEG tubes can be used to accommodate liquids with very high viscosities or high suspended-solids loadings. "This would be the choice for colloidal dispersions for dewatering to the maximum extent possible," says Donahue.

While the economy may be forcing processors to ask for more, it is fortunate that separation specialists are finding ways to improve existing products and are developing new designs to provide process improvements that can help processors make the right product at the right time for the lowest cost possible. ■

Joy LePree

Photos: Dechema/Helmut Stettin

ACHEMA 2009 DOESN'T DISAPPOINT

Despite global economic turmoil, attendance was on par with that of 2006

On Sunday morning before the start of Achema 2009 (May 11–15; Frankfurt, Germany) — organizers of the world's largest exhibition and congress on chemical engineering and biotechnology, Dechema e.V. (Frankfurt; www.dechema.de), as well as industry experts participating in the traditional press conference, were somewhat edgy. Even though the ten halls' 134,000 m^2 of exhibition space was fully booked, and more than 900 scientific papers were scheduled for presentation throughout the week — not only a record number of lectures, but the first time that organizers had to turn away submissions — the question remained: will the visitors come?

For Ulz Tillmann, director general of the German Chemical Industry Association (VCI; Frankfurt; www.vci.de), the answer was clear. Attending Achema is a must for just about anyone working in the chemical process industries (CPI). They may travel coach instead of business class, and stay at less expensive hotels, but employees in our industry cannot afford to miss it, he said. Held every three years since 1920, Achema is the largest venue for information exchange between vendor and user, academics and industry, and even to some extent, industry and government.

Despite Tillmann's prediction, the climate for a successful turnout seemed to be working against it: a world economy at a record low, causing increased layoffs and production cutbacks; the outbreak of the swine flu in Mexico just a week before, which had organizers ordering thousands of face masks in case it got worse; even the Frankfurt weather was forecast to be a dreary, rainy week.

The halls of the Frankfurt fairgrounds were full of equipment and visitors throughout the week of Achema 2009

Positive start

Nevertheless, the crowds did come when the doors opened on Monday. By Wednesday, Aldo Belloni, chairman of the Achema committee and member of Linde AG's (Munich, Germany; www.linde.de) executive board was able to begin the mid-term press conference "with a big sigh of relief." The first two days' attendance at the exhibition surpassed the levels for the first two days of Achema 2006 (+1.7% on Monday, +0.7% on Tuesday). Attendance figures for international representation were likewise in step with those of 2006, despite rumors of travel restrictions, noted Gehard Kreysa, chief executive of Dechema.

Upbeat finish

Over five days, 173,000 visitors from all over the world visited the 3,767 exhibitors at Achema 2009. Although slightly below 2006's results (178,000 visitors and 3,880 exhibitors), both exhibitors and organizers were highly satisfied with the outcome. "The high number of exhibitors and visitors sent out an unmistakable message that will resound far beyond the Achema: our branches are going to tackle the challenges and leave the economic crisis behind them," says Kreysa.

The 29th Achema was more international than ever before, with 46.6% of the exhibitors and 28% of the visitors coming from abroad. The number of Chinese exhibitors doubled since 2006, while that of Indian exhibitors increased by 23%.

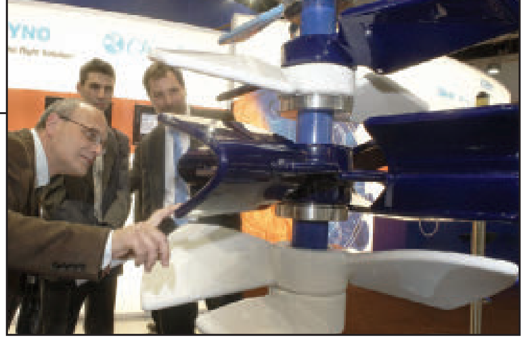
Views from the top

Besides positive reviews from the organizers of Achema, top executives also had good thing to say about the week. The following quotes were published in the Friday edition of the *Achema Daily*, a joint publication of *Chemical Engineering* and Vogel Business Media GmbH & Co. KG (Würzburg, Germany; www.vogel.de):

• "There is nothing like Achema," says

John D. Allen, president of Pump Solution Group (Redlands, Calif.; www.pumpsg.com), who has been coming to Achema for 27 years. “In Hall 9 you can see the entire global pump industry in one place. In this down economy, it’s the only show where I can imagine so many vendors coming together. Achema is also a driving force in distribution, and our customer numbers are up at 2006 levels, too.”

- “We are extremely happy with the number of attendees at the show, and the number of visitors to our booth. Exhibition at Achema has allowed us to visit with several of our current customers, create many new contacts for future business, and continue to understand the challenges facing the chemical industry. We have six [employees] in our booth, and we have been busy throughout the show meeting visitors.” — Steve Brown, COO, Chemstations, Inc. (Houston, Tex.; www.chemstations.com)
- “This Achema feels like a success, and we are very happy with the resonance,” says Helmut Gänser, Geschäftsführer, Ekato Holding GmbH (Schopfheim, Germany; www.ekato.com). “It has been much better than we expected — even better than 2006. Achema is very important to Ekato. We have been at every Achema since the 1920s, and this year our stand is twice as big as last time.”
- “I was very curious about the turnout, given the downturn, but have been pleasantly surprised. We are very pleased at the number and high quality of visitors.” — Rich Altice, vice president, commercial services, Solutia, Inc., St. Louis, Mo.; www.solutia.com)
- “Achema 2009 is the best opportunity for us to meet customers from all over the world. In this economic climate, we were a little bit worried about the outcome, but for the first three days we had more leads than Achema 2006.” — Markus Steinke, international marketing manager, Metrohm AG (Filderstadt, Germany)
- “We are more than pleased with the way Achema has progressed this year. There was no sign of katzenjammer [distress] here; in fact, just the opposite. We could discuss very concrete project enquiries, something that was not anticipated in light of the current economic climate. Also, the quality of the technical visitors has again increased.” — Michael Ziesemer, COO and member of board, Endress+Hauser (Reinach, Switzerland; www.endress.com)
- “For over 25 years, Achema has been a traditional event for us to meet customers and business partners. This year the expectations were admittedly somewhat dampened. But the interest in our technology is high, the number of visitors is good and there doesn’t seem to be any slump at the moment.” — Harald Nothstain, Geschäftsführer (Lurgi GmbH, Frankfurt; www.lurgi.com).


Achema visitors get a hands-on look at equipment

Looking ahead to 2010

Following the successful Achema 2009, preparations are already underway for the 8th AchemAsia, which will take place at the new China National Convention Center (CNCC) in Beijing (June 1–4, 2010). With its convenient and central location in the immediate vicinity of Beijing’s Olympic park — the building was the press hub for the Olympics, so its well equipped with the latest IT technology — and its modern hall layout, CNCC will offer AchemAsia the long-awaited opportunity for development, said Kurt Wagemann, deputy chief executive of Dechema. (Wagemann will assume the chief executive position following the retirement of Professor Kreysa at the end of this year). “The new facilities will, for the first time, enable the desired integration of the congress and the exhibition,” he says. ■

Gerald Ondrey

FOCUS ON

Weighing and Proportioning

Zinsser Analytic

Spiroflow Systems

Distribute and weigh solid library compounds automatically

Compound libraries are critical to pharmaceutical companies. Liquid handling for the dissolution of library compounds has been automated for many years, but the distribution and weighing of the original solid dry-stored library compound is still done manually. The Calli-L (photo) is specifically designed for the distribution of dry, powder library samples for dissolution, distributing samples directly from the original library vial without any additional preparation step. Calli-L is an automatic platform with a robotic arm supplied with a powder dispensing probe and a handler for transportation of vials in the range from less than 1 mg to 50 mg. The Calli-L uses an algorithm that chooses the best aspiration technique, and in combination with the balance, allows precise target weighing. The final target weight is documented with the container data (number, position on the container, time of distribution and so on) in the database. — *Zinsser Analytic GmbH, Frankfurt am Main, Germany*
www.zinsser-analytic.com

These bulk bag fillers have options for automatic operation

The Model C1-2 Spirofil Bulk Bag Filler (photo) includes a load cell mounted weigh platform that can be NTEP approved if the contents of the filled bags are for re-sale by weight. The bulk bag fillers are designed to ensure bags are filled in a dust-free manner, without spillage and to the desired weight. Filling rates of up to 20 bags/h are possible with integral roller conveyors and other options that allow further automation of the system. The C1-2 Model Spirofil offers the option of automatic operation of the bag hook latches, automatic deflation of the neck seal and automatic operation of powered rollers. This means that upon reaching the targeted weight, other than for the manual removal of the bag neck from the fill head, the bag is automatically removed from the filler and placed on an accumulating conveyor. — *Spiroflow Systems, Inc., Charlotte, N.C.*
www.spiroflowsystems.com

For explosive areas, this weight indicator is flexible and mobile

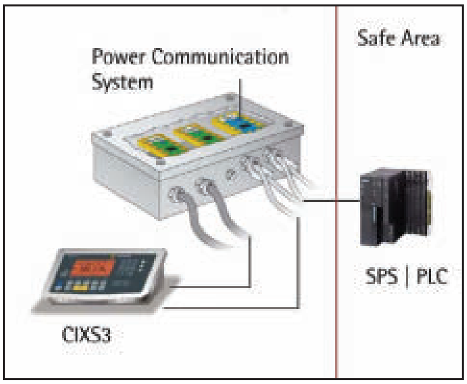
This firm has added new performance features and interfaces to its Combics Ex weight indicator (photo, p. 29) for Zone 1 and Zone 21 hazardous areas. The indicator is designed to be connected with high-resolution digital platforms and memory-programmable controllers. The core of the new options for the intrinsically safe Combics Ex indicator is the power supply with highly flexible configuration — the YPSC power communication system. Barcodes are often used in potentially explosive environments to record material and logistics data. Also new is a barcode reader connection that consists of a base station that can be operated via radio control with up to six barcode scanners. Additionally, the WLAN Ex Client provides mobile balance solutions in hazardous areas, with the mobile explosives balance being integrated into a WLAN network via access points. — *Sartorius AG, Göettingen, Germany*
www.sartorius.com

A weighing terminal with functions that improve filling accuracy

The IND226x weighing terminal, with IP66-protected stainless-steel housing, is able to withstand tough operating and cleaning conditions in chemical and pharmaceutical facilities. It guarantees exact container filling with a LED display and integrated over/under control weighing mode. The MinWeigh function guarantees weighing within acceptable limits, and the CalFREE function allows for electronic calibration with weighing modules. The IND226x is compatible with all of this company's analog weighing platforms and is equipped with the mountable IND serial data interface and ACM200 interface converter, thereby enabling its connection to PCs or printers via an RS232 interface. The IND226x's various power supply options allow for its use in a wide range of application areas, including mobile weighing via a mains-free rechargeable battery. — *Mettler Toledo, Inc., Columbus, Ohio*
us.mt.com

Note: For more information, circle the 3-digit number on p. 54, or use the website designation.

Flexicon



Sartorius

Collect dust while dumping materials with this unit

A new sanitary bag dump weigh batch station (photo) with an integral mechanical conveyor collects dust created during manual dumping of bulk materials from bags, boxes, drums and other containers, and discharges bulk material by weight. A high-velocity vacuum fan draws airborne dust from the atmosphere onto two cartridge filters. Automatic reverse-pulse filter cleaning releases short blasts of compressed plant air inside the cartridge filter on alternating cycles, causing dust buildup on the outer filter surfaces to fall into the hopper. The hopper discharges into an integral flexible screw conveyor, which runs until the accurate batch weight has been discharged. A mechanical hopper agitator improves the flow of material into conveyor, which handles both free- and non-free-flowing materials that pack, cake or smear, with no separation of blended products. — *Flexicon, Bethlehem, Pa.*
www.flexicon.com

These new scales are unaffected by chemical spills

These new spill-containment scales weigh only the chemical dispensed into the water treatment system and are not affected by chemical spills. The scales have four load cells that are completely sealed in PVC and vinyl plastic enclosures to protect from spilled chemicals. The scale platforms are resistant to most water treatment chemicals such as: fluoride, sodium hypochlorite, sodium hydroxide, sodium bisulfate, polymers, ammonia, phosphate, alum, caustic, sodium aluminate or other liquids or powders. The chemical containers do not have to be centered, balanced or leveled. The scales have a low-profile design, with a frame height that does not exceed 1.5 in., facilitating easy on and off loading of heavy containers. The Model 4042 spill-containment scale contains moderate spills, while the Model 4042WB has the additional benefit of a special rollout bladder to hold the contents of the container being weighed if spilled or leaked. — *Scaletron Industries, Ltd., Plumsteadville, Pa.*
www.scaletronscales.com

Dust buildup won't affect this scale

The Quarry King Single-Idler Belt Scale is designed for outdoor conveyor weighing of dusty fines and stone-like aggregate materials. The scale combines "Rocking Flexure" fulcrums with a new pipe-stem, single-idler suspension system, incorporating built-in storage means for its calibration weight, ideal for areas where dust buildup fouls suspension designs. Troughed belt conveyors of 14–48-in. belt widths (Series 1RF-3A for 14-, 18-, 24- and 30-in.; Series 1RF-4A for 36-, 42- and 48-in. belt widths) are available, operating at speeds up to 600 ft/min and inclines up to 18 degrees. — *Thayer Scale, Pembroke, Mass.*
www.theyarscale.com ■

Kate Torzewski

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Kate Torzewski

Flowmeter Selection

When a flowmeter is needed, the selection process should include studying the characteristics of respective measurement technologies and analyzing the advantages/disadvantages for different plant environments. This effort will help ensure that a meter with the right performance and reliability, for a particular installation, is selected. Some of the most common industrial flowmeter designs are described here.

Flowmeter	Accuracy (full scale, F; rate, R)	Turn-down	Fluids (liquid, gas, solid, slurry)	Pipe Sizes, in.	Maximum pressure, psig	Tem-perature range, (° F)
Square-edged, orifice differential pressure	0.5–1.5% R	4 to 1	L, G, S	0.5–40	8,800	–4–2,300
Electromagnetic	0.2–2% R	10 to 1	L	0.15–60	5,000	–40–350
Turbine	0.15–1% R	10 to 1	L, G	0.5–30	6,000	–450–600
Ultrasonic (doppler)	1–30% R	50 to 1	L, G, SL	0.5–200	6,000	–40–250
Ultrasonic (transit time)	0.5–5% R	down to zero flow	L, G	1–540	6,000	–40–650
Vortex	0.5–2% R	20 to 1	L, G, S	0.5–16	1,500	–330–800
Positive displacement	0.152% R	10 to 1	L	0.25–16	2,000	–40–600
Coriolis	0.1–0.3% R	10 to 1, to 80 to 1	L, G	0.06–12	5,700	–400–800
Thermal (gases)	1% F	50 to 1	G	0.125–8	4,500	32–572
Thermal (liquids)	0.5% F	50 to 1	L	0.06–0.25	4,500	40–165

DIFFERENTIAL PRESSURE

A differential pressure meter operates by measuring the pressure differential across the meter and extracting the square root. These meters have a primary element that causes a change in kinetic energy, which in turn creates differential pressure in the pipe. A secondary element measures the differential pressure and provides a signal or readout, which is converted to the actual flow value.

Two basic types of primary elements rely on this measurement: orifice plates and Venturi tubes. Both element types rely on the law of conservation of energy and Bernoulli's energy equation to determine volumetric flowrates.

ELECTROMAGNETIC

Electromagnetic meters (commonly referred to as "mag" meters), employ Faraday's law of electromagnetic induction, which states that voltage will be induced when a conductor moves through a magnetic field. The liquid serves as the conductor. Energized coils outside the flow tube create the magnetic field. The amount of voltage produced is directly proportional to the flowrate.

Magnetic flowmeters are only applicable for fluids with some electrical conductivity, typically those with conductivity values above 5 µS/cm. Most aqueous solutions contain enough conductive dissolved solids to meet this requirement. However, ultrapure water, some solvents, and most hydrocarbon-based solutions do not.

CORIOLIS

Coriolis meters provide mass-flow data by measuring fluid running through a bent tube, which is induced to vibrate in an angular, harmonic oscillation. Due to the Coriolis forces, the tube will deform, and an additional vibration component will be added to the oscillation. This causes a phase shift over areas of the tube, and this shift can be measured with sensors. Density measurements are made by analyzing the frequency shift of the vibrating pipe as the fluid flows past the pickup.

THERMAL MASS

Thermal mass meters utilize a heated sensing element that is isolated from the path of fluid flow. The flow stream conducts heat from the sensing element, and this heat is directly proportional to the mass flowrate. The meter's electronics include the flow analyzer, temperature compensator and a signal conditioner that provides a linear output, which is directly proportional to mass flow.

The electrical current required to maintain the temperature at the temperature sensor is proportional to the mass flow through the flowmeter. These flowmeters are commonly used in automobiles to determine the air density as it travels into the engine.

VORTEX SHEDDING

In this instrument, fluid vortices are formed against the meter body. These vortices are produced from the downstream face of the meter in an oscillatory manner. The shedding is sensed using a thermistor, and the frequency of shedding is proportional to volumetric flowrate.

TURBINE

Turbine meters incorporate a freely suspended rotor that is turned by fluid flow through the meter body. Since the flow passage is fixed, the rotor's rotational speed is a true representation of the volumetric flowrate. The rotation produces a train of electrical pulses, which are sensed by an external pickoff and then counted and totalized. The number of pulses counted for a given period of time is directly proportional to flow volume.

Turbine meters are used extensively to measure refined petroleum products, such as gasoline, diesel fuel or kerosene in custody-transfer applications.

POSITIVE DISPLACEMENT

Positive displacement (PD) meters separate liquid into specific increments. The accumulation of these measured increments over time is given as the flowrate. As the fluid passes through the meter, a pulse, which represents a known volume of fluid, is generated.

Some of the design types included in the positive-displacement flowmeter family include oval gear, rotary piston, helical, nutating disk and diaphragm flowmeters. In all design types, the fluid or gas forces a mechanical element, such as a set of gears, a disk, or a piston, to move within the primary device. For every revolution of a gear, or the complete movement of a piston or plate, a known volume of material is displaced.

ULTRASONIC

Ultrasonic meters operate by comparing the time for an ultrasonic signal to travel with the flow (downstream) against the time for an ultrasonic signal to travel against the flow (upstream). The difference between these transit times is proportional to the flow, and the flowmeter converts this information to flowrate and total flow.

They are particularly useful for measuring the flow of non-conductive fluids, such as solvents and hydrocarbons in large pipes — applications for which a magnetic flowmeter will not work. Ultrasonic flowmeters are also often used in district heating and chilled-water systems.

Doppler ultrasonic flowmeters have one transducer mounted at an oblique angle to the pipe. The transducer generates a signal into the fluid, which is reflected back from suspended particles or air bubbles.

Transit-time ultrasonic flowmeters have two transducers, likewise mounted at an oblique angle to the pipe, on opposite sides of the pipe. Alternating, one transmitter sends sound waves through the fluid to the other.

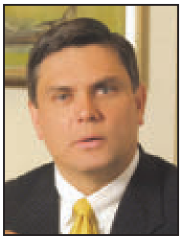
References

1. Keith, J., Evaluating Industrial Flowmeters *Chem. Eng.*, April 2007, pp. 54–59.
2. Kohlmann, M., Selecting the Right Flowmeter for the Job. *Chem. Eng.*, September 2004, pp. 60–64.
3. "Perry's Chemical Engineers' Handbook," 8th ed. New York: McGraw Hill, 2008.

WHO'S WHO

Gustavsson

Lepoutre



Dudas

Cappellino

Magnarini

Jonas Gustavsson becomes president of the Kanthal heating systems product line of **Sandvik Materials Technology** (Sandviken, Sweden).

GE Water (Vista, Calif.) appoints *Frederick Liberatore* global director of process separations.

Thomas Walter and *Charles Prisco* become principal engineers with **Mechanical Solutions** (Whippany, N.J.).

Manoelle Lepoutre is now executive vice-president, sustainable development and environment for **Total Exploration & Production** (Paris).

Roberto Penno becomes managing director of global sales, marketing and strategic planning for the global engineering and construction group of **Foster Wheeler AG** (Zug, Switzerland).

Spiroflow Systems (Charlotte, N.C.) names *Jeff Dudas* CEO.

Charles Cappellino is now vice-president of research, development and engineering for **ITT Industrial Process** (Seneca Falls, N.Y.).

Chris Ryan joins **Gevo, Inc.** (Englewood, Colo.) as vice-president of business development — downstream.

Mark Magnarini becomes COO of **Fontarôme Chemical, Inc.** (Milwaukee, Wisc.).

Robert Race is now director of engineering services for **Deltalok USA** (Ferndale, Wash.). ■

Suzanne Shelley

JULY
New Products

Raytec

Munson Machinery

Syrris

Kason

Examine reaction kinetics and more with this system

With integrated mid-infrared (IR) capabilities, the fully automated Atlas FT-IR System (photo) for reaction monitoring combines the technology of the Atlas automated reactor with Bruker Optics' Matrix-MF, a process-ready fourier transform infrared (FT-IR) spectrometer. This system can be used to examine product yields, impurities, reaction kinetics, end points and more, with upgrades available to provide further functionality, such as reaction calorimetry, pH control, gravimetric or volumetric reagent addition, crystallization control. The system is available for a range of temperatures of –80 to 180 °C, pressures of up to 200 bar, and wavenumbers from 560 to 3,500 cm^{-1}. — *Syrris, Royston, U.K.*
www.syrris.com

This inline rotary batch mixer evacuates batch with no residual

The Model 700-TH-5-SS inline miniature rotary batch mixer (photo) blends batches of up to 5.0 ft^3 in parts as small as one per million with complete uniformity in less than 3 min, then evacuates the batch with no residual. This stainless-steel, sanitary unit features a stationary inlet and outlet for inline operation, and a rotating drum with proprietary mixing flights that tumble, turn and fold material gently, imparting minimal energy to the batch while rapidly achieving uniformity regardless of disparities in the bulk densities, particle sizes or flow characteristics of batch ingredients. A batch weight capacity of 500 lb is standard, with higher capacities optional.— *Munson Machinery, Utica, N.Y.*
www.munsonmachinery.com

This infrared thermometer has variable configuration software

Raytek CM (photo) is an integrated infrared temperature-measurement sensor with precision, high-resolution silicon optics. An RS232 digital interface allows the configuration of all programmable sensor variables via Raytek DataTemp Multidrop software. These include a 24-V-d.c. alarm output triggered by target temperature or head ambient temperature, and more. The remote configuration capability simplifies installation and troubleshooting, especially when the sensor is located in a hostile or remote location. The Raytek CM sensor is designed to measure target temperatures ranging from –20°C to 500°C. Its onboard electronics are protected by a rugged IP 65 (NEMA-4) stainless-steel housing, allowing the sensor to function in ambient temperatures to 70°C without cooling. — *Raytek, Santa Cruz, Calif.*
www.raytek.com

Screen large particles while drawing out air and dust

This circular vibratory bag dump screener removes oversize particles from manually dumped bulk materials while protecting against dust contamination. The 40 in.-dia. Vibroscreen separator (photo) causes bag scraps, agglomerates and other

Note: For more information, circle the 3-digit number on p. 54, or use the website designation.

oversize material to travel across the screen and discharge through an upper spout, while on-size particles pass through apertures in the screen and a lower discharge spout. Ambient air and dust from dumping activities are drawn onto the exterior of two cartridge filters that derive vacuum from a top-mounted exhaust fan. On-size material gravity-discharged from the screener's outlet can be fed into a conveyor or other process equipment. The Bag Dump Screener is also offered in 24- and 30-in. dia., and available to industrial, 3-A, FDA, BISSC and other sanitary standards. — *Kason Corp., Millburn, N.J.*
www.kason.com

Arc Machines

A power supply for a wide range of welding applications,

The new Model 205 Orbital Gas Tungsten Arc Welding (GTAW) Power Supply (photo) is the latest addition to this firm's range of orbital tube welding products. Whether joining 1/4-in. stainless-steel tube for a semiconductor plant, 3/4-in. titanium aircraft fuel lines, 1-1/2-in. electro-polished tube for a pharmaceutical application, a 2-in. schedule, 40-carbon-steel pipe steam line, or simply tack-welding two components together, the Model 205 fits the application. Key features include: a full size color touch screen; multi-use USB port; automatic weld schedule development; programming by time or temperature; and compatiblity with all AMI fusion weld heads. — *Arc Machines, Inc., Pacoima, Calif.*
www.arcmachines.com

These vapor-degreaser solvents are safer and greener

Precision-V cleaners (photo, p. 32D-3) for vapor degreasing are powerful, leave no residue, evaporate quickly and are non-flammable with no flashpoint. They are designed for the removal of oils, greases, silicones and other common industrial contaminants. Electronics, optics, and metal parts are quickly and thoroughly cleaned, eliminating the need for further rinsing. Precision-V is non-ozone depleting, making it an ideal replacement for cleaners containing Freon, HFC-141b or AK225. Exposure to Precision-V solvents is less hazardous than with many other solvents commonly used in vapor-degreasers. The Precision-V Vapor-Degreaser Parts Cleaner and Flux Remover have azeotropic properties that allow them to maintain stablity as they are cycled in a vapor-degreaser. They are not reactive nor corrosive to metals commonly found in the construction of vapor-degreasers.— *Techspray, Amarillo, Tex.*
www.techspray.com

Techspray

Dolomite

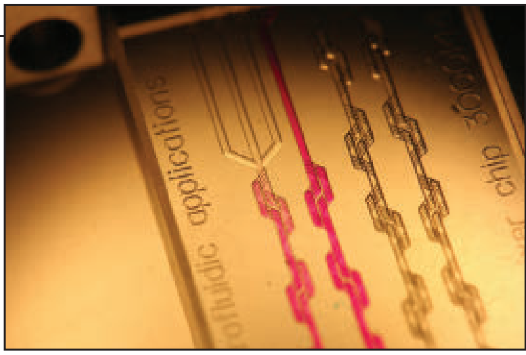


ABB Instrumentation

For clean processes, this magmeter has onboard sensor memory

This range of electromagnetic flowmeters is designed for clean applications in the food and beverage, pharmaceutical and biotechnology industries. Part of the new FlowMaster product family, the HygienicMaster magmeter (photo) is available in sizes from 1/10 to 4 in. It is manufactured from FDA-approved materials and certified in accordance with EHEDG and 3A. The units feature electrodes that are embedded into the liner to ensure a smooth surface without any gaps, and a sensor that is clean-in-place (CIP) capable. A reinforced PFA liner improves vacuum stability and prevents liner deformation. Data storage inside the sensor eliminates the problems associated with pluggable data memory modules.— *ABB Instrumentation, Warminster, Pa.*
www.abb.com

This microfluidic chip offers rapid fluid mixing

The glass Mitos Micromixer Chip (photo) is designed for the rapid mixing of two or three fluid streams. Compatible with the Mitos four-way edge connector, this novel chip enables extremely rapid mixing across a wide range of flowrates. This chip is ideal for the study of reaction kinetics, sample dilution, improving reaction selectivity, rapid crystallisation and nanoparticle synthesis. The chip measures 45 X 15 mm and incorporates two independent micromixer channels, each with a volume of 8 µL, to ensure efficient mixing of the fluid streams. Mixing of two or three fluid streams occurs within milliseconds.— *Dolomite, Royston, U.K.*
www.dolomite-microfluidics.com

Two-way valves with online configuration tool for easy ordering

The 8262/8263 Series two-way direct acting solenoid valves are now available with increased pressure ratings and realtime online configuration and ordering. The valves come in normally-closed, brass and stainless-steel

Rockwell Automation

constructions. They can be used to control the flow of air, water, and light oil, and are available in 1/8-, 1/4-, and 3/8-in. pipe sizes. The online configuration tool allows customers to quickly build a valve to meet a set of specific requirements. It then displays the list price, availability, CAD drawings and specifications for the configured product. — *Asco Valve, Inc., Florham Park, N.J.*
www.ascovalve.com

Communication modules for extreme environments

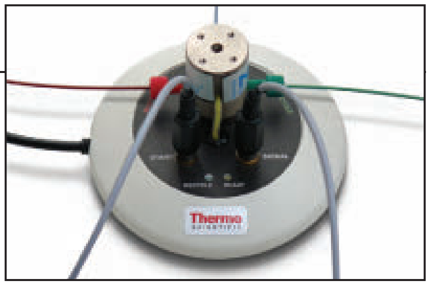
The Logix-XT product family (photo) is designed for applications requiring increased reliability in high-temperature and corrosive environments, such as those found in oil-and-gas, wind-turbine and ship-building applications. The Logix-XT product family includes the Logix-XT controller, Allen-Bradley FLEX I/O-XT products and ProSoft Technology communication modules. This product family operates in a broad temperature spectrum, –20° to 70°C, and meets ANSI/ISA-S71.04-1985 Class G1, G2 and G3, as well as cULus, Class 1 Div 2, C-Tick, CE, ATEX Zone 2 and SIL 2 requirements for increased protection against salts, corrosives, moisture condensation, humidity and fungal growth.— *Rockwell Automation, Milwaukee, Wis.*
www.rockwellautomation.com

Sealing across a full range of pressures, up to 15,000 psig

The FKB series ball valve provides a leak-tight seal for applications up to 15,000 psig. The Trunnion-style ball valve features a direct-load design, which delivers a more consistent seal across a full range of pressures. These valves feature a 0.209-in. orifice, 316-stainless-steel body construction, and reinforced PEEK seat seals. The valves are rated for temperatures of 0–250°F and maintain a full pressure rating throughout the operating temperature range. Available O-ring materials include nitrile, fluoroelastomer and perfluoroelastomer. All wetted materials are compatible with most hydrocarbons. Offered in a two-way configuration, the valves are available with medium-pressure tube fitting end connections, which provide single-turn makeup, or makeup by torque. The end connections employ a two-ferrule design to deliver robust tube grip, leak-tight gas seal and vibration resistance. End connections sizes are 1/4, 3/8, and 1/2 in. — *Swagelok, Solon, Ohio*
www.swagelok.com ■

Kate Torzewski

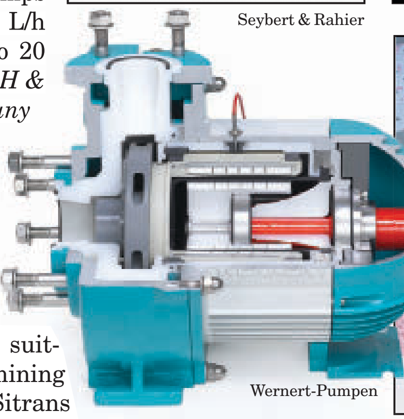
JULY New Products



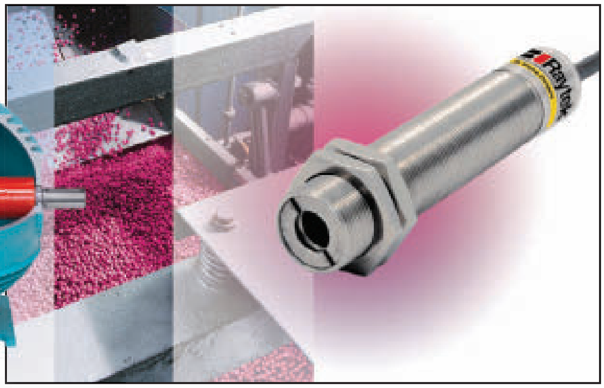
Thermo Fisher Scientific

Seybert & Rahier

Siemens Industry



Wernert-Pumpen



Raytek

A new range of dosing pumps

This firm now offers four new series of multilayer diaphragm pumps and piston diaphragm pumps featuring the multilayer diaphragm technology. These include two series for local, manual control (R-Series) and two series with integrated control electronics (C-Series). The new piston diaphragm pumps (photo) handle flowrates of 7.5–900 L/h at an operating pressure of 80 bar, and the multilayer diaphragm pumps handle capacities of 10–1,200 L/h for operating pressures up to 20 bar. — *Seybert & Rahier GmbH & Co. KG, Immenhausen, Germany*
www.sera-web.de

This positioner is SIL 2 certified

Developed according to SIL (safety integrity level) guidelines, the Sitrans VP300 positioner (photo) is especially suitable for use in the paper, mining and oil-and-gas industries. Sitrans VP300 is said to be the first positioner on the market to feature SIL-certified partial-stroke testing. Air exhausting in the single-acting device is SIL 2 rated. Both the single-acting and double-acting versions of the positioner feature an aluminum housing with high protection (IP66/NEMA 4x), and are especially resistant to vibrations. The device can be used in applications down to –40°C and can even operate in damp air that is contaminated with oil droplets. The positioner has a travel distance of up to 150 mm and can be rotated by up to 120 deg. — *Siemens Industry — Industry Automation Div., Nuremberg, Germany*
www.siemens.com/automation

A new IR thermometer for industrial applications

Raytek CM (photo) is a compact, integrated infrared (IR) noncontact thermometer intended for continuous temperature monitoring in a wide range of industrial manufacturing processes. The IP65-sealed, single-piece integrated sensor can easily replace traditional contact probes with a J- or K-type thermocouple output, or with a user-scaleable 0–5 V output, if the application is susceptible to noise. An RS232 digital interface allows the user to configure all programmable sensor variable via the company's DataTemp Multidrop software. The sensor is designed to measure temperatures ranging from –20 to 500°C, and can operate from ambient temperatures up to 70°C without cooling. — *Raytek, a Fluke company, Berlin, Germany*
www.raytek.de

New features for this mag-drive pump

Three years after its initial launch, the Monsun magnetically coupled pump (photo) that was on display at Achema 2009 has new features. For example, the rotor is designed completely without static seals, thereby reducing the static seals from four to two within the pump. There are two defined slide bearings made of silicon carbide. If the pump is operated in a critical situation, such as intermittent flow, an emergency reservoir takes over the lubrication of one of the SiC slide bearings. A rise in temperature is directly detected with a central, chemical-resistant sensor instead of indirect methods used to protect the pump, such as magnetic-field distortion, power consumption or vibration. The temperature rise can be analyzed by a low-cost unit, which is installed beside the pump, and can safely shut down the pump when the temperature limit is reached. — *Wernert-Pumpen GmbH, Mülheim an der Ruhr, Germany*
www.wernert.de

Solvent recycling for HPLC analyzers

With the ability to reduce mobile-phase consumables by up to 90%, the

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

New Products

SRS Pro Solvent Recycling System (photo, p. 32I-1) redirects untainted mobile phase to the solvent reservoir during isocratic HPLC (high-performance liquid chromatography) operation. Powered directly from a USB connection, with easy plug-and-play operation, this system is ideal for any chromatography laboratory looking to conserve solvent use. Easy-to-use software enables simple configuration of the system parameters and includes online monitoring and audit-trail facilities. Through continuous monitoring of the HPLC detector output signal, the mobile phase is recycled to the solvent reservoir when the baseline is below a threshold value. When the threshold is exceeded, the eluent flow is redirected to waste, accounting for the transport time from the detector to the switching valve. — *Thermo Fisher Scientific Inc., Milford, Mass.*
www.thermofisher.com

Swagelok

A smart seal for screw pumps

Allseal consists of an opto-electronic sensor that detects wear of the mechanical seals as soon as it begins and immediately warns the operator of any leaks. The system instantly detects if a liquid escapes around the mechanical seal. Unusual leaks trigger acoustic and visual warning signals, which can also be integrated into a centralized control system or forwarded to a monitoring station. Allseal technology is now available for the company's screw pumps and will be extended to other pumps on a step-by-step basis, says the manufacturer. This modular sealing concept now makes it possible for the user to choose between conventional mechanical seals, the Allseal version with leak detection, and hermetically sealed pumps with magnetic drive. — *Allweiler AG, Radolfzell, Germany*
www.allweiler.de

An expanded line of temperature-measurement devices

With the addition of bimetal thermometers and thermowells for general industry, this firm expands its existing line of temperature measurement devices. The dampened-movement bimetal thermometers (photo) operate in measurement ranges from –100 to 1,000°F and are available in adjustable-angle, center-back, and lower-back mount process connections. Each thermometer is factory calibrated, and features external reset for field calibration. The sensors are accurate to ±1% of full scale, in accordance with ASME B40.200 and are actuated by a sensitive bimetal helix coil. The thermowells are designed to protect the thermometers from contact with viscous, pressurized, corrosive or abrasive process fluids. — *Swagelok Co., Solon, Ohio*
www.swagelok.com

This large control valve has a high accuracy

Together with its joint-venture partner DS Control Technologies (Novgorod, Russia), this firm has recently demonstrated a new benchmark in large-valve positioner accuracy. The Smart Valve Interface II Advanced Performance (SVI IIAP) positioner controls a massive ANSI 150 measurement AST ball valve — the largest valve in a natural-gas-compression station designed by contractor Kukdumalakgaz in Uzbekistan. The double-acting positioner delivers a 0.3% valve-control accuracy rate, which is an order of magnitude above the average of 1–3% for this type of application, says the firm. The built-in self-calibration and self-tuning functionality also makes installation and setup easier. The SVI IIAP positioner integrates with the AST valve configuration that includes a Servovalve Engineering actuator and two volume boosters. — *Dresser Masoneilan, Houston, Tex.*
www.dresser.com

Several designs available for this weighing feeder

The Multidos L Weighfeeder delivers outstanding results in gravimetric feeding tasks or when recording mass flow of special products. Available both in an open design and with a dustproof housing variant, the system is economic, space-saving and virtually maintenance free. The system is now available with a hygienic design. The weighing module is easy to dismantle and assemble, saving time and effort for frequent cleaning intervals and wet cleaning. The standardized module system with a band width of 300 to 1,2000 mm and wheel bases of 1,000–3,500 mm is available in all stainless steel. The system has a maximum output of 170 m^3/h with measurement accuracy of ±0.25% and feeding precision of ±0.5%. — *Schenck Process GmbH, Darmstadt, Germany*
www.schenckprocess.com

Beumer Maschinenfabrik

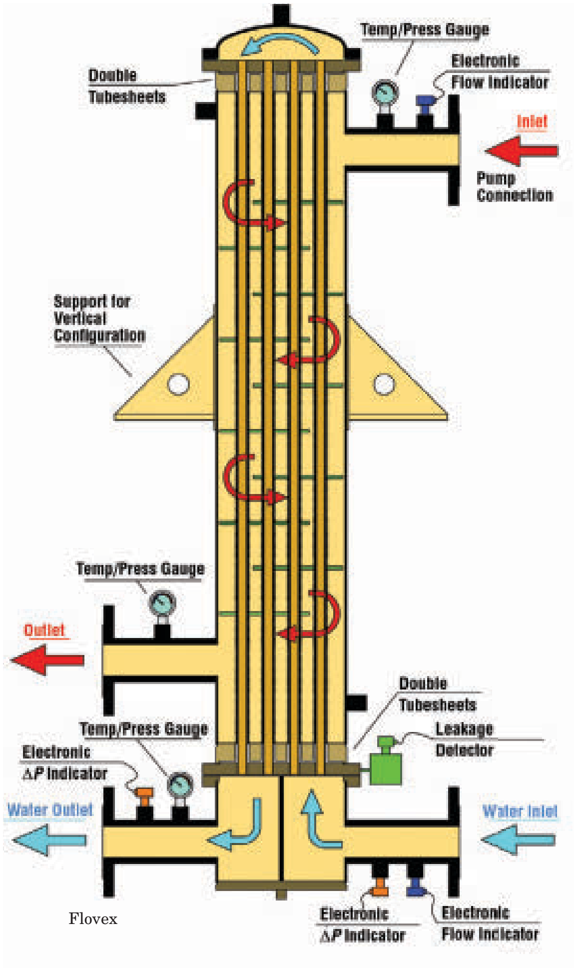
This packaging system does two operations in one machine

This packaging machine does not use separate plastic bags to produce inliners for octatainers (orthogonal containers made of corrugated cardboard; photo). Instead, the plastic film for the inliners comes from a roll. The company's Stretch Hood cuts and seals the film, which allows the length to be adjusted freely. The packaging machine then crumples up the inliner in order to guide it over the edge of the octatainer. The inliner falls into the center of the container by its own weight and fits perfectly against the side wall during filling, after which, the inliner is sealed and the lid put on the container. After this, the stretch hood applies a film around the container to secure it. Both operations — creating and inserting the inliner, and securing it — are thus performed by a single machine, avoiding time-consuming and problematic manual operations. — *Beumer Maschinenfabrik GmbH & Co. KG, Beckum, Germany*
www.beumer.com

A station for filling and transferring drum contents

The Flow Line Safety cabinets for the active storage of hazardous substances are in accordance with TRbF 20 Annex L, TRbF 30 and BGR 120. The concept of the filling and transfer stations enables users to link their daily work with modern, economic handling of hazardous substances. The media can be safely transferred from a 200-L drum to fill smaller containers. The system is easy to put into service due to integral plug and preassembled connections for media pipe, power supply (compressed air) and venting. The highest safety level is ensured by extensive testing: the removal and storage unit of the drum station are tested together according to DIN EN 14470-1 by recognized test institutes (TÜV Süd, iBMB Braunschweig); TÜV-tested to DIN EN 14727 (laboratory furniture standard); classification Type 90 in accordance with DIN EN 14470-1; GS-/CE mark. — *Düperthal Sicherheitstechnik GmbH & Co. KG, Kleinostheim, Germany*
www.dueperthal.com

New Products



Flovex

Calibration gases that last longer

The HiQ 60 range of calibration gases includes pure gases and non-reactive gas mixtures that have an extended 60 month (5-yr) shelf life and flat-line guarantee, allowing for greater reliability in the accuracy of instrument measurement and longer-term usability of gas. Previously, gas suppliers had offered product expiration guarantees of 36 months, with many products available with only 12 or 24 months of shelf life. The HiQ 60 pure gases include Ar, CO_2, He, H_2, N_2 and synthetic air. — *Linde Gases, Munich, Germany*

www.linde-gas.com

A split butterfly valve for contained transfers

The Müller Containment Valve (MCV) is a stable and robust split butterfly valve that is also pressure tight, making it suitable for transferring highly potent or toxic substances. The seal around the valve disk has been made very small to reduce costs, and the valve disk can be exchanged in less than 5 min. The MCV is suitable for OEB 4 (OEL 1–10 µm/m^3), is GMP compliant and is available in sizes of DN 100, 160, 200 and 250. The valve is dust and liquid tight at pressures up to 2 barg, with higher pressures possible upon request. Product-contacted components are in AISI 316L stainless steel (or Hastelloy upon request), with a PTFE seal. — *Müller GmbH, Rheinfelden, Germany*

www.mueller-gmbh.com

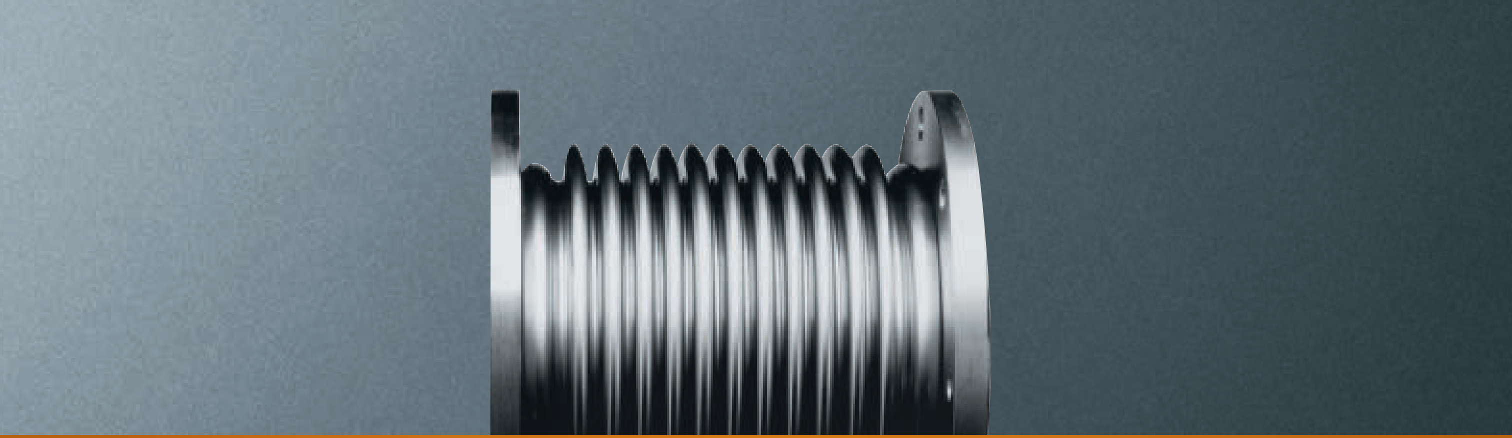
Dual-walled tube bundles keep fluids contained

This manufacturer of shell-and-tube heat exchangers has developed a new safety heat exchanger for applications where the fluids cannot be mixed or contaminated. Compared with the single-wall tube bundle, this double-wall design is characterized by a construction with two tube sheets at each end of the bundle (diagram). Then, two tubes are fitted one inside the other, with leakage space between them designed in such a way as to guarantee the thermodynamic performance of the heat exchanger. Should the inner or outer tube leak, the process fluid enters the leakage space and triggers an alarm. The units can be designed with a wide range of shell diameters and tube bundle lengths, and it is possible to select different materials for the inner and outer tubes. — *Flovex S.p.A., Grezzago, Italy*

www.flovex.it

More functionality for a smart flowmeter

Smart-Trak 2 is a significant redesign of this company's Series 100 Digital Mass Flowmeters and Controllers. The expanded functionality of Smart-Trak 2 includes: true linear performance for high accuracy and increased flexibility in multiple gases; Dial-a-Gas technology, which allows users to select from up to ten pre-programmed gases or substitute their own; the ability to



adjust calibration in the field for each of the ten gases independently; Pilot Module, which allows users to view and change critical control functions in the field; and proprietary frictionless hovering, direct-acting control valve technology. — *Sierra Instruments, Monterey, Calif.*
www.sierrainstruments.com

Hans Turck

Dual sensors for manual valves

This firm's dual sensor (photo) can now be used on hand-operated valves for transmitting the valve's position. This is possible thanks to new, stainless-steel mounting brackets, which are easily mounted on the valve with two screws and attached to the manual lever by a threaded bolt. This mounting bracket enhances the dual sensor's functionality because it allows the use of reliable detection principle even in non-automated plant areas. Simple maintenance procedures, such as manual operation of drain valves, can be reliable monitored and verified off-site. — *Hans Turck GmbH & Co., KG, Mülheim an der Ruhr, Germany*
www.turck.com

Software for controlling biotechnology processes

This firm's control software BioSCADA versatilely and flexibly implements visualization, control and automation of biotechnology processes. BioSCADA is not designed as a fixed software package, does not require a common programmable logic controller (PLC), and is designed to meet 21 CFR Part 11 requirements. This system is said to be not only economical, but also enables integration of numerous interfaces for a wide variety of functionalities as well as progressive upgrading for additional process demands. — *Bioengineering AG, Wald, Switzerland*
www.bioengineering.com

A new version of simulation software

The latest release of this firm's steady-state simulation software, ProSimPlus, is now available. ProSimPlus is used in design and operation of existing plants for process optimization, units troubleshooting, or debottlenecking, plant revamping or for performing front-end engineering analysis. It provides a unique thermodynamic module and a comprehensive unit operations library that allow modeling of a wide variety of processes. The new release provides users with a flexible environment that helps them meet today's engineering challenges, increase efficiency and productivity. A new, easy-to-use graphical interface ensures quick learning and optimizes access to simulation results. Simulis Thermodynamics, the company's ther-

Perfect adhesive strength!

When producing chemicals the excellent quality of a steel belt from Berndorf Band is shown in every detail, such as mechanical, physical or geometric properties. The belts are characterized by perfect flatness and dimensional stability as well as by their straight tracking.

Both, process and transport belts, can be provided with vee-ropes and / or product retaining strips. A special process developed by Berndorf Band guarantees perfect adhesion of vee-ropes and retaining strips.

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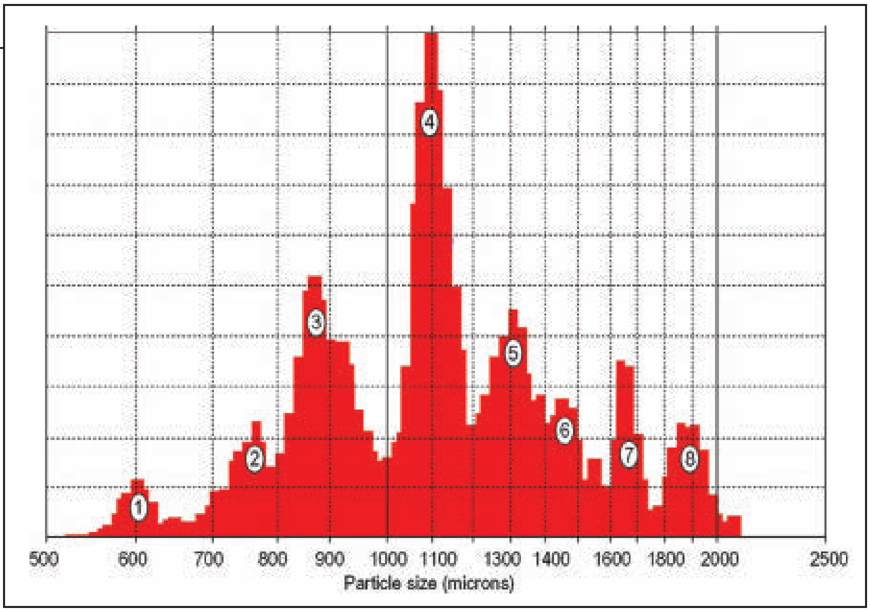
www.berndorf-band.at

modynamic server, is now fully embedded in ProSimPlus. Transport or thermodynamic properties and phase equilibria on streams can be calculated in only a few clicks. — *ProSim, Labege, France*
www.prosim.net

Raman imaging has never been faster
StreamLine Plus is said to be the fastest, fully-scaleable Raman imaging system available today. Readout times can be as short as 6 ms per spectrum, and a high-quality image of an entire tablet can be collected in less than 4 min. A combination of line focus (which minimizes sample damage), a high-speed encoded stage and synchronized readout of the CCD (charge coupled device) detector enables images to be collected both rapidly and at variable spatial resolution. — *Renishaw Plc., Wotton-under-Edge, U.K.*
www.renishaw.com/raman

GF Piping Systems

A butterfly valve for aggressive media
The Type 567/568 butterfly valves (photo) feature a passage seal made of polytetrafluoroethylene (PTFE) in combination with the FPM backing seal and the PVDF media-contacting parts, which guarantee better chemical resistance and expands the application range possibilities. The butterfly valves are suitable for conveying aggressive media and operate over the temperature range from –20 to 120°C. The valves are available with a handle lever for manual operation, with manual gears, as well as with pneumatic or electric actuation from DN 50 to DN 300 for wafers and lug-style installation. With the new PVDF/PTFE butterfly valves, a homogeneous



Whitehouse Scientific

plastic piping system is now available from this firm, with pipes, fittings and butterfly valves. — *GF Piping Systems Ltd., Schaffhausen, Switzerland*
www.piping.georgfischer.com

Simulate solids flow faster than ever

CoRheoGrain is part of the CoRheoS Software Suite, which enables the simulation of industrial-scale processes involving various types of grains and powders. A novel approach makes it possible to simulate the flow of granular material in computer times much faster than those of any DEM software, claims the institute. Both rapid granular processes and slow and arresting granular material can be simulated. Applications include simulations of mixing, powder injection molding and bulk-material transport. — *Fraunhofer Institute for Industrial Mathematics, Kaiserslautern, Germany*
www.itwm.fraunhofer.de

Particle-size standards for high-resolution calibration

As particle sizing methodologies become more sophisticated, it is becoming increasingly difficult to measure the degree of resolution offered by state-of-the-art instruments. Image analysis methods, for example, offer one of the highest resolutions available, but until now, it has been difficult to quantify the resolution. To address this challenge, this firm is launching a new Multimodal Standard (photo). In this standard, eight distinct peaks have been produced between 500 and 2,000 microns. For very small particle sizes, a Multimodal Standard with ten peaks between 0.1 and 1.5 microns has also been prepared for evaluation. *Whitehouse Scientific, Waverton, U.K.*
www.whitehousescientific.com

Versatile user interfaces for Ethernet-enabled process gauge

Two completely new interfaces, the HMI (Human Machine Interface) and the OWS (Operator Workstation), provide different levels of user access for this firm's recently launched Ethernet-enabled CM710e NIR gauge for moisture measurement in industrial manufacturing processes, such as chemicals, minerals and ore-extraction, ceramics, detergents and construction products. The HMI provides supervisory access to up to 16 networked Series 710e Gauges while the OWS connects to an individual gauge. Both multi-lingual interfaces feature 1/4 VGA high-resolution color touchscreens to provide intuitive access to a range of measurement information, diagnostics and other functions, appropriate for the level of access required. All variants are available in high-impact polymer housings, rated to IP65, and suitable for use in ambient temperatures to 50°C. Optional stainless housings meet the need for safety and hygiene in food processing and other environments. The HMI provides scalable analogue outputs and digital I/O as well as extensive Fieldbus connectivity options, including all common EtherNet-based protocols and DeviceNet, Profibus and CANbus Open. — *NDC Infrared Engineering Ltd, Maldon, U.K.*
www.ndcinfrared.com ■

Gerald Ondrey

SpecPlast 2009

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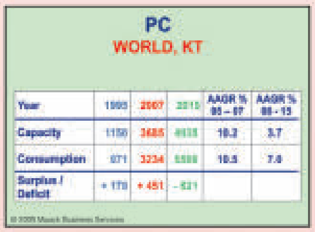

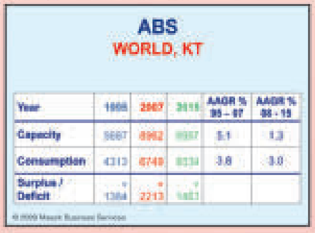

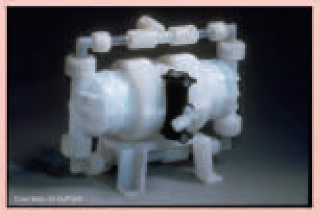

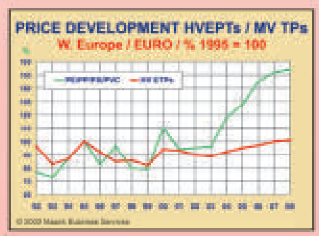

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Revamps: Strategies for A Smooth Turnaround

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Energy Systems Engineering

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Tie-in opportunities are few and far between. These rules of thumb will help make sure everything and everyone line up in time

A majority of capital projects today are either debottlenecks or revamps that are intended to increase capacity, squeeze out incremental revenues or comply with impending regulations. A unique goal to the planning of these projects is avoiding excess downtime during the turnaround that would quickly erode the project economics.

Meanwhile, the revamp opportunities that a turnaround provides are, themselves, few and far between. Petrochemical refineries, for instance, typically try to get five years between major turnarounds to maximize onstream time. Some equipment can be connected before an actual shutdown, but most of the so-called tie-ins must fall into place during the turnaround, which usually lasts only 20–50 days.

Since the typical duration for the design, production and construction of a major revamp can take a year or longer and involves many stages (see box, Project Stages, p. 37), advanced planning is critical. Equipment with long lead time must to be ordered well in advance of the date required onsite, and engineering has to be contracted-out well in advance to find a quality engineering contractor with the experience required to execute the project without rework.

PLANNING FOR SHUTDOWN

Shutdown plans have to be well organized so that all the work dovetails within the allotted shutdown period. Figure 1 shows a portion of a typical project schedule.

This schedule breaks down the activities into a large number of steps, each of which has an early start date and last completion date to keep it from becoming schedule limiting. The objective is to pre-install and do as much of the construction as possible in advance of the shutdown. Because shutdown time is very limited, only tasks that must be done with the unit shut down are undertaken at this time. This approach also allows for fewer people onsite during the crunch time, shutdown activities.

Ordering equipment

Before a high level of schedule detail is developed, a simpler bar-chart type schedule is used to develop the timing used for ordering the long lead time equipment, such as thick walled reactors, alloy equipment and high pressure vessels. Working back from the desired start of work in the field, the project manager can determine the latest time in which an order can be placed. This requires some lead time ahead of the order to do the necessary pre-purchasing activities. This sometimes requires that equipment purchases be made before the final design is completed. Figure 2 shows an example of back calculating how soon development of the purchase order must be started in order that equipment arrives onsite to fit the overall construction schedule work.

Tie-ins

The tie-in list is the key to the piping. It needs to differentiate the type of tie-in, including the hot tap (done during unit operation) and shutdown tie-ins (made after unit is shut down in preparation of construction).

Most tie-ins are handled during shutdown. A typical tie-in would include two block valves and a pipe stub with another valve leading to the connection to the new equipment.

In some instances, tie-ins can be made in advance with the unit operating. So called hot tie-ins are usually avoided, however, because of the inherent danger to process fluids if something goes wrong. The split tee is one type of hot tie-in. It is basically a tee in two pieces that has an inside diameter identical in size to the outside diameter of the pipe being tapped. It is welded into the existing line, and then the connection to the tie-in line is made through the lateral.

STAFFING

Most operating companies no longer have the luxury of maintaining a dedicated, fulltime and experienced engineering team required for executing small to mid-sized projects. Revamp projects are instead mainly staffed by using a mixture of contract engineers and managers, supplemented with the owner's key staff. Only a limited number of key plant personnel are dedicated to the overall team. The contractor's team is usually kept together during the project and quickly demobilized once the need no longer exists for personnel, which minimizes costs. Another advantage to contracting staff is that an expert in a specific field can be obtained for a short duration.

One strategy for avoiding excessive learning curve requirements and reducing costs of a contracted staff is to use the same contractor to perform multiple projects.

Figure 3 shows a typical staff scenario, including the owner's team, the owner's contracted staff, and the en-

	MAJOR TASK SUMMARY: DURATION, START AND FINISH			
1	**PHASE 1: Packaging**	170 d	9/3/07	4/25/08
2	Engineering required prior to packaging	10 d	9/3/07	2/1/08
3	Procure, fabricate and deliver long-lead items	113 d	10/17/07	3/21/08
4	Build skid package	60 d	2/4/08	4/25/08
5	**PHASE 2: Off-skid engineering, design and construction**	147 d	11/5/07	5/27/08
6	Approval of conceptual documents	25 d	11/5/07	12/7/07
7	Detailed engineering	84 d	11/6/07	2/29/08
8	Permitting	22 d	1/21/08	2/19/08
9	Construction	92 d	1/21/08	5/27/08

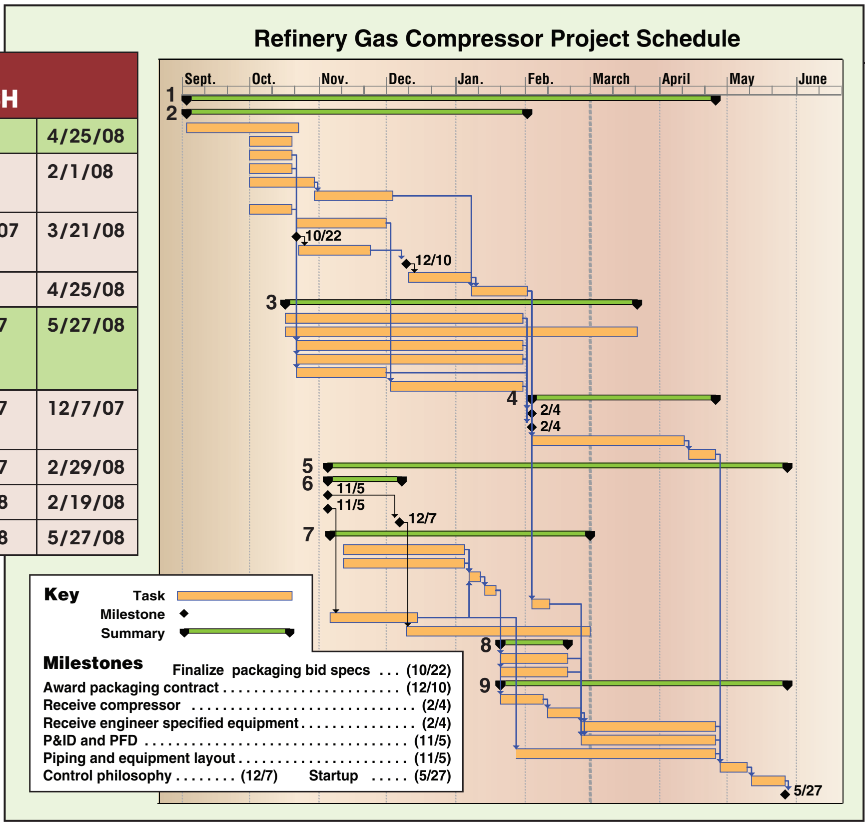

FIGURE 1. This example schedule breaks down the activities into a large number of steps, each of which has an early start date and last-possible completion date to keep it from becoming schedule limiting. The two major phases and seven major steps are indicated by numbered, green lines and identified in the table

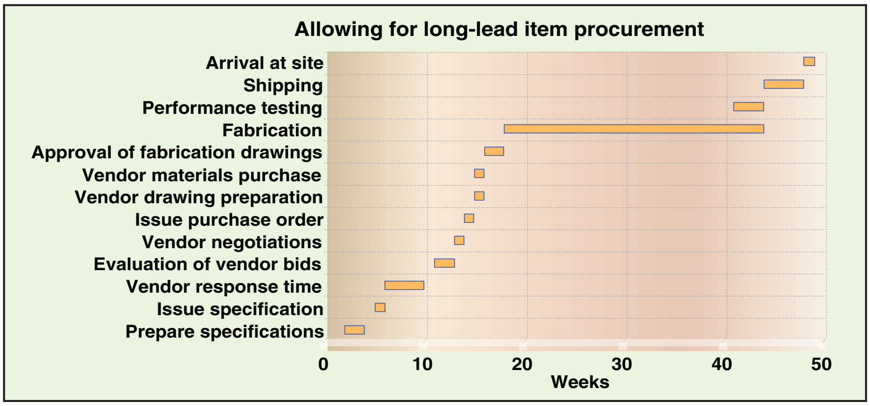

FIGURE 2. A simple bar chart is useful in back calculating how soon development of the purchase order must be started to ensure that equipment arrives on time

gineering contractor staff. Not shown is the construction team, which is directed independently.

Planning, engineering design, construction-management and commissioning/startup constitute the project life cycle. The project is turned over to operations people for commissioning and startup.

Owner's staffing

The number of plant personnel assigned to a project varies but is usually limited to a few key people including the project manager, process engineer (as required), a safety lead, the operational lead (sometimes part time) and a cost-control/scheduling person.

Engineering contractor

A bell curve represents a typical staffing scenario for the engineering contractor's home office, the initial phase starts with very few people until the project is developed. Then, staffing ramps up as engineers and designers are added for the production and construction phases. At the end of the project, demobilization of the staff starts to occur.

Engineering cost breakdown

For the engineering part of a project, the overall engineering costs for so-called grassroots or all-new designs are about 10% of the project costs. For revamps and retrofits the portion increases to between 15 and 20% because of the complexity of the equipment interfaces. Based on $100/h contractor engineering average rate, the total number of engineering hours can be estimated. From here, with the allowed engineering schedule, the number of people months can be back calculated. Using say 165 h/mo, the average number of people required on the project can be estimated.

Typically, the allocation of the various disciplines can be estimated from Table 1. Note the process and systems people tend to come on early and the instrumentation and electrical engineers come on late.

A good way to cross check the staffing is to show the number of staff on a simplified bar chart for the various disciplines during the engineering phase. Then total up the number of man weeks or man months to see if it agrees with the overall hours estimated.

In addition to the engineering contractor's team, which is usually not onsite other than having some members in trailers either part time or full time, there is the owner's field team.

Onsite project team

The following onsite team members have to be either hired on contract or supplied by the operating company. It is desirable to bring on the team just when needed for their work on the project and then release them back to the hiring organization (job shop). Getting quality contract people is not easy. There are only a few hiring organizations that specialize in providing the staff of people for the project execution phase. These companies staff projects

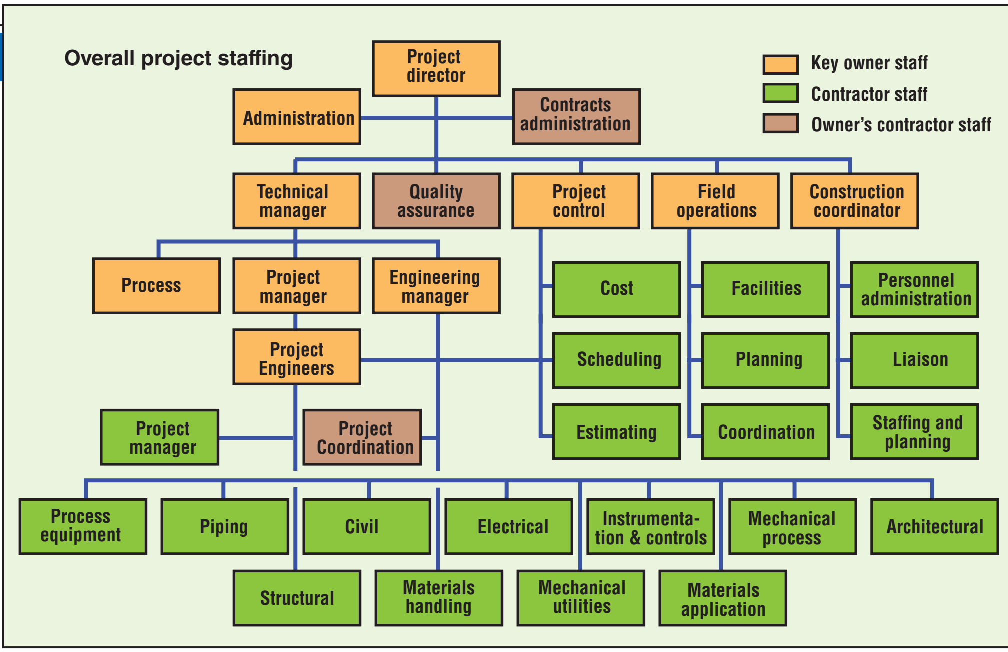

FIGURE 3. Typical staffing scenarios today include the owner/operator's staff, the owner's contracted staff and the engineering contractor's staff

worldwide. The other option is to hire from a number of different agencies. The personnel required to execute a project include at least the following:

- Project engineers
- Project construction managers
- Cost control specialists
- Records- and file-keeping supervisors
- Purchasing
- Welding specialist
- Rigging engineers
- Materials specialist
- Piping supervisors
- Excavation and foundation supervisors
- Transportation and delivery experts
- Field construction supervisors

A team of these experts supplemented with the owner's representatives is usually housed in temporary trailers onsite. The arrangement has not changed much since the days when the team was comprised primarily of owner's personnel.

Detailed engineering

It is typically necessary to contract out the detailed engineering team. The detailed-engineering-contractor team performs the engineering from its home office, once the project is defined by the operating company. The owner selects the engineering company that best fits the type of project, size of project and local availability. In former times, the engineering company was almost always local. However, with the proliferation of electronic drawings (and their transmission and sharing), cell phones, telephone conference calls and so on, the engineering team even for revamps is no longer required to be onsite. The onsite demands can usually be met by a small local team that acts mainly as the interface between the field and the home office team. Some revamps and retrofits still require a local company to be effective in the day-to-day field changes.

ENGINEERING EXECUTION

The following is the order in which the engineering at the contractor's office normally takes place:

1. Process engineering

The process engineering is usually staffed by the owner and takes the lead through the conceptual design phase. It must be involved early on to decide what is to be included in the project. The objective is to determine how the proposed concept can make maximum use of the existing facility equipment and minimize the new major equipment. This is somewhat of a trial-and-error procedure in determining the existing limitations of the major equipment (that would be too costly to replace).

Three alternatives may be evaluated either by inspection or by a "quick and dirty" cost evaluation. Process engineering usually is concentrated in the first two to three months of engineering and then goes down to one or two people.

2. Detailed engineering

Once the process concept is firm, then the detailed engineering begins. The systems engineering is the key in this phase. It starts with marking up existing process flow diagrams (PFDs) and providing a project description that defines what modifications are to be made, what new equipment is required and other significant project requirements. This basis becomes the vehicle to make sure everyone is on the same page and in agreement with the concept. Detailed engineering begins once the PFDs, piping and instrumentation diagrams (P&IDs), equipment specifications and overall scope of the project are completed.

TABLE 1. TYPICAL ALLOCATION BY ENGINEERING DISCIPLINE

Discipline	%*
Project management	10
Process and mechanical process engineering	5 to 10
Civil/structural	10 to 15
Electrical	10
Instrumentation and controls	15
Purchasing/expediting	≤ 5
Equipment engineering (rotating equipment, heat exchangers, heaters, reactors, vessels and so on)	10
Piping	15
Mechanical design	10
Support staff	≤ 5
Accounting	≤ 5

* Percent of overall engineering staff

Usually the existing (as-built) P&IDs are marked up showing modifications to piping, modifications to the existing equipment, addition of new equipment and reuse of existing equipment in a new service. Increasing a line size, using a larger control valve size, increasing the pump impeller diameter to the limits of the casing, changing to a larger motor size or going to a new larger pump are considered to be acceptable, cost effective modifications.

Some modifications are allowed on major equipment as long as they are

PROJECT STAGES

The following traditional steps are aimed at sorting out the projects and determining which of the potential projects should go on to execution:

- ***Conceptual design*** where the overall project goals and approach are defined and the ballpark costs are identified by comparing the costs of other projects and expected increases in revenues or reductions in operating costs
- ***Preliminary design*** where enough of the design is done, including PFD and equipment identification, so a cost curve can be developed and the expected additional revenues can be further defined
- ***Detailed design*** where full PFDs, P&IDs, equipment data sheets are prepared and sent to vendors for verbal quotes, marked up plot plans for feasibility evaluation. A factor type cost estimate can be prepared for the inside battery limits (ISBL) portion and the outside battery limits (OSBL) portion can be estimated as a percentage
- ***Final basic design*** where PFDs are firmed up, P&IDs are finalized; equipment locations are set; piping, electrical and utility runs are defined; and instrumentation counts are made. From there, a conceptual take-off estimate can be made for both the ISBL and OSBL portions
- ***Contracting detailed engineering*** can be performed using the final basic-engineering-design package by getting bids from various contractors. The owner has the choice of also including the construction with the detailed engineering. The detailed engineer usually provides the purchasing except for some of the advanced purchasing that the owner might perform in order to get long lead items delivered
- ***Construction*** can be done either by an overall general contractor or be sub contracted out to say a civil, electrical/instrumentation and a piping/equipment contractor. It may be desirable to have certain portions of the project supplied as skids to minimize the field time
- ***Commissioning*** is usually done by owner operators and should include final checks of the construction matching the P&ID and other drawings. Motor rotation, check valves facing the correct direction, piping matching the piping codes all need to be reviewed
- ***Startup*** is the final step to completing the project ❑

cost-effective and can be performed in a reasonable shutdown period. Examples are larger nozzles, new internals, replacement of distillation trays with higher capacity trays or structured packing and alloy lining. Major modifications to major compressors, fired heaters and large diameter distillation columns is usually not cost-effective. In gauging the feasibility of major equipment replacement, the rule of thumb is to parallel-up with a smaller or identical item.

New data sheets are developed for the required new equipment. Check-rating data sheets for the existing equipment are provided for documentation that the equipment fits the new requirements. This information should be compiled together to serve as backup for the project definition and cost estimates. Put the following information in a set of binders available to the task force to keep everyone on the same page: process description, PFDs, P&IDs, data sheets, preliminary layouts and preliminary piping runs.

Electrical and instrumentation activities should be minimized until the project design is developed to the point that no rework would is required.

3. Long-lead item procurement

Long lead times on alloy and high pressure equipment requires some of the procurement activity to be done in advance of the project being fully defined. This subjects the project to some financial risks if the equipment ultimately requires extensive modifications or is not used at all. The key to procurement is always having firm specifications.

Good equipment data sheets are the minimum, with alternate case information provided as footnotes or a second data sheet. The detailed specification is key to getting out a purchase order with the minimum number of change orders. Just referring to the general codes (API, ANSI, TEMA) is not adequate. Any specific fabrication requirements must be called out. The associated specifications should be included with the general specification. Consider, for example, that requirements for corrosion protection are becoming more prevalent where wet acid gas is present. These requirements can add considerable cost. Welding specifications can be provided by the buyer or the manufacturer can supply specifications, and have them approved.

STAGGERING REAL-WORLD INSIGHT

In the following example, three small engineering projects were executed as part of a single overall project during a petroleum refinery turnaround. The strategy was to stagger the work on the projects so a single contractor team could be used throughout the entire engineering execution. This eliminated the need to retrain an engineering contractor multiple times to the operating company's accepted approach.

One of the projects was well defined and allowed a contractor team to be formed early and to begin work. The other two projects were still in development stage and required additional time before starting engineering. This set of circumstances allowed the engineering company to keep a dedicated staff of engineers and designers on the combined effort, which ended up being the key to the overall project success.

Piping design

The overall project consisted of a lot of piping design work. Much of the piping was run from tie-in point to tie-in point. For the purposes of accuracy, the engineering contractor used a laser-type spotting method where the coordinates of the various locations were identified. The unfortunate part of this particular method was that the location of various runs was referenced to imaginary coordinates, which are set up by a reference coordinate system. Converting these coordinates to reference a particular pipe run to, say, a location on the pipe rack was time consuming.

Since the sub-project schedules were staggered, the same piping crew was available throughout the whole project. To avoid the need for field welding on the job site, the piping isometric drawings were converted into piping spools.

Modular equipment

On one part of the project modular assemblies were used to minimize field time and costs associated with the engineering, equipment contracting and installation of equipment, piping and controls. This strategy proved to be valuable in that craft labor in the site area was very limited. It also provided for a lot of the work to be performed in the shop where productivity is higher than out in the field. The modules were prefit together in order to ensure field connections would be troublefree.

The key to the equipment module concept is to have at least a hand drawn battery limits interface of the piping coming to and from the skids. It is also desirable to plan how the skids will be delivered so that there is no obstruction from the skids already put on foundations with those still arriving.

Civil work

All of the civil work was contracted to a firm in the area on a time and material basis. The contractor was well aware of the potential for unknown underground obstructions. As it turned out, many field changes had to be made on the fly to minimize the disruption to the existing underground obstacles. This site required the use of piles in order to provide the support necessary for the marshy plant site area. In hindsight, spread-foot foundation might have saved money versus the traditional civil approach selected.

Structural steel

Structural steel became a problem from a permitting standpoint. The equipment modules were engineered out of state by a company that did not have an engineering license in the state of construction. It was considered unethical to have a local engineer approve drawings that he was not involved with during design. So the local engineer had to virtually recheck all of the design calculations. Meanwhile, the local inspectors took exception to staircase and handrail specifications that did not meet some arbitrary local requirements.

In another area of the project, major excavation and tie-in of new subsurface foundations was required to support the additional weight of some new elevated equipment. This work became very prolonged due to the necessity to cordon off large areas during the excavation, the installation of new rebar in tight spaces and the inability to get trucks close to the area where new foundations needed to be poured.

Piping packages

In order to organize the piping portion of the project into an easily understood format, the field project engineers took the engineering documents produced by the engineering contractor and assembled them into work packages. Each work package was generally a pipe run from one location to another.

The run usually consisted of several isometric drawings, which are 3-D sketches showing the routings. The software used by the contractor also included a bill of materials for each isometric drawing, which served as the materials requirement for a piping task.

Project engineering assembled these into packages, which included the tie-in photograph that was taken by the piping designer field team. Then, the associated vessel drawing was included with a portion of the plot plan where each pipe run was marked in a particular color depending on piping code. This allowed the people doing the work to very quickly identify where the work would be done and provided an approximate (plot plan) routing plan.

High-point vents and low-point drains were included on the drawings. Most of these included threaded plugs, which were seal welded (closed) after pressure testing.

Special instructions were provided to the pipe fitters to indicate the potential presence of hydrogen sulfide or other hazardous gases that might not have been fully purged during shutdown. These instructions identified which control room had authority over the given area in order to minimize the standard check-in procedure with the authorizing operations staff.

Materials and welding

Wet acid gas was present in several sections of the new addition. This required evaluation of corrosion standards including the requirements for special welding procedures and post weld heat treatment. This adds cost to the plant, so prudent selection of where the treatment made sense was used to keep the costs under control.

Critical lifts

An attempt was made to avoid all critical lifts (lifts over existing equipment or operating piping). Special safety forms and personnel were required to be in attendance for critical lifts.

Vessel work

The heads were replaced on four large sized vessels. You can almost guarantee that legacy vessels will be out of round (warped). So you need to have personnel and equipment that can bring the vessels back into round in advance of facing the problem; otherwise, schedule is going to slip.

Safety

Safety is the ultimate concern of the project. Early recognition of the staffing and procedures to assure a safe work environment is critical. The permitting process is also a key to being sure each of the sub steps is in compliance with the house rules. Some permit streamlining can be used on revamps and retrofits by applying for an all inclusive permit with the same information as a number of permits used on smaller, individual projects. ❑

4. Use of skid mounted modules

Prefabricated equipment modules can save a considerable amount of field time and money, especially for a revamp. Having the equipment supplier provide a full skid for the equipment, including all of the auxiliaries, can be a win-win for both parties. Using the manufacturers' control-system standard rather than a custom design can also save money. Reciprocating compressor systems can typically include, for instance, the inter-stage knock-out drums, inter-stage coolers, pulsation dampeners, lube oil system and control panel.

Skids are especially attractive for harsh climates and areas where skilled labor is limited. The Alaskan North Slope oil-production plants, for example, were built using very large modules shipped-in during short periods when the access water was clear of ice.

Pre-fitting the modules together before shipment is a must. Flange-to-flange connections, where permissible, reduce field welding demands, which is especially attractive for alloy lines.

CONCLUSIONS

Thinking ahead is the key to a safe, successful, on-time project that is performed without a major cost over run and without major surprises.

It is important to remember schedules are just plans. Doing things faster than can reasonably be expected usually results in rework and more cost in the longrun. There is typically a learning curve that results in efficiency and time saving measures being developed as the work progresses.

Coordination meetings, although time consuming, are a must in the efficient use of manpower. Changes to a plan may be required as unexpected obstacles are encountered. ■

Edited by Rebekkah Marshall

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Disperse Difficult Solids

Recent advances in mixing technology offer increased efficiency in dispersing powdered additives into liquids for both low- and high-viscosity applications

Ken Langhorn and **Christine Banaszek**, Charles Ross & Son Company

FIGURE 1. In a high shear rotor/stator mixer, a rotor turns at high speed within a fixed stator. As the blades pass each opening in the stator, the mixer applies intense shear to the liquid material, which is rapidly accelerated and ejected radially through the stator

It's easy to understand why R&D engineers love performance-enhancing additives like fumed silica, carbomers, cellulose gum, alginates and bentonite clay. These all-purpose ingredients offer incredible versatility for a multitude of products from cosmetics to ketchup, wallpaper paste and the thermal grease used to bond a heat sink to a microprocessor. They can serve as thickeners and fillers. They can impart rheological properties such as thixotropy or pseudoplasticity. They can bind moisture or promote the free flow of solids. They can correct the mouthfeel of an artificially sweetened drink or improve the tear strength of silicone rubber.

Despite the immense value and universal appeal of these additives for product designers, process engineers facing the day-to-day reality of full-scale production face a unique set of challenges. Dispersing these powdered additives into a liquid is one of the most formidable challenges in the chemical process industries (CPI). Although most can be dispersed fairly easily in a common laboratory mixer, when scaled-up for batch, semi-continuous or continuous production, it's much more difficult, time-consuming and costly.

Only a few years ago, in a less intensely competitive business environment, the long mix cycles devoted to dispersing these additives did not receive much attention. The fact that inefficient mixing often led to underperformance of additives, and therefore excessive loading to compensate, was also overlooked. Today, competitive pressures have amplified the importance of every possible improvement in process efficiency — especially those that might yield a significant competitive advantage.

Because of the ubiquitous use of "hard-to-disperse" additives (Table 1) and the inefficiency of the old-fashioned mixing techniques generally used to disperse them, modern mixing techniques present an extraordinary opportunity for manufacturers throughout the CPI. Recent advances in mixing technology enable dramatic gains in process-line efficiency and end-product quality.

A recipe for "fish eyes"

The mechanisms by which thickeners and other modifiers operate vary considerably. However, when they are added to an open vessel with a propeller generating a vortex, the results are usually the same: many hours of mixing, an imperfect dispersion, and often an unsafe plant environment.

In a traditional batch-mixing process, lightweight powders often float persistently on top of the liquid batch. A variety of factors may contribute to this familiar and frustrating sight, including the material's low surface energy, low molecular weight and hydrophobic properties. The material simply drifts on the surface and resists wetting, even when subjected to vigorous agitation.

Over a period of hours, a low-shear, top-entering agitator will gradually coax these materials to submerge into the batch. However, most will readily hydrate to form clumps with a tough outer layer that inhibits dispersion of the particles within. Especially when using low-shear mixing devices, such as turbines and propellers, the dispersion can take many hours to complete. Even in the best-case scenario, this process produces a dispersion of reasonable quality, but only after many hours of processing. All too often, the final mix includes a variety of solution defects, such as a grainy texture, viscosity below target levels and insoluble particles that resemble "fish eyes."

The cost of this imperfect dispersion can be measured in numerous ways. Even if the product is deemed adequate to proceed to downstream processing, these defects usually reduce the efficacy of the additive. This in turn requires more solids to be added in order to generate the desired properties, which drives up the cost of raw materials. Every hour wasted on unnecessary mixing also wastes power, lowers productivity and constrains overall production.

There are also indirect costs that can be traced to inefficient mixing of these additives. For example, in a batch-mixing environment, fluffy powders like fumed silica, carbon black, and many other pigments and flavorings are notorious for "dusting" in the plant. When they are poured into the open vessel, a cloud of airborne particles immediately swirls into the air. This can require a great deal of labor to clean up. It can also elevate the risk of contamination and expose workers to significant safety hazards.

Batch high-shear mixing

A switch to a high-shear rotor/stator mixer is the first essential step to-

TABLE 1. MATERIALS APPROPRIATE FOR HIGH SPEED INDUCTION

Material	Typical Applications
Alginates	Paper and textiles, beverages and soups, cosmetics, dental and prosthetic molds
Alumina	Coatings, ceramics
Aluminum Isopropoxide	Lubricating greases
Bentonite clay	Drilling mud, coatings, cement, adhesives, ceramic bodies and glazes, cat litter and rocket nozzles
Boric acid	Specialty lubricants
Calcium carbonate	Building materials, road-building materials, drilling fluids, latex gloves, adhesives and sealants, decorative fillers, ceramic glazes
Carbon black	Adhesives, inks, coatings
Carbomers	Pharmaceuticals, cosmetics, personal care products
Cellulose gum / Carboxymethylcellulose (CMC)	Adhesives, ceramics, coatings, detergents, mining, paper products, textiles, pharmaceuticals, food, cosmetics, personal care products
Fumed Silica	Defoamers, coatings, pharmaceutical gels, cosmetics, personal care products
Hydroxyethyl Cellulose	Coatings, drug capsules, dental gels
Milk Powder	Food
Rosin Ester Resin	Water-based adhesives, coatings
Starch	Food, paper, adhesives
Sugar	Food and beverages
Talc	Pharmaceuticals, adhesives, cosmetics, ceramics
Titanium Dioxide	Textile chemical, inks, coatings, food coloring
Xanthan Gum & Sodium Cyanurate Powders	Swimming pool water stabilizer

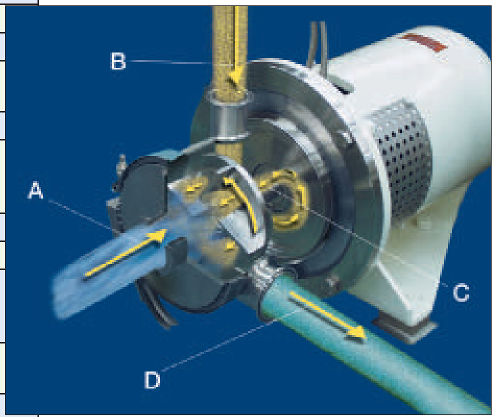


FIGURE 2. The liquid stream (A) enters the mixer and immediately encounters the powder addition. Drawn into the mixer by a powerful vacuum, the powder (B) is injected through the ported rotor directly into the high shear zone (C), where it is subjected to intense hydraulic shear. With particles instantly dispersed, the resulting dispersion is ejected from the mixer (D)

ward improving the dispersion of difficult solids. In its simplest form, this mixer consists of a rotor that turns at high speed within a stationary stator (Figure 1). Tolerances are close (0.010–0.015 in. typically), and as the blades of the rotor pass each opening in the stator, they apply intense shear.

In a batch configuration, the portable rotor/stator generator is suspended in the vessel, slightly off-center. Material is expelled at high speed through the stator and into the surrounding mix, which applies hydraulic shear to surrounding material and stimulates vigorous flow. As fast as material is expelled, more material is drawn into the rotor/stator generator from below, which promotes continuous flow, a strong vortex beneath the mixer, and thorough mixing.

For dispersing troublesome powders, the traditional rotor/stator mixer is far more efficient than a low-shear propeller or turbine, but in a batch configuration, it still presents significant limitations:

- Once powders are wetted out, they are dispersed readily. But first, they must be drawn into the mix by the vortex created on the surface. Materials that float or "raft" persistently resist even a vigorous vortex.
- Exposure to intense shear is not sufficiently controlled for all the material in the batch. While the operator waits for the remaining powder on the surface to wet out, solids already hydrated are subjected to more passes through the high shear zone. For some materials, such as synthetic carbomers, this over-shearing can result in a permanent decrease in viscosity.
- As batch size increases, the size of the rotor/stator mixer required to generate adequate flow goes up, too. As the mixer size increases, power consumption rises and portability eventually becomes impractical. Mixers exceeding 10 h.p. are generally installed in a permanent, fixed-tank configuration.

Inline high-shear mixing

Inline rotor/stator units provide a high-shear mixing process that is closed and far more controlled than batch units. A liquid stream enters the mixer (Figure 2), and it is immediately subjected to intense shear in the rotor/stator generator. It may be mixed with a powder (or another liquid) in the high shear zone, where the addition is immediately dispersed with highly predictable results.

In an inline, high-shear rotor/stator mixer, the point at which powdered ingredients are added to the stream is a critical factor in determining maximum effectiveness of the device. Early design concepts first combined powdered ingredients with the liquid stream using an eductor. Note that in this scenario, the solids and liquids are first combined; then they travel downstream to the rotor/stator generator, where mechanical shear is applied. During the transit from the point of simple combination to high-shear mixing in the rotor/stator generator — even if it is a distance of just inches — agglomerates are likely to form, which makes the device highly vulnerable to clogging or fish-eye formation.

The rotor/stator generator easily breaks agglomerates apart, but only if the device does not clog between the eductor and the rotor/stator. This realization led to the next major advance in rotor/stator design: mixers that combine ingredients and subject them to high shear simultaneously.

Inline powder dispersion

The many ancillary benefits of an inline, high-shear rotor/stator mixer have been recognized for years, but they were mainly considered little more than a welcome bonus. The primary function of this mixer has always been high-speed dispersion, emulsification and suspension with the application of high shear. The fact that a rotor/stator generator behaves like a centrifugal pump, for example, merely adds convenience and value to the unit. In fact, these mixers often provide sufficient pumping capacity to eliminate the need for an auxiliary pump to move product downstream. These mixers also have the benefit of enabling the easy introduction of powder and liquid additions.

During the first 50 years of rotor/stator mixer design, development continued to focus mainly on the application of intense shear. In the last surge in

FIGURE 3. Equipped with helical blades, the double planetary mixer's operating viscosity range is extended from approximately 2 million cP to at least 8 million cP. The mixer's ability to disperse powders rapidly is also dramatically improved. As the helical blades advance, they continuously push powders forward, down and inward

development — since the early 1990s — multi-stage rotor/stator generators became quite sophisticated, and their ability to create sub-micron emulsions and dispersions improved dramatically. Then, about 10 years ago, mixer manufacturers began to recognize the value of driving rotor/stator design toward even higher levels of shear while also focusing on the optimization of rotor/stator design for the injection of solids into a liquid stream.

Note the path of solids in Figure 2 as they are sucked into the mixer by a powerful vacuum generated by a specially modified rotor and stator. Once they have entered the mixer, they are re-routed through the ported rotor into the interior of the rotor/stator generator. There, the solid ingredient meets the liquid stream for the first time, and together they are immediately subjected to intense shear forces. The dispersion is then ejected centrifugally through the mixer outlet with sufficient force to eliminate the need for a downstream pump in many applications.

With simultaneous combination and high-shear mixing, agglomerates have no chance to form. Agglomerates are sheared and injected into a high-quality dispersion virtually instantly. By reducing the risk of clogging, this design concept has removed a significant constraint on production.

Direct injection for batch mixers

The principle of simultaneous combination and high-shear rotor/stator mixing can also be applied to batch rotor/stator mixers. While the rotor/stator generator is running beneath the surface of the batch, a feed tube allows powdered ingredients to be added from above. As in the inline mixer, the solids are drawn down the tube by a vacuum created by the rotor/stator generator, remaining dry until the moment they enter the high-shear zone and are simultaneously combined with the liquid batch and dispersed.

While this configuration does not offer the close process control of the inline system, it greatly improves the performance of the batch mixer and accelerates the dispersion of solids that would otherwise float on the surface and drive up processing costs.

Rotor/stator powder injection

For most veteran process engineers, appreciating the production gain possible with rotor/stator powder injection requires "out of the box" thinking. The scale, in many cases, is quite large, with cuts in the mix cycle ranging from 50% to as much as 98%.

Certain variables are of high importance in their effects on the process line. Viscosity, for example, is a key driver in optimizing the configuration of the powder injection equipment. Depending on the peak viscosity encountered during the mix cycle, performance of the device may be improved with additional agitators that stimulate flow and homogeneous mixing throughout the vessel. Other important process variables include the shear-sensitivity of the solids added to the batch as well as other ingredients already present. Rotor/stator mixers can be modified to inject shear-sensitive powders like carbomers while minimizing the risk of damaging the polymers.

New rules for rising viscosity

The high-speed, powder-injection equipment discussed thus far is ideal for low-viscosity mixes. In a batch configuration, as viscosity rises above approximately 20,000 cP, however, supplemental agitation from a multi-shaft mixer may be required. A slow-speed anchor agitator generates additional flow needed to move material from the vessel walls and bottom toward the interior of the batch and "feed" the high-shear rotor/stator device. Even with this addition, the mechanism remains essentially the same: the injection device sucks flowable powder and liquid into the rotor/stator generator, where it applies intense shear and drives the powder into dispersion. This process works well for products that flow with or without additional agitation, but materials that do not flow easily require a completely different strategy. Instead of drawing free-flowing material to the mixing head, we must literally bring the mixer's agitators to the non-flowing batch material.

Many products — from structural adhesives to aerospace composites and fuel-cell-electrode pastes — require dispersion at the high end of the viscosity range, for which the double planetary mixer is most often chosen. Compared to multi-agitator mixers for mid-range viscosities, this mixer is distinguished in that its agitators are not stationary. Each of the two rectangular planetary blades turns on its own axis as they orbit the vessel on a common axis. While continuously moving material from the vessel walls and bottom toward the interior of the batch, the blades travel through the vessel and physically contact every point in the batch within only a few revolutions.

The drive components and agitators in a double planetary mixer are engineered to apply immense power and move material that is often so dense you can easily stand on it, yet the mixer was limited for decades to materials of about 2-million cP, or even less when working with sticky materials like silicone sealants that are inclined to "climb" the blades during the mix cycle and collect in the upper region of the process container.

Helical blades extend capacity

The most dramatic recent advance in planetary mixing is the development of helical planetary agitators. Unlike the vertically oriented agitators used for decades, these precisely-angled, helical agitators slope gracefully. As they travel through the batch, they continuously force material forward, down and inward (Figure 3). With close tolerances, they also remove material efficiently from the vessel sidewalls. The result is that powder additions, such as carbon black and fumed silica, are quickly wetted out and thoroughly dispersed, and 'climbing' is eliminated.

Compared to traditional agitators, the slope of the helical blades greatly reduces the drag induced by the motion of the agitators through the batch. The absence of a horizontal crossbar

OBSERVED INDUCTION-RATE TABLE & SUPPORTING DISCUSSION

A key step in applying high-speed powder-induction technology to any application is sizing the mixer to match target production rates, operating budget, and the flow characteristics of the materials being dispersed. This table reports maximum induction rates observed for a variety of materials, for both inline and batch injection systems of various sizes. In general, larger mixers — operating with greater horsepower and larger rotor/stator generators — will apply more energy and produce higher powder-injection rates and greater production.

For a mixer of any particular size and configuration (batch or inline), variation in injection rates is due to a number of factors, including material density, particle size and shape, electrical charge and the presence of moisture. Injection rates for any mixer size and configuration, as well as scaleup performance, are highly predictable. ■

Rotor/stator mixer size & batch/in-line configuration		Sample materials & maximum induction rates by rotor/stator mixer size (lb/min)							
h.p.	Rotor diameter (in.)	Alumina	Calcium carbonate	Carboxy-methyl cellulose (CMC)	Carbomers	Fumed silica	Starch	Sugar	Titanium dioxide
Inline rotor/stator powder induction mixers									
30	7.0	500	590	340	280	110	450	700	560
25	3.5	90	105	60	50	20	80	125	100
15	2.5	45	53	30	25	10	40	63	50
Batch rotor/stator powder induction mixers									
50	10.5	270	315	180	150	60	240	375	300
25	4.5	158	183	105	88	35	140	219	175
5	3.5	68	79	45	38	15	60	94	75

also contributes to a reduction in drag (though the principal benefit of eliminating the crossbar is the greater ease with which the agitators may be lifted out of a viscous, sticky batch). Also unlike vertical rectangular blades, the sloped helical blades pass one another with a slicing motion in the vessel. With tolerances very close, this prevents the sudden spike in power that typically occurs when the vertical flights of rectangular blades pass one another. By reducing drag and suppressing this power spike, the working viscosity of a planetary mixer equipped with helical blades is extended from 2 million cP to 8 million cP or higher. This offers manufacturers some surprising new possibilities for fast dispersion needed to produce both high-viscosity and low-viscosity products.

Dispersions for high viscosity

Compared to the high speed devices discussed earlier, the rotational and orbital motion of double planetary agitators is plodding. This slow-motion contact with mix materials does not mean that the double planetary is necessarily a low-shear mixer. Instead, with subtle manipulation of agitator speed and batch viscosity, it can be either a low-shear or high-shear mixing device.

With close clearances between the blades and between each blade and the vessel wall, shear increases quickly as agitator speeds increase. At low speeds, the mixer gently disperses such shear-sensitive materials as micro-spheres to produce syntactic foams and lightweight composites. At faster speeds, it quickly crushes agglomerates and disperses non-shear-sensitive materials such as carbon, alumina, fumed silica, and PTFE to produce battery and fuel cell components.

...and for low viscosity products

Keeping speed constant, shear can also be elevated and dispersion accelerated simply by increasing the viscosity of the batch. In some cases, this may even provide a superior approach to mixing a low-viscosity product.

A case in point is a high-temperature polymeric insulating material used for electrical applications in aerospace. The material consists of micronized calcium carbonate dispersed in resin. The final viscosity of the product is only about 500 cP, but a test in a multi-agitator mixer equipped with a slow-speed anchor and high-speed injection equipment resulted in a final particle-size distribution that was too wide.

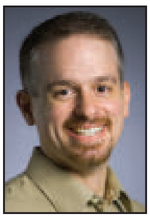
Further tests revealed that the process required high-viscosity mixing in a double planetary mixer. The viscosity was artificially raised to approximately 5 million cP by withholding a significant amount of solvent at the beginning of the mixing cycle. At this initial level of viscosity, the friction induced by the planetary blades within the batch generated intense shear, which quickly dispersed all agglomerates of polymer particles and produced a narrow, sub-micron particle size distribution in only 30 minutes. Afterward, the mixed material was let down quite slowly to avoid over-lubricating the product and creating a new generation of agglomerates. Overall, the batch duration was approximately 60 minutes.

Hybrid dispersion strategies

The drive to explore the crossover possibilities between high-viscosity and low-viscosity mixers for dispersion has led to a variety of additional strategies for mixing. One such design strategy produced the hybrid mixer concept that combines a single planetary blade and a high-speed disperser. As in a double planetary mixer, the two agitators orbit the batch on a common axis while each turns on its own axis. This design is extremely versatile, but it is especially suitable for high-viscosity materials that are heat-sensitive but not shear-sensitive. With the high-shear device moving through the batch and the planetary blade continuously feeding material to it, the mixer is quite effective at dispersing heat generated by the high-speed disperser. This lowers the risk of creating a localized buildup of heat that might damage sensitive ingredients. Another approach to "crossover" mixing involves mixing an initial stage in a low- to mid-viscosity mixer, then finishing the process in a high-viscosity mixer. ■

Edited by Kate Torzewski

Author



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The Shotgun Approach

Removal of Fouling Deposits on heat transfer surfaces in Coal-Fired Process Heaters & Boilers

When conventional soot blowers are inadequate, an automated shot-blasting system offers a powerful solution

Alan Cross

The heat transfer surfaces of coal-fired process heaters and boilers often undergo severe fouling. If left intact, such deposits, consisting of slag from mineral matter contained in the coal, can reduce heat-transfer-surface availability, reduce thermal efficiency and cause corrosion.

If the deposits are adherent and cannot be removed by conventional steam soot-blowers, shutdown and more rigorous cleaning is required. Maintenance personnel have been known to use shot cleaning as a means of removing stubborn deposits.

Operating costs for heaters and boilers of the type described above, can be reduced, due to increased on-stream time, through installation of permanent, on-stream shot-blasting equipment for adherent deposit removal. This equipment consists of strategically placed semi-automatic shotguns (see box on p. 47), utilizing steel shot backed by a solid propellant in the form of shotgun ammunition. The ammunition contains the normal quota of shot, backed by a tailored amount of propellant such that the shot impact force on tube fouling deposits would be several or many times that created by conventional soot-blowers.

Calculations based on realistic cost data [7], indicate that if an outage of 15 days per year could be avoided, through use of the proposed shot-blasting equipment, a boiler having an electrical generating capacity of 125 MW, could avoid a loss of electricity sales sufficient to pay for the cost of the shot blasting equipment described herein, in about one year if shot blasting were provided for the radiant section only, or in about two years, if shot blasting were provided for both the radiant and convection sections. It should be noted, however, that because the flu-egas temperatures prevailing in the convection section may be below the ash-fusion temperature, it is possible that lighter tube-slag deposits may be seen in the upper convection section than in the lower radiant section of the boiler. Thus, convection section shot blasting may not be necessary at this location.

However, shot blast cleaning is applicable for process heaters only with tubular heating surfaces devoid of exposed refractory, which could be damaged by the shot [4]. Likewise, to be applicable for this technique coal-fired boilers must be, and usually are, provided with tubular heating surfaces without open spaces between tubes. Such surfaces are often referred to as membrane surfaces.

FIGURE 1. Shot Blasting Data
ln *PBR* versus ln P_X

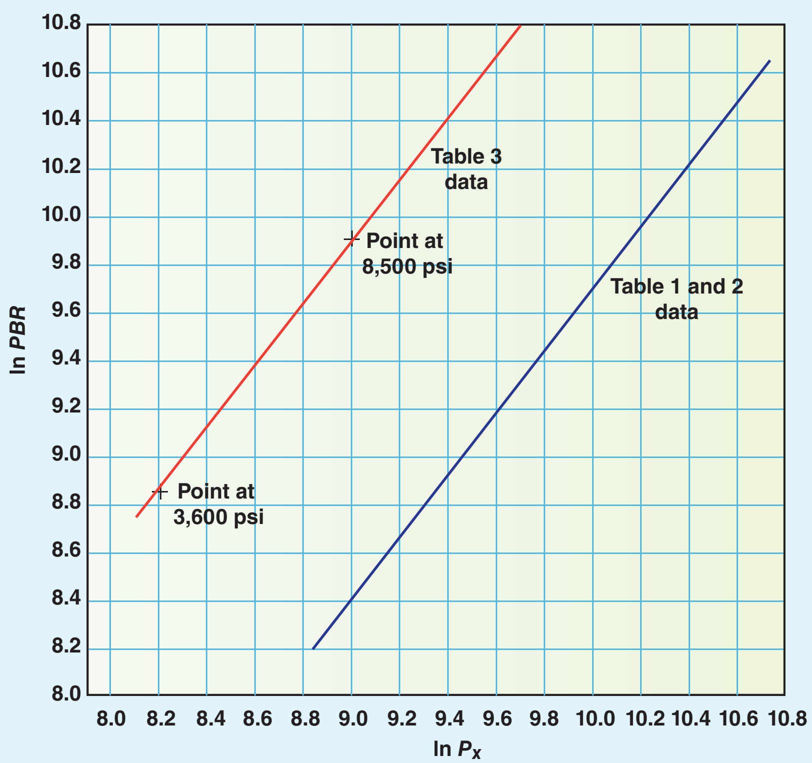


FIGURE 1. The linear relationship of ln P_X versus ln *PBR* is of great practical importance in calculating unknown performance characteristics

Design calculations

If the impingement areas of the steam jets or shot diameters are known, the

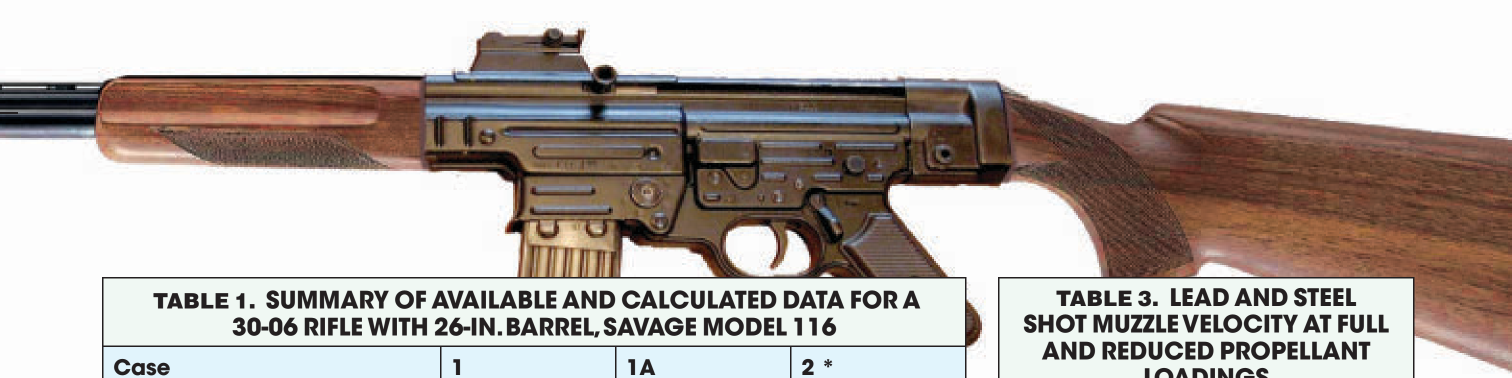


TABLE 1. SUMMARY OF AVAILABLE AND CALCULATED DATA FOR A 30-06 RIFLE WITH 26-IN. BARREL, SAVAGE MODEL 116

Case	1	1A	2 *
L_x, Calculated	24.5	25.5	21.6.
V_m, Specified	2,400	2,400	2,700
R_o, Calculated	2,000	1,920	2,480
P_x, Calculated /Specified	28,285/N.S.	27,200/N.S.	35,100/37,400
P_m, Calculated	26,665	27,000	27,000
V_x, Calculated	2,274	2,261	2,492
PBR, Calculated	27,900	26,700	35,300
W_p, Specified	50.1	51.0	51.0
W_b, Specified	180	180	150

* See Ref. [8]; N.S. = not specified
Cases (1A) and (2) in accordance with Equations (5),(6),(8) and (10)
Case (1) in accordance with base straight line ln–ln plot of Figure 1

TABLE 2. SUMMARY OF AVAILABLE AND CALCULATED DATA FOR 0.44 MAGNUM HANDGUN WITH 4-IN. BARREL SMITH AND WESSON MODEL M29

Case	1	1A	2	2 A	3	3A
L_x, Calculated	3.0	2.0	3.0	2.0	2.5	2.0
V_m, Specified	926	926	853	853	1,203	1,203
R_o, Calculated	1,628	2,443	1,791	2,690	3714	4,642
P_x, Calculated	10,718	16,076	11,789	17,700	24,440	30,546
P_m, Calculated	8,038	8,038	8,842	8,842	15,273	15,273
V_x , Calculated	718	714	652	648	857	852
PBR, Calculated	7,180	10,200	7,172	10,692	19,540	28,200
W_p, Specified	5.0	5.0	5.5	5.5	9.5	9.5
W_b, Specified	180	180	240	240	240	240

Cases (1A), (2A) and (3A) in accordance with Equations (5), (6), (8) and (10).
Cases (1), (2) and (3) in accordance with base straight line ln–ln plot of Figure (1).

TABLE 3. LEAD AND STEEL SHOT MUZZLE VELOCITY AT FULL AND REDUCED PROPELLANT LOADINGS

	Lead Shot	Steel Shot
L_b, in.	20	20
L_x, in.	6.9	7
W_b, grains	547	373
W_p, grains [6]	25	11.0
P_x, psi	8,500*	3,668
P_m, psi	2,920	1,284
V_x, ft/s	918	735
V_m, ft/s	1,383	1,102

* 8,500 psi is the approximate maximum barrel pressure measured by the so-called "lead cup method" wherein the degree of deformation of a lead cup, exposed to barrel pressure, is used as a measure of the peak pressure (see Ref. [5].

force on the tube-surface fouling materials can be predicted and the following equation is applicable:

$$\frac{W_{shot} \cdot (V_i - V_f) \cdot (V_i + V_f)}{2 \cdot g \cdot L_s} = \frac{K \cdot W_s \cdot V_s^2 \cdot A_s}{g} \quad (1)$$

Where:

W_{shot} = Individual steel shot weight, lb
V_i = Velocity of shot at slag layer, ft/s
V_f = Velocity of shot at tube wall, ft/s, and should be zero
K = A multiplication factor, experimentally determined or calculated, so as not to cause tube damage, would be based on a full loading of shot in combination with a reduced loading of propellant. An approximate value of K is 4, based on 1/16-in.-dia. steel shot at 1,100 ft/s, a 1/16-in. slag layer, and a 2-in.-dia. steam jet at 1,200 ft/s
W_s = Steam density, lb/ft^3
V_s = Sonic velocity of steam, ft/s
L_s = Thickness of slag layer, ft
A_s = Cross-sectional area of steam jet, ft^2
g = Acceleration of gravity, ft/s^2

Note that the data required to completely define shot blasting performance and mechanical design include such variables as: muzzle velocity, recoil force, peak barrel pressure, velocity at propellant burnout, pressure and velocity at the muzzle, and properties of the propellant, such as propellant burn rate. These variables are determinable from the equations derived in the box on p. 46.

Propellant burn rate (*PBR*), as determined from these equations, also shows the relationship between burn rate and propellant weight (W_p), velocity at the point of propellant burnout (V_x) and barrel length at the point of burnout (L_x), as determined from an analysis of firearm performance for a number of different firearms having known values of propellant weight, bullet weight (W_b), muzzle velocity (V_m) and barrel dimensions (see Tables 1 and 2). These data have shown that a straight line relationship exists when the natural logarithm of pressure at propellant burnout (P_x) is plotted as a function of the natural logarithm of the burn rate (Figure 1). The same relationship has been demonstrated by other investigators [3]. This would indicate that the propellants used for all of the cases investigated had comparable burn rates.

The linear relationship of ln P_x versus ln *PBR* has been shown to be of great practical importance in calculating unknown performance characteristics, when the only available data for calculation purposes, to determine values of P_m, P_x, V_m, V_x, L_x and *PBR*, consists of W_p, W_b, D_b, L_b, and P_x for at

PERFORMANCE CALCULATIONS

The pressure in the shot blasting barrel can be calculated from Equation (3), which was derived assuming ideal gas behavior, and from data obtained from Ref. [3].

$$P_{barrel} = \left(\frac{V_2}{V_1}\right)\cdot\left(\frac{W_1}{W_2}\right)\cdot P_{max} \tag{3}$$

Where

V_2 = The volume (in.^{3}) of a fully enclosed experimental vessel in which a sample of a propellant is burned, in this case a sample of nitrocellulose
V_1 = The volume (in.^{3}) of the cavity formed from the barrel breech to a point in the barrel where internal pressure is at a maximum due to complete burning of the propellant used
W_1 = The weight of propellant used, grains
W_2 = The weight of propellant charged and burned in the enclosed experimental vessel, grains
P_{barrel} = Pressure in barrel corresponding to W_1 and V_1, psi
P_{max} = The maximum pressure developed in the experimental apparatus based on complete burning of the sample charged, psi

The maximum pressure so developed is 57,000 psi and should be practically the same for any nitrocellulose-based propellant because the gas generated and temperature developed is primarily a function of the chemical composition of the propellant and does not vary much, unless the overall propellant composition is considerably different from that of nitro-cellulose.

The following equations are the result of substituting appropriate variables in Equation (3):

$$P_x = \frac{1,245 \cdot W_p}{D_b^2 \cdot L_x} \tag{4}$$

Where:

P_x = Maximum barrel pressure at the point of complete propellant burnout, psi
W_p = Weight of propellant used, grains
D_b = Inside diameter of the barrel, in.
L_x = Length of barrel from the breech to the point of maximum pressure, in.

$$P_m = \frac{1,245 \cdot W_p}{D_b^2 \cdot L_b} \tag{5}$$

Where:

L_b = Total barrel length, in.
P_m = Pressure at the muzzle, psi

Dividing Equation (4) by Equation (5) results in the following:

$$\frac{P_x}{P_m} = \frac{L_b}{L_x} \tag{6}$$

Equation (7) is based on the well known relationship between force and acceleration:

$$P_b \cdot A_b = \frac{W_b}{g}\cdot\frac{dV}{dT} = \frac{W_b}{g}\cdot V \cdot \frac{dV}{dL} \tag{7}$$

Where

P_b = Average barrel pressure, psi
W_b = Total shot weight, lb
g = Acceleration of gravity = 32.2 ft/s^2
V = Bullet or shot velocity, ft/s
T = Time, s
A_b = Inside cross-sectional area of barrel, in.^{2}

The following equations are the result of integrating Equation (7) between appropriate limits as follows: In the zone of ascending pressure, V varies from 0 to V_x as L varies from 0 to L_x. In the zone of decreasing pressure, V varies from V_x to V_m as L varies from L_x to L_b.

$$\frac{(P_x + 0)}{2} = \frac{0.0000339 \cdot W_b \cdot V_x^2}{L_x \cdot D_b^2} \tag{8}$$

Where

W_b = Total shot weight, grains
V_x = Velocity at point of maximum barrel pressure at propellant burnout, ft/s
P_x = Maximum barrel pressure, psi
L_x = Length of bullet or shot travel corresponding to V_x, in.
D_b = Barrel inside dia., in.

$$\frac{(P_x + P_m)}{2} = \frac{0.0000339 \cdot W_b \cdot (V_m^2 - V_x^2)}{D_b^2 \cdot (L_b - L_x)} \tag{9}$$

Where

P_m = Pressure at muzzle, psi
V_m = Muzzle velocity, ft/s
L_b = Barrel length, in.

Dividing (8) by (9) gives,

$$\frac{P_x}{(P_x + P_m)} = \frac{V_x^2}{(V_m^2 - V_x^2)} \cdot \frac{(L_b - L_x)}{L_x} \tag{10}$$

The propellant burn rate (*PBR*, grains/s) can be calculated from Equation (11)

$$PBR = \frac{6 \cdot W_p \cdot V_x}{L_x} \tag{11}$$

As noted previously, *PBR* is a function of P_x. The equations correlating these variables are:

$$PBR = 1.082 \cdot (P_x - 8,103) + 4,447 \tag{12}$$

$$R_O = 0.785 \cdot P_x \cdot D_b^2 \tag{13}$$

Where

R_o = Recoil force (lb) based on maximum barrel pressure, without considering effects of shot-barrel friction. The recoil force would be needed for the mechanical design of the shot-blasting device. ❑

least one set of data. (See box, "Performance Calculations," Equations (5), (6), (8) (10) and (11), Table 3 and Ref. [5]).

Unfortunately, the barrel length, L_b, of Table 3 was not specified, so an average barrel length of 20 in. has been assumed.

The calculated data of Table 3, namely, the muzzle velocity, V_m, and maximum barrel pressure, P_x, compared favorably with the specified values, as did the calculated barrel wall thickness, as given by Equation (2).

$$t = \frac{P_{max} \cdot D_{bo}}{(2 \cdot S_d + P_{max})} \tag{2}$$

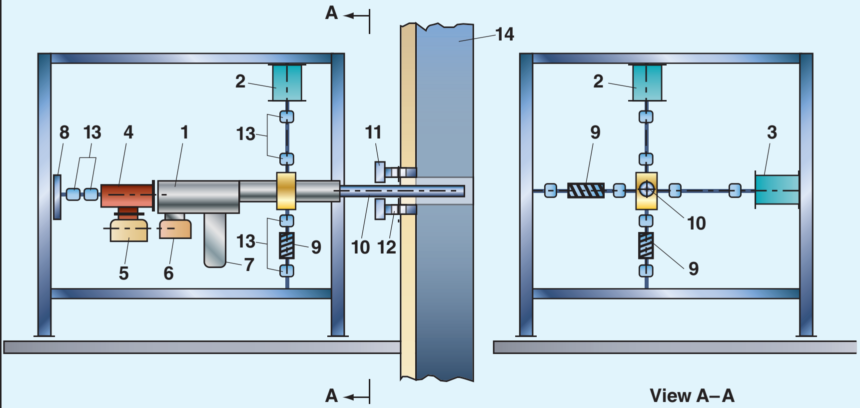
Where:

t = Barrel thickness, in.
P_{max} = Maximum pressure, psi
D_{bo} = Barrel outside dia., in.
S_d = Barrel design stress, psi

The propellant burn rates for rifles and hand guns are similar to those for shotguns (Tables 1 and 2), but the calculated data for these tables are based on W_p, W_b, L_b, D_b and V_m, in as much as peak barrel pressure data were unavailable.

As regards the data of Tables 1 and 2, there is some uncertainty, as to the

ARRANGEMENT OF EQUIPMENT



A general arrangement of the proposed shot blasting equipment is shown here. Equipment items are identified by number as follows:

1. A steel shot propulsion device consisting of a semi-automatic 12-gauge shotgun
2. A stepping motor to provide for linear movement of the gun barrel in a vertical, *y* direction
3. A stepping motor to provide for linear movement of the gun barrel in the horizontal, *x* direction
4. A hydraulic shock absorber to dissipate the recoil force generated on firing
5. A firing solenoid
6. A trigger bracket activated by the firing solenoid
7. An ammunition magazine
8. A recoil plate
9. Tension springs to prevent rotation of the of the barrel
10. Barrel
11. Barrel pivot plate
12. Cooling air ports to prevent barrel overheating
13. Universal joints to allow for free barrel movement in the *x* and *y* directions
14. Coal fired heater or boiler enclosure wall

The entire system consisting of the above components is to be sequentially controlled by means of an appropriate programmable control device. ❑

accuracy of peak barrel pressures calculated using data obtained from Table 1, Case (1), and Table 2, Cases (1), (2), and (3). These results were used to obtain the slope of the straight line plot of ln PBR versus ln P_x, which were used in extrapolating the available data of Figure 1. The uncertainty results from the lack of maximum barrel pressure data, so that a comparison could not be made between calculated and measured values of P_x. The data of Table 1, Cases (1A) and (2) and Table 2, Cases (1A), (2A) and (3A) based on Equations (5), (6), (8) and (10), are considered much more accurate, good agreement having been obtained with data from the References. A certain amount of caution must nevertheless be exercised, when these data are to be used for mechanical design purposes, such as selecting an appropriate barrel material or determining barrel wall thicknesses. Thus, if the appropriate data of Tables 1 and 2, as discussed above, are to be used for peak barrel pressure or barrel wall thickness determination, a reasonable factor of safety 1.25 or more must be applied to the values of P_x.

Similar precautions must likewise be taken in evaluating maximum allowable barrel design stresses. A multiplication factor of 1/2 applied to the ultimate tensile strength, or 2/3 applied to the yield strength of the barrel material would not appear to be unreasonable.

Basis for the equations

The objective of the calculation procedure described above is the numerical evaluation of all pertinent firearm operating variables. Four operating variables are used as a basis for the design: W_b, W_p, L_b and D_b.

Note that there are a total of 11 variables of interest, as regards to

TABLE 4. COVERAGE OF HEATING SURFACE ELEMENTS BY STEEL AND LEAD SHOT		
Shot Material	**Steel**	**Lead**
Shot diameter, in.	1/16	1/16
Distance, muzzle to target, ft.	50	20
Shot muzzle velocity, ft/s	1,200	1,200
Shot velocity at target, ft/s	1,170	1,165
Shot spacing at target impact, in.	0.56	0.28
Shot pattern diameter, ft.	2.0	1.0
Shot surroundings	Flue-gas	Air
Temperature of surroundings, °F	2,000	60

the performance of the shot-blasting equipment; V_m, V_x, P_x, P_m, L_x, D_b, L_b, W_p, W_b, *PBR*, and R_o. The unknown variables and known variables must therefore equal 11. Furthermore, there are a total of seven independent Equations (4), (6), (8), (10), (11), (13), and the straight line defined by the plot of ln *PBR* versus ln P_x. The total number of unknown variables must not, of course, exceed the total number of equations if the unknown variables are to be evaluated.

At first, the solution does not appear feasible since, in some cases, only five independent defining equations are available. As seen in Table 1 and 2, however, a fifth variable, V_m, is usually provided in addition to the four above. These data are readily available from such sources as hand loading books and magazines, and allow for full evaluation of all pertinent operating variables, including *PBR*, P_x, and R_o, as well as the straight line relationship between ln *PBR* and ln P_x.

The value of P_x obtained from Figure 1, as a function of *PBR*, is somewhat different than would be predicted using the equations derived in this article. However, the slope of the original straight line relationship between ln *PBR* and ln P_x, is used in conjunction with the equations presented here, the four data points defined above, and at least one additional data point providing for a value for P_x. With these data and a straight line constructed parallel to the straight line obtained using the data of Tables 1 and 2, it is possible to obtain performance data for any combination of the four variables referred to above.

However, the point-slope calculation method should be used only if absolutely necessary. The preferred calculation method is one wherein at least two base data points, based on the same propellant, are made available, so as to ensure that a proper slope is obtained for the log-log plot, thereby lending confidence to the calculation and extrapolation of data points lying inside and outside of the base points, and for other cases involving a different set of variables, but using the same propellant.

Data for the design

Performance data used as a design basis for an automated shot blasting system for coal-fired process heater or boiler are summarized in Table 4. The calculated data are based on the use of conventional shotgun ammunition, loaded with steel instead of lead shot. Use of steel instead of lead shot is preferred in this application in order to avoid potential heating-surface damage and lead emissions that might otherwise be carried into the atmosphere by the fluegas effluent.

The data for lead shot are based on field observations using conventional ammunition. The calculation methods used to determine performance with this ammunition were found to very nearly duplicate the field observed shot pattern size. The same methods were therefore used to calculate performance data for steel shot, which is required to pass through hot fluegas instead of relatively cool air surroundings.

Modified conventional semi-automatic 12-gauge shot guns should be used in an automated blasting system in much the same way as soot-blowers are presently used. A major difference, in the case of the blasting system, however, is the need for positioning the blasting gun at an angle, both horizontally and vertically, at which a gun must be fired in order to achieve full coverage of the available heating surfaces. This is to be accomplished automatically, at each blasting station, by means of two linear-step movement motors, one for horizontal movement in the *x* direction and one for vertical movement in the *y* direction. For the case in point, wherein each firing covers an area of about 2 ft in dia., there would be a 4 × 4 firing grid comprising a total of 16 firing positions having 16 (*x, y*) coordinates and covering a total area of 64 ft^2. If operating experience were to indicate that all of the firing positions available were not necessarily needed, an appropriate set of coordinates could be chosen as input to the sequencing control device to be provided, and positioning and firing would only occur at the chosen coordinates. ■

Edited by Gerald Ondrey

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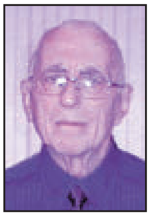

Alan Cross (73-34 244th St., Little Neck, NY, 11362; E-Mail: Across8588@aol.com) is a B.S.Ch.E. graduate from The City College of N.Y. and an M.S.Ch,E. graduate from the Polytechnic University of N.Y., and has had more than 30 years of fired heater design experience with ABB Lummus Heat Transfer (now CB&I Lummus Technology). Accomplishments include authorship of direct-fired heater patents and patents pending, relating to the design of coal fired heaters, and compact, low-cost fired heaters capable of processing low- and high-boiling-point petroleum-based fluids, using design strategies that reduce fouling of internal tube surfaces due to coke deposition, and the design of direct-fired heaters using particulate matter as a heat transfer medium.

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BUSINESS NEWS

PLANT WATCH

PET resin capacity expands in Saudi Arabia

June 15, 2009 — Uhde Inventa-Fischer GmbH (Berlin, Germany) has entered into a contract with the Saudi Basic Industries Corp. (SABIC) to provide the technology license and the basic engineering for the second PET (polyethylene terephthalate) resin expansion of its manufacturing affiliate, Arabian Industrial Fiber Co. (Ibn Rushd) at its site in Yanbu, Saudi Arabia. The plant will have a capacity of 420,000 ton/yr.

BASF to close Styropor plant at Tarragona

June 12, 2009 — BASF SE (Ludwigshafen, Germany) will shut down the Styropor plant (EPS, expandable polystyrene) at its site in Tarragona, Spain. The closure is scheduled for August 2009. The Styropor plant has become uneconomical due to its relatively small production capacity, which has resulted in an unfavorable cost-structure.

Uhde wins major polymer contract in Qatar

June 8, 2009 — Qatar Petrochemical Co. (QAPCO), a subsidiary of Industries Qatar and Total Petrochemicals of France has awarded Uhde GmbH (Dortmund, Germany) a contract to build a 300,000 metric ton per year (m.t./yr) low-density polyethylene (LDPE) plant within the scope of its LDPE-3 project. The plant will be based on the Lupotech T technology licensed by LyondellBasell. The plant, planned to be completed in December 2011, will be integrated into the polyethylene production area inside QAPCO's petrochemical complex in Mesaieed.

Endress+Hauser expands its production in Indiana

June 4, 2009 — Endress+Hauser (Reinach, Switzerland) inaugurated a new production facility at its Greenwood, Ind. site. The more than $18-million investment brings a facility dedicated to manufacturing and calibrating electromagnetic flowmeters. The facility houses the largest calibration rig in the U.S. for electromagnetic flowmeters as well as the most accurate calibration laboratory for Coriolis meters, according to the company.

A new hydrogen plant to be built in the Ukraine

May 29, 2009 — Caloric Anlagenbau GmbH (Gräfelfing, Germany) has won a contract to supply a hydrogen plant in the Ukraine based on Caloric's steam-methane-reforming technology. The H_2 production plant will be shipped by mid 2010 and will produce 2,000 Nm^3/h of H_2.

Hemlock Semiconductor Group brings new polysilicon capacity online

May 28, 2009 —The Hemlock Semiconductor Group (Hemlock, Mich.), which includes two Dow Corning joint ventures, has commenced operation of a new 8,500 m.t./yr polycrystalline silicon (polysilicon) production facility at its Hemlock, Mich. location. This new capacity represents the completion of the first phase of a $1-billion expansion at the site. The second phase of expansion will come online in 2010 and, together with the first phase, will increase the total capacity to approximately 36,000 m.t./yr. Later this year, Hemlock Semiconductor Group will also begin construction of a new polysilicon manufacturing facility in Clarksville, Tenn., which is scheduled to be operational in 2012.

Wacker Schott Solar expands silicon-crystal production capacity in Jena

May 27, 2009 — Wacker Schott Solar GmbH, a joint venture between Wacker Chemie AG (Munich) and Schott Solar AG (Alzenau, both Germany), has commissioned a new building in Jena, Germany, which will be used to produce solar-grade silicon crystals. Overall capacity should reach 275 MW by the end of this year. The company intends to gradually expand its manufacturing capacity to 1 GW by 2012. Investments of over €300 million are planned for the Jena site.

MERGERS AND ACQUISITIONS

Holly Corp. acquires Sunoco Tulsa refinery

June 9, 2009 — Holly Corp. (Dallas, Tex.) has completed its $65-million acquisition of the Sunoco Tulsa, Okla. refinery. The Tulsa facility, which will now operate as Holly Refining & Marketing – Tulsa, LLC, a wholly owned subsidiary of Holly Corp., is a major producer of base stocks, process and specialty oils, and wax. The refinery is capable of processing about 85,000 bbl/d of oil.

Lanxess acquires two companies in Asia

June 8, 2009 — Lanxess AG (Leverkusen, Germany) is underpinning its longterm growth strategy with two acquisitions in Asia. Lanxess subsidiary, Lanxess India Private Ltd., will acquire the chemical businesses and assets of Indian company Gwalior Chemical Industries Ltd. for €82.4-million, including debt. The transaction is subject to formal approval by Gwalior's shareholders and clearance by the relevant antitrust authorities. Lanxess will also acquire the business and production assets of Chinese-based Jiangsu Polyols Chemical Co. Parties have agreed not to disclose the purchase price. Closings of both transactions are expected in the 3rd Q of 2009.

Strategic partnership for MEMS-based products

June 8, 2009 — Endress+Hauser Flowtec AG (Reinach, Switzerland) and Integrated Sensing Systems, Inc. (ISSYS; Ann Arbor, Mich.) have announced a strategic partnership. The objective of this agreement is to collaboratively develop and commercialize advanced sensing products based on ISSYS' MEMS (Micro-Electro-Mechanical Systems) technology. Targeted markets include both the traditional industrial process industries as well as emerging process and original equipment manufacturing applications.

DSM acquires Biopract to enter biogas market

June 3, 2009 — Royal DSM N.V. (Heerlen, Netherlands) has acquired privately held Biopract GmbH (Berlin, Germany). The acquisition will serve as an entry point for DSM into the growing biogas market. The acquisition has been finalized and both parties agreed not to disclose financial details.

AkzoNobel to sell stake in Pakistan PTA activities

May 29, 2009 — AkzoNobel (Amsterdam) has agreed to divest its 75% stake in the pure terephthalic acid (PTA) activities of its Chemicals Pakistan business to Korean company KP Chemical Corp. (KPC). AkzoNobel acquired the holding in Pakistan PTA Ltd. in 2008 as part of the acquisition of ICI. The transaction is expected to be completed in the 4th Q of 2009. Financial details were not disclosed.

Mitsubishi Rayon completes its acquisition of Lucite International

May 29, 2009 — Mitsubishi Rayon Co., (Tokyo) has completed its purchase of Lucite International Group Ltd. of the U.K. The total acquisition cost was approximately $1.6 billion. Mitsubishi Rayon will become the sole possessor of the world's three main technologies for MMA monomer. ■

Dorothy Lozowski

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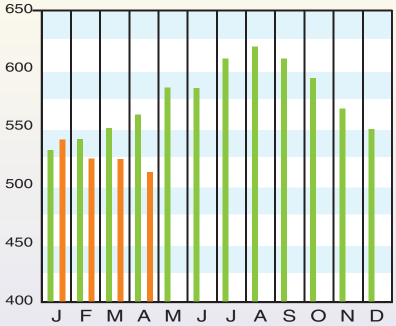
***CE* Index**	511.8	522.6	560.9
Equipment	600.5	616.6	676.7
Heat exchangers & tanks	534.3	563.2	660.0
Process machinery	585.0	597.3	628.0
Pipe, valves & fittings	752.5	761.0	804.7
Process instruments	390.1	385.1	437.7
Pumps & compressors	897.5	898.0	860.2
Electrical equipment	460.2	459.6	451.6
Structural supports & misc	609.0	636.1	720.4
Construction labor	326.9	325.7	317.8
Buildings	488.0	494.9	492.4
Engineering & supervision	348.5	349.0	354.3

Annual Index:

2001 = 394.3
2002 = 395.6
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4



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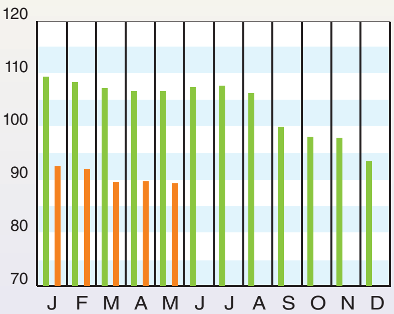
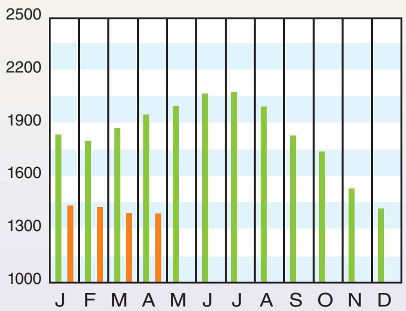
CPI output index (2000 = 100)	May. '09	=	89.3	Apr. '09	=	89.7	Mar. '09	=	89.6	May. '08	=	106.7
CPI value of output, $ billions	Apr. '09	=	1,392.2	Mar. '09	=	1,394.7	Feb. '09	=	1,430.2	Apr. '08	=	1,953.0
CPI operating rate, %	May. '09	=	65.2	Apr. '09	=	65.4	Mar. '09	=	65.3	May. '08	=	78.3
Producer prices, industrial chemicals (1982 = 100)	May. '09	=	218.8	Apr. '09	=	218.3	Mar. '09	=	224.0	May. '08	=	285.6
Industrial Production in Manufacturing (2002=100)*	May. '09	=	94.4	Apr. '09	=	95.4	Mar. '09	=	96.0	May. '08	=	111.5
Hourly earnings index, chemical & allied products (1992 = 100)	May. '09	=	146.6	Apr. '09	=	146.1	Mar. '09	=	145.5	May. '08	=	141.1
Productivity index, chemicals & allied products (1992 = 100)	May. '09	=	131.0	Apr. '09	=	129.7	Mar. '09	=	128.0	May. '08	=	133.7

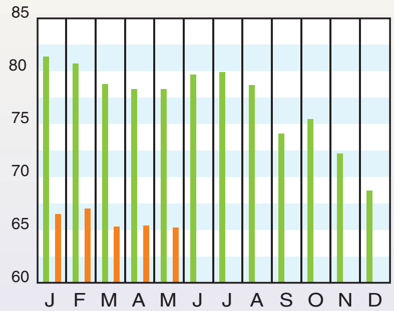
CPI OUTPUT INDEX (2000 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



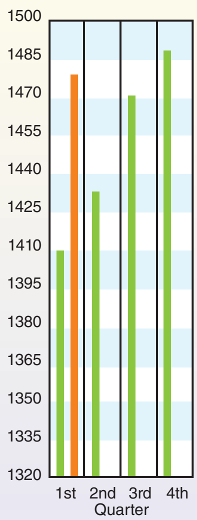
*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
Current business indicators provided by Global insight, Inc., Lexington, Mass.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	1st Q 2009	4th Q 2008	3rd Q 2008	2nd Q 2008	1st Q 2008
M & S INDEX	1,477.7	1,487.2	1,469.5	1,431.7	1,408.6
Process industries, average	1,553.2	1,561.2	1,538.2	1,491.7	1,463.2
Cement	1,551.1	1,553.4	1,522.2	1,473.5	1,448.1
Chemicals	1,523.8	1,533.7	1,511.5	1,464.8	1,438.5
Clay products	1,526.4	1,524.4	1,495.6	1,453.5	1,429.1
Glass	1,439.8	1,448.1	1,432.4	1,385.1	1,359.7
Paint	1,554.1	1,564.2	1,543.9	1,494.8	1,467.6
Paper	1,453.3	1,462.9	1,443.1	1,400.0	1,377.7
Petroleum products	1,663.6	1,668.9	1,644.4	1,594.4	1,555.8
Rubber	1,600.3	1,604.6	1,575.6	1,537.5	1,512.3
Related industries					
Electrical power	1,425.0	1,454.2	1,454.4	1,412.8	1,380.4
Mining, milling	1,573.0	1,567.5	1,546.2	1,498.9	1,473.3
Refrigeration	1,807.3	1,818.1	1,793.1	1,741.4	1,711.9
Steam power	1,509.3	1,521.9	1,499.3	1,453.2	1,426.8

Annual Index:

2001 = 1,093.9	**2003 = 1,123.6**	**2005 = 1,244.5**	**2007 = 1,373.3**
2002 = 1,104.2	**2004 = 1,178.5**	**2006 = 1,302.3**	**2008 = 1,449.3**



CURRENT TRENDS

Significant month-over-month declines returned in April equipment prices, but preliminary estimates for the May CEPCI (out next month) show that capital equipment prices declined only slightly from those of the previous month. Meanwhile, after edging up slightly in April, the operating rate was down by 0.2% in May, hovering around what many consider to be the bottom of the recent over-capacity correction.

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

Circle 02 on p. 54 or go to adlinks.che.com/23016-02