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January 2012

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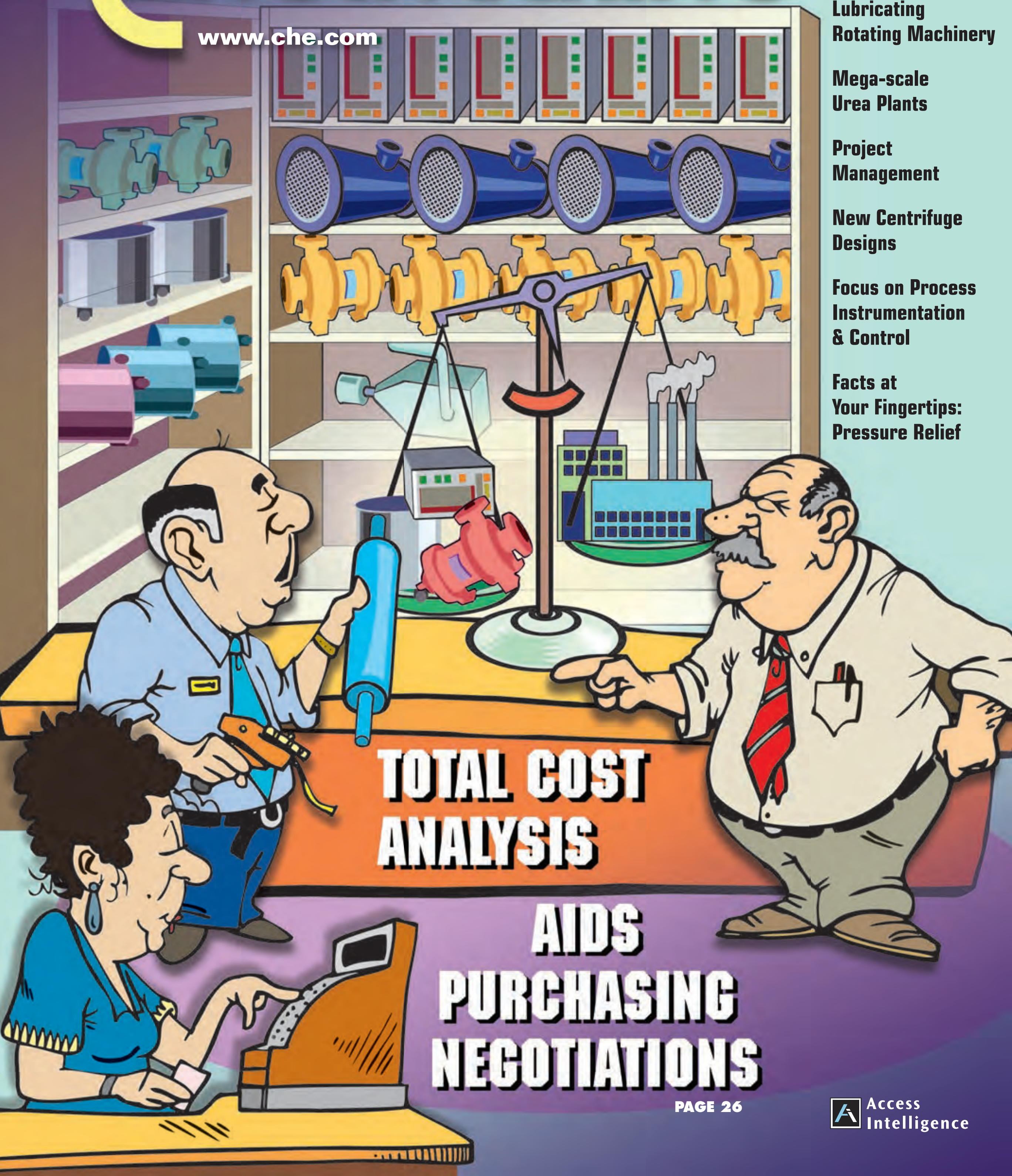

TOTAL COST ANALYSIS AIDS PURCHASING NEGOTIATIONS

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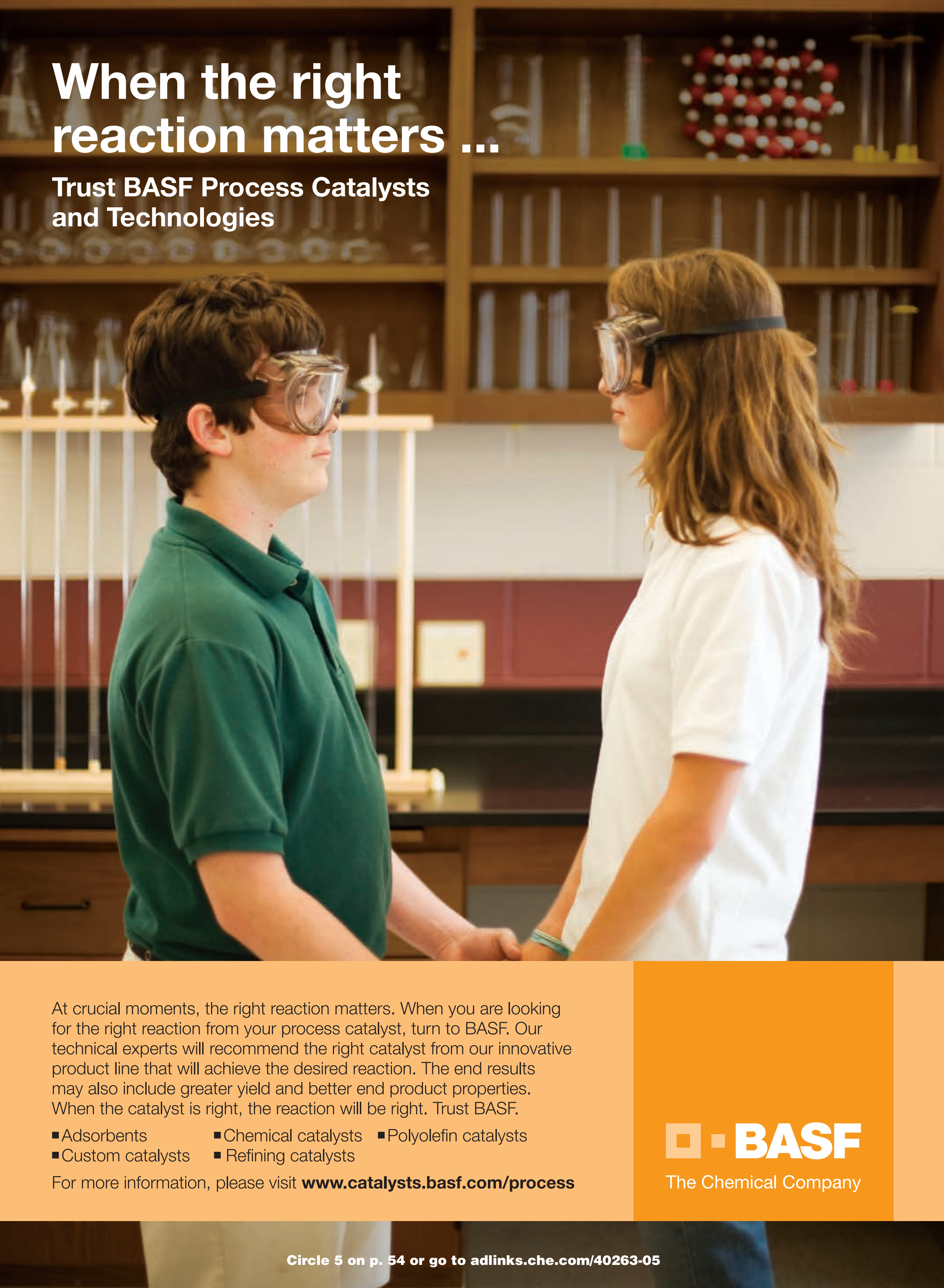
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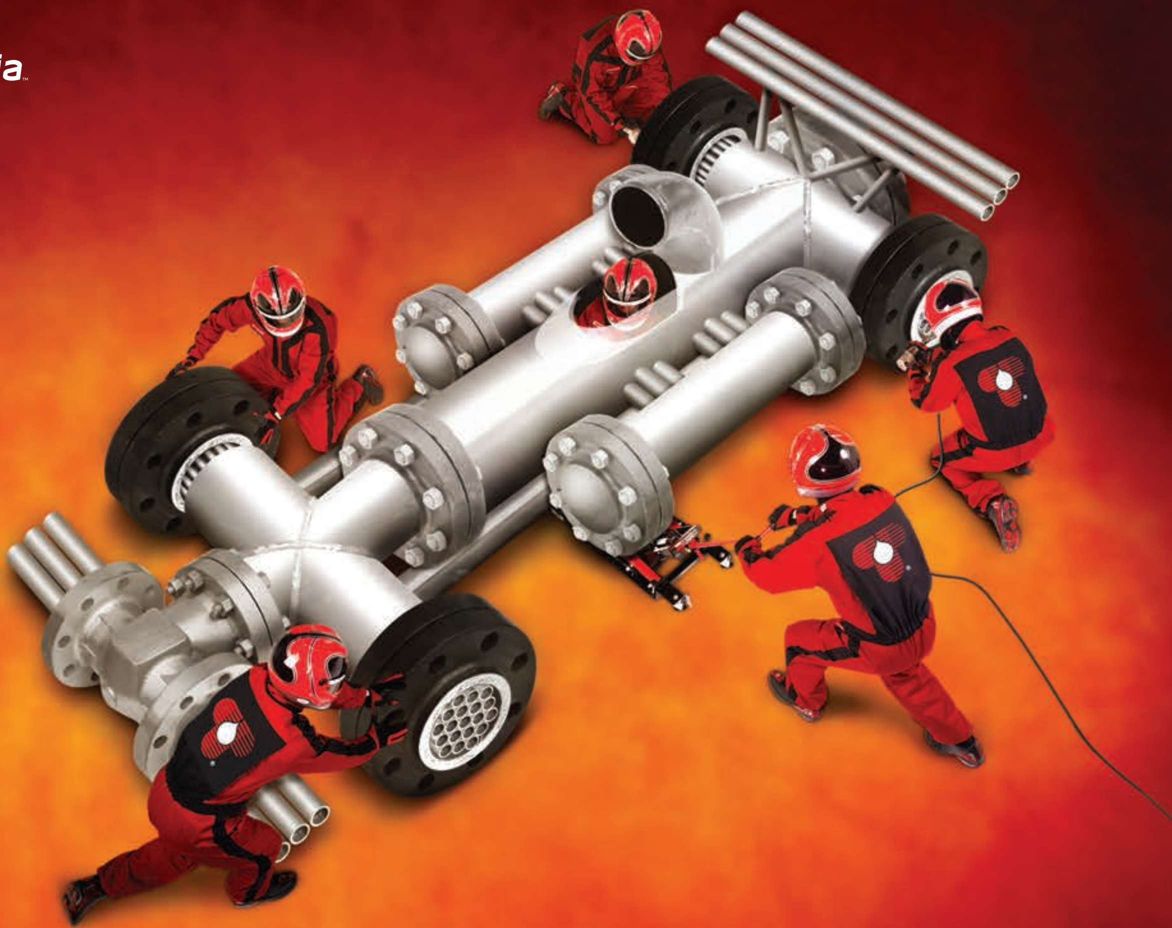

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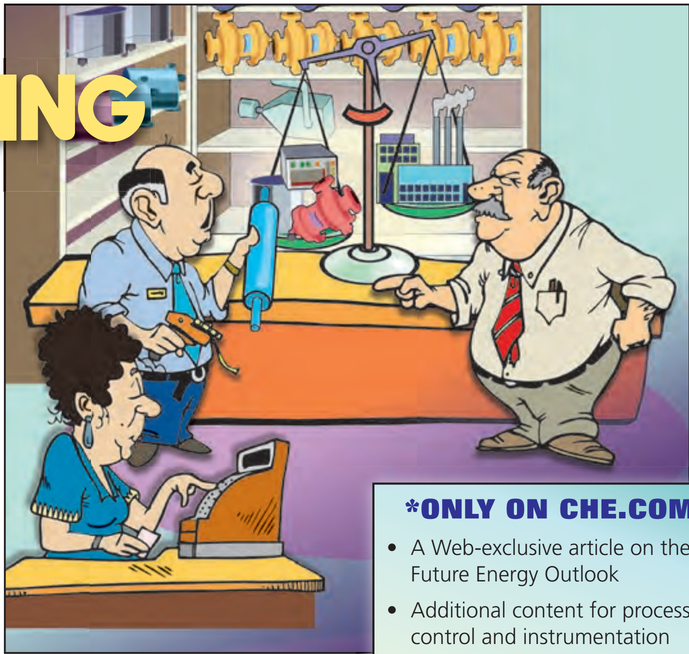

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Editor's Page

The game changer for 2012

As we round the corner from 2011 to 2012, economists are painting dimming pictures for global economic recovery. For instance, a report from IHS (Lexington, Mass.; www.ihs.com) chief economist Nariman Behravesh says, "World growth will slow in 2012 — the only question is how much." Meanwhile, Kevin Swift, chief economist at the American Chemistry Council (ACC; Washington, D.C.; www.americanchemistry.com) puts it this way, "The recovery from the worst recession since the Great Depression has stalled."

The reasons for the expected slowdown are higher energy prices, the disasters in Japan, the Eurozone crisis, the slowdown in China and the influence of other negative factors, ACC says.

So, while it might seem unlikely that one of the bright spots in economic analysis would fall on capital spending in the chemical process industries (CPI) — particularly in the U.S. — that is precisely what experts at ACC are forecasting. The basis for their prediction is their belief that the investment cycle has reengaged, and their confidence is fueled (at least figuratively, if not literally) by shale gas.

As ACC explains in its Year-End 2011 Situation & Outlook, capital spending cycles generally lag cycles of industrial activity, with profits and operating rates being the leading determinants of spending. So, looking back on 2010 and 2011, improved production and utilization rates, cost containment from earlier cost reduction efforts, low feedstock costs and other raw-material costs (compared to Europe and Northeast Asia) and higher selling prices resulted in a strong recovery of profits. Add that to the new dynamics from shale gas, and there is a possibility that the current upcycle in profits will last longer than recent cyclical upswings, ACC says.

The bottom line is that with improving operating rates and profit margins, and a low cost of capital, increases in new plant and equipment investments in the U.S. are forthcoming. The need to replace existing capital is apparent and will be a driver, ACC says. ACC economists also believe that the industry investment cycle has likely reengaged, and therefore forecast that capital spending in the U.S. CPI will rise 7.3% in 2012 to $31.5 billion, surpassing the most recent peak. Sustaining capital (capital that is required to maintain operations at existing levels) will support investment in the U.S., with the largest proportion of capital spending allocated toward replacement of worn-out plant equipment.

As a recovery strengthens into an expansion in future years, ACC expects that replacement spending will make way for increased spending in capacity additions. Already, with improving competitiveness resulting from developments in shale gas, a reevaluation of the U.S. as a favorable location for investment is occurring. As ACC points out in its report, a number of projects have been announced and discussed, and the dynamics for sustained capital investment are in place.

Strong gains in capital spending by the U.S. CPI are thus expected during the next several years, the result of new investment in petrochemicals and derivatives arising from shale gas developments. In other words, ACC says that "After years of high, volatile natural-gas pries, the new economics of shale gas are a 'game changer', creating a competitive advantage for U.S. manufacturers, leading to greater investment and industry growth."

Look for more on the technical aspects of processing shale gas and its implications for the chemical engineering profession in next month's news feature. ■

Rebekkah Marshall

Letters

Excellent simulation article

I thought the December article "Simulation spreads its wings" was very timely with respect to competitive conditions currently being experienced in U.S. Industrial Markets. With competitive pressures continually driving industry to find improvements in cost effectiveness, next generation tools are needed to meet these challenges. A common obstacle in many manufacturing processes is the lack of ability to effectively quantify the important metrics of a particular process, and thus its efficiency, and ultimately its cost effectiveness. This, in turn, often makes prediction of operational performance something of a trial-and-error process. The U.S. economy currently is not very forgiving for the error part of this approach. The article was quite informative as to the prevalence and acceptance, across many applications, of the modern tools for mathematical process control. And more importantly, the article explains how the new frontier in the advancement of these tools lies in the delivery of simulation modeling from the engineering design community to the operating level arena. Refinery Water Engineering & Associates clearly observes these trends in its work with wastewater treatment process-simulation modeling.

David Kujawski, vice president
Refinery Water Engineering & Associates

Input sought on interesting ChEs

The Chemical Engineer (*tce*) for the past two years has run a series of articles in which it profiles some of the most interesting chemical engineers. At the end of the year *tce* invites members of the global chemical engineering community to cast their vote for who was the most influential featured that year. The votes for the 2011 season will be open until January 9, 2012. The shortlisted entries this year are as follows:

- Yoshio Nishi (lithium-ion batteries)
- Nicholas Leblanc (soda production)
- Victor Mills (disposable diapers)
- Wilbert and Robert Gore (outdoor fabrics)
- Arthur D. Little (unit operations)
- Charles E. Howard and Norbert Rillieux (vacuum evaporation and multi-effect evaporators)
- Tomio Wada (LCD screens)
- Vladimir Haensel (platforming process)
- Reginald Gibson, Eric Fawcett, Michael Perrin and Dermot Manning (polyethylene)

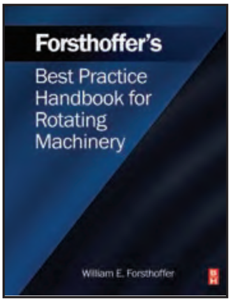
A summary of each entry with links to the full article is available at www.tcetoday.com/changedtheworld. Votes are being collected here: https://www.surveymonkey.com/s/changedtheworld2011

Postscripts, corrections

December, Simulation spreads its wings: on pp. 24 and 27 the name of Scott Thibault, vice president of sales and marketing for CPFD Software, is misspelled; also on p. 25 the website for Bryan Research & Engineering should be www.bre.com, not ber.com.

Bookshelf

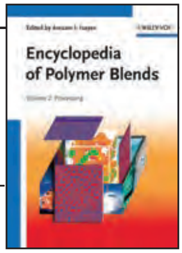
Forsthoffer's Best Practice Handbook for Rotating Machinery. By William Forsthoffer. Elsevier Inc., 30 Corporate Drive, 4th floor, Burlington, MA. Web: elsevierdirect.com. 2011. 672 pages. $295.00.



Update on Silica-based Mesoporous Materials for Biomedical Applications. By Luigi Pasqua. iSmithers Rapra Publishing., Shawbury, Shrewsbury, Shropshire, SY4 4NR, U.K. Web: ismithers.net. 2011. 182 pages. $130.00.

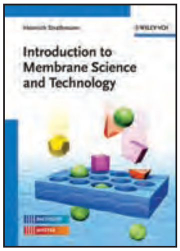
Up and Running with AutoCAD 2012: 2D and 3D Drawing and Modeling. 2nd ed. By Elliot Gindis. Elsevier Inc., 30 Corporate Drive, 4th floor, Burlington, MA. Web: elsevierdirect.com. 2011. 754 pages. $79.95.

Encyclopedia of Polymer Blends, vol. 2: Processing. Edited by Avraam I. Isayev and Sanjay Palsule. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ. Web: wiley.com. 2011. 422 pages. $195.00.

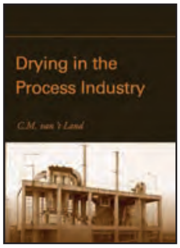


Metal Fatigue Analysis Handbook. By Yung-Li Lee, Mark Barkey and Hong-Tae Kang. Elsevier Inc., 30 Corporate Drive, 4th floor, Burlington, MA. Web: elsevierdirect.com. 2011. 632 pages. $125.00.

Introduction to Membrane Science and Technology. By Heinrich Strathmann. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ. Web: wiley.com. 2011. 544 pages. $105.00.



Drying in the Process Industry. By C.M. van't Land. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ. Web: wiley.com. 2011. 400 pages. $115.00.



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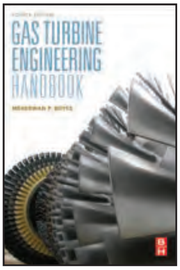
Analysis of Transport Phenomena. By William M. Deen. Oxford University Press USA, 198 Madison Ave., New York, NY 10016. Web: oup.com. 2011. 688 pages. $139.00.



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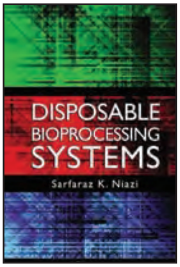
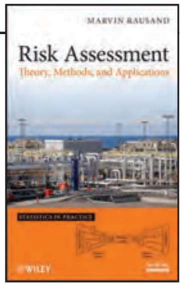


Disposable Bioprocessing Systems. By Sarfaraz K. Niazi. CRC Press Taylor and Francis Group, 6000 NW Broken Sound Parkway, Suite 300, Boca Raton, FL 33487. Web: taylorandfrancis.com. 2011. 322 pages. $149.95.

Quantitative Process Control Theory (Automation and Control Engineering). By Weidong Zhang. CRC Press Inc., 6000 NW Broken Sound Parkway, Suite 300, Boca Raton, FL 33487. Web: taylorandfrancis.com. 2011. 473 pages. $109.95.



Risk Assessment: Theory, Methods and Applications. By Marvin Rausand. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ. Web: wiley.com. 2011. 664 pages. $125.00.

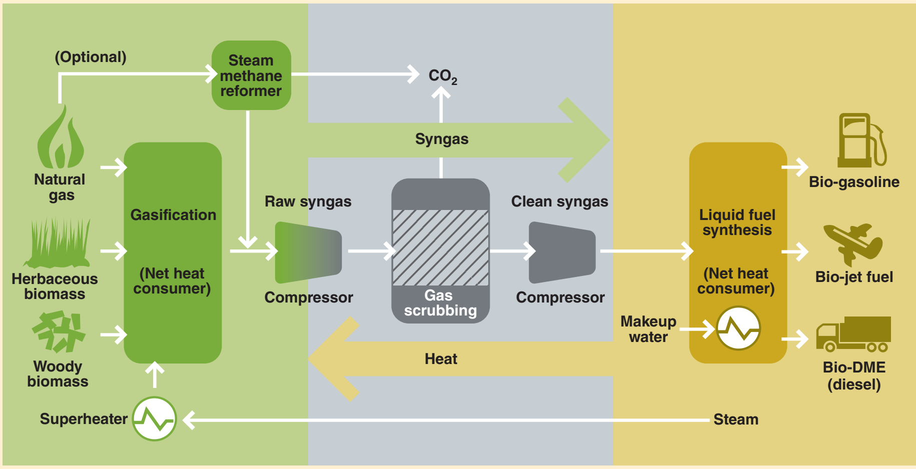
Principles and Case Studies of Simultaneous Design. By William L. Luyben. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ. Web: wiley.com. 2011. 344 pages. $149.95.

Nanocoatings and Ultra-thin films. Edited by Abel Salam Hamdy Makhlouf and Ion Tiginyanu. Woodhead Publishing Ltd., 80 High Street, Sawston, Cambridge, CB22 3HJ, U.K. Web: woodheadpublishing.com. 2011. 448 pages. $255.00.

Predictive Control in Process Engineering: From the Basics to the Applications. By Robert Haber, Ruth Bars and Ulrich Schmitz. John Wiley & Sons Inc., 111 River Street, Hoboken, NJ. Web: wiley.com. 2011. 629 pages. $190.00. ■

Scott Jenkins

Demo plant for high-yield biomass-to-gasoline process under construction



Construction of a demonstration plant has begun for a biomass-to-gasoline process that boosts biomass conversion efficiency in producing bio-gasoline. The demonstration, to be located at the Hillsborough, N.J. headquarters of Primus Green Energy (www.primusge.com), is slated for completion in the middle of 2012.

Primus recently announced the successful pilot-scale operation of its gasification and liquid-fuels-synthesis process (diagram), which converts pelletized biomass into hydrogen-rich synthesis gas (syngas), with ash as a byproduct. As feedstock, dry woodchip waste or miscanthus, a bioenergy crop that grows on marginal land at high biomass-per-acre rates, is used.

The Primus gasifier uses superheated steam at elevated pressures to produce a raw syngas with low tar content. The syngas is further treated to yield a product with a H_2-to-CO ratio of about 2.2, explains Primus vice president of business development George Boyajian. In addition, the process allows conversion efficiencies of 33%, Boyajian points out, a level close to the theoretical maximum. The process can generate 110 gal of gasoline per ton of dry biomass.

After a scrubbing stage that removes CO_2, the syngas passes into a catalytic liquid-fuel synthesis system, where 93-octane gasoline is formed. The fuel-synthesis stage is a proprietary variant of the ExxonMobil methanol-to-gasoline process (1972). In Primus' patent-pending variant, methanol is not separated, and a final hydrogenation step produces a light gasoline that is nearly free of durene (1,2,4,5-tetramethylbenzene).

Compared to petroleum-derived gasoline, Primus Green Energy's drop-in fuel has higher octane and aromatics contents, and can be used in an automobile engine without modification. Primus bio-gasoline can be produced profitably with crude oil prices in the range of $64/bbl, Boyajian notes.

The company plans an expandable, commercial-scale facility in Pennsylvania (to be completed in Q1 2014) that will convert 444,000 tons of biomass into 4.8 million gal of gasoline annually. The Primus fuels-synthesis process can be modified to generate other chemicals, such as paraffins, olefins and jet fuel.

Modeling algorithm adjustment can improve equipment sizing

The Brinkman method is one of several approaches used to predict the effective viscosity of oil-water mixtures, and is effective in simulations when one or the other phase is dominant. However, a significant level of uncertainty exists in mixtures where the oil and water levels are comparable. Engineers from software developer AspenTech (Burlington, Mass.; www.aspentech.com) have applied a proprietary adjustment to the Brinkman equations that improves predictions of effective viscosity in oil-water mixtures near the inversion point (when the dominant phase switches), and when high-viscosity oils are involved.

The improved predictive tool enables engineers to more accurately size equipment, which can reduce capital costs and increase safety. Steve Noe, AspenTech manager of industry marketing, explains that when uncertainty exists in predictions of two-phase behavior, process engineers tend to overdesign, using the viscosity of the oil phase to specify equipment conservatively, when, in fact, the larger-sized

(Continues on p. 11)

New cellulase enzyme

Last month, Codexis, Inc. (Redwood City, Calif.; www.codexis.com) introduced the CodeXyme Cellulase enzyme product line for converting biomass to sugar. The company is in its final stages of customizing the enzymes with currrent partners, and plans to have commercial samples available in the second half of this year.

Microbial control

Dow Microbial Control (www.dowmicrobialcontrol.com), a business group of The Dow Chemical Company (Midland, Mich.; www.dow.com) launched Bioban 551S, a new generation of in-can preservatives based on the company's new antimicrobial active ingredient MBIT [2-methyl-1,2-benzisothiazol-3(2H)-one]. Bioban 551S is a water-based, solvent-free solution that can be used for preserving paint and latex. It has "excellent" chemical and thermal stability, does not release formaldehyde and its active ingredients do not contain organohalogens or heavy metals, says the manufacturer.

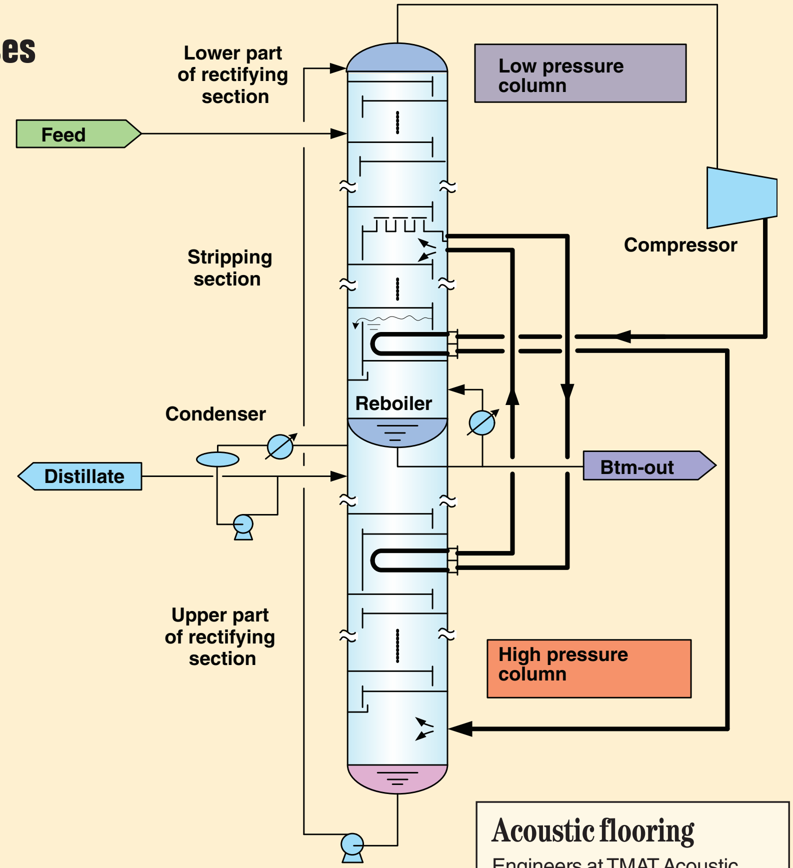
Note: For more information, circle the 3-digit number on p. 54, or use the website designation.

This distillation column promises substantial energy reductions

A new distillation system capable of reducing energy consumption by up to 50% compared to conventional columns has been developed by Toyo Engineering Corp. (Toyo; Chiba, www.toyo-eng.co.jp), in collaboration with the National Institute of Advanced Industrial Science and Technology (AIST; Tokyo; www.aist.go.jp). Toyo has an exclusive license for the process, tradenamed SuperHIDiC, and plans to use the technology in petroleum refining, petrochemicals and fine-chemicals production plants.

SuperHIDiC is based on the Heat Integrated Distillation Column (HIDiC), which Toyo has further developed to improve the performance and overcome difficulties associated with "conventional" HIDiCs. SuperHIDiC has a much simpler mechanical configuration, but can achieve a comparable or better energy-saving performance as previous HIDiCs, says Toyo.

The new system (diagram) divides the distillation column into two sections of rectifying and stripping, with heat exchange performed at the middle part of each section. A thermo-siphon system was adopted for recycling the mixture without using pumping operation. A compressor is used to raise the pressure and temperature within the column, and the combination of side heat exchange and heat-pumping is said to reduce the energy consumption in half.



Toyo says that, in addition to energy savings, the SuperHIDiC is easier to maintain and can be used for a wider range of applications compared to existing HIDiC systems.

First inline, direct measurement of wall shear

To date, determination of the shear forces exerted on vessel walls by moving fluids has required inferring the value from other measurements. Now Lenterra Inc. (Newark, N.J.; www.lenterra.com) has introduced the first instrument capable of direct measurement of wall-shear forces without process flow interruption. The instrument, known as the RealShear sensor, also allows operators to measure fluid viscosity changes in a mixing process using known parameters.

The Lenterra sensor depends on a floating element that is installed flush to the vessel wall, and an attached cantilever beam that deflects in response to shear stress as fluid flows across its surface. The cantilever transmits the shear force to a fiber-optic microresonator, which has its resonance centered at a particular light wavelength. Shear stress felt by the cantilever places strain on the optical resonator, which causes a shift in the resonant wavelength. The shift is proportional to the shear stress.

Because the RealShear sensors are optically based, they are unaffected by electromagnetic interference and are explosion-safe. They offer measurement rates in the kilohertz range, and can have the sensitivity to measure forces from a fraction of one pascal to millions of pascals. The sensors also have the ability to operate at high temperatures — up to 1,000°C is possible, the company says. RealShear sensors could be especially useful in foods, cosmetics, chemical and pharmaceutical processes where a viscosity change needs to be monitored during processing, as well as in other industries, such as oil and gas transportation and water treatment plants.

Acoustic flooring

Engineers at TMAT Acoustic Technologies (Derbyshire, U.K.; www.tmatuk.com) have developed a process for making polyurethane acoustic insulation for flooring in vehicles and machinery. Using a proprietary catalyst, along with an improved mold design, the TMAT process controls polymer viscosity tightly, which allows for production of a castable honeycomb structure with high definition and physical integrity. The result is a lighter and less expensive material made from liquid elastomer that has the same sound-dampening properties as rubber alternatives.

Lightweight parts

Teijin Ltd. (Tokyo, Japan; www.teijin.co.jp) is building what is said to be the world's first pilot plant for fully integrated production of carbon-fiber-reinforced thermoplastic (CFRTP) components from carbon fiber. The new plant, located at the company's Matsuyama Factory in Ehime Prefecture, Japan, will use Teijin's mass-production technology

(*Continues on p. 12*)

This gold catalyst takes the crown for high activity and selectivity

Gold catalysts have been shown to have superior activities for oxidation reactions, especially at low temperature, compared to other metal-based catalysts. But the high price of gold makes it necessary to develop Au catalysts with ever-higher activities, reducing the amount of Au needed. A promising step in this direction is a new type of catalyst developed by Professor Naoki Toshima and his research group at the Tokyo University of Science, Yamaguchi (Yamaguchi, Japan; www.ed.yama.tus.ac.jp/toshima), with support from Japan's Science and Technology Agency.

The catalyst is a nano-cluster of gold and palladium with a crown-jewel (CJ) structure (CJ-Au/Pd NC). The group has developed a very simple procedure for synthesizing the CJ-Au/Pd NC in which reactive Pd atoms at the corners of the nanocluster are replaced by Au atoms. A nanocluster (1.8-nm dia.) with 135 Pd atoms and 12 Au atoms was produced, and the Au atoms arranged at the special positions that result in extremely high catalyst activities.

As a test reaction, the researchers studied the oxidation of glucose into gluconic acid — a widely used food additive. The CJ-Au/Pd NC was shown to have an activity 3.8 and 3.1 times higher than existing Pd and Au clusters, and the selectivity for gluconic acid was 100%.

The group believes the new catalyst can lead to a more economical route to gluconic acid, which is now produced by the fermentation of glucose — a process that also generates side products that must then be separated. And the simple process for producing the CJ-Au/Pd NC catalyst with strategically positioned Au atoms is also said to be easily scaled up for industrial applications. The amount of gold needed is one fourth that used by the best reported catalyst so far.

Equipment Sizing

(*Continued from p. 9*)

equipment may be unnecessary. "Gross overdesigns can drive up capital costs, and negatively affect ROI [return on investment], whereas, conversely, underdesigning can introduce process risk," Noe says.

This proprietary adjustment to the predictive algorithms was devised in a collaboration between Jim McNaught of TÜV Süd NEL Ltd. (Glasgow, U.K.; www.tuvnel.com) and AspenTech's technical manager for Exchanger Design & Rating (EDR), Laurie Haseler. "Accurately representing the physical properties is the linchpin for accurate simulation," Noe comments. "Simulations are only as good as how well you handle the underlying physics."

The algorithm adjustment was included in AspenTech's release of Version 7.3 of its Aspen EDR software. Among the many situations where the method could be useful, AspenTech points to offshore oil as an area where the adjustment could have a large impact.

Reforming ethanol into hydrogen

A group from the University of Canterbury (www.canterbury.ac.nz), and Industrial Research Ltd. (both Christchurch, New Zealand; www.irl.cri.nz), has produced hydrogen from ethanol via steam reforming in a non-thermal plasma reactor. The project is part of an Industrial Research concept called Hylink that proposes using H_2 as an energy storage medium and carrier for remote-area power systems.

Current systems for producing H_2 from ethanol are constrained by limitations within conventional catalytic reactors. This is in contrast to methanol, which is easily reformed, but which is produced mainly from natural gas and is, therefore, regarded as a non-renewable fuel. Another advantage of ethanol over methanol is that 6 mol of H_2 are released per mole of ethanol as opposed to 3 mol of H_2 per mole of methanol.

The group says there is presently no catalytically based system that can reform ethanol at low temperatures (about 300°C) and atmospheric pressure with high conversion and high selectivity to H_2 via a steam reforming reaction. Successful ethanol reforming reactors rely on high temperatures (above 450°C) and expensive catalysts to achieve satisfactory results. Less expensive catalysts and lower temperatures tend to favor side reactions next to the required breakdown of ethanol into H_2 and CO_2.

In the group's method, a vaporized mixture of ethanol and water is fed to a plasma reactor where it passes through a region of ionized gas, which is generated between electrodes by a high-voltage (7 kV), low-current field. Single-pass ethanol conversion through the plasma reactor was around 14%, with product gas mixture compositions of 60–70 mol% H_2. Total hydrocarbon by-products in the gas were low (5–8 mol%).

The group said the results are encouraging in terms of hydrogen selectivity, indicating an improved reaction mix compared with catalyst-based systems. Future work will focus on improving reactor design to increase the ethanol conversion.

(Continued from p. 10)

for CFRTF components, which significantly reduces cycle times required for molding composite products to under a minute, thus enabling rapid production of prototypes for evaluation tests.

The pilot plant — an investment of 2-billion ($26 million) — is slated to start operations mid 2012, and will enable the company to further accelerate the commercialization of CFRTF components. The technology promises to realize "revolutionary" weight reductions for a wide range of applications besides automobiles.

Pyrochlore catalyst

Researchers at the U.S. Dept. of Energy's National Energy Technology Laboratory (NETL; www.netl.doe.gov), URS Corp. (both Morgantown, W.V.) and Louisiana State University (Baton Rouge) have developed a catalyst that is capable of reforming diesel fuel into synthesis gas, which can be used for

(Continues on p. 14)

PDVSA will commercialize a heavy-oil upgrading process

Venezuela's state-run petroleum company, PDVSA Petroleo, S.A. (PDVSA, Caracas; www.pdvsa.com), will commercialize a company-developed process for upgrading heavy crude oil in its Puerto La Cruz refinery, about 300 km (190 miles) east of Caracas. The 210,000-bbl/d plant will employ PDVSA's HDH Plus process (for hydrocracking, distillation and hydrotreating) to produce light and middle distillates and vacuum gasoil from heavy crude. The refinery specializes in light crude oil products and the new facilities will enable PDVSA to expand the output of such products from Venezuela's abundant heavy crude reserves.

HDH is said to have a conversion rate of more than 90% in a single pass, versus about 65% for traditional processes. The process operates at 450–480°C and a moderate pressure of 1,900 psig. It uses a low-cost iron oxide catalyst that can be disposed of after one pass, thereby avoiding the problem of catalyst poisoning by metals that occur in heavy oil. A contract for detailed engineering, procurement support and construction management services for the project has been awarded to Chiyoda Corp. (www.chiyoda-corp.com), together with JGC Corp. (both Yokohama, Japan; www.jgc.co.jp) and Inelectra SACA, a Venezuelan engineering company.

Making biodiesel with SC methanol

A team from the School of Chemical Engineering, Universiti Sains Malaysia (Penang; www.eng.usm.my) has carried out a study for optimizing non-catalytic supercritical (SC) methanol extraction and transesterification of *Jatropha curcas* seeds to produce biodiesel fuel.

Jatropha curcas is a species of flowering plant native to the American tropics. The seeds contain up to 40 wt.% oil that can be processed to produce high-quality biodiesel fuel. Several methods for processing the plant's oil to produce biodiesel have been developed.

The team says its method promises to be superior to conventional biodiesel processing regarding reaction time, product separation, fatty acid methyl ester yield, and process integration. It used a high-pressure batch reactor with *n*-hexane as a co-solvent. Methanol was selected due to its mild supercritical condition (513.15K, 8.1 MPa) and low boiling point (338.15K) for easier separation. At higher temperature and pressure (300°C and 24 MPa), the extraction of oil from the seeds was more efficient than in the case of conventional oil extraction, either with chemical solvent or mechanical pressing. Also, no catalyst was required, which greatly simplified downstream processes such as catalyst separation and washing.

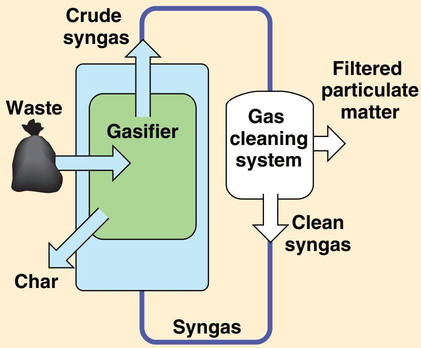
Supercritical methanol served as both oil-extraction solvent and as a reagent for the esterification and transesterification reactions, which proceed simultaneously in the reactor. Co-solvent is used to accelerate the initial oil-extraction phase and to improve the overall kinetics of the reaction.

Waste disposal system for military operations

The Micro Auto Gasification System (MAGS) is a compact solid-waste disposal system that is designed for energy-efficient operation onboard naval vessels, in forward-operating military bases and in other isolated installations.

Developed by the Office of Naval Research (ONR; Arlington, Va.; www.onr.navy.mil) and Terragon Environmental Technologies Inc. (Montreal, Ont.; www.terragon.net), the MAGS uses a highly controlled pyrolysis process (diagram) to reduce up to 40 kg of as-received solid waste into synthesis gas (syngas) and inert carbonaceous material. The pyrolysis is carried out at 750°C in the MAGS' insulated drum. The process sequesters a significant portion of carbon as char, preventing the formation of significant portions of CO_2. The syngas produced is used to sustain the process, and air emissions are environmentally compliant, the ONR says.

In one day, a single MAGS unit can treat the waste generated by a community of 500 people. In 2 h, the system reduces 40 kg of typical solid waste by more than 95%, ONR remarked. Materials safely destroyed by MAGS include paper, wood, plastic, chemicals, food, cloth, grease and oil, sludge, agricultural waste and others. Metals and glass are sanitized and left intact for recycling, and the inert ash remaining after the gasification can be landfilled safely, ONR points out.



A MAGS unit is currently under evaluation by the U.S. Marine Corps Forces, Pacific, at Camp Smith on the Hawaiian island of Oahu. Additional evaluation sites are under consideration. ■

(Continued from p. 12)

powering solid-oxide fuel cells in auxilliary power units of long-haul vehicles. The researchers incorporated rhodium into the pyrochlore crystal structure and applied the catalyst to a monolith support. Compared to current reforming catalysts, the pyrochlore structure is said to withstand poisoning by the high levels of sulfur and aromatics present in heavy-carbon fuels, as well as the intense heat of the reforming reaction, thus giving it a much longer life, says NETL. The new catalyst technology has been licensed to Pyrochem Catalyst Co. (Pittsburgh, Pa.).

Recycling WEEE

Tecnalia Research & Innovation (Donostia, San Sebastián, Spain; www.tecnalia.com) has developed a recycling system for classifying waste from electrical and electronic equipment (WEEE) that cannot be sorted by conventional methods. The company won the 2011 EARTO prize. ❑

RECOGNIZING YOUR COLLEAGUES

Consider nominating a deserving colleague for our 2012 Personal Achievement Award. Entries are due April 15

In professional life, the influences that teach us, inspire us and drive us to succeed tend to come more from individuals than corporations. If you would like to bring recognition to someone whose excellence in chemical engineering you admire, consider nominating him or her for *Chemical Engineering's* 2012 Personal Achievement Award. The nomination period is now open.

The aim of this award, which *Chemical Engineering* (*CE*) has offered biennially since 1968, is to honor individuals for distinguished careers. It complements *CE*'s Kirkpatrick Award for Chemical Engineering Achievement, presented in the alternate years, which honors companies — as opposed to individuals — for specific chemical-process accomplishments (see October, p. 19–22).

Our Personal Achievement Awards have saluted excellence in diverse areas — research, development, design, plant operations, management and other activities. The distinction can emerge in less-ordinary ways, such as government service. The criterion is that the career must have related, fully or largely, to the use of chemical engineering principles in solving industrial, community or other problems.

It's easy to nominate

Submitting an award nomination is a simple matter:

1. State the name, job title, employer and address of the candidate.
2. Prepare a summary, in up to about 500 words, that highlights your nominee's career and brings out his or her creativity and general excellence in the practice of chemical engineering technology. At least some of the activity must have taken place during the three-year period ending Dec. 31, 2011. Be specific about key contributions or achievements. But do not include confidential information in your writeup.
3. Please be sure to include your own name and address, in case we need to contact you.
4. Send your nomination no later than April 15 to:

Jennifer Brady
Chemical Engineering
TradeFair Group
11000 Richmond Ave, Suite 690
Houston, TX 77042
Email: awards@che.com

We encourage you to ask others to provide information in support of the nominee; ask them to write to us by April 15. Such input has often proved to be decisive during the judging.

What's next

Once we receive a nomination, we will ask the candidate whether he or she is willing to be considered (you may instead do so yourself and include a note to that effect in your nomination). Meanwhile, we might take any steps that seem called for to verify the accomplishments stated in the brief or the supporting letters.

Next, we will send all the nominations to a panel of senior chemical engineering educators, who will evaluate and rank them. Based on the voting of these judges, we will designate one or more winners. Then we will inform all the nominees and nominators about the results of the voting.

An article in *Chemical Engineering* around the end of this year will profile the winners. Around the same time, we will present physical embodiments of the awards to these individuals.

Points to keep in mind

Nominees can be from any country. They need not hold a degree in chemical engineering. But their achievements must have involved use of chemical-engineering principles in solving problems, and part of the activity must have been in 2007 – 2009.

The Personal Achievement Award has been hailed and respected since its inception. We welcome your nomination, to help us maintain this worthwhile activity. ■

Rebekkah Marshall

RECENT AWARD WINNERS

When thinking about whom to nominate, keep in mind that a distinguished career can take many forms. Here, for instance, are the most recent winners:

Thomas F. McGowan, president and founder of TMTS Associates Inc., a firm that specializes in thermal systems and air pollution control. For more than 35 years, McGowan has made significant contributions in the areas of combustion, air-pollution control, solids handling and industrial ventilation, including drying, combustion and gasification of biomass. His functions have ranged from process and project engineering, to process safety and sales.

Kris Mani, currently serves as president and chief executive officer of NSR Technologies, Inc., an innovative, research-driven chemical technology and manufacturing company, which he founded in 2006. Driven by the need for technology that would lead to greener and cleaner production of hazardous chemicals, Mani raised more than $12 million from outside investors to fund the construction of the world's first chemical plant to manufacture commercial grade caustic potash (45–50 wt.% potassium hydroxide solution) via membrane electrodialysis technology and chromatographic separation. ❏

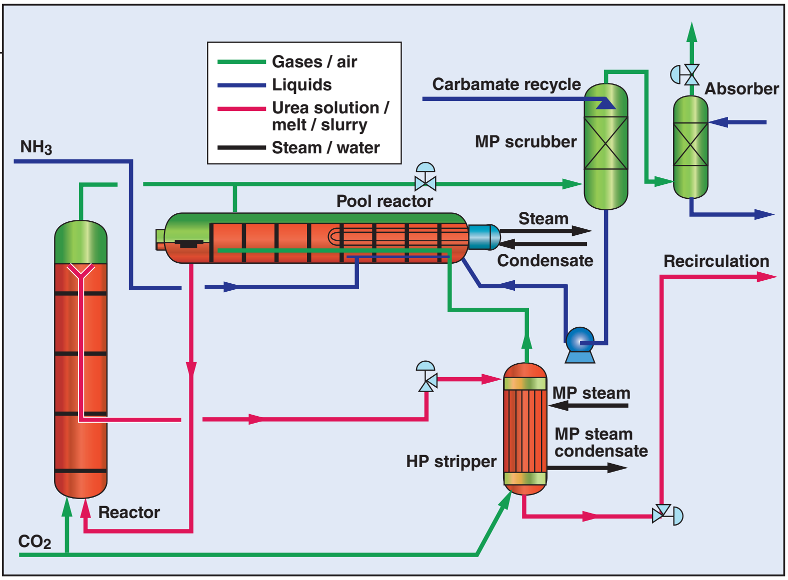


FIGURE 1. The Stamicarbon Avancore urea process is a further development of the company's Urea 2000plus technology, and reduces the required plant height to just 22 m — even for large-scale plants (MP and HP = medium and high pressure)

ment items (and the associated costs).

For example, the plant will use Safurex stainless steel — an improved duplex steel developed with Sandvik Materials Technology (Sandviken, Sweden; www.smt.sandvik.com). Thanks to the improved corrosion resistance of this new material, the air supply normally used for passivation is no longer required. As a result, the absence of oxygen means there is no need to combust hydrogen; so the H_2 converter is eliminated, and the synthesis section has become intrinsically safe with respect to explosion risks. With the quantity of inert gas substantially reduced, less gas has to be vented from the urea synthesis section, so the high-pressure (HP) scrubber can be replaced by a medium-pressure (MP) scrubber.

Meanwhile, Stamicarbon continues to find buyers for its Urea 2000plus technology, which was commercialized over ten years ago — still recent for this conservative industry. For example, last July the company signed a license agreement with Hengang Huahe Coal Chemical Industry, Ltd. in the China for a urea granulation plant with a capacity of 1,860 m.t./d. The plant will be built in Hegang City, Heilongjiang Province, PRC. The urea plant will use Stamicarbon Urea 2000plus Technology, which features a pool reactor, minimum equipment and minimum plant height.

Stamicarbon will deliver the process design package, related services and all proprietary high-pressure equipment, the pool reactor and piping. The high-pressure equipment, pool reactor and piping will be alloyed with Safurex. Start up is planned in 2014.

Over the last 15 years Stamicarbon has licensed a total of 15 grassroots and revamped plants in China with capacities up to 3,520 m.t./d.

Meanwhile, Toyo's ACES21 process, which saw its commercial debut in 2002, has now been selected for eight urea projects (most recent listed in Table 1). In the ACES21 process (*Chem. Eng.*, October 2008, pp. 28–31), urea is made by reacting liquid ammonia with liquid CO_2 to form ammonium carbamate, which is then decomposed into urea. In previous designs, the urea synthesis loop consisted of a reactor, a stripper, two carbamate condensers and a scrubber. Energy and investment savings are achieved by integrating the two condensers and the scrubber into a single condenser that has a vertical, submerged carbamate-condensing section (the heat exchanger tubes are submerged in the carbamate solution at the bottom of the condenser). A packed bed on top of the condenser facilitates the absorption of uncondensed NH_3 and CO_2 into the recycled carbamate solution.

Other recent announcements

Last month, the Saudi Arabian Fertilizer Co. (Safco; www.safco.com.sa), a manufacturing affiliate of the Saudi Basic Industries Corp. (SABIC; Riyadh, Saudi Arabia; www.sabic.com), awarded a turnkey contract for

TABLE 1. A SELECTION OF NEW AND PLANNED MEGA-SCALE UREA PLANTS					
Owner*	**Location**	**Capacity (m.t./d urea)**	**Contractor**	**On stream**	**Urea form/licensor**
Engro Fertilizers	Pakistan	3,835	Saipem	2010	Prilled/Snamprogetti
Yara Sluiski	The Netherlands	3,500	Uhde	2011	Solution/Stamicarbon
Petroquimica de Venezuela	Venezuela	2,200	Toyo	2012	Urea synthesis and granulation/Toyo
Qafco V	Qatar	3,850	Saipem, Hyundai	2012	Urea synthesis/Saipem; granulation/UFT
Qafco VI	Qatar	3,850	Saipem, Hyundai	2012	Urea synthesis/Saipem; granulation/UFT
National Petrochemical Co.	Iran	3,250	PIDEC, Toyo	2012	Synthesis and granulation/Toyo
Orascom/Sonatrach	Algeria	3,450	Uhde	2012	Granulation/Stamicarbon/UFT
ENPC	Egypt	2x1,925	Uhde	2012	Granulation/UFT
Fertil	United Arab Emirates	3,500	Samsung, Uhde	2012	Granulation/Stamicarbon/UFT
Egyptian Fertilizer Co.	Egypt	2x revamp to 2,250	Uhde	2012	Granulation/UFT
Matix Group	India	3,850	Saipem	2013	Synthesis and prilled/Saipem
Dangote Group	Nigeria	2x3,850	Saipem	2014	Urea synthesis/Saipem; granulation/UFT
P.T. Pukuk Kalimantan Timur	Indonesia	3,500	Toyo	2014	Synthesis and granulation/Toyo
Jaiprakash Associates	India	2x1,925	Owner/EIL	2014	n.a.
Safco V	Saudi Arabia	3,600	Saipem	2014	Urea synthesis/Saipem, Granulation/UFT
Petrobras	Brazil	3,600	To be determined	2014	Granulated/Stamicarbon/UFT
Petronas Chemicals Fertilizer Sabah	Malaysia	3,500	MHI	2014	Urea synthesis/Saipem; granulation/UFT
Gabon Fertilizer Co.	Gabon	3,850	Technip	2014	Urea synthesis/Saipem; granulation/ UFT

*Note: Qafco = Qatar Fertilizer Company; Safco = Saudia Arabian Fertilizer Company; Petrobras = Petróleo Brasileiro S.A.; ENPC = Egyptian Nitrogen Products Company; UFT = Uhde Fertilizer Technology; MHI = Mitsubishi Heavy Industries

the engineering, design, supply and construction of the Safco-5 fertilizer plant to Saipem. The new plant will have a capacity of 1.1-million ton/yr of urea (3,600 m.t./d), and is expected to begin production in the third quarter of 2014.

Last October, Mitsubishi Heavy Industries, Ltd. (MHI; Tokyo, Japan; www.mhi.co.jp), jointly with APEX Energy Sdn. Bhd. (Kuala Lumpur, Malaysia) and PT Rekayasa Industri (Rekind; Jakarta, Indonesia), received an order from Petronas Chemical Fertilizer Sabah Sdn. Bhd. (PCFSSB) for a project to construct a large-scale ammonia/urea fertilizer plant. PCFSSB is a subsidiary of Petronas Chemicals Group Berhad (PCG), which is an affiliate company of Petronas, the national oil company of Malaysia. The plant will be the first large-scale fertilizer plant order from Malaysia in 15 years since 1996 when MHI received an order from Petronas.

The new urea fertilizer plant will be built in Sipitang on the Island of Borneo. Using natural gas as its feedstock, the plant will have a capacity to produce 2,100 m.t./d of ammonia and 3,850 m.t./d of urea fertilizer. It will adopt process technologies from Haldor Topsøe, Saipem, and UFT. The plant is slated to go into production in 2015.

The order calls for plant engineering, procurement and construction (EPC). MHI, as leader of the consortium, will be responsible for the basic and detailed design work, the procurement of equipment and the dispatch of technical advisors for installation and test operation. APEX Energy and Rekind will take charge of a portion of the equipment procurement and construction work.

PCFSSB is the company selected by PCG to implement the fertilizer plant construction project and its operation after completion. APEX Energy is a construction company, which locates its head office in Kuala Lumpur, the capital of Malaysia. Rekind is a plant engineering company headquartered in Jakarta, Indonesia.

The Sabah State of Malaysia, which has prospered as a tourist destination and timber supply area, is abundant in natural gas and increasing its interest in fertilizer production as the State seeks higher value from its natural gas resources and pursues advances in industrial development and agriculture. The fertilizer plant construction project is in line with these initiatives.

The demand for fertilizer is expected to continue expanding steadily due to rising food-production needs in response to global population growth. In Asia in particular, demand for fertilizer plants is increasing for the replacement of old plants. MHI, building on the strength of this latest large-scale order, now looks to conduct aggressive marketing activities in a quest to boost its presence in the fertilizer plant market in Asia while also targeting orders worldwide in the fields of synthetic gas and petrochemicals.

Last September, Gabon Fertilizers Co. awarded an engineering contract to Technip (Paris, France; www.technip.com) for a world-class grassroots ammonia-urea fertilizer project to be developed at Port Gentil, Gabon. The proposed project includes a 2,200-m.t./d ammonia plant and a 3,850-m.t./d granulated-urea plant with self-sufficient utility and offsite units and product export facilities. It will adopt process technologies from Haldor Topsøe, Saipem and UFT.

Under this contract, Technip will perform the front-end engineering design (FEED) for the project as well as the detailed cost estimate for the engineering, procurement and construction phases. Upon completion of the front-end engineering and detailed cost estimate, this contract can be converted to a lump-sum turnkey contract. Technip will also assist Gabon Fertilizers Co. in its project financing efforts. Apart from giving considerable flexibility in the optimal design of the plant, this methodology is expected to result in significant savings in both the capital expenditure cost and project schedule. This is ideally suited for projects in remote locations where the costs and the time schedule are difficult to estimate accurately. ■n

Gerald Ondrey

SAY GOOD-BYE TO OLD-SCHOOL CENTRIFUGES

More modern equipment provides increased efficiency, flexibility and safety

Many chemical processes in the U.S. that use centrifuges were established between the 1950s and the 1980s. As a result, most of these machines employ technology that was outdated literally generations ago. In addition, many processes have changed since installation, and doing more with less is now a key method of survival in today's global economy. At the same time, regulatory and environmental issues have become more important. This combination of outdated equipment, the advent of more modern processes, a tighter economy and bumped up compliance creates challenges for chemical processors using old-school centrifuges. Fortunately, more modern equipment is available to bring these processes into the 21st century.

"Processors are working to optimize product throughput, product yields and separation efficiency while keeping an eye on energy costs," says Chad Mendelsohn, sales manager of chemical centrifuges with TEMA Systems (Cincinnati, Ohio). "In our applications, the largest energy costs are often in the downstream-process thermal dryers — where for every 1% of extra moisture removal through mechanical separation of a solid, a dramatic longterm savings is produced. Lower discharge moistures can also increase the potential throughput of a whole process line."

Mendelsohn adds that as plants try to keep up with demand for their products with less and less staff available, processors look to maximize production up time while limiting operator interface requirements and the need for maintenance. Certain applications also have environmental reasons to minimize personnel interaction with the process equipment.

All these challenges lead to one thing: The need for modern equipment that is highly efficient and flexible, as well as safer and more automated.

Centrisys

FIGURE 1. Thickened sludge is discharged efficiently with the THK Series's Hydraulic Assist Technology, so the process of centrifugal thickening offers a low-cost and smaller footprint approach to reduce volume while increasing digesting capacity and performance

Higher efficiencies

Chemical processors are looking for higher recoveries and higher captures from their centrifuges, says Victor Norton, vice president of sales with Andritz Separation (Arlington, Tex.). In addition, they want dryer cake discharges and less moisture so downstream drying costs are reduced, he says. This demands more efficiency and effectiveness out of the machines.

One of the ways this is accomplished, says Norton, is by improving the internals of the centrifuge. A typical decanter centrifuge has a bowl and scroll or conveyor within the bowl to move the settled solids. There are different pitches on the blades of the conveyor and differing numbers of leads (usually single, double, triple or more). "The variations here have the ability to provide a dryer cake discharge and more capacity, and we are improving the internals all the time," says Norton. "Years ago a 40-in.-dia. machine on a PVC line would process 7 ton/h. Now the same size machine can handle up to 15 or 20 ton/h due to the speed of the machine and new designs on the pitch of conveyors."

Heinkel USA

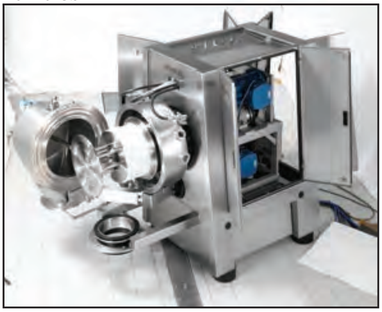
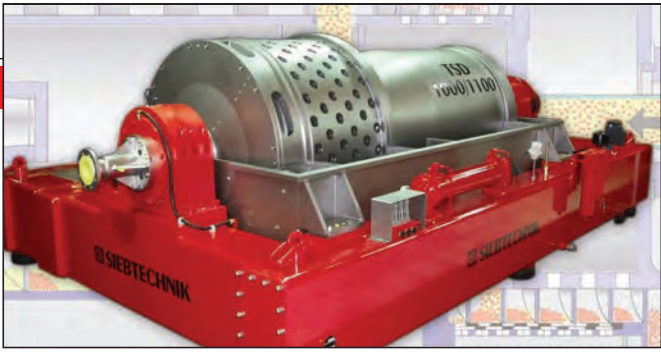


FIGURE 2. The inverting filter centrifuge technology allows difficult-to-filter material that traditionally could not be processed on a centrifuge to be turned into a dry powder

He adds that materials of construction for the bowl and type of drive used also increase the speed of the machine. Stainless steel was previously the typical material of choice, but now heavier strength alloys like duplex steel are needed for corrosion resistance and strength. New controls, too, such as variable frequency drives (VFDs), which allow soft starts that don't consume as much horsepower as an across-the-line start and move things along at a faster, more consistent rate, are also being employed. "Scroll drives can be VFD, which



TEMA Systems.

FIGURE 3. The design of the Turbo Screen Decanter combines the advantages of the solid bowl centrifuge and the screen centrifuge into two distinct stages

influences the performance of the machine to get dryer cakes out of some applications and it often leads to a more uniform process," says Norton. "Without good control, the early feed off the tank is usually consistent, but once the bottom of the tank is reached, there is usually a thinner slurry coming into the centrifuge. Better controls provide more uniform feed, which leads to more uniform centrifuge performance."

Michael Kopper, CEO at Centrisys (Kenosha, Wis.), agrees that these improvements lead to more efficient machines. "The improvement of materials of construction (away from stainless toward duplex) along with the ability to increase the speed of the machine and overcome the performance-handicaps processors have been dealing with go a long way towards helping processors overcome their separation challenges."

Kopper says many of his company's machines include a newly designed back drive system, which conveys the scroll inside and allows the centrifuge to run at higher torques. "Higher torques help increase the loading of the machines," he says. "And often when you put more load in, you get a drier product out."

Centrisys's THK Series of thickening centrifuges embraces this type of improvement in some applications like sludge thickening, which uses centrifugal force to increase the concentration of waste-activated sludge for further processing. During operation, sludge is continuously fed into the unit. The moving shaft has a set of helical scrolls, which push the solid waste toward one end, away from the liquid moving in the opposite direction. "The thickened sludge is discharged more efficiently with the THK's Hydraulic Assist Technology (Figure 1), so the process of centrifugal thickening offers a low-cost and smaller footprint approach to reduce volume while increasing digesting capacity and performance," explains Kopper.

Greater flexibility

"It is true that the need for shorter cycle times, reduced downtime and drier cakes has become the new mantra among chemical processors," says Tom Patnaik, director of sales and marketing with Heinkel USA (Swedesboro, N.J.). "In addition to that, the need to perform more than one action within the same space has led to the need for centrifuges with multi-functional traits and more flexibility."

He says the Heinkel inverting filter centrifuge (Figure 2) can help here. "Modern innovations have allowed the equipment to extend the traditional dewatering role of the centrifuge into the realm of separation and drying with the incorporation of PAC (pressure added centrifugation)," says Patnaik. This feature, which utilizes high-pressure air or nitrogen, either at ambient or elevated temperatures, further reduces cake moisture. "In some applications it makes using a downstream dryer unnecessary."

The unit is able to handle a variety of materials that traditionally could not be processed using a centrifuge and can optimize a process using Heinkel's thin-cake filtration along with the PAC system to turn difficult-to-filter materials into dry powders.

Derek Ettie, managing director of the process division, with GEA Westfalia Separator (Northvale, N.J.), also cites "multi-use equipment" as a great need in the chemical process industries (CPI). "We used to sell a machine for one process or product and now our customers are looking for a machine that they can use on many products," he says. "We are also seeing existing customers that already have our equipment, asking us to modify it so it can be used in different ways."

One of the biggest game changers, he says, is the use of new materials of construction, such as special duplex stainless steel or Hastelloy. "When you are running a variety of materials through the same piece of equipment, you have to make sure it won't corrode, erode, dissolve or be susceptible in any way to chlorides, high temperatures or low pH," explains Ettie. "Because with different processes, there will be different process variables, chemicals or cleaning solutions being introduced frequently. The equipment needs to stand up to this sort of abuse."

"Another way to provide flexibility, embraced by TEMA, is through customized equipment. Hybrid machines, like decanting centrifuges with internal screening sections have become more common in spite of the fact that they are more expensive upfront," says Mendelsohn. "We find ourselves supplying more machines with built-in flexibility as end users seek to protect themselves from potential process changes," he says. "Having a more flexible piece of equipment can often take a process that has normal process variation and dampen the variability of the end product."

One such hybrid is the Turbo Screen Decanter (Figure 3). With usual screen-bowl centrifuges, the screen section connects to the drum cone at the point of its smallest diameter with identical dimensions. This design often restricts volume and creates a higher solids layer, with reduced centrifugal forces in the dewatering section of the centrifuge. To combat this issue and boost flexibility, TEMA's Turbo Screen combines the advantages of the solid bowl and the screen centrifuge into two distinct stages. This permits clarifying and drying in two separately designed stages, eliminates compromise between clarifying and drying sections, and allows pre-thickening of the solid material and optimum removal of residual moisture from the pre-thickened solids cake in the large-volume screen drum due to higher centrifugal force. Higher yields with minimum loss of solids and re-circulation of the separated liquid are added benefits.

Increased safety

The CPI are characterized by extreme processing conditions and challenging substances, such as concentrated acids and explosive materials. No-

GEA Westfalia Separators.

FIGURE 4. Gas-tight decanters are designed for applications where excess pressure and temperatures are a safety consideration

where does safety hold such a high priority. For this reason the development of safer equipment is just as important, if not more so, than developing more efficient, flexible equipment. One of the most important safety boosts to come along has been the advent of gas-tight units.

"Where people are using solvents for extractions and separation of flammable materials it is essential to have a gas-tight unit or a nitrogen blanket to avoid explosions," says GEA's Ettie. "Customers rely on us to supply solutions that ensure the purge gas is delivered to the centrifuge properly, so we offer a gas-tight decanter (Figure 4) and gas-tight disk-type centrifuge."

The line of gas-tight decanters is built in accordance with European ATEX regulations and is designed for situations with excess pressure and temperatures. Electrical components are designed for operation in explosion-protected zones.

Even when the material is not explosive, it can still be hazardous, adds Greg Cybulski, vice president of sales and marketing with Celeros Separations (Foxboro, Mass.), which makes separation equipment for the biotech and biochemistry industry. "Many of the applications we deal with include a hazardous or biological agent that requires a certain set of standards and qualifications of personnel," he says. "Our customers need equipment that manages the safety and hazards surrounding the material they are processing, and that almost always requires a closed and sealed process."

To that end, Celeros introduced the APD (Automatic Piston Discharge) Centrifuge. Cybulski says the centrifuge allows end users to maintain an isolated environment, which is an important safety consideration compared to traditional bioprocess centrifuges where the recovery of clarified liquid and concentrated paste was a manual effort. "The APD technology allows the process of paste recovery to be automated so that there's no requirement for an operator to get involved," he says. "The entire process can be done in a completely enclosed manner and deliver paste in a form that's very easy for downstream handling."

Similarly, in the biopharma industry, there's been a trend toward smaller, more flexible batches, requiring greater containment and less handling. "Equipment has responded to this market force and, one of the best examples of that is the pressure Nutsche filter-dryer," says Patnaik.

In many applications, the Nutsche overlaps a centrifuge and dryer combination effectively. The Nutsche can accept a slurry and put out a dry powder, all without any material handling. Sometimes the Nutsche is combined with an isolation or glove box so that the product being discharged goes directly into containers without any operator exposure.

"Its ability to work in a fully contained manner, in conjunction with an active isolation glove box, under slightly negative pressure has tremendous safety advantages and many customers with highly potent, active-pharmaceutical-ingredients applications prefer this equipment over other filtering or dewatering equipment," says Patnaik.

CENTRIFUGE VENDORS

Andritz	www.andritz.com
Celeros Separations	www.celerosinc.com
Centrisys	www.centrisys.us
GEA Westfalia Separator	www.westfalia-separator.com
Heinkel USA	www.heinkelusa.com
TEMA Systems	www.tema.net
The Western States Machine Co	www.westernstates.com

More automation

In addition to allowing hands-free centrifugal operations, automation is also helping make operations safer and more efficient. The introduction of plant-wide Ethernets and distributed control systems has spawned a new generation of smart devices for the measurement of pressure, temperature and flow control in the CPI. The control system may communicate directly with these smart devices or via an intermediate Scada system. In addition to providing realtime optimization, realtime asset management and alarm control, it also provides remote realtime information on a range of process parameters, troubleshooting and diagnostics.

"When the equipment is automated and it can measure variables such as vibration and temperature, it ensures both uptime and safety," says Ettie.

And the addition of remote monitoring capabilities only increases these benefits. "The increased complexity of PLC systems and drives allows an unparalleled amount of automation capability, as well as the ability to remotely monitor the centrifuge," explains Cybulski. "This level of automation enables us or end users to look at the operation of the machine, wherever it may be, and see when certain things like vibration or bearing temperature are going off spec. It enables action to be taken before something happens that would stop the process or cause an unsafe condition." ■

Joy LePree

A neighborly research organization

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

At the Chicago AIChE meeting last spring, Henry Kister and Mike Pritchett named the distillation symposium in honor of James R. Fair, who had recently passed away. Fair was probably best known for his leadership of the Separations Research Program (SRP) of the University of Texas at Austin. Fair and Jimmy Humphrey founded SRP in 1984, and a significant part of Fair's legacy is continued through the work at SRP.

For instance, at the most recent AIChE meeting (Minneapolis, Minn.; October 16–21) Micah Perry presented a paper entitled "Consistent Measurements of Hydraulic and Mass Transfer Packing Characteristics." His coauthors were colleagues from SRP, Chao Wang and A. Frank Seibert. That presentation described the results of a massive undertaking regarding acid-gas absorption with a chemical reaction. Data were collected using seven different structured and random packings. Those packings were provided by Koch-Glitsch, Sulzer Chemtech, Raschig-Jaeger and GTC Technology. Four different chemical systems were employed to build a mass transfer model. Using the air-water system, pressure drop and liquid hold-up models were created. The absorption of CO_2 from air, into caustic solution, was used to develop a model for effective interfacial area. The absorption of SO_2 from air, into caustic solution, was used to develop a k_G model. The stripping of toluene from water, using air, was used to develop a k_L model. The database comprised over 400 runs! Dr. Fair would have been proud. Based on my long R&D career, I know that each of those runs required appreciable planning, time, care, work, manpower, sweat and head-scratching.

Since its inception, SRP has been a busy place. Separations research has been performed in several arenas. I am personally extremely familiar with SRP's simulation program for liquid-liquid extraction, LLE 8.02. The correlations in that program were generated and refined using SRP's 16.8-in. extractor, 4-in. low-pressure extractor, 4-in. supercritical extractor and from commercial-scale data.

SRP members also have access to a distillation computer program that can be used to rate sieve trays, baffle trays, CoFlo trays, random packings and structured packings. The latest version of that program is named DISTILL 2.1 and is similar in function to FRI's program DRP 2.1. (Yes, both presently have the same version number). SRP and FRI both have databases that are available to their members. A portion of the data generated by these organizations has been released to the public.

Of late, SRP has aligned with Texas A&M University and the University of South Carolina to form the Process Science and Technology Center (PSTC). The PSTC extends and enhances the separations technology work that was performed by SRP. The PSTC also studies instrumentation, process control, process safety, energy reduction, water purification, environmental protection and "the development of novel methods of producing fuels and chemicals from renewable resources." The U.S. Department of Energy (DOE) has historically, and rightfully, supported these universities' efforts.

Some people regard FRI and SRP as competitors. I do not. Instead, I regard them as neighbors. Both are located "on" U.S. Interstate 35 and only 441 miles apart. Whenever I need to borrow a cup of sugar, or hexane, I know exactly where to go. ■

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CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Avoiding Pressure Relief Problems

Pressure relief valves and rupture disks are critical safety devices for protecting personnel and processing equipment from overpressurization situations. Presented here are several engineering practices that can help to identify and address common problems with the pressure relief systems of chemical process industries (CPI) facilities.

Common causes of overpressurization

Overpressure situations can have a variety of causes. Here are some common situations that may cause increased pressure in processing facilities. Each potential cause is followed by one or more factors that contribute to the overpressure.

- ***External fire:*** Potential vapors from the fire must be relieved with a safety valve on the vessel
- ***Blocked outlets:*** Blocked outlets can be caused by control valve failure, inadvertent valve operation and others
- ***Utility failure:*** General or partial power failure, loss of instrument air, cooling water, steam, fuel gas or fuel oil
- ***Loss of cooling duty:*** Loss of quench steam, air-cooled exchanger failure, loss of cold feed or loss of reflux
- ***Thermal expansion:*** External heat can cause liquid volume to rise in fluids that are blocked in a vessel or pipeline
- ***Abnormal heat input:*** Increased supply of fuel gas, or faster heat transfer after exchanger revamp, and others
- ***Abnormal vapor input:*** Failure of upstream control valve to fully open, or inadvertent valve opening
- ***Loss of absorbent flow:*** Interruption of absorbent flow when gas removal by absorbent is more than 25% of total input-vapor flow
- ***Entrance of volatile materials:*** Ingress of volatile liquid into hot oil in a process upset
- ***Accumulating noncondensibles:*** Blocking of noncondensible vent
- ***Valve malfunction:*** Human error or check-valve malfunction, resulting in backflow, control valve failure
- ***Process control failure:*** Failure of distributed control systems (DCS) or programmable logic controller (PLC)

VALVES

To avoid problems with pressure relief systems, plant managers should consider these practical guidelines.

Assess risk. Many factors can increase the risk and impact of pressure-relief-system failure. If several of the conditions in Table 1 apply, plant managers should consider planning a detailed study of the pressure relief systems, such as a quantitative risk analysis (QRA) or a relief-system validation study.

TABLE 1. CONDITIONS THAT INCREASE THE PROBABILITY AND IMPACT OF RELIEF SYSTEM FAILURE

Conditions that increase the probability of relief system failure	Conditions that increase the impact of relief system failure
The plant has over 20 years of service	The plant handles toxic, hazardous or flammable fluids
The plant currently handles different products to those it was originally designed for	The plant handles gases
The plant operates at a different load or at different conditions to those it was originally designed for	The plant operates at high pressures
There have been contingencies that have required the replacement of equipment or lines in the past	The plant operates at high temperatures
Rotating equipment (pumps, compressors) has been modified (for instance, new impellers) or replaced	The plant has furnaces or other types of equipment that add considerable heat input to the fluids
The relief valves have not been checked or validated in the last ten years	The plant has high-volume equipment (such as columns, furnaces)
Modifications have been made to existing relief valve lines (that is, they have been rerouted)	The plant has exothermic reactors, or chemicals that could react exothermically in storage
A complete and up-to-date relief valve inventory is not available	The plant has large relief valves, or the relief header has a large diameter
The relief load summary has not been updated in the last ten years	The plant has a high number of operations personnel
A relief-header backpressure profile is not available, or the existing model has not been updated in the last ten years	The plant is located near populated areas

Maintain up-to-date relief-valve data. Plant managers should maintain accurate and up-to-date relief-valve data, including relief valve inventory, relief-valve load summary and relief-header backpressure profile. The inventory is a list of basic information that applies to each valve, such as process unit, location, discharge location, connection sizes, orifice size, manufacturer, model, installation date, and date of last inspection. The loads summary contains all the overpressure scenarios and relief loads for each device at the plant. The backpressure profile of the pressure-relief network is valuable when evaluating the critical contingencies of the systems, as it can be used to identify relief valves operating above their backpressure limits.

Relief-system study. A relief-system validation study comprises three phases: (a) survey and information gathering; (b) modeling of the existing relief system; and (c) relief system troubleshooting.

Modeling. Results from accurate modeling can identify the need for replacement of a relief valve. However, developing an accurate model for every relief valve in a plant is costly and impractical. A compromise that minimizes time and effort while targeting potential problem areas is to verify each system starting from a simple model with conservative assumptions, and to develop more accurate models only for those items that do not comply with the required parameters under the original assumptions. See Ref. 1 for an example.

RUPTURE DISKS

Rupture disks are often installed as the last line of defense against overpressurization. When handled and installed properly, rupture disks are a safe and economical way to protect personnel and process equipment. To help avoid problems with rupture disks, consider the following guidelines:

Evaluate pressure measurement. Since most rupture disks react to overpressure within milliseconds, it is important to sample and measure the pressure near the rupture disk, and at time intervals that are narrow enough to catch rapid pressure spikes.

Evaluate fatigue and corrosion of disks. Process engineers should pay attention to the effects of corrosion and fatigue on the performance of rupture disks. In some cases, rupture disks are operating at up to 95% of their rated burst pressure. And rupture disks can have thicknesses of 0.001 in. If a change in material thickness occurs because of corrosion or changes in operating pressure occur, failures can occur.

Check installation. As precision devices, rupture disks have tight burst tolerances. Because of this, it is critical that the rupture disk be installed correctly, with attention to torque, position and possible inadvertent damage to seating surfaces. See Ref. 2 for features that aid installation.

Check process temperature. The strength of the materials used to manufacture rupture disks is always dependent upon the temperature. It is important that rupture-disk burst pressures are specified for the temperature at which they will operate. It is important to keep in mind that it is possible that the specified burst pressure may not be the same as the temperature inside the vessel, especially if the vessel is insulated.

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WHO'S WHO


Clausen


Hirai


Snyder


Stehle


Taylor

Haldor Topsøe (Lyngby, Denmark) promotes *Bjerne Clausen* to CEO.

SmartKem (St. Assaph, North Wales), a developer of flexible, printable semiconductor materials, appoints *Yutaka Hirai* to be its representative in Japan.

Intelligrated (Somerset, N.J.), a provider of materials-handling solutions, names *Michael Snyder* sales engineer.

Carsten Stehle becomes managing director of the **Sera Group** (Immenhausen, Germany), a provider of products and systems for dosing, feeding and compression applications.

Wes Bolsen becomes vice president and chief marketing officer of **Codexis** (Redwood City, Calif.), a biotechnology company that produces chemicals, fuels and pharmaceuticals.

Bob Mayer becomes CEO and chairman of **Cobalt Technologies** (Mountain View, Calif.), which converts biomass into *n*-butanol for use in chemicals, biofuels and jet fuels.

Veolia Water Solutions & Technologies (Birmingham, U.K.) welcomes *Stephen Taylor* as busness development director, industrial outsourcing.

BASF (Ludwigshafen, Germany) names *Michael Ceranski* senior vice president of its global human nutrition business unit.

Cray Valley USA LLC (Exton, Pa.), a business unit of Total, promotes *Kathleen Shelton* to business manager for functional additives. ■

Suzanne Shelley

Total Cost Analysis Aids Purchasing Negotiations

Rich Waldrop
Scotwork (NA) Inc.

Use a total cost of ownership approach to optimize value when purchasing equipment and support services

Maximizing value during the procurement of equipment assets and raw materials is critical to the business functions of companies in the chemical process industries (CPI). Today's tough economic environment places added pressure on chemical engineers to secure the best value for money spent on design and equipment. Whether the items your company needs are chemicals, pieces of equipment or skid-mounted packages, the focus should be on maximizing the total value of the item over its full lifetime, rather than on finding the lowest initial price. For example, a great purchase price for a heat exchanger may turn out to be a poor value if the materials of construction do not provide the required corrosion resistance.

One approach to thoroughly assessing the value of an asset for purchase is to use a total cost of ownership (TCO) analysis. This article explains how to conduct a TCO analysis, and how that information can be used, along with other strategies, to prepare for and conduct negotiations with suppliers in equipment purchasing transactions.

The TCO approach

Undertaking a TCO analysis involves two general steps: gathering raw data on the offerings of different suppliers, including price, reliability, expected lifetime and customer support; and then assigning a weight to each aspect of the equipment, according to its value and importance to your company's particular situation.

The TCO approach positions a company for negotiating with suppliers to maximize the longterm value of equipment, supplies and services, even in cases where an item might have a higher initial pricetag.

A TCO analysis helps to account for all costs associated with a purchase, including tangible ones that appear at the time of acquisition (hard costs), as well as those that come into play later (soft costs). Hard costs would include price, shipping, installation and spare parts, while soft costs might be maintenance support services, training and amount of downtime. Soft costs, which can sometimes be more important in the CPI, are often overlooked in budgets — a situation that can lead to unexpected cost increases, or worse, projects that miss their start dates or processes that have critical quality problems.

The TCO approach allows both your company and the supplier more flexibility in negotiating terms and fees. For example, if the length of the service contract for a vacuum pump is more important to your company than the size of the fee, then the supplier can offer higher overall value to your company by providing a longer contract as part of the deal — raising its standing in the TCO analysis. This also helps create a win-win situation where the supplier can realize a price increase while your company gets the longer service contract, which may be a key consideration.

Figures 1 and 2 illustrate an example TCO analysis. The raw numbers

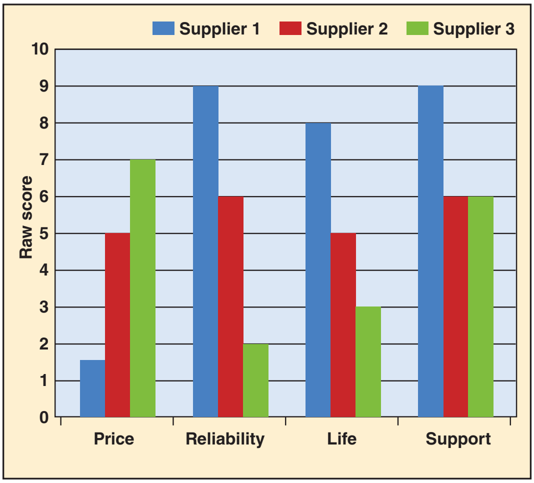

FIGURE 1. The TCO model first compares the value that each supplier offers in different categories. Here, price is graphed inversely for value, so a higher cost equals a lower value

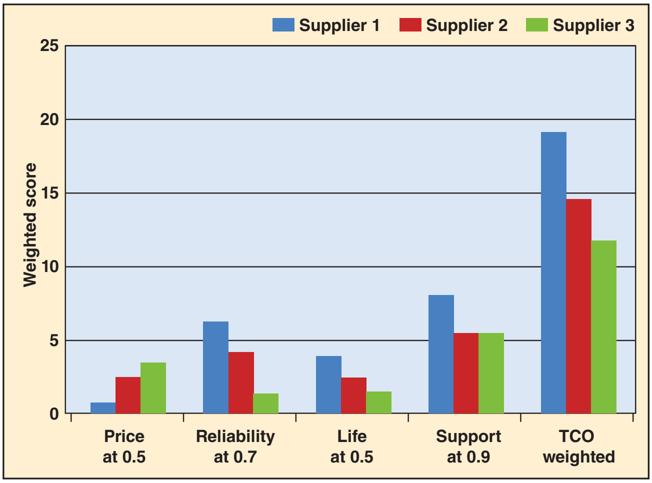

FIGURE 2. After assigning weights to the values, according to company preferences, and multiplied by the raw values, the total TCO score is calculated by adding the four categories for each supplier

offered by various suppliers in price, reliability, life and support are multiplied by the weighted values assigned by the company based on their importance. For example, if a total onsite service availability for a low-temperature cooling system has a weighted value of 0.8, and the vendor scores a value scale of 8, its net value is 6.4 (0.8 × 8). This means that the better service availability of the higher-priced machine could outweigh the lower price of a competitor's machine with less service availability. In the hypothetical case shown here, buying from Supplier 1 would result in the highest weighted value overall, despite the fact that it charged the highest price.

Engage procurement early

In developing a TCO model and preparing to negotiate with suppliers, your organization's procurement, purchasing or buying department can serve a vital function in helping to maximize value. By viewing the procurement specialists as a resource, and engaging them from the beginning of the process, you will enable them to help you develop your TCO model. Working with procurement up front can improve understanding of how commercial aspects of a transaction mesh with the engineering analysis.

In addition to helping with the TCO model, procurement personnel can also help you direct effective questions to suppliers, as well as recommend alternatives and evaluate supplier bids as you prepare to negotiate. Then, when the order is placed, procurement will expedite the process. If procurement employees are kept in the dark until a request for purchase is complete, they may not be in a position to help, and they are less likely to view the project favorably, since they were not involved in its progression.

Involving procurement personnel early may require a change in company culture because most engineers and stakeholders consider their knowledge of the process and equipment to be significantly greater than that of the procurement specialists. On the other hand, many procurement professionals believe that engineers are more concerned with getting the project completed based on their personal preferences and don't always look at lower cost alternatives. Both groups need to understand the other's strengths and recognize the power of working together. Working together begins with considering open-ended questions, such as whether engineers would be interested in an alternate supplier that could cut costs by 25%.

If you wait until the end of the purchasing process to involve procurement specialists, they will face pressure to "extract" a savings — usually by lowering price — when the deal is virtually done. At this point, most variables have been decided and the procurement department may feel forced to persuade or haggle. Involving procurement personnel as soon as the scope of work or specifications are discussed will help ensure that multiple variables are in play.

One organization in the midwestern U.S. familiar to the author has been particularly effective in fostering interaction between procurement and engineering departments. The engineering group on that site had been trained to inform the procurement department of any new contact with a vendor. The two procurement officers for this large site (3,000 employees working on multiple processes in multiple buildings) would then contact the prospective vendor and assist the purchasing engineer throughout the process, advising him or her about the procedures.

At every step, the procurement group was informed about any subsequent conversations regarding specifications or costs, and asked for comments. As a result, the organization was able to bring its other experiences into play and help the engineers ask the right questions and gather the correct information. Vendors and engineers who didn't comply had a hard time getting their projects through on schedule.

Interview users

To properly weigh values as part of a TCO analysis, it is imperative for engineers to interview internal users of equipment. Once the weighted scale of importance is applied to the hard and soft costs, the results can lead to the correct procurement decision. Some examples of good questions to ask internal users are the following:

- Why is that particular quality important to you?
- What are your main priorities in purchasing this item? (This can help develop a weighted scale of the various hard and soft costs)
- What would be the consequences if we were unable to find the item with a particular characteristic?
- Under what circumstances would you agree to consider supplier B? (if supplier B had a poor delivery history, then you might put reliable delivery on a higher weighted scale)
- What consequences would result if the supplier refused one or another of our requests?

Using the answers to these questions, you can then identify the requirements for weighting a scale of both hard and soft costs.

Analyze the balance of power

The next part of preparing for any significant negotiation is a thorough analysis of the balance of power. When working with an internal client or colleagues, you need a robust and creative process. First, identify your company's strengths and weaknesses relative to those of the supplier. List what you believe the supplier wants and what your company wants. Then plan your objectives, opening statement and strategy.

The next step is creating a wish list that includes items that would be nice to have as outcomes of the negotiation, but are not the focal point of the negotiation — perhaps better payment terms, a 24-h service hotline and a specific engineering contact in the organization. The wish list should be accompanied by a concession list of items in areas where your company is willing or able to sacrifice — maybe faster payment terms or a requirement to include the supplier's engineering staff on quarterly capital-spending review meetings.

When your power balance analysis reveals that the supplier has more bargaining power, enter the negotiation armed with a series of proposals. Then drive the process by putting proposals on the table without spending too much time talking with the supplier. Be ready to ask what needs to be done to a previously rejected proposal to make it acceptable. This will help keep you and your company on the offensive while you stick to the agenda.

For example, if a supplier of a skid-mounted equipment package has allowed its prices to erode to preserve market share, you could both agree on the value scale categories. Then, by allowing the supplier to maintain or even increase price, you can demonstrate that, with other attributes, the total cost of ownership is less than other suppliers and you're improving the original terms. Additionally, it may allow the supplier to use the "take away" method, where actions typically taken by the supplier are eliminated to influence the price category, as long as they don't skew another category in the wrong direction. So if the supplier normally paints its equipment with a two-coat epoxy used in salty, humid areas, and you plan to install the equipment in the high desert, you might offer to the supplier the chance to use a less-costly paint and use the savings to lower the selling price.

Often, the internal partners within your own company who request equipment or material are quick to give in to terms to get the need fulfilled. This weakens your position and may create an unfavorable imbalance of power. Whenever you allow yourself to be put under time pressure, the other side gains more negotiation power because he or she can simply wait for you to change your position to get the deal done on time.

Prepare effective RFPs

Your role as an engineer is not just to specify equipment, but also to think like a buyer and consider information from both vantage points. Using the TCO approach will help identify key questions when developing a request for proposal (RFP) and interviewing possible suppliers, so you can place the proper value scale on the potential categories.

When working in a competitive bid process, make an RFP as specific as possible to arm yourself with more power by structuring the supplier's expectations. Always think about what information should be disclosed to the supplier. Failing to reveal certain facts could work against you and lead to uninformed responses to your request. For example, if your company had recently been fined for a hazardous-chemical vapor leak from a heat exchanger and was facing severe fines for future leaks, you should explain the situation carefully so the vendor can understand the value you will put on this point. Prepare plausible answers that are clear enough to support your position without revealing sensitive information, such as the amount of the fines.

In this case, longterm corrosion resistance might have a weighted value of 0.9 (on a scale of 0 to 1). If vendors know that, they can address your value proposition correctly and try to score higher in that category. If the vendor performs well in this area, they will improve their weighted score to 9 (10×0.9).

Negotiate for value

When negotiating with suppliers, engineeers in the CPI must balance their attention between price and value — they can't be too narrowly focused on price and forget about value, or vice versa. As the economy slowly recovers, many suppliers that have cut their prices deeply are now looking for increases. That means CPI engineers should be aware of different strategies for accurately valuing the products their company needs and obtaining them cost-effectively.

In some situations, you may be able to persuade a supplier to concede in certain areas or exploit leverage from a competitive situation, but those approaches are time-consuming and yield limited results. For example, if you've gotten competitive bids for a two-stage vacuum pump from four suppliers, you could use them against each other to push down the price. But if you persuade the supplier to lower the price to complete the deal, they may cut corners elsewhere, such as offering a more limited package of support services.

Structure expectations. During the negotiation process, structuring the expectations of the supplier correctly can be crucial to maximizing value for your company. Generally, it is beneficial to explain the qualities your company is seeking, rather than leaving the vendor to guess. Remember that vendors don't have crystal balls and aren't mind readers. Allowing the supplier to guess your needs may result in a long process before the two parties arrive at a proposal that your company is comfortable accepting. But by structuring expectations, you increase the likelihood that the supplier's first proposal will be closer to your ideal position.

For example, if you have a specific budget that cannot be exceeded, do you tell the supplier up front or wait for a bid to come in? If you reveal this up front, the vendor may be able to package a proposal that meets your budget requirement, but at the same time allows the vendor to obtain additional value in other areas, such as supplying a longterm service contract or multiple years of recommended spare parts. If the budget ceiling is not revealed upfront, the vendor's price may come in high and you will need to get the person to change his or her mind or lower the price.

Be ready to explain additional information to the other side, as long as it helps you clearly structure the supplier's expectations in the right direction. So by telling a vendor you have multiple qualified suppliers, you're structuring expectations that he or she will need to provide your company with good value to be selected.

Any information that may lower or minimize the other party's expectations gives you more bargaining power and should be revealed early on, even if not requested. If the supplier is reluctant to share information, you can trade information that you deem important for other information that the supplier wants from you, such as the total potential business your company might offer.

Ask open-ended questions. In negotiations, ask open-ended questions designed to induce the other side to provide more detailed information. If you've been dealing with a supplier for a long time, through multiple rounds of negotiations against commodities or services that have remained constant over time, its margins may be nearing a limit. You may have gotten the best price on a particular heat exchanger, programmable logic controller (PLC) system, pump or raw material. But this supplier may have manuals, online tutorials and service plans that could add a level of value to your plant engineering and service personnel — which may be more important than the purchase price. In this case, you should use provocative questions like, "Under what circumstances would you [the supplier] provide what I am asking for?" For example, the supplier might have an online tutorial on Type 21 pump seal change-out that your maintenance staff could use. So it may be a good idea to ask under what circumstances you could get access to the tutorial.

If you're considering several suppliers, reveal that to a vendor — but if, internally, your team believes that this vendor's equipment is best, keep that information confidential.

Propose first. In cases where the TCO model is relatively simple, you know the market pricing, and there are few variables, such as the purchase of a readily available bulk-chemical commodity, you may want to make the first proposal to the supplier. The worst that could happen is that the supplier says, "Yes," leaving you to wonder what you left on the table. But if you are happy with the deal, move on and sharpen your pencil for the next transaction.

Add value. Another useful technique for negotiating is known as the "add on," where bare-bones, stripped models are quoted to meet the low-cost category, and you must ask for specific items to be included based on their importance and value scale. This enables you to start with a low price and then add value back in specifically where it is needed to meet the requirements of your company's internal users. This technique will also allow the internal user to be involved in the process while seeing the cost and value of the required specifications.

For example, if you were specifying a process chiller, you could start with an indoor, water-cooled, standard electrical, no-process pumps specification. After receiving bids, you could ask for all of the above — but you could do so one at a time, as equipment options, until you have built the package that is best for your company's situation. Usually, the seller will quote the lowest price on the base package and offer the best price for each option, thinking that each successive option will be the one to close the deal. In this way, you can then build up the package to the level you want or need based on the costs.

If you're considering leasing equipment, then leasing would need a high relative value in the TCO process. In some cases, the total leased price over the full contract length could be less expensive on the surface, but would be offset by extension costs or equipment-replacement costs. So in this instance, it may be better to purchase a piece of equipment that seems more expensive on the surface, but comes with lower additional costs.

TCO helps reach company goals

Turbulent economies demand that we continually seek value in buying and selling. The TCO process can better position you and your company to maximize results. It will help you defend why, for example, you might not be purchasing the least expensive heat exchanger, PLC, or pump from a purely price-tag perspective — as you explain the critical value proposition.

When you begin to look at total cost of ownership, you may be able to partner more closely with the supplier to meet your monetary goals, and just as important, maintain the guiding principles of your plant, process and maintenance professionals. ■

Edited by Scott Jenkins

Further reading

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Feature Report Part 1

DESIGNING SHELL & TUBE HEAT EXCHANGERS: Avoid Vibration From The Start

Making vibration an integral part of the design process can save money up front and trouble later on. But care should be taken in accepting the computer's results

Graham T. Polley and **M.A.Vidal Farfan,**
University of Guanajuato, Mexico

Simon J. Pugh,
IHS ESDU

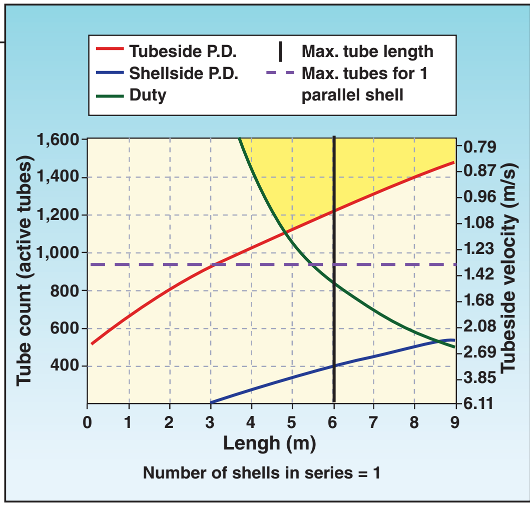

FIGURE 1. The parameter plot approach to heat exchanger design allows the engineer to identify a design space (yellow area; characterized by tube count, tube length and number of shells in series or parallel) providing geometry that satisfies both the required thermal duty and observes the pressure drop (P.D.) constraints

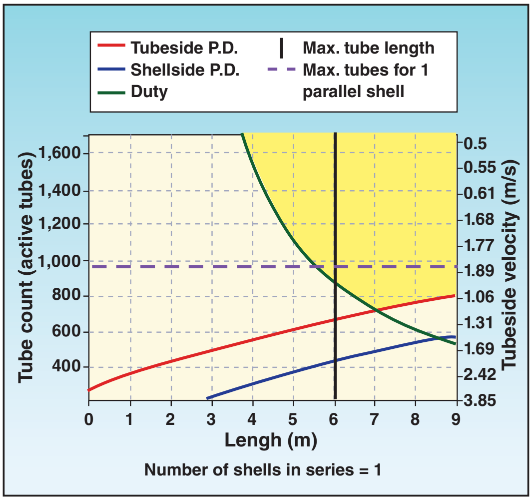

FIGURE 2. With the initial assumption that six tube passes will be used, the design space in Figure 1 is controlled by the tubeside pressure drop. Changing to four passes, we obtain the design space shown here, which is bound by the shellside pressure drop

Mechanical integrity is an essential consideration in heat exchanger design. The most common threat to this integrity is tube bundle vibration. So, the computer programs used for heat exchanger design incorporate procedures that assess this threat. However, such analysis is generally undertaken after exchanger geometry has been identified. The result can be that geometry that is optimal in terms of thermal performance is rejected for a more expensive alternative. This added expense is often unnecessary. This article shows that identification of geometry that avoids dangerous vibration can be undertaken as an integral part of the design process and provides insight on doing so. (Part 2 of this report, pp. 35–38 addresses the challenges of two-phase flow)

Modern computer programs allow the engineer to explore a very wide range of bundle geometry. Baffle cut can be set anywhere within the range 15 to 45% and baffle spacing up to a maximum allowable span set by manufacturer's standards. Beware, however, that the fact that a computer program provides a prediction of performance (sometimes of questionable validity) for a poor geometry does not justify the engineer in accepting the result. The best heat transfer is obtained for conditions in which there close to uniform flow across the tube bundle. Perhaps more significantly, most procedures used to assess the dangers of damaging vibration actually assume that such uniformity exists.

Recent computational fluid dynamics (CFD) analysis has indicated that uniform distribution of flow is only approximately true for a quite narrow range of geometry. Therefore, engineers must be especially vigilant to verify computer results with proven design principles and overrule the computer when there is disagreement (for more, see box, p. 33).

The approach outlined here illustrates the primary causes for tube bundle vibration and how their analysis can be considered at the same time that heat transfer and pressure drop analyses are being conducted. The technique is based on a plot method for heat exchanger design that is easily adapted to handle tube-bundle vibration analysis and thermal design simultaneously. When such analysis is placed in a framework where changes can be easily made to the design features that control vibration (such as inlet and exit clearances, baffle spacing, and nozzle sizes), it becomes possible to quickly and easily identify geometry that both satisfies thermohydraulic performance and avoids damaging vibration during operation.

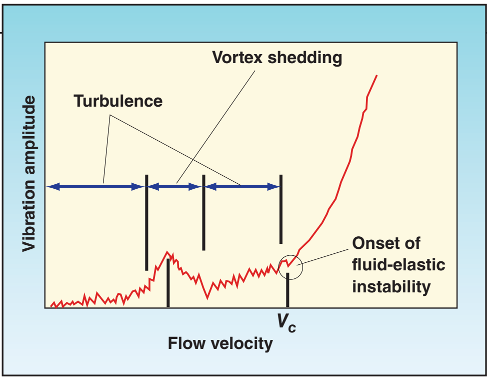

FIGURE 3. Of the mechanisms that can cause tube bundle vibration, the most serious and the one generally leading to damage of a heat exchanger is fluid-elastic instability

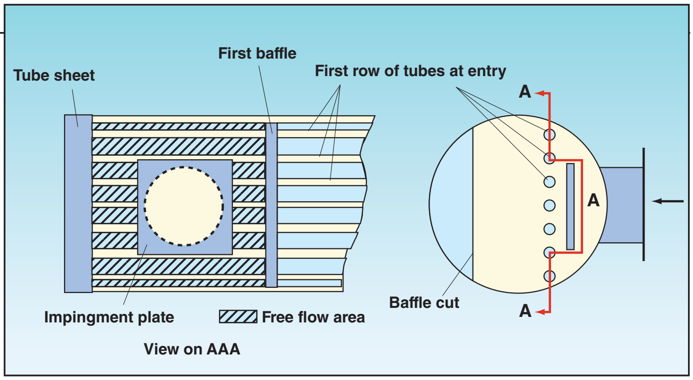

FIGURE 4. The bundle entry area is the first region where vibration is likely to occur. This is set by the location of the first tube row (set by the distance between the top of the shell and the first tube row, the "entry clearance"), the length of the exchanger end zone, the dimensions of the impingement plate and the layout of the tube bundle

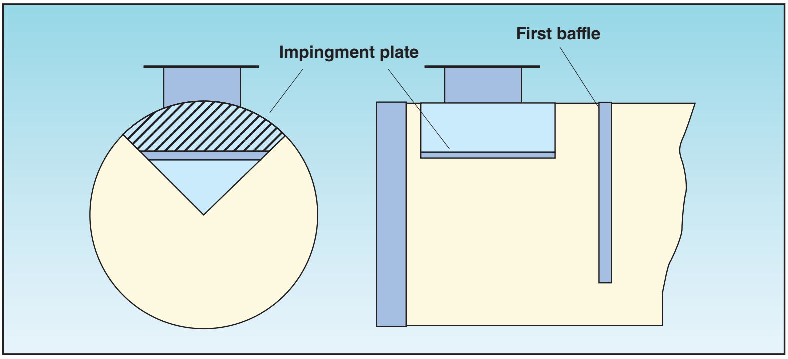

FIGURE 5. The second region where vibration occurs is the edge of the impingement plate (where the flow area is set by similar measurements to those for bundle entry)

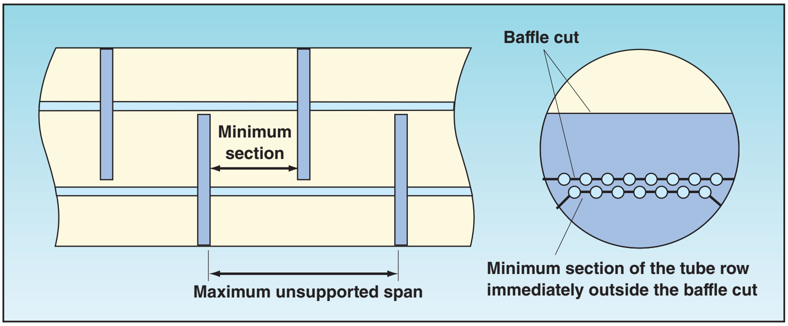

FIGURE 6. The third region where vibration can occur is the edge of the baffle plate. This is controlled by baffle cut

The Podar or 'parameter' plot

The old approach to thermal design was to generate a large number of options, determine those that provided the required performance and then rank them in terms of cost. The advent of the parameter plot by Podar [*1*] allowed this exhaustive search approach to be replaced with one in which a full range of successful and unsuccessful geometries could be displayed for given basic factors (such as baffle type and cut, tube diameter, number of tube passes and bundle layout). Given this picture, the designer could then change these basic factors in order to quickly identify the better designs.

This so-called parameter plot approach to heat exchanger design allows the engineer to identify a design space (characterized by tube count, tube length and number of shells in series and/or parallel) providing geometry that satisfies both the required thermal duty and observes the pressure drop constraints. An example is shown in Figure 1.

The "design space" has two axes. These are tube length (from zero and extended for visual clarity beyond a maximum allowable design value) and tube count (which is usually between zero and a count that provides a minimum velocity based on a minimum Reynolds Number).

The "duty line" (moving downward and to the right across the plot) relates tube count with the length of tube required to just transfer the required quantity of heat. Acceptable geometry is positioned on or above this line.

The lines moving upward across the plot from the left show the length of tube that for any given tube count will absorb the allowable pressure drops. In this example, the upper line relates to the tubeside pressure drop. The lower line relates to shellside pressure drop. (The relative positioning of these lines is, of course, related to many factors — the maximum pressure drop specified for the stream being one important factor). Acceptable geometry is positioned above the higher of these two lines.

So, geometry that provides the required heat transfer while observing the constraints placed on stream pressure drop lies in the approximately triangular region bounded by the duty line and the higher of the pressure drop lines (yellow-shaded area, top right-hand corner).

Using this plot, one can quickly evaluate the effects of changing bundle layout, baffle arrangement and tube pass arrangement on the design space. For instance, we observe that the design space is controlled by the tubeside pressure drop. The initial assumption has been that six tube passes will be used. If we move to four passes, we obtain the design space shown in Figure 2.

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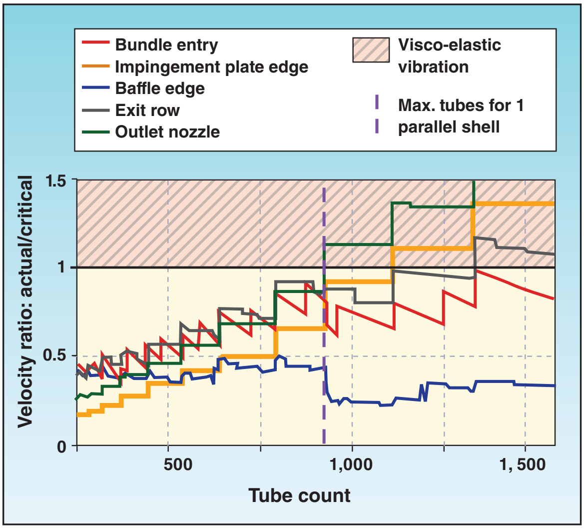

FIGURE 7. Figure 2 illustrates that using a single shell containing around 900 tubes would provide a good thermo-hydraulic design. However, the vibration analysis (displaying the ratio of local to critical velocity) shows that the velocities in the outlet nozzle, at the edge of the impingement plate and in the bundle exit row all exceed permitted value

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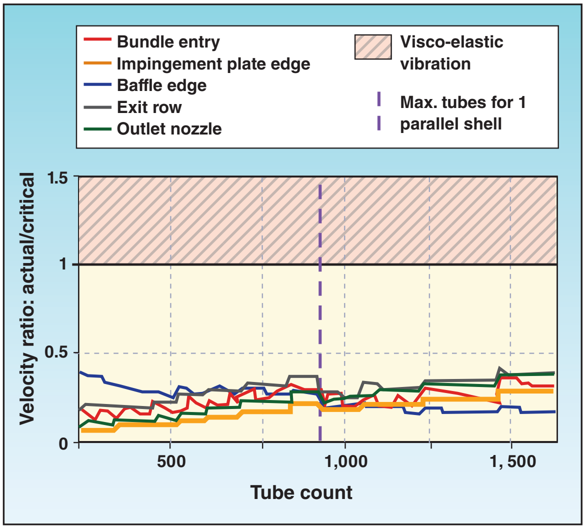

FIGURE 8. Based on the results of Figure 7, the sizes of both nozzles were increased by changing the allowable momentum, and the bundle layout was changed from a 90-deg. layout to a 45-deg. layout. Now the velocities in all of the critical locations are well below the critical value

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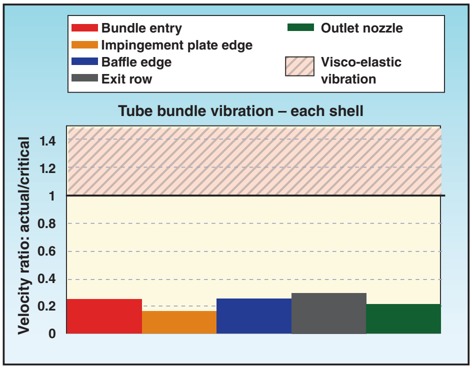

FIGURE 9. The vibration analysis for the selected geometry indicates that the unit should not experience any damaging vibration under a wide range of operating conditions

Now the space is controlled by the shellside pressure drop. Most significantly, rather than needing two shells-in-parallel to accommodate the tubeside pressure-drop constraint, we only need a single shell. This is evident from the dashed line that shows the maximum tube count of selected size and layout that can be accommodated in a single shell with its selected inside diameter.

The parameter plot is a powerful graphic that provides the designer with understanding of the factors controlling the design. Beneficial design changes can be identified and quickly evaluated, particularly when there is an ability to superimpose the plot for one basic specification — baffle cut, bundle geometry, tube size, tube count and so on — on another.

Generation of the plot involves systematically working along the tube count axis. For a specific tube count, a representative exchanger is rated. The results are then scaled in order to generate the relevant lines.

For any given tube count, it is possible to determine the size of shell required. A maximum value can be specified. This then allows the designer to observe where multiple shells operating in parallel are required.

Benefits for vibration analysis. A very major benefit of this approach is that for each point within the design space, we have sufficient information to undertake a vibration analysis. This means that just as engineers can adjust design parameters in order to select geometry that meets a pressure drop constraint, they can identify the "range" of geometry that is free from damaging bundle vibration.

The procedure is enhanced by providing the engineer with the ability to adjust factors that have a direct bearing upon vibration. These factors include adjusting inlet and outlet clearances, end zone lengths and baffle spacing.

The result is a design procedure that allows vibration to be considered as an integral part of design, rather than considering the problem of tube bundle vibration after the geometry of the design has been fixed and then searching for alternatives that are free from vibration.

Causes of bundle vibration

Vibration of a tube bundle can be caused by a number of mechanisms [2]: turbulence, vortex shedding, acoustic resonance and fluid-elastic instability (Figure 3). The most serious of these mechanisms and the one generally leading to damage of a heat exchanger is fluid-elastic instability.

The onset of this type of vibration is controlled by several factors. Those that can be controlled by the exchanger designer are the rigidity of the bundle and the velocity field.

The rigidity of the bundle is dependant upon exchanger end-zone length, baffle spacing and baffle count.

There are five regions where vibration is likely to first occur [2]. In the

DO NOT ASSUME THAT THE FLOW FIELD IS UNIFORM

Software currently in use in the chemical process industries allows design analysis for geometry that is a long way outside a range that was considered acceptable by experienced engineers working prior to the 1980s. The result is that engineers in a younger, less-experienced generation accept geometry that would have previously been rejected. The consequences can be poorer-than-expected thermal performance, increased fouling within heat exchanger shells and unexpected tube-bundle vibration.

The philosophy behind the current design approach for avoiding the onset of serious vibration is essentially conservative. It involves comparing maximum velocities encountered within the heat exchanger to a critical value associated with the location where that velocity occurs. However, in the application of this approach it is assumed that velocities across a tube are uniform. This is only approximately true for a narrow range of bundle geometry. Recent work by Alonso Vidal and others [5] uses CFD to determine the relationship between bundle geometry and the flow distribution within the bundle. It shows that with some geometries the fluid will "jet" from one baffle edge to the other. Local velocities can be substantially higher than mean velocities. It can be expected that the onset of fluid-elastic vibration will occur sooner in bundles where the flow is poorly distributed than in those in which the flow is nearly uniform.

In Figure 10 we show the flow field predicted within a tube bundle having a 40% baffle cut. The ratio of window-to-crossflow area is 0.79 (a value that would be expected to give a fairly uniform flow field). However, we observe the velocity at the edge of the baffle is twice that in the rest of the window. There is a jetting effect between the two baffle edges with the velocity down the side of the facing baffle being three times higher than along the face of the other baffle, and over 30% greater than a uniform velocity.

In Figure 11 we show the flow field predicted within a tube bundle having a 20% baffle cut. The ratio of window-to-crossflow areas is 0.78 (close to that for the 40% baffle cut). Here we observe that the velocity variation in the window is just 18%. The velocity distribution across the crossflow region is more uniform. For a 20% cut it was found that the velocity distributions in the window deteriorated as the area ratio increased above 1.2 and that in the crossflow region they deteriorated as the area ratio fell below 0.7.

Our recommendation is that only geometry that provides close to uniform flow fields should be used. On the basis of the CFD studies, these recommendations are that baffle cut should be in the range of 15–30%, with a window-to-crossflow area ratio in the range of 0.8–1.2

This is close to the recommendations of Gilmour [6], who stated that baffle cut should not exceed 25%. According to Saunders [7] that advice was widely accepted in the industry. ❑

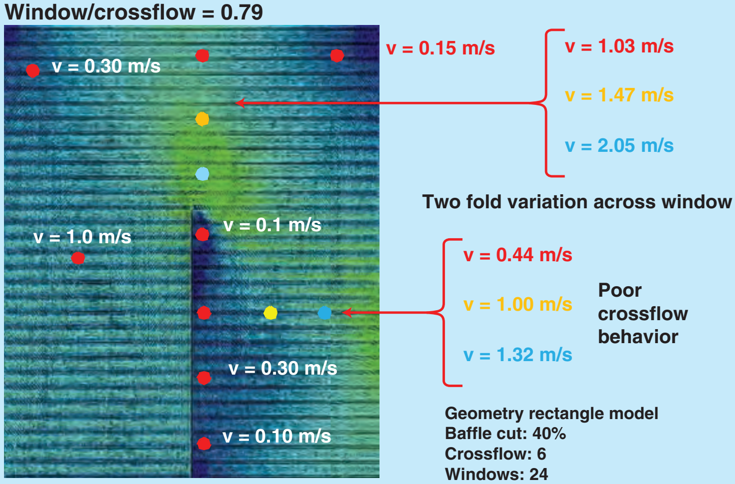

FIGURE 10. Although the window-to-crossflow area would be expected to give a fairly uniform flow field, the CFD analysis shows the velocity at the edge of the baffle is twice that in the rest of the window. There is a jetting effect between the two baffle edges with the velocity down the side of the facing baffle being three times higher than along the face of the other baffle and over 30% greater than a uniform velocity

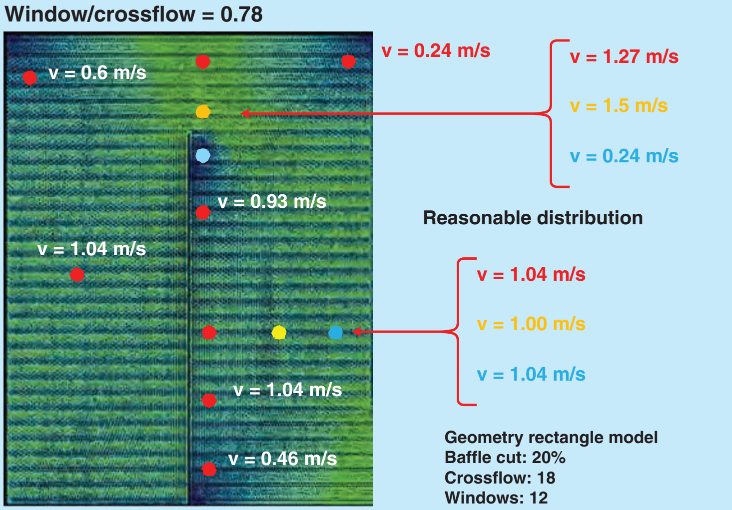

FIGURE 11. For a 20% baffle cut it was found that the velocity distributions in the window deteriorated as the area ratio increased above 1.2 and that in the cross-flow region they deteriorated as the area ratio fell below 0.7.

following descriptions we assume that the entry nozzle is positioned at the top of the shell and the exit nozzle at the bottom of the shell.

The first region is entry into the tube bundle itself. This is set by the location of the first tube row (set by the distance between the top of the shell and the first tube row, the "entry clearance"), the length of the exchanger end zone, the dimensions of the impingement plate and the layout of the tube bundle (Figure 4).

The next region is the edge of the impingement plate, where the flow area is set by similar measurements to those for bundle entry (Figure 5).

The third region that needs to be considered is the edge of the baffle plate (Figure 6). This is controlled by baffle cut and spacing.

The fourth region is the exit from the tube bundle prior to entry into the exit nozzle. Here the location of the exit tube row is important. This is set by the distance between the bottom of the shell and the exit tube row (termed the "exit clearance").

Finally, the velocity through the exit nozzle needs to be considered. This is, of course solely a function of nozzle diameter.

Vibration criterion

The critical velocity (V_c) at which fluid-elastic vibration starts is given by an equation developed by Connors [*3*]:

$$V_c = f_t d_p \beta \sqrt{\frac{m_e \delta}{\rho_s d_o^2}}$$

Equations for the calculation of tube bundle natural frequencies covering both plain and low fin tubes and each type of exit header, bundle damping parameters and log decrements for the differing bundle layouts are provided in Ref. 2.

The velocities in the regions described above can be calculated for the given throughput, and then the ratio of actual to critical velocities at each of these positions can be determined. There is danger of fluid elastic vibration if any of these ratios exceeds unity.

Applying the vibration plot

The baffle arrangement has an inherent influence on the design space. It has been demonstrated that to make best use of available pressure drop the window and cross-flow areas should be similar [*4*]. (These areas are set by spacing.) Consequently, development of a design best starts with a bundle geometry in which these two areas are equalized. The parameter plot should be produced for such geometry. The tube count sets the shell diameter. The baffle spacing that results in the same crossflow area is then determined.

The rigidity of the bundle is dependant on the number of baffles used in the design. With baffle spacing fixed, this is a function of tube length. So, the vibration analysis was conducted at four individual tube lengths (3, 4, 5 and 6 m). In the design example illustrated in Figure 2 it is observed that a single shell containing around 900 tubes would provide a good thermo-hydraulic design. However, when the vibration analysis is applied, the plot reveals unacceptable results (Figure 7).

Here the ratios of local to critical velocity are displayed for the five critical regions. Looking at the right-hand side of the plot, the top curve relates to the outlet nozzle, the next to the edge of the inlet impingement plate, the third curve relates to exit row, the next to bundle entry row and the final curve to the edge of a baffle.

From this plot we observe that the velocities in the outlet nozzle, at the edge of the impingement plate and in the bundle exit row all exceed permitted values. The plot indicates that the size of the outlet nozzle (which had been designed on the basis of a standard allowable momentum) needs to be increased. It also indicates that the tube-bundle flow-areas need to be increased in both entry and exit regions.

Consequently, the size of both nozzles was increased by changing the allowable momentum, and the bundle layout was changed from a 90-deg. layout to a 45-deg. layout. The result is the vibration plot shown in Figure 8. Here the velocities in all of the critical locations are well below the critical value.

With these modifications in mind, the designer can now select geometry (from the parameter plot) where the duty line crosses the maximum allowable length line.

The vibration analysis for this selected geometry (Figure 9) indicates that the unit should not experience any damaging vibration under a wide range of operating conditions. ■

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NOMENCLATURE

d_o	Tube outside dia., m
d_p	Equivalent bundle dia., m
f_t	Natural frequency of tube, Hz
m_e	Effective mass of tube, kg/m
β	Stability factor
δ	log decrement
ρ_s	Density of shellside fluid, kg/m^3
V_c	Critical velocity, m/s

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DESIGNING SHELL AND TUBE HEAT EXCHANGERS: Consider Two-Phase Flow

Homogeneous overpredict pressure drop and thermal performance for two-phase flow. This insight helps avoid associated design flaws

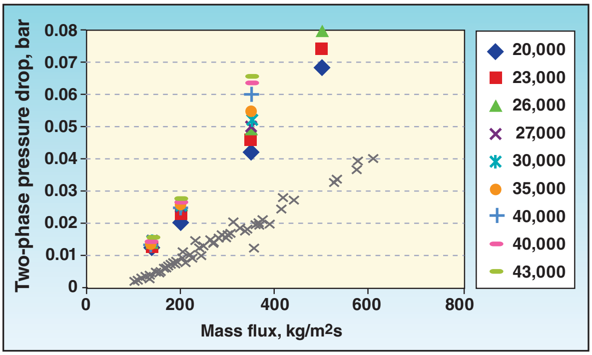

FIGURE 1. Homogeneous models overpredict pressure drop for two-phase flow by a factor between 2.5 and 4 because they ignore the significant separation of liquid and vapor phases that occurs within the heat exchanger. Experimental data is represented by black and grey marks

G.T.Polley, E.E. Vazquez –Ramirez, and M. Riesco Avila
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In the chemical process industries (CPI) it is relatively common to use a homogeneous two-phase flow model to predict the pressure drop through the shell-side of horizontal heat exchangers that handle two-phase mixtures. Recent experimental studies reported by HTFS [1, 2], however, have shown that this approach leads to overprediction of pressure drop and to overprediction of thermal performance. As a result, many designs are flawed and perform below expectations.

Homogeneous model vs. data

Doo and others [*1*, *2*] studied the evaporation of R134A in a TEMA AEW type heat exchanger fitted with 97 tubes of 1,240 mm length. Three different baffle arrangements were studied. In the first series of tests the unit was fitted with six vertically cut baffles (providing a horizontal side-to-side flow). The baffle pitch was 156 mm. In the second series of tests the orientation of the baffles was changed such that the flow was vertical. In the final set of tests the unit had only four baffles (with a baffle pitch of 260 mm) and flow was again side-to-side.

The first step taken in the analysis was a comparison between the predictions of a "homogeneous" model for two-phase pressure-drop with the experimental measurements. For all test conditions it was found that the homogeneous model grossly overpredicted the pressure drop. The comparison for the first series of tests is shown in Figure 1.

The homogeneous model overpredicts pressure drop by a factor between 2.5 and 4. This overprediction is an indication that significant separation of liquid and vapor phases is occurring within the heat exchanger.

This means that design codes that use a homogeneous model will not yield accurate predictions of pressure drop, re-circulation rate or heat transfer. It also has significant implications for re-boiler design.

Alternative flow models

When a homogeneous model overpredicts pressure drop, it is a strong indicator that phase separation is taking place. This article uses a stratified flow model (similar to the one proposed by Doo [2]) to model two-phase flow in a bundle fitted with baffles having a vertical cut (thereby promoting side-to-side flow) and a "stream analysis model" for two-phase flow through exchanger shells for bundles fitted with baffles having a horizontal cut (thereby promoting vertical flow). The aim is to help identify potential design limitations and define safeguards for avoiding them.

The predictions of the model are compared with the experimental data published by HTFS. In the case of side-to-side flow, the stratified model (as also reported by Doo [2]) provides good prediction of observed pressure drops and heat transfer coefficients.

In the case of vertical flow, reasonable predictions of pressure drop and heat transfer are obtained for cases in which the mass flux exceeds 200 kg/m^{2}s. Below this value the heat transfer is significantly overpredicted.

Significance of phase separation within the bundle

Side-to-side flow. With side-to-side flow, phase stratification can lead to large areas of tube bundle being wetted only by liquid entrained by the vapor issuing from the baffle space. This will result in poor heat transfer in the tube rows at the top of the bundle. It can also cause excessive fouling in these regions and in some cases tube erosion and corrosion.

As noted by Doo [2], by using a stratified flow model it is possible to predict the effect that vapor generation has upon bundle submergence. Charting of these values can provide a guide to reboiler design.

Vertical flow. Phase separation also occurs where vertical up-and-down flow is selected. As already noted for this arrangement, a two-phase stream analysis model provides good predictions of pressure drop and heat transfer.

However, good agreement was only obtained for flows providing a mass flux in excess of 200 kg/m^{2}s. What is happening at lower flows? Here the stream analysis model predicts very high va-

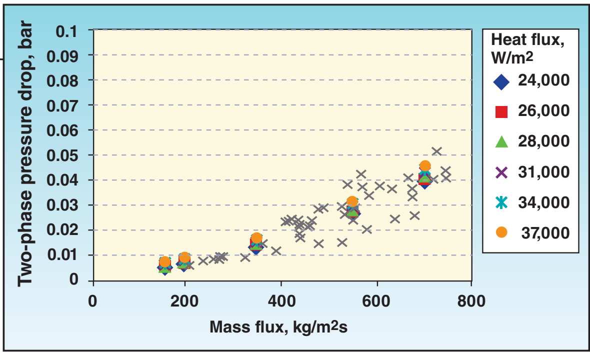

FIGURE 2. The predictions for the new stratified-flow model (unit with six baffles) agree well with experimental data (black and grey marks)

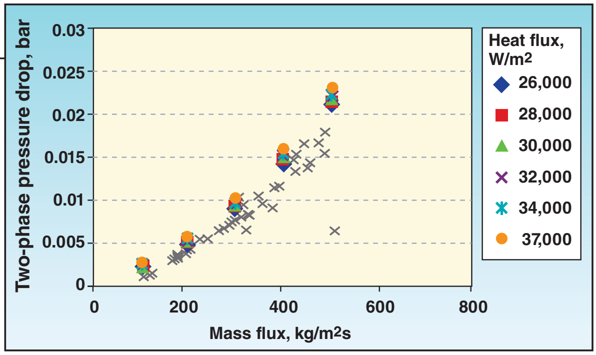

FIGURE 3. The predictions for the new stratified-flow model (unit with four baffles) agree well with experimental data (black and grey marks)

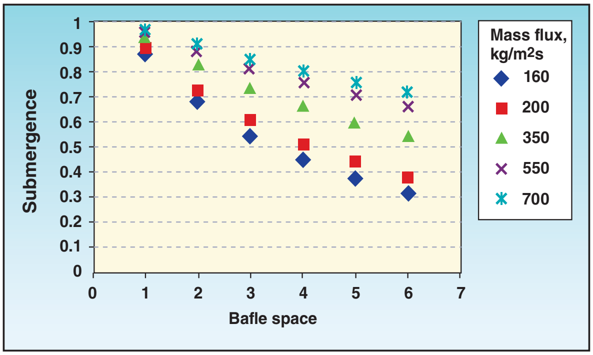

FIGURE 4. Here the new model shows the predictions for bundle submergence under a range of mass fluxes, which indicate a serious decline in submergence as the vaporization progresses

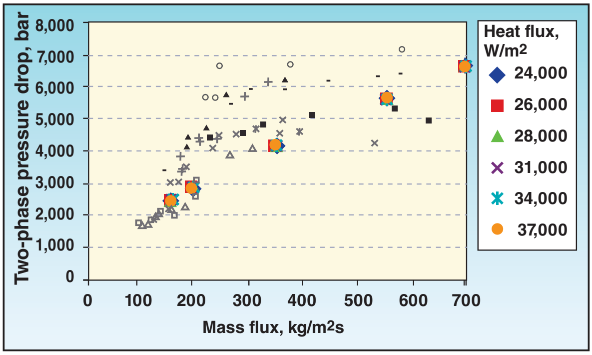

FIGURE 5. Here the predicted and observed (black and grey marks) heat transfer coefficients are compared for horizontal flow in a six-baffled unit

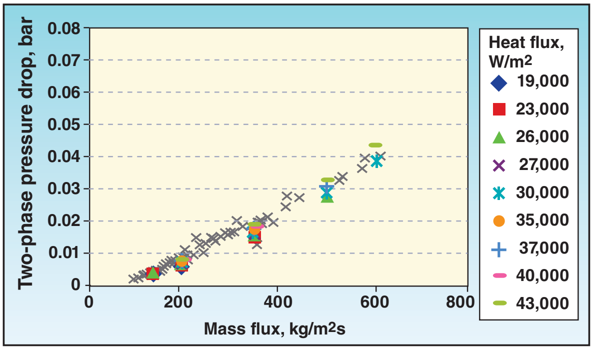

FIGURE 6. Pressure drop predictions of the new model are compared with the experimental measurements (black and grey marks) for vertical flow

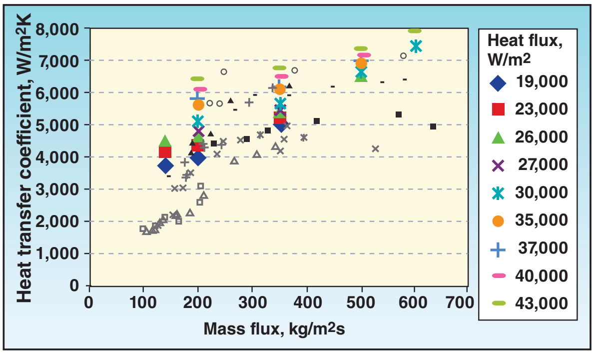

FIGURE 7. Heat transfer predictions for vertical flow are compared with experimental data (black and grey marks), indicating an increase in the vapor mass quality of the mixture passing through the tube bundle as more liquid is vaporized

por-mass quality within the center of the bundle itself, suggesting that dry-out is occurring within the bundle.

The role of the flow models. With side-to-side flow we can specify a minimum bundle submergence. With up and down flow we can specify a maximum vapor quality for the core of the exchanger. Using the flow models, we can then determine the conditions under which these constraints are met. These conditions can then be used to control design.

About our models

Side-to-side flow. For modeling side-to-side flow, we opted for a "stratified flow" model very similar to that proposed by Doo [*1*], the main difference being that we consider that flow consists of a gas stream and a liquid-rich layer containing the vapor generated within a given baffle space. The assumption is made that liquid and gas separate at each baffle edge and flow through the exchanger separately. Since, the change in vapor-mass quality occurring within a single baffle space is small, we chose to model the flow as one liquid stream and one vapor stream. The "interface" between these streams is such that each stream exhibits the same pressure drop. So, the pressure drop encountered when the vapor stream flows alone and when the liquid stream flows alone are calculated.

Position of the interface is given by:

$$(1 - Z) = \frac{X_{tt}}{1 + X_{tt}} \qquad (1)$$

Where Z is the fraction of the bundle immersed in liquid and X_{tt} is the Lockhart-Martinelli parameter. Knowing the position of the interface it is possible to calculate the two-phase pressure drop.

Comparisons between the experimental data and the predictions of this model for the first series of tests

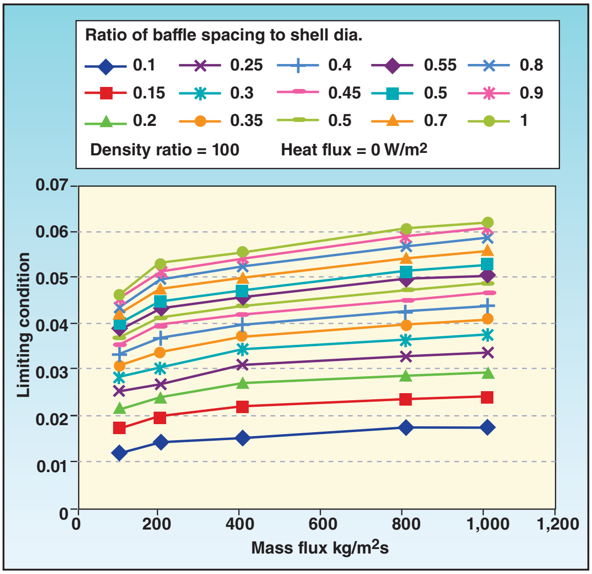

FIGURE 8. For a fluid having a density ratio of 100 (typical of an organic substance having a molecular weight of 100 being vaporized at an absolute pressure of 2 bar), large baffle spacing is favored. Given such spacing, the maximum quantity of liquid that should be vaporized in the reboiler (y-axis) is around 5%

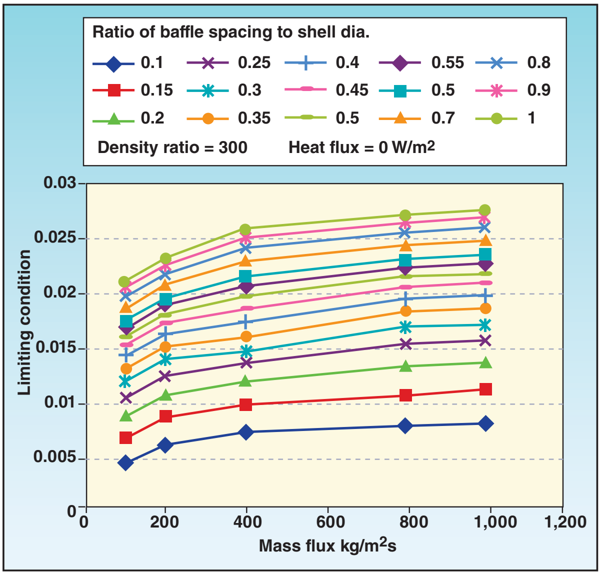

FIGURE 9. When the density ratio is 300 (typical of boiling an organic substance having molecular weight of 70 at atmospheric pressure), the limiting baffle-space inlet conditions dictate that the maximum quantity of liquid that should be vaporized in the reboiler is just 2.5 %. This suggests that such duties are best undertaken in a vertical thermosiphon reboiler

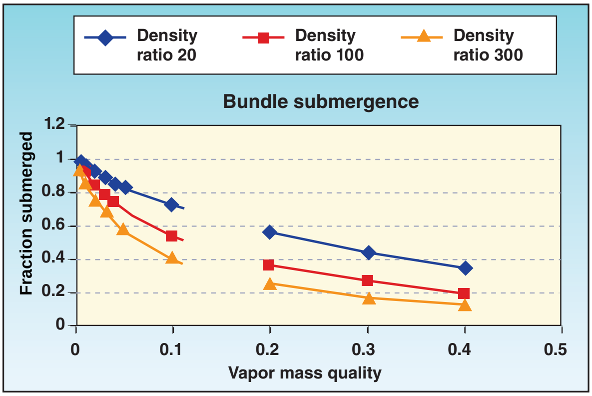

FIGURE 10. Bundle submergence during horizontal flow is presented for a range of density ratios

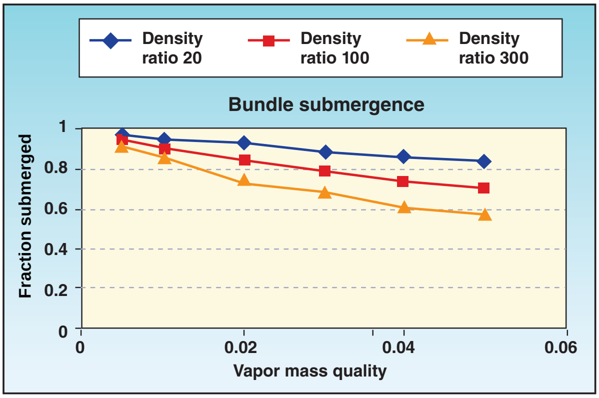

FIGURE 11. Here, bundle submergence (see Figure 10) is presented for only the important range of inlet quality (up to 5%)

are given in Figure 2. Those for the unit fitted with four baffles are given in Figure 3. The predictions compare well with the experimental data.

The significance of the new model is the ease with which the bundle "submergence" is calculated. This is found to vary significantly across the heat exchanger. In Figure 4 we show the predictions for the first test section under a range of mass fluxes. We observe a serious decline in submergence as the vaporization progresses. (The presence of a vapor only zone was detected experimentally by Doo and others using thermocouples at the end of individual exchanger tubes).

This decline is confirmed by analysis of the heat transfer data. In this analysis the heat transfer in the vapor zone is very much lower than that occurring in the boiling zone, and can be ignored. The heat transfer coefficient (α) in the boiling zone was calculated using a model of the form:

$$\alpha = \left(\alpha_{NB}^3 + \alpha_{FC}^3\right)^{1/3} \quad \textbf{(2)}$$

The nucleate boiling term (α_{NB}) is calculated using a modified form of the Gorenflo-Leiner correlation [*3*]. The convective heat-transfer coefficient (α_{FC}) is that encountered when the liquid flows through the submerged section of the bundle.

Vertical flow. For up-and-down flow, where the vapor mass fraction of the mixture flowing through the bundle is much larger, the convective term was calculated using

$$\alpha_{TP} = (1 - Z)\alpha \quad \textbf{(3)}$$

Where the void fraction (ε_G) is calculated with the Armand equation, and α_L is for liquid flowing alone:

$$\alpha_{FC} = \alpha_L \left(\frac{1}{1 - \varepsilon_G}\right)^{0.744} \quad \textbf{(4)}$$

Predicted and observed heat transfer

coefficients for the first series of tests are compared in Figure 5.

Pressure drop during vertical two-phase flow through tube bundles is calculated using a modification to the "stream analysis" method proposed by Wills and Johnston [*4*] for single-phase pressure drop.

With two-phase flow it is assumed that the bypass, the tube-baffle leakage and the shell-to-baffle leakage streams consist solely of liquid. Two-phase flow is only present in the cross-flow and window regions of the bundle.

Predictions of this model are compared with the experimental measurements in Figure 6. Heat transfer predictions are compared with experimental data in Figure 7.

Guide for design

The following is a design guide for the limiting conditions.

Vertical flow. In line with the observations made above, the maximum acceptable core quality is set at 0.7. The model is then used to determine how reboilers operating under other conditions will behave. The flow conditions at entry to the final baffle space that yield a core quality of 0.7 are determined. These conditions are found to be dependant upon the ratio of liquid to vapor density, upon mass flux and upon the ratio of baffle spacing to shell diameter.

In Figure 8 we present a plot of limiting inlet conditions for a fluid having a density ratio of 100. (Typical of an organic substance having a molecular weight of 100 being vaporized at an absolute pressure of 2 bar). Large baffle spacing is favored. Given such spacing we observe that the maximum quantity of liquid that should be vaporized in a reboiler on this duty is around 5%.

An increase in density ratio has a very large effect upon the limiting conditions. In Figure 9 we present the limits when the density ratio is 300 (typical of boiling an organic material having molecular weight of 70 at atmospheric pressure). Here the maximum quantity of liquid that should be vaporized in the reboiler is just 2.5%. This suggests that such duties are best undertaken in a vertical thermosiphon reboiler.

Submergence in side-to-side flow. We can also produce plots of bundle submergence for a range of density ratios and flow conditions. For the stratified model presented here the submergence is independent of mass flux. In Figure 10 we present plots for density ratios of 20, 100 and 300 across a full range of inlet vapor qualities. The important range is inlet quality of up to 5%. Values in this range are shown in Figure 11. ■

Edited by Rebekkah Marshall

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Ten Tips For Smart Project Managers

Alfred Chiu
S & B Engineers and
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Some of the less tangible aspects of project management, such as culture, how to break bad news and acknowledging limitations are just as important to success as schedules and budgets

FIGURE 1. Communication is key to effective project management. A project manager should repeat important messages, using different formats of communication, such as meetings, posters, awards and more

Projects have been undertaken by nations, private enterprises and individuals for more years than recorded history. Over the last three decades, project execution in the chemical process industries (CPI) has become almost standardized, with the general adoption of certain well-known project management procedures including the Front-end Loading (FEL) process and the "Body of Knowledge." Those who are selected to manage the projects are generally the winners of rigorous elimination processes in their companies. You would have thought that everyone would get it right by now. But as every practitioner of the business knows, "war" stories of disasters abound; some of them making it to the business page of the news. What seems to be the problem? In this article, we focus on ten key areas in project management, where mistakes can have overreaching impact on the outcome.

Manage the uncertainty

Everyone in the project management business has heard the phrase, "Plan the work. Work the plan." It seems so simple. All smart project managers do that. The difficult part is that in project execution, as in life, there are uncertainties. The FEL process is a procedural way to control some of those uncertainties and minimize their impact on the bottom line. Most owner-company project departments and engineering contractors now have similar procedures with checklists or pass gates. But the missing ingredient in doggedly following this exercise is that there is no room for contingency planning.

Business economics, which affect project execution, are never linear due to constantly changing global events. Neither are technical traps that exist on every project, because each project is unique. The question that is seldom asked in the FEL process is: "What if the plan, for whatever reason, no longer works?" Setting aside the political ramifications of truthfully asking this question, what must the project manager do in this instance?

His or her task must focus on identifying the change from the original project premise, large or small, and then managing the change that is required. The task of managing the uncertainty of life means being prepared to make changes to that "sacred" project-execution plan as circumstances dictate. Every plan is based on a set of facts and assumptions. It is the project manager's responsibility to recognize when new developments show that the facts need updating or assumptions are proven false. In all cases, time is of the essence, and revisions to the plan must be immediately put into place. In the most drastic cases, it may

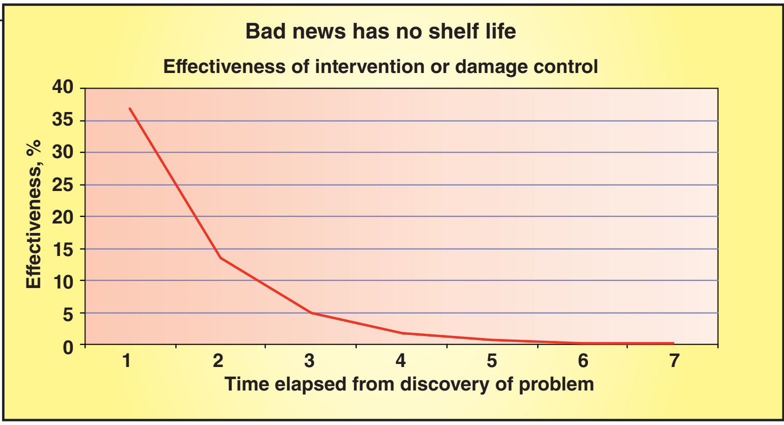

FIGURE 2. This sketch demonstrates that prompt action is needed when a project is confronted by bad news in order for it to be effective. The unit of time is arbitrary in this graph, as it depends on the magnitude of the problem

mean wholesale redirection of the project in priorities and targets for budgets and schedules.

Educate the client

Perhaps once upon a time, long long ago, there was a place where the owners of a project (referred to here as the client) knew what it took to implement a project. Given the changes in demographics, the outsourcing trend and the involvement of so many investment companies, a project manager is often confronted by a client who may only be vaguely familiar with the implementation process. At a large international engineering and construction firm, we once joked that, "What the customer doesn't know will not hurt us!" Unfortunately, the truth is quite different from that. An ignorant client will hurt himself, and in the process, possibly hurt the contractor even worse.

This is indeed the worst case scenario come true. And its management is the most difficult task for a project manager. The problems of an ignorant client have many facets. Among them are unrealistic expectations, misplaced skepticism, focusing on the wrong details and making the wrong technical decisions. There is no room in this article to describe in detail how each type of these can negatively impact a project. Suffice it to say that since we are not all-knowing and omnipotent, every one of us will have to admit to being ignorant of something. It is therefore important for the smart project manager to recognize the strengths and weaknesses of a client. The unpublished portion of the project execution plan must include a plan to bring the client on board and include, if necessary, a way to conduct some degree of education. All this must be accomplished early in the project without insulting the client. This is a necessary condition for the success of a project. If it is not done, or not done in the early part of the project, the consequences will not be pretty.

Manage the culture

Every project or task force, whether it is large or small, develops its own culture. The smart project manager ignores the effects of that culture on the outcome of the project at his or her own peril. The management of the culture is perhaps the second-most-difficult part of a project manager's job. Engineers by training, and in nature, are most likely to be creatures of the mind. We value hard data and analysis and predictable procedures. But culture is more of a manifestation of the heart. "Culture is defined by the group's norms. It is manifested in the group's habits and symbols," says J. Timothy McMahon, a professor at Bauer College, University of Houston. There is no correct answer as to which is the "best culture." One will know it's good when one feels it; and it will feel different for each person. There are successful projects that revolve around strictly hierarchal teams and others with egalitarian teams. Culture cannot be managed by procedures and forms.

At one company, there is a procedure for procurement specification that involves at least eight signatures and three internal transmittals to move the document 100 ft down the hall. In the dark history of the procedure, there were instances of omissions and errors. Not surprisingly, the undesirable behavior continued with the implementation of procedures that only served to provide a shield for the perpetrators. Instead of searching for the right culture, identify those parts that are a manifestation of a bad culture, such as lack of trust, lack of respect, fear, jealousy and isolation. In the most drastic case, project team members may have to be removed because they become poisonous to the team culture. There is a great deal of truth to the saying that one rotten apple spoils the barrel.

Wealthy corporations that can afford to hire expensive consultants often conduct team building exercises. Vast resources are spent to bring the team to a special location with one or more facilitators who purport to ferret out the organizational problems in a few hours or a couple of days, and of course discover procedures to resolve these issues. In the course of the project, the results of the team building exercise are supposed to be implemented so that everyone lives happily ever after. I have often wondered during the numerous exercises that I have attended whether everyone would be much better off if they just got a day off with pay to take care of whatever urgent business is in their lives.

Someone with a true understanding of culture would know that a "vanilla" session of team building can only do harm by raising expectations without a guarantee of improvements. Culture must be managed in small increments by a project manager. The other way, to bring about quick cultural change, is via life-changing and often catastrophic events. The great depression and the murderous events of 9/11 were times when cultural changes were dramatically brought about.

For the project manager, bringing about the desired cultural change means action by small increments. On one taskforce at a petroleum refinery, a discussion on who was a better cook evolved into a potluck lunch for a few of the contractor team members. The event grew to become the theme-of-the-month potluck lunch to celebrate different types of cooking. Eventually, it became a taskforce endeavor that included many of the client personnel. This tradition brought about improved team relationships with the client, which translated to better performance of the whole team. This was a textbook case of changing culture by celebrating small victories (people sitting down at the same table to eat) with shared gains (getting some good food for free).

Acknowledge the limitations

We live in a world of limited resources. Therefore, it is always a puzzle to me why clients and project managers persist in making a statement like, "We have to meet the schedule. Money is no object." Or the evil twin statement, "We have to conserve capital. Schedule is not important." A simple analysis of either statement would quickly show that if either is true, there is no business reason to execute the project at all. Why would the project be necessary if one does not make money from it or if it does not matter when it is to be finished?

A smart project manager must acknowledge to the team that he or she understands the limitations placed on the project team. This is also an important aspect of educating the client if this is one of his blind spots. It is not a crime to say that you want "x" while admitting that you only have resources to get "y". A key part of this acknowledgement is an execution plan that meshes with the reality. It is in our human nature to reach higher than where we stand. However, all incentive to do so is quashed when the project manager refuses to acknowledge that certain objectives may be difficult to reach with the available resources at hand. This mistake is then compounded by the lack of a realistic project execution plan. "Damn the torpedoes! Full speed ahead!" makes for a good headline. However, the smart project manager must not forego careful analysis and good planning. An open discussion about limited resources allows the entire team to buy-in on confronting the challenge and come up with ways to achieve the project objectives in spite of the limited resources.

Frame the message

A project team and the client are always on the receiving side of messages given by the project manager. Whether these messages are consciously thought out or just comments tossed off the cuff, they are received and interpreted. This requires that the smart project manager must carefully gauge what can be said in public and what must be discussed in a limited audience with a long preamble on what the content of the message means. Without developing an overwhelming sense of isolation and paranoia, a project manager must realize that he or she is to a great extent, the messenger with the clay tablets in the universe of the project team.

Sound bites of hallway conversations are easily misinterpreted and spread with the speed of the internet. Use of humor may not be well received, especially with team members from other parts of the world. This is not to say that humor is to be avoided, but what is said in the privacy of one's home or small gathering should probably be left there. Remember that a large part of humor requires a target. Do not make someone or some group the butt of a joke unless that target is a willing participant. Even then, be careful of overly sensitive feelings. On a task force where the joke was that the project manager and his management team were all shorter than five feet four inches, a much taller member of the team was actually concerned for my feelings. I, being at five feet two inches, was having a lot of fun. But it was a lesson in empathy that others may not feel the same, even when they are not the butt of the joke.

The two taboo topics of politics and religion should also be carefully weighed. The objective of the project manager is to organize an effective team to execute a project. This objective does not include converting others to your political or religious beliefs. Such discussions, while intellectually stimulating, risk destroying the team cohesion instead of uniting the team, and thereby undermine the delivery of the message.

The key to the delivery of messages is that the majority of them should be balanced in tone, and always in the context of the objectives of the project. This leaves room for those critical times when it is necessary to make sure that the team understands the gravity of the situation and responds accordingly, such as when there are major changes in project direction or when extra effort is required. Balanced messages also keep the evil extremes of over-optimism or pessimism from overshadowing the actual information that is needed by the team.

Manage the bad news

In the course of the execution of a project, there will be times when we will be confronted by bad news. As Dr. Brookshire at S&B says, "Bad news has no shelf life." Thus prompt action is required. The first rule for handling the situation is to not sweep it under the rug. The second rule on managing the bad news is that if you do not manage it, then someone else will do it for you. Invariably, that someone else is the one controlling the rumor mill. A smart project manager will not let that person hijack the project. Two other rules in these situations are: "Honesty is the best policy." and "Bad news is bad. Bad news late is worse."

It is a natural reaction, in an unhappy circumstance, to wish it would go away. There is also a strong psychological tendency to deny the full extent of the damage. The project manager

THE TEN TIPS

Project management involves much more than the technical steps outlined in standardized procedures. Even experienced project managers would benefit from keeping the following key points, which are explained in this article, in mind:

1. Manage the uncertainty
2. Educate the client
3. Manage the culture
4. Acknowledge the limitations
5. Frame the message
6. Manage the bad news
7. Communicate, communicate, communicate
8. Manage what you know
9. Finish the job
10. Stay connected to the business objectives

must be able to overcome both of these natural reflexes in order to analyze the situation and determine the best course of action. The outcome must be a decision or action plan.

Keeping the mentioned rules in mind, the smart project manager communicates the bad news to the team and the clients as soon as possible. The number of details disseminated may be limited with an explanation of the justifiable need for business secrecy, but it is important to stick to the truth. This communication should include the action plan needed to manage the impact of whatever is not right, or if that is not immediately available, include a promise issue date.

By being the messenger, the project manager is able to control the message and avoid the damage from rampant misinformed gossip, which serves to undermine the precious culture of trust and respect that was carefully nurtured.

Communicate

My mother used to say, "If I have told you once, I have told you a thousand times!" The message was then reinforced with a slap to the back of the head. Okay, now I have got it. Maybe my mother read the survey that shows that our information absorption is somewhere less than 20% of what was transmitted. So at the risk of sounding repetitious, the smart project manager should say it again and again. But in order to limit the number of people falling out of their chairs while asleep (a safety hazard), the message may be put into a different format each time. So put up that safety banner, talk about it in the monthly project meeting, hold a safety award meeting, remind the team about working safely before they head out to the plant or drive home, and give the team a free safety lunch where you remind them about the job safety bonus. It is all the same message repeated over and over.

Manage what you know

It is hard for top performers like project managers to acknowledge that they do not know everything that they are trying manage. But this is something that cannot be hidden from the project team. Any attempt to gloss over this would only highlight the dishonesty of the situation and lead to weakening of the good culture. Instead, the project manager must assign qualified subordinates who can take over the task of managing those aspects where the project manager is not strong. At large engineering and construction firms, there is typically a position of "project engineering manager" that has the responsibility for the technical integrity of the design. But even here, it is unrealistic to believe that a chemical engineer by training has sufficient knowledge to oversee the details of electrical design. So it is smart to make more than one senior level assignment to assist the project manager in those areas that need additional knowledge.

By delegating parts of the project management to qualified individuals, the project manager has more time to focus on what he or she knows, and the flexibility to manage the greater issues of the overall project direction and client relationship. The individual project team member also has greater access to the technical decision maker and so can minimize the delays associated with waiting for a decision.

Finish the job

The successful completion of a project means taking care of all the small details and pieces of information that were generated over a course of months. They must be collated, filed and transmitted to the end user. Unfortunately, the deluge of information invariably comes amid the chaotic destaffing of the discipline that generated it. For the project manager, the delivery of the information is a critical part of the project contract — so it must be done in an orderly and timely fashion.

The key to the success of this final phase of the project is to have a closure plan in place and the personnel responsible for the execution of that plan should be assigned from the beginning of the project. By identifying specific items that go into the "job books" or any other transmittal early on, and having the specific personnel committed to the task of assembly, it can be carried out throughout the life of the project. The last minute scramble for information should not be left to the last clerk on the project.

Stay connected to the business

Ask what are the most important aspects of project management, and the answer will be safety, cost and schedule. And so indeed, those are the correct answers if the only concern is to manage the everyday grind of detail design and installation. However, for a project to succeed, the project manager must make sure that the project satisfies the basic business objective.

In several extreme cases, more than one major international company has seen projects to successful completion only to discover that the market no longer needed its products. The lack of a clear connection to the business objective resulted in the unnecessary expenditure of scarce capital. While the retrenchment or even complete shutdown of a project is a drastic measure, it must nonetheless remain on the table as part of the risk-to-reward calculation.

Conversely, it is also important that if market conditions dictate, the project manager must be ready to redirect the project so that the company is able to take advantage of the new economics. In the case of a gas processing company, a pipeline project that was conceived to transport products from one region to another was completely revamped to be able to reverse the flow direction during certain times of the year. The original project schedule was still met with the revision of the project execution plan, which included the judicious addition of resources and contribution of the project team working above expectations to accomplish the goal. ■

Edited by Dorothy Lozowski

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Engineering Practice

Lubricating Rotating Machinery

Follow this guidance to improve lubricant selection, process operation and asset reliability

FIGURE 1. In an oil-injected, twin-screw compressor, the lubricating oil is injected into the gas stream to absorb the heat of compression and act as lubricant and sealant. This enables a much higher pressure ratio in a single stage and provides significant protection against corrosive gases. In multi-stage machines, inter-cooling is usually not required

Amin Almasi
WorleyParsons Services Pty Ltd.

Lubricants in rotating machines reduce friction and wear, dissipate heat, protect surfaces, keep out foreign contaminants and remove wear particles. Commonly used liquid lubricants fall into two main categories: mineral (petroleum-based) oils and synthetic oils.

Mineral oils are produced by refining crude petroleum. They usually contain trace amounts of some unwanted substances. By contrast, synthetic oils are engineered, so their properties can be more tightly controlled. Synthetic oil lubricants include synthesized hydrocarbons (such as polyalphaolefin, or PAO), organic esters (such as diesters and polyol-esters), polyglycols, polyalkylene glycol (PAG), phosphate esters and silicone lubricants.

Mineral oils are more frequently used in chemical process industries (CPI) applications, but the importance and use of synthetic oils has been steadily increasing in recent years. In general, they offer superior performance in terms of higher oxidation stability, improved corrosion resistance, and the ability to withstand both higher and lower temperatures.

Compressors and pumps

Some compressors operate with gas discharge temperatures exceeding 160°C. This calls for a lubricating oil that has good oxidation properties and thermal stability. Meanwhile, in some compressors or pumps, the lubricant is in contact with moisture (from the handled fluid), so the lubricant must have good demulsibility (that is, resistance to emulsification, or good resistance to mixing with water).

Today, the overwhelming majority of compressors and pumps are best served by premium-grade oils with ISO VG 32 or 46 (sometimes ISO VG 68 or 100 grades). However, there are many different types of compressors and pumps, and each manufacturer is likely to recommend only those lubricants that have been used successfully before. Occasionally, compressor lubricants have to be formulated for exceptional severe-service performance.

Reciprocating and screw compressors. During operation, lubricants used in screw compressors and in the cylinders of reciprocating compressors are in direct contact with compressed gas. With conventional mineral oils, such gas can become dissolved in the oil. Additionally, any oil that becomes dissolved in the gas can be carried away, depleting the lubricating film. This can result in machine component scoring and higher wear rates. Specially formulated synthetic lubricants generally perform better in these instances.

When selecting a lubricant for reciprocating or screw compressors, low solubility in compressed gas should be a key selection criteria. The selected lubricants should also have relatively high viscosity indexes, minimal viscosity loss, good thermal stability over an extended temperature range, excellent wear protection, excellent lubricity. They should be non-poisoning to catalysts, since some oil will be transferred downstream by the gas.

For reciprocating or screw compressors, the lubrication oils that meet all of these criteria are mainly synthetic lubricants formulated with PAG base stock. Overall, these provide excellent oxidative and thermal stability, which are particularly important for high-temperature applications. Relatively high viscosity indexes facilitate low-temperature startup and help to maintain acceptable viscosity over a wide temperature range.

PAG lubricants are highly stable, even at sustained high temperatures, and thus have very low deposit-forming tendencies. And importantly, any decomposition products that may form tend to be soluble in the lubricant and thus do not tend to separate as sludge or contribute to the formation of varnish or lacquer. Similarly, because of their close contact, it is important to select lubricants that are compatible with the elastomer and coatings used in the compressor's wetted parts.

Minimizing lubricant carryover to downstream discharge streams is important for any compressor, particularly for screw compressors and reciprocating compressors. In general, gas solubility increases roughly linearly with increasing pressure. As a rough indication, PAG lubricants typically have a gas solubility that is less than half of that of mineral oils or PAO synthetic oils. High-pressure reciprocat-

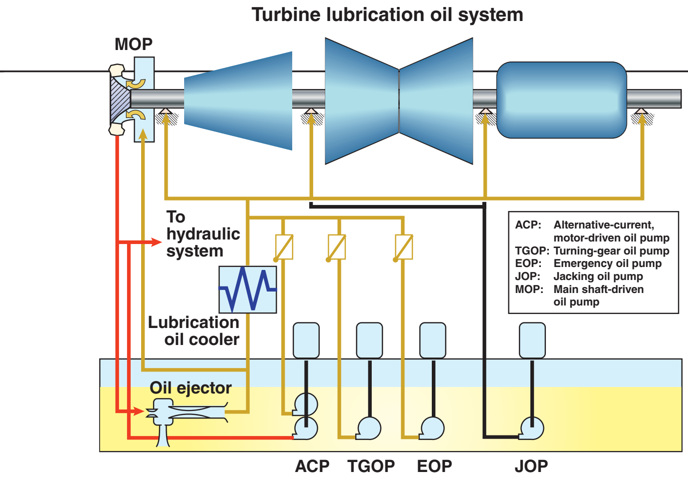

FIGURE 2. A typical turbine lubrication oil system requires a combined oil system that supplies lubrication oil for bearings and hydraulic oil for the turbines

ing compressors (that is, those above 300 bar, up to several thousand bar) need special attention in this regard.

Another important consideration is water solubility. PAG lubricants show less than 20% of the water solubility of typical mineral oils. Generally, mineral oils (or petroleum oils) are complex mixtures of naturally occurring hydrocarbons, but synthetic base fluids have a controlled molecular structure with predictable and advanced properties.

When it comes to reciprocating compressors, the traditional approach has been to ensure that the lube oil that is supplied to the crankcase (bearing) is the same as the lube oil supplied to the cylinder and packing. The goal has been to keep lubricant types to a small number, to bring down costs and avoid lubricant misapplication. However, in a majority of cases, it is more appropriate to provide a different lubricant to the cylinder and packing working space to improve overall performance.

For instance, lubricants for the crankcase and crankshaft mechanism should be suitable for the particular bearing application. In many cases, this will involve using a suitable mineral oil (or sometimes a synthetic lubricant that is suitable for bearing applications) in relatively large volumes in a closed lubrication loop.

On the other hand, cylinder and packing lubricants must be suitable for use in contact with gases. In many cases, separate lubricant-supply systems are used for working space (cylinder packings) and running components (crankshaft bearings), to enable the most optimal lubrication for each.

Synthetic lubricants with ISO VG 100 to 220 ratings are extensively used for reciprocating compressor cylinder-packing for process services. In the lubrication of double-acting compressor cylinders, one of the most important factors is the rate of oil feed. In general, the risk of over-lubrication is greater than that of supplying too little oil. Because many problems associated with reciprocating compressor operation can be overcome by preventing excessive lubrication, proper control of the supply of oil to the cylinder is the key.

Nearly 45% of reciprocating compressor shutdowns are due to cylinder valve and unloader problems. About 20% of reciprocating compressor shutdowns result from packing or piston ring problems. Proper selection and use of cylinder and packing lubricant is essential to improve the performance of cylinder valves, unloaders, packings, piston rings and bearings.

Operators should examine how closely the applied lubricant's feedrate meets the actual cylinder packing's lubricant requirements. This can be done by examining internal surfaces, such as cylinder walls. When properly lubricated, these surfaces should be covered with a thin film of oil. There should be no evidence of oil accumulation. If the cylinder surfaces are wiped with a piece of paper, oil should stain paper evenly, but should not soak in. If the paper is dry or unevenly spotted, the feedrate is too low. If the paper is saturated, the feedrate is too high. Lubricant feedrate should be adjusted to provide no more than the minimum lubricant requirement.

There is violent mixing of lubricant and gas inside rotary screw compressors (oil-flooded screw compressors). In general, screw compressors need lubricants with extra oxidation resistance to ensure long service life in closed circulatory systems. They also require lubricants with lower viscosity compared to cylinder-packing lubricants. In rotary screw compressors, the same lubricant is often used for bearings as well as internal compressor lubrication.

Inside screw compressors, the lubricant is used to lubricate mating metal surfaces and seal compression chambers (which form as a result of screw mashing) and to cool the compressed gas. Lubricant films seal and lubricate all contact lines between male and female screws.

Oil viscosity plays an important role in ensuring machine performance and minimizing power losses. The selected lubricants should maintain a dependably strong lubricant film to provide dependable wear protection, thermal stability, and appropriate viscosity across the temperatures they are likely to encounter during operation (Figure 1). At the same time, the viscosity should be appropriate to limit power losses.

Dynamic compressor and pump lubrication. Dynamic compressors and pumps are machines that achieve a pressure rise by adding kinetic energy and velocity to a continuous flow of fluid. These machines deliver relatively large volumes of fluid at relatively low or medium pressure increases. Common types of dynamic machines include centrifugal and axial compressors and pumps.

Optimal lubricants for dynamic compressors and pumps are usually premium extreme-pressure (EP), multipurpose oils designed for dependable performance over a wide range of temperatures and operating conditions (extreme-pressure lubricants are oils that can work under shock or sudden high pressure rises). The most appropriate lubricants for dynamic machines tend to be synthetic lubricants formulated from PAG base stock, and that have dedicated anti-wear, severe-service and long-life properties.

Specifically, when specifying a lubricant for dynamic machinery, users should opt for ones that have the following characteristics:

1. Superb oxidative and thermal stability
2. Relatively high viscosity indexes (values depend on the application and can vary considerably)
3. Relatively low pour points for easy cold temperature startup (again,

optimal values depend on application and can vary considerably)
4. Excellent lubricity for enhanced resistance to friction and wear
5. Extreme pressure lubrication
6. Good resistance to mechanical breakdown
7. Good resistance to sludge and varnish formation
8. Non-corrosive and stain resistant
9. Suitable compatibility with elastomers and coatings (particularly seal system components, gear unit internal paints and so on)

Lubricants with ISO VG 32, 46 and 68 grades are commonly used in dynamic compressors and dynamic pumps.

Turbine lubrication

Turbine lubricants must have excellent thermal and oxidation resistance at bearing oil temperatures, which can approach 100°C in typical steam turbines or heavy-duty industrial gas turbines, and can exceed 200°C in aero-derivative gas turbines. Turbine lubricants must control the rust and corrosion that could destroy precision surfaces, and resist foaming and air entrainment, which could impair lubrication and lead to equipment breakdown.

Such lubricants must also have suitably high viscosity indexes that allow more uniform lubricating performance over a wide range of ambient and operating temperatures. They should also be easily filterable without additive depletion (additive separation or sludge formation).

Turbine lubricants should be versatile, able to serve as both lubricating oil and hydraulic fluid for various turbine systems, generators, driven equipment, gear units and other auxiliary components. The goal is to simplify lubricant inventories to a relatively small number of multi-purpose products, thereby minimizing the chance of potentially costly lubricant misapplications. Products of interest for turbine operators are ISO grades 32, 46 and 68.

Steam and gas turbine oils are expected to provide years of trouble-free operation (Figures 2 and 3). In-service monitoring of turbine oils is a valuable means of assuring optimum oil performance and extended turbine life. The following recommendations are intended as a general guideline. If the limit is passed, the lubricant should be replaced, and the problem root-cause should be studied so that required corrective action may be taken at the first opportunity:

- Total acid number increase — The warning limit is 0.3 mg KOH/g)
- Water content — The warning limit is 0.2%)
- Cleanliness — It is necessary to find the source of particulates (for example, makeup oils, dust or ash entering system, wear and so on), so that steps can be taken to address the problem
- The Rotary Bomb Oxidation Test (RBOT) warning limit is less than half of the test result value of the original oil (RBOT is a method of comparing the oxidation life of lubricants. For more information refer to ASTM 4378 and ASTM D-2272)

Steam turbines. A steam-turbine oil system is usually required to provide oil for bearings, trip-and-throttle valves, governor systems, power cylinders and similar accessories. Trip-and-throttle valves have two major functions — as an emergency shut-off valve to trip the steam turbine (that is, to cut steam flow immediately at the inlet) and to admit and throttle steam to the steam turbine, particularly during startup. The use of a combined oil unit — one that provides both lubrication oil for bearings and hydraulic control oil for trip-and-throttle valves, governors and similar applications — is very common.

Steam turbine lubricants must readily shed any water that becomes entrained during operation. Water in the steam-turbine train's oil reservoir typically comes from one of the three following sources (A water analysis can usually determine the source):

1. Simple condensation from air within the reservoir can be minimized by maintaining the manufacturer's specified oil level within the reservoir and maintaining good ventilation around the turbine train.
2. A leak in the shell-and-tube oil cooler(s) may allow cooling water into the oil loop. If the oil pressure is greater than the water pressure, oil will be forced into the cooling water in the case of leakage. Operators should adjust or select oil operating pressures greater than the cooling-water's operating pressure.
3. The main contributor to entrained water in the oil system is steam bypassing the steam seals, and subsequently mixing with the lubricant oil. This is particularly prevalent in steam turbines with high back pressure or high first-stage pressure, once the seals are worn. It is good practice to provide air purge connections on the bearing seals of steam turbines. Dry instrument air will provide positive pressure in the lube oil area.

FIGURE 3. Tilting-pad bearings are commonly used for high-speed rotating machines. Each bearing consists of a series of pads. Because oil is basically incompressible, pressure builds within the oil film, which provides a means for the oil film to transfer the load

Gas turbine lubrication. In general there are two classes of gas turbines:

1. *Heavy-duty gas turbines.* Lubricant selection for these types of gas turbines is similar to the selection for steam turbines. Standard components of these turbines are fairly massive and the bearings are typically located at some distance from the heat sources. In most cases, petroleum-based lubricants perform suitably for these gas turbines.
2. *Lightweight aero-derivative gas turbines.* These turbines tend to be compact, as they are mainly based on aircraft gas turbine engines. As a result, size and weight are extremely important, and the bearings are typically located relatively close to sources of heat. Aero-derivative gas turbines tend to require that the oil not only lubricates under more-severe thermal and oxidative conditions, but that the oil also serves as a heat transfer fluid, to carry heat away from the bearings and shafts. Additionally, aero-derivative gas turbines are subjected to repeated and rapid starts, as well as hot peaks. The extreme operating conditions of aero-derivative gas turbines generally re-

CASE STUDIES

Hot gas fans at a very large refinery complex. At this facility, various hot gas fans were experiencing frequent bearing failure. The fan manufacturer originally recommended mineral oil. With the bearing housing typically reaching 130°C, the cooled and filtered mineral oil would still overheat to the point of coking. Several bearing failures occurred less than five months from refinery startup. The solution was to switch to a properly formulated synthetic oil, which provided superior high-temperature capabilities.

Mid-size gear unit of a special fan unit in a petrochemical plant. Using mineral oil (ISO VG 160) results in some excessive wear and oil oxidation. Lubricant drain intervals of four months and a gear unit life less than two years were reported. Changeover to an appropriate synthesized hydrocarbon lubricant with appropriate additives, specifically, an optimized temperature stabilizer, wear reducer, oxidation inhibitor and anti-corrosive agents, allowed the lubricant drain intervals to be extended to more than 20 months after lubricant changeover.

Unscheduled shutdowns of centrifugal pumps as a result of cold weather. Rolling element bearings in 18 centrifugal pumps in a large chemical plant were experiencing serious problems that resulted in plant shutdown, due to wax plugging when using ISO VG-68 grade conventional mineral oil (the pump manufacturer's recommended oil). The bearings of both pumps and motors were failing because of lubricant starvation.

In addition to the downtime costs, significant labor and hardware costs totalling $300,000 were required to restore the unit to normal operation. After extensive evaluations, a synthetic wax-free lubricant was used in place of the mineral oil. Since making this change, no cold weather plugging has been experienced.

Large gear unit in a power-generating station. The unit was having lubrication problems with its originally selected petroleum-based lubricant. Specifically, the following was experienced:

- The lubricant was losing viscosity and had to be changed every four months
- Air entrainment in the lubricant was causing cavitation in oil pumps
- The gear unit was experiencing an unacceptable level of wear
- On cold mornings the lubricant was so viscous that it had to be heated before the unit could be put in service, and many operators complained about the impact of significantly varied viscosity

A synthesized hydrocarbon lubricant, with good shear resistance, was selected to address these problems. In addition to solving viscosity problems, reducing wear and eliminating cavitations, this newer lubricant helped to reduce power losses by around 8%. With the resulting efficiency gains and reduction in energy cost, the higher cost of the new lubricant was paid off in six months. ❑

quire a high-quality synthetic-base-oil (often one with an ester base).

Gear unit lubrication

Lubricants in gear units are often subjected to shock loads and associated overloading. This creates extreme pressure (EP) requirements for gear-unit lurication oils. Gears should be continuously lubricated, and at the same time, the oil must be kept clean.

Viscosity is probably the single most important factor in lubricant selection for a gear unit. A lubrication oil must be selected with a viscosity that can withstand the anticipated load, speed and temperature. Other important factors are: EP additives (relates to load and speed), viscosity index (relates to temperature), and oxidation stability (relates to temperature and contamination).

Lubrication-oil film thickness is mainly a function of operating speed. Based on experience, high-speed gear units (above 5,000 rpm) often require heavier oil (for example sometimes, heavier than ISO-grade 100).

Mineral oils. Mineral oils are still widely used for gear units. EP additives of the lead-napthenate, sulphur-phosphate or similar types are recommended for gear drives when a lubricant with higher load capacity is required. As a general rule, mineral oils should be used in relatively low speed, highly loaded gear drives, with a low or medium operating temperature (below or around 75°C). EP oils are more expensive compared to straight mineral oils. Some EP oils have a relatively short life at operating temperatures above 75°C.

Compounded oils, that incorporate several different additives, are also available for gear units. The most commonly available additive is a molybdenum disulfide compound, which has been successfully used in some gear applications. However, it is difficult for a gear manufacturer or operator to recommend these oils since some of these additives have a tendency to separate from the base-stock. As a result, such compounded oils are not generally recommended by vendors.

Similarly, viscosity improvers in gear drives should be used with great care. In some cases, these polymer additives can nominally improve the viscosity index and extend the operating temperature range of oil. However, what must be remembered is that polymers are non-Newtonian fluids (so shearing reduces viscosity). A gear unit is a very high-shear environment, and as a result, the viscosity of the oil will be reduced rapidly if too much polymer is added.

Synthesized hydrocarbon lubricants. Synthesized hydrocarbon lubricants are gaining more wide-spread acceptance in gear unit applications. If properly formulated, synthesized hydrocarbon lubricants (typically based on diesters and PAO) can significantly improve gear unit (gears and bearings) reliability.

Synthesized hydrocarbons (diesters and PAOs) are highly recommended for gear units. Other synthetic lubricants, such as polyglycols (high-temperature lubricants), phosphate-esters (fire-resistant lubricants) or silicone lubricants (high-temperature and heat-resistant lubricants) are not recommended for gear unit applications. This is because of their very high cost (because of high volume of oil required in a typical gear unit), possible reliability issues and lack of referenced experience in gear unit applications.

In extreme applications (those involving higher or lower temperatures or with a need for fire protection), true synthetic lubricants (such as polyglycols, phosphate-esters, or similar) may be used for gear units. The user must be careful when selecting these lubricants since some of them remove paint and attack rubber seals.

The more recent synthesized hydrocarbons (again, based on diesters and PAOs) have many desirable features such as compatibility with mineral oils and excellent high- and low-temperature properties.

Engine lubrication

Engine manufacturers and lubricant manufacturers offer lists that recommend lubricants that are suitable for each engine type and model (in general, the engine makeer's preferred lubricants must take precedence). If experience indicates abnormally severe conditions, it may be necessary to reduce the oil drain interval or recommend an oil that provides higher detergency.

Detergent additives are often added to help keep the engine clean by minimizing sludge buildup. For instance, superior engine lubricants are usually formulated from specially selected, solvent-extracted naphthenic base stocks, which have inherent resistance to carbon formation in the engine's combustion chamber, port and valves.

Generally, engine oils (whether petroleum-based or synthetic, which are more common) are available in a wide range of viscosities and are suitable for both crankcase and cylinder lubrication. They should be highly effective to reduce ring-zone suppressing, port deposits and the formation of crankcase sludge.

The following list indicates desirable properties for engine lubricants:

1. Full synthetic engine oil designed for superior performance under severe conditions, suitable for critical service engines 1 MW or above.
2. Premium ash-less lubricant for two cycle engines.
3. Detergent dispersant lubricant (with around 0.4% ash), recommended for most four-cycle engines.
4. Premium medium-ash lubricant for lean-burn and cogeneration applications.

For most operators, an engine overhaul at two- to five-year intervals is common (five-year interval is reported for low-BMEP gas engines; BMEP means brake mean effective pressure). Piston-ring and valve problems are often reported as the main reasons for the unscheduled shutdown of engines, and this is closely related to proper lubricant selection and use. When using ordinary petroleum-based lubricants, it is necessary to punch carbon (remove carbon deposits) from engines ports more frequently (let say every 12–18 months). When using superior oils (mainly synthetic lubricants), there is no need to punch carbon between major overhauls (for instance, once during three- to five-year intervals).■

Edited by Suzanne Shelley

Suggested reading

Bloch, H.P.,"Practical Lubrication for Industrial Facilities," 2nd Ed., Fairmont Press, Lilburn, Ga., 2009.

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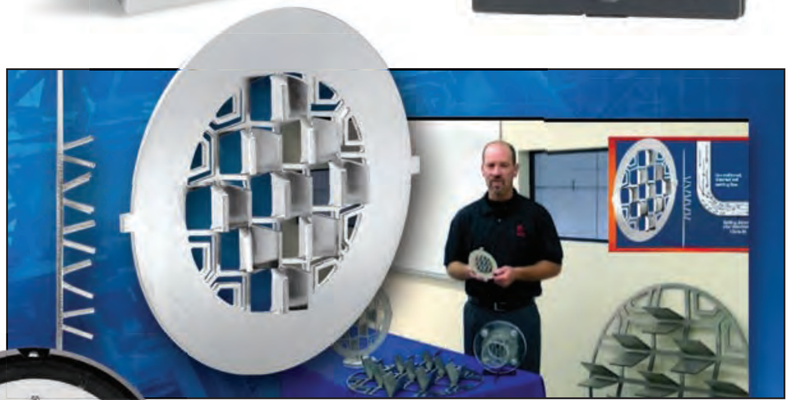


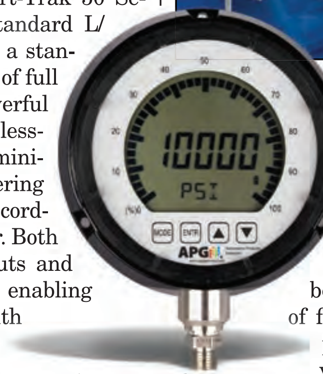
Fluid Components International

A limit controller that is suited for oven applications

This company has recently introduced the UT35A-L Limit Controller (photo), which is an FM-approved instrument suited for oven, furnace and kiln applications. The UT35A-L can be configured as a high or low limit. It comes standard with universal input, three alarm outputs and retransmission output. There is also a timer for exceeded duration and a display for maximum temperature. RS485 and Ethernet communications are available as an option. — *Yokogawa Corp. of America, Sugar Land, Tex.*
www.yokogawa.com/us

A new mass flow controller expands this series' flow range

The Smart-Trak 50 Series Medium Flow Controller (photo) is a mass flow controller that increases the maximum flow range of the Smart-Trak 50 Series from 50 to 200 standard L/min. The 50 Series has a standard accuracy of ±1.5% of full scale. A flexible and powerful direct-acting frictionless-hovering control valve minimizes leak-by, while offering ±0.25% repeatability, according to the manufacturer. Both analog and digital inputs and outputs are available, enabling the 50 Series to work with older analog systems or the newest multi-drop digital tools. Field adjustment of zero and span enable the small adjustments in calibration necessary to align with onsite process conditions. — *Sierra Instruments, Monterey, Calif.*
www.sierrainstruments.com



Automation Products

New digital pressure gage offers simple set up and readability

The PG10 Digital Pressure Gauge (photo) is an IP65-rated indoor/outdoor gage featuring a 5.5-in. display casing, a full five-digit display with characters at 0.68-in. tall, and a 270-deg. digital "dial" or radial bar graph that shows a user-selectable pressure range from 0 to 100%. Standard features include tare, peak hold, and maximum and minimum readings, as well as user-selectable units of measure and an auto-off timer. The gage has an operating temperature range from 0 to 160°F, boasts ±0.25% accuracy of full scale, and features pressure ranges from vacuum to 500 psi, or 0 to 10,000 psi. Data logging provides local access to the latest 60 readings. These features and functions make the PG10 digital pressure gage well-suited for use in applications where visibility, functionality and stability are of primary concern. — *Automation Products Group, Inc., Logan, Utah*
www.apgsensors.com

An airflow conditioner that increases accuracy

A new video demonstrates how the Vortab VIP (Vortab Insertion Panel) Flow Conditioner (photo) can maximize the accuracy of air/gas flowmeter-measurement performance with a design that significantly reduces flowmeter straight-run requirements. Vortab tab-type flow conditioning technology greatly reduces line pressure drop compared to alternative technologies, such as tube bundles, screens and perforated plates, says the manufacturer. Many flowmeter technologies require several diameters of straight pipe run to provide the flow profile required for accurate and repeatable measurement. Most chemical process industries (CPI) plants, however, are rich with elbows, valves and tees. The Model VIP Insertion Panel Flow Conditioner's tab-type plate design neutralizes distorted flow profiles caused by elbows, valves and tees that commonly occur in piping and duct runs. The thin, lightweight panel design of VIP is easily installed between flanges or can be welded in place. — *Fluid Components International (FCI), San Marcos, Calif.*
www.fluidcomponents.com ■

Dorothy Lozowski

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12	27	42	57	72	87	102	117	132	147	162	177	192	207	222	237	252	267	282	297	312	327	342	357	372	387	402	417	432	447	462	477	492	507	522	537	552	567	582	597
13	28	43	58	73	88	103	118	133	148	163	178	193	208	223	238	253	268	283	298	313	328	343	358	373	388	403	418	433	448	463	478	493	508	523	538	553	568	583	598
14	29	44	59	74	89	104	119	134	149	164	179	194	209	224	239	254	269	284	299	314	329	344	359	374	389	404	419	434	449	464	479	494	509	524	539	554	569	584	599
15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390	405	420	435	450	465	480	495	510	525	540	555	570	585	600

If number(s) do not appear above, please write them here and circle: ______________

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BUSINESS NEWS

PLANT WATCH

Linde to build hydrogen plant for chemical complex in China

December 5, 2011 — The Linde Group (Munich, Germany; www.linde.com) plans to build and operate a new hydrogen plant in the Jilin Chemical Industrial Park in China. The company will invest around €42 million in the first phase of this project. The plant will produce 25,000 Nm^3/h high-purity hydrogen and is expected to come onstream by the end of 2013.

AkzoNobel to invest €45 million in DCP plant at Ningbo

November 18, 2011 — AkzoNobel (Amsterdam, the Netherlands; www.akzonobel.com) intends to invest €45 million in a new dicumyl peroxide (DCP) plant at its Ningbo multi-site in China. The new facility will expand AkzoNobel Functional Chemicals' DCP production capacity by more than 30% to 25,000 metric tons (m.t.) and allow for future expansion. The plant is expected to be completed by mid-2014.

Japanese firms plan large fertilizer plant in Angola

November 16, 2011 — Mitsubishi Heavy Industries, Ltd. (MHI; Tokyo, Japan; www.mhi.co.jp), Toyo Engineering Corp. (Toyo; Chiba, Japan; www.toyo-eng.co.jp), Sojitz Corp. (Tokyo; www.sojitz.com) and Sumitomo Corp. (Tokyo; www.sumitomocorp.co.jp), entered into an early work agreement covering a portion of the engineering work for an ammonia and urea fertilizer plant with the Ministry of Geology, Mining and Industry (MGMI) of the Republic of Angola. The ammonia and urea plant will be constructed in Soyo, Zaire Province. Planned capacities for the plant are 2,000 ton/d of ammonia and 1,750 ton/d of urea. Construction is scheduled to be completed by the end of 2015. The project will be worth more than ¥100 billion.

Cristal Global and Outotec partner for TiO_2

November 11, 2011 — Cristal Global (Jeddah, Saudi Arabia; www.cristalglobal.com) has selected Outotec Oyj (Espoo, Finland; www.outotec.com) to build a new ilmenite-processing plant for Cristal Global in Yanbu, Saudi Arabia. The plant, estimated to become operational in the 4th Q of 2013, will be constructed on a turnkey basis and will require 800,000 m.t. of ilmenite ore to produce 500,000 m.t. of 85% TiO_2 slag with 235,000 m.t. of high-purity pig iron as a valuable co-product.

MERGERS AND ACQUISITIONS

Outotec to acquire all interests in Energy Products of Idaho

December 1, 2011 — Outotec Oyj strengthens its portfolio of energy and environmental technologies by acquiring all interests in Energy Products of Idaho Limited Partnership (EPI; Coeur d'Alene; www.energyproducts.com). EPI has pioneered in the area of biomass and difficult-waste-materials combustion. The transaction, subject to regulatory approval, was expected to close by the end of 2011

Kroff expands its water-treatment operations to South America

November 29, 2011 — Kroff, Inc. (Pittsburgh, Pa.; www.kroff.com) is establishing operations in South America, and creating a new company called Kroff Chile - Tecnologías y Procesos Limitada. Based in Santiago, Kroff Chile - Tecnologías y Procesos Limitada is positioned to provide custom-blended chemicals and processes for water and wastewater treatment to companies in a variety of industries in that country.

Uhde acquires Otto Corp. in Japan

November 28, 2011 — As part of its drive to expand its market presence in the field of coke plant technologies, ThyssenKrupp Uhde GmbH (Dortmund, Germany; www.uhde.eu), has acquired the Tokyo-based company Otto Corp., which will operate in Japan as a wholly owned subsidiary under the name of ThyssenKrupp Otto.

BASF creates new global business unit for battery activities

November 23, 2011 — BASF SE (Ludwigshafen, Germany; www.basf.com) is creating a new global business unit that will bring together its battery-related electromobility activities. As part of this transition, a new global business unit, Battery Materials, will be integrated into the Catalysts div. effective January 1, 2012. This business unit will integrate the existing battery activities of BASF's Catalysts and Intermediates divisions, as well as BASF Future Business GmbH. This operating consolidation will take place throughout the first half of 2012.

Lanxess acquires U.S. biocide specialist Verichem

November 11, 2011 — Lanxess AG (Leverkusen, Germany; www.lanxess.com) is strengthening its portfolio of biocides with the acquisition of Verichem Inc. (Pittsburgh, Pa.). Verichem will be integrated into the Lanxess business unit Material Protection Products (MPP). Both parties have agreed not to disclose financial details.

Siemens to acquire engineering-software supplier Vistagy

November 9, 2011 — Siemens AG (Munich, Germany; www.siemens.com) is expanding its industrial software portfolio with the acquisition of Vistagy, Inc. (Waltham, Mass.), a supplier of engineering software and services with emphasis on designing and manufacturing structures made of advanced composite materials. The parties agreed not to disclose the terms of the acquisition. The transaction is subject to customary approvals, and was expected to close by the end of 2011.

Evonik acquires the pharmaceuticals business of SurModics

November 2, 2011 — Evonik Industries AG (Essen, Germany; www.evonik.com) has reached an agreement to acquire the pharmaceuticals business of SurModics, Inc. (Eden Prairie, Minn.). Following the acquisition of the Resomer business from Boehringer Ingelheim in March 2011, Evonik is now strengthening the formulation services business for pharmaceutical applications.

SABIC creates new venture-capital arm to invest in innovative technologies

November 1, 2011 — The Saudi Basic Industries Corp. (SABIC; Riyadh, Saudi Arabia; www.sabic.com) has announced the launch of a new, global corporate venture-capital arm, SABIC Ventures, in the Netherlands. The primary goal of this new entity is to seek out innovative technologies and businesses consistent with the company's global strategy. SABIC Ventures aims to build up a portfolio of technology options for the company's future businesses. It will do this by investing directly in seed stage, early stage and late stage companies. The targeted areas for sourcing venturing investments are the U.S., Europe and Asia. ■

Dorothy Lozowski

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

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

Economic Indicators

2009 2010 2011

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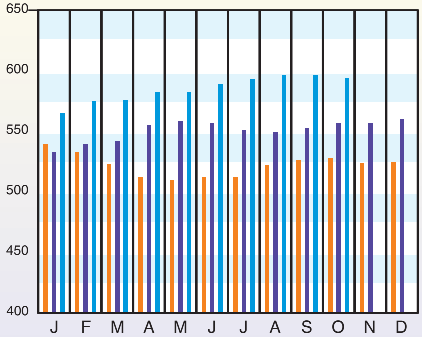
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Oct.'11 Prelim.	Sept.'11 Final	Oct.'10 Final
***CE* Index**	594.0	596.0	556.3
Equipment	724.7	727.6	667.5
Heat exchangers & tanks	691.5	692.4	617.8
Process machinery	674.9	677.4	627.0
Pipe, valves & fittings	906.3	912.6	840.2
Process instruments	432.5	439.4	426.0
Pumps & compressors	911.5	909.9	902.5
Electrical equipment	508.8	510.1	484.7
Structural supports & misc	769.8	772.5	689.6
Construction labor	329.7	330.7	331.0
Buildings	521.2	520.4	503.3
Engineering & supervision	330.4	330.9	336.6

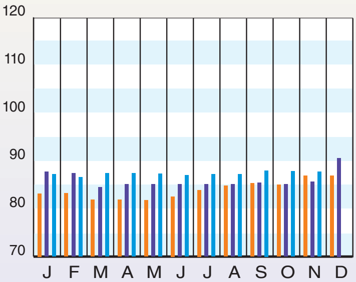
Annual Index:
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8



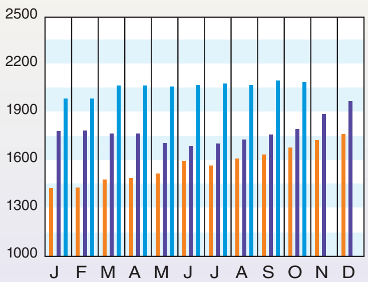
CURRENT BUSINESS INDICATORS

	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2007 = 100)	Nov.'11	=	87.7	Oct.'11	=	87.8	Sep.'11	=	88.0	Nov.'10	=	85.7
CPI value of output, $ billions	Oct.'11	=	2,094.8	Sep.'11	=	2,102.2	Aug.'11	=	2,075.1	Oct.'10	=	1,797.2
CPI operating rate, %	Nov.'11	=	75.9	Oct.'11	=	75.9	Sep.'11	=	76.0	Nov.'10	=	73.7
Producer prices, industrial chemicals (1982 = 100)	Nov.'11	=	320.2	Oct.'11	=	331.0	Sep.'11	=	338.7	Nov.'10	=	278.2
Industrial Production in Manufacturing (2007=100)	Nov.'11	=	91.2	Oct.'11	=	91.6	Sep.'11	=	91.1	Nov.'10	=	87.9
Hourly earnings index, chemical & allied products (1992 = 100)	Nov.'11	=	156.4	Oct.'11	=	157.0	Sep.'11	=	157.2	Nov.'10	=	154.9
Productivity index, chemicals & allied products (1992 = 100)	Nov.'11	=	111.4	Oct.'11	=	109.7	Sep.'11	=	111.0	Nov.'10	=	111.4

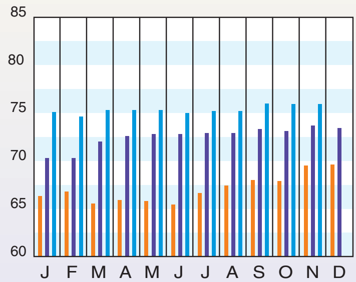
CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



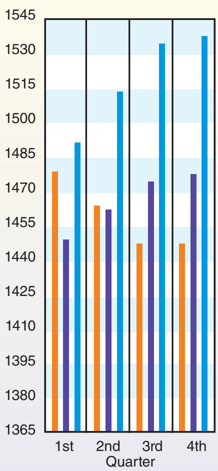
Current Business Indicators provided by Global Insight, Inc., Lexington, Mass.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	4th Q 2011	3rd Q 2011	2nd Q 2011	1st Q 2011	4th Q 2010
M & S INDEX	1,536.5	1,533.3	1,512.5	1,490.2	1,476.7
Process industries, average	1,597.7	1,592.5	1,569.0	1,549.8	1,537.0
Cement	1,596.7	1,589.3	1,568.0	1,546.6	1,532.5
Chemicals	1,565.0	1,559.8	1,537.4	1,519.8	1,507.3
Clay products	1,583.6	1,579.2	1,557.5	1,534.9	1,521.4
Glass	1,495.7	1,491.1	1,469.2	1,447.2	1,432.7
Paint	1,613.6	1,608.7	1,584.1	1,560.7	1,545.8
Paper	1,507.6	1,502.4	1,480.7	1,459.4	1,447.6
Petroleum products	1,704.9	1,698.7	1,672.0	1,652.5	1,640.4
Rubber	1,644.2	1,641.4	1,617.4	1,596.2	1,581.5
Related industries					
Electrical power	1,515.0	1,517.6	1,494.9	1,461.2	1,434.9
Mining, milling	1,659.6	1,648.6	1,623.5	1,599.7	1,579.4
Refrigeration	1,889.4	1,884.4	1,856.4	1,827.8	1,809.3
Steam power	1,574.3	1,572.2	1,546.5	1,523.0	1,506.4

Annual Index:

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



CURRENT TRENDS

Capital equipment prices, as reflected in the *CE* Plant Cost Index (CEPCI), decreased 0.35% from September to October, following a very slight decrease the previous month and escalation in all but one of the previous twelve months. Meanwhile, the Marshall & Swift Equipment Cost Index (left) shows a slight increase in the 4th Q.

See p. 5 for a summary of economists' forecasts for 2012 and visit www.che.com/pci for more information and other tips on capital cost trends and methodology. ■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