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Combustible Dust Standards

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Focus on Pipes, Tubes and Fittings

Reliability and Maintenance

Developments in Petroleum Refining

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Monitoring Flame Hazards

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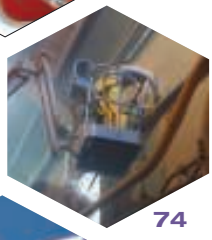
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Cover Photo: Photo of planetary mixer courtesy of Charles Ross & Son Company

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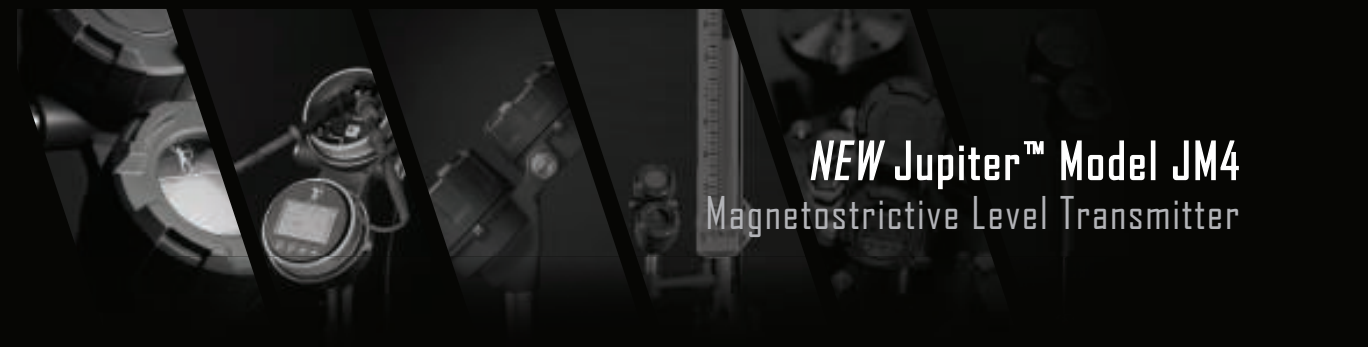

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BPA

Editor's Page

Communicating in acronyms

Language evolves. As the needs of the users change, language adapts to meet those needs. One way to adapt is to add new words. "Selfie," for example, now a well-known word, has only been in popular use for a few years. Additional examples of new words come to mind rather quickly, such as emoji, and photobomb; and some old words have taken on new meaning — for example, tweet.

The popularity of texting (itself a rather recent word, shortened from text messaging) has brought with it a seemingly whole new language — the abbreviated word form of acronyms. There are numerous resources online to help those of us who are not regular "texters" to sort through the maze of acronyms such as AFK, BRB and TTYL (away from keyboard, be right back, talk to you later).

But acronyms are not new. When a group of words is used often, whether in personal communications or in business, we find ways to shorten it. Some acronyms were in common use long before technology allowed for the popularity of texting, such as FYI and ASAP (for your information, as soon as possible).

And in business situations, trade-specific acronyms abound. Terms like SEO (search engine optimization) may be well-known across multiple business segments, while other terms may be known only within a specific area.

The abbreviated CPI

In the chemical process industries (CPI), we commonly come across numerous acronyms — FEED, PSV, HAZOP, PSM, PFD, FCC and P&ID to name a few (front-end engineering and design, process safety valve, hazard and operability study, process safety management, process flow diagram, fluid catalytic cracking, and piping and instrumentation diagram). Most chemical engineers would probably recognize these acronyms and know what they mean in their industry. Others, however, may have different ideas as to what they stand for. When I type PFD into my browser, for example, the top responses are about personal flotation devices.

Even within the CPI, various sectors and experts in their fields use abbreviations that may not be immediately recognized or known to many chemical engineers. Examples might include MBBR, CCS and PSA (moving-bed biofilm reactor, carbon capture and storage, pressure swing adsorption). Sometimes meanings can become clear through context, but not always. Experts in specific subject areas are often surprised to learn that the acronyms they commonly use are not well-known to all chemical engineers, and in fact, might have a different meaning in another sector of the CPI.

Acronyms and abbreviations are great tools for fast communication. We have to keep in mind, though, that the main purpose of language is communication. If the recipient of our acronyms and abbreviations doesn't understand them, then we have failed in that endeavor.

In this issue

This issue covers a broad range of topics, including mixer designs, agitator seals, petroleum refining, reliability, flame monitoring, dust hazards, cybersecurity for industrial control systems and much more. We hope you enjoy it. ■

Dorothy Lozowski, Editor in Chief

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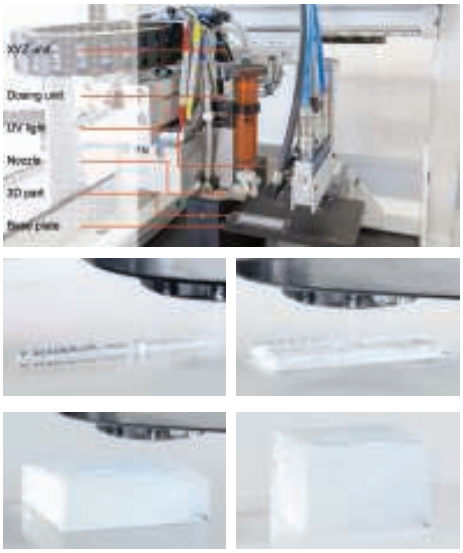
Making complex silicone parts by 3-D printing

The field of additive manufacturing (AM) — often referred to as 3-D printing — has seen explosive growth in recent years (*Chem. Eng.*, February 2015, pp. 20–23). In AM, no tools or molds are required to shape the desired part; instead, the workpiece is built up in successive layers. While the technology has evolved over the last 25 years, the main materials used have been photopolymers and thermoplastics, says Bernd Pachaly, vice president, Innovation Silicones at Wacker Silicones (Berghausen, Germany; www.wacker.com). "Up to now, there is no full-stop [3-D printing] technology for elastomers, and in particular, silicones," he says.

Because of silicones' unique properties, such as thermal resistance, flexibility (also at low temperatures), transparency, biocompatibility and more, Wacker — together with a local prototyping specialist — began a development project for silicone 3-D printing in the second quarter of 2014, taking a holistic approach to develop material, hardware and software. This year, Wacker plans to commercialize its 3-D technology under the tradename, ACEO. The company already has second-generation prototype systems capable of "printing" complex parts from silicone with extremely precise contours. The devices are used for further process and material development. A third-generation printer is already on its way. Five production units are planned for Burghausen. The 3-D technology will be launched at the K-Show (October 19–26; Düsseldorf, Germany).

Wacker's patent-pending technology (photo) is based on a ballistic dosing of silicone "voxels" (3-D pixels), explains Pachaly. The silicone's viscosity is adjusted in a way that allows the droplets to flow together before they are exposed to ultraviolet light, which activates the curing. Software controls the droplet size and the avoidance of bubbles. The voxels and layers of silicone produce a homogeneous material that does not differ much from injection-molded silicone. But in contrast to injection molding, the 3-D-printed parts can be extremely complex, says Pachaly. "For complex shapes with overhangs and hollow structures, the technology makes use of a support material, which is used during printing to enable the product design. After printing, the support material is removed by dissolving it in water." The company believes the technology will find applications in the medical field, for example for printing individualized orthoses or hearing aides that combine hard and soft materials.



Syngas-to-lipids process demonstrated

Researchers at the Massachusetts Institute of Technology (MIT; Cambridge, Mass.; www.mit.edu) have demonstrated a two-stage process to convert synthesis gas (syngas) into lipids that can be used in biodiesel production. Eventually, such a process could be used to convert waste gases from steel mills into liquid transportation fuels. In the first stage of the process, an anaerobic bioreactor converts a mixture of CO_2, CO and H_2 to acetic acid, using the anaerobic bacterium *Moorella thermoacetica*. The acetic acid product is fed as a substrate to a second bioreactor, where it is converted aerobically into lipids by an engineered oleaginous yeast, *Yarrowia lipolytica*, the research team explains. The MIT group's integrated, continuous, bench-scale reactor system produced 18 g/L of C16 to C18 triacylglycerides directly from synthesis gas. Although the productivity of the overall system still needs to be optimized, the integrated system demonstrates the feasibility of substantial net fixation of carbon dioxide and conversion of gaseous feedstocks to lipids for biodiesel production, the teams says.

Edited by:
Gerald Ondrey

BIOMASS TO SUGAR

Plans are underway to build a commercial-scale sugar-production facility that uses a novel process for converting corn stover into high-purity glucose. The 95%-pure glucose syrup produced there will be used as a raw material in the production of bio-based chemicals. The plant, to be located in Sarnia, Ont., will be owned and operated by Comet Biorefining (London, Ont.; www.cometbiorefining.com), and will produce 60 million pounds per year of glucose when it comes online in 2018.

To convert corn stover to glucose at low cost, Comet's technology focuses on separating the three components of biomass (cellulose, hemicellulose and lignin) and producing highly reactive cellulose. The company has developed a proprietary, two-stage activation process that is used to convert reactive cellulose into glucose at significantly lower enzyme loading than traditional processes, Comet says. The highly reactive cellulose generated by the activation process requires less post-processing than comparative chemical approaches, Comet adds, which lowers production costs.

The Comet technology also requires a smaller facility footprint than related technologies, which lowers capital costs and helps reduce feedstock transportation costs, since facilities can be located closer to biomass catchments, the company says. The technology is feedstock-flexible, with the ability to process the agricultural residues corn stover and wheat straw, as well as wood chips.

In March, Comet announced the receipt of a

(Continues on p. 8)

Note: For more information, circle the 56-digit number on p. 94, or use the website designation.

$10.9 million grant from Sustainable Development Technology Canada (SDTC), a government-funded supporter of cleantech projects.

CO_2 TO ETHYLENE

The research group of Shouheng Sun, professor of chemistry and engineering at Brown University (Providence, R.I.; www.brown.edu), has developed a new composite catalyst using nitrogen-rich graphene dotted with copper nanoparticles. A study, published in Nano Energy, shows that the new catalyst efficiently and selectively converts carbon dioxide to ethylene.

The study shows that 7-nm copper particles deposited on graphene doped with pyridinic nitrogen (an arrangement that causes nitrogen atoms to be bonded to two carbon atoms) had a selectivity for ethylene of 79%, significantly higher than other approaches.

CH_4 TO METHANOL

Chemists at ETH Zurich (www.chem.ethz.ch) and the Paul Scherrer Institute (PSI; Villingen, both Switzerland; www.psi.ch) have found a new, direct way to convert methane into methanol — a first step to utilizing natural gas instead of flaring it. The process is based on a copper-zeolite-catalyzed reaction. Up to now, this cyclical reaction had to be conducted at various temperatures. Activating the catalyst requires very high (up to 450°C) temperatures, but the reaction of CH_4 and O_2 to form methanol cannot be carried out at temperatures significantly higher than 200°C, otherwise any methanol formed will be combusted. As a result, the reactor has to be heated and cooled repeatedly. For this reason, this approach has never moved from the laboratory into production scale.

The Swiss researchers have demonstrated that this reaction can now be performed at a constant temperature of

(Continues on p. 10)

A patent granted for this self-diagnostic technology used in boilers

The Clark-Reliance Corp. (Strongsville, Ohio; www.clark-reliance.com) has been awarded a U.S. Patent for its Eye-Hye SmartLevel system for remote indication of water level for industrial boilers. The patent recognizes the uniqueness of the system's self-diagnostic technology, which intelligently monitors the condition of its sensing probes. When probe cleaning is needed to remove residue and mineral build-up, the system's smart technology notifies the control room before the probe becomes unreliable.

By reliably indicating that probe cleaning is required, blowdowns to the system can now be performed only when needed, eliminating nuisance inspections and blowdown frequency while reducing personnel exposure to hazardous areas. Probe life and valve life are extended because unnecessary cleaning is avoided. Additionally, after a blowdown, the Eye-Hye SmartLevel system has the intelligence to identify probes that did not get fully cleaned and have remained unstable and need to be replaced, further simplifying maintenance while improving system reliability.

A joint effort to enable the production of sulfur-enhanced urea at large scale

Shell Thiogro (www.shell.com/sulphur/thiogro) and Uhde Fertilizer Technologies (UFT; www.uhde-fertilizer-technology.com), part of thyssenkrupp Industrial Solutions AG (Essen, Germany), have established a partnership to integrate UFT's fluidized-bed (FB) granulation technology with Shell's Urea-ES (enhanced sulfur) technology, which was introduced in May 2015. Recently, the two companies successfully granulated Shell-developed Urea-ES emulsion in UFT's FB granulation pilot plant in Leuna, Germany. Combining the two technologies will enable the largest urea plants in the world to produce granulated sulfur-containing urea.

Urea-ES technology seeks to provide vital sulfur nutrient to soils by incorporating elemental sulfur into urea, the world's most commonly used fertilizer. Shell Thiogro's patented technology emulsifies micron-sized particles of elemental sulfur evenly throughout urea. This is in contrast to existing elemental-sulfur-containing urea technologies, which typically coat urea in a layer of elemental sulfur. The microscopic size (under 40 µm) of the sulfur particles in Urea-ES promotes the oxidation of the sulfur within the crop season.

The advantages of Shell's technology have been combined with the features of UFT's FB granulation process, where the granulation mode is accretion instead of layering. The elemental sulfur liquor is finely dispersed in the urea melt before the solution is fed to the granulator. Just as in the normal urea granulation, the Urea-ES particles grow collectively through the solidification of tiny droplets on the seed material. The result is a very hard granule, far superior in quality to granules produced through layering or agglomeration-based processes. This slow accretion process is unique in permitting the water present in the urea solution to be thoroughly stripped on a continuous basis, resulting in an end product having a "remarkably low" moisture content, say the companies.

The bulk of the heat of crystallization, which is released as the Urea-ES solidifies, is removed by evaporating the water in the urea solution. This method of heat release reduces the amount of ambient air required for cooling, and the evaporation is highly efficient because it takes place directly on the granule surface.

Natural film for food packaging

A novel food-packaging material that is free from chemical additives and that can slow down fungal growth — doubling the shelf-life of perishable foods — has been developed by researchers from the National University of Singapore (www.nus.edu.sg). The researchers used chitosan, a natural and biodegradable polymer derived from the shells of crustaceans. Chitosan has several properties that make it especially suitable for applications in food technology. It is biocompatible, non-toxic, biodegradable and has good film-forming ability.

The researchers, led by associate professor Thian Eng San, combines fortified natural chitosan-based composite film with grapefruit seed extract (GFSE) — an antioxidant that possesses strong antiseptic, germicidal, antibacterial, fungicidal and antiviral properties.

Thian and associates worked for three years to create a composite film that prevents the growth of fungi and bacteria and also has mechanical strength and flexibility comparable to polyethylene (PE) film commonly used for food packaging. The composite film also blocks ultraviolet light, which also contributes to slowing down the degradation of food products. Laboratory experiments showed that the shelf-life of bread samples packaged with chitosan-based GFSE composite films was twice as long as those packaged using synthetic packaging films.

The research is supported by the A*STAR Singapore Institute of Manufacturing and Technology (www.a-star.edu.sg/simtech) and the Food Innovation & Resource Centre of Singapore (www.firc.com.sg).

Microbes make a meal of PET

Research groups at Keio University (Hiyoshi; www.bio.keio.ac.jp/labs/kmiyamoto) and Kyoto Institute of Technology, in collaboration with Teijin Ltd. and Adeka Corp., have discovered a bacterium that can degrade and assimilate poly(ethylene terephthalate) (PET), and have clarified the decomposition mechanism. This is said to be the first observation of the biodegradation of PET, which had been deemed to be highly stable and resistant to microbial degradation.

PET is used extensively in plastic products around the world, and its accumulation in the environment has become a global concern. Because the ability to enzymatically degrade PET has been thought to be limited to a few fungal species, biodegradation is not yet a viable remediation or recycling strategy.

By screening natural microbial communities exposed to PET in the environment, the researchers isolated a novel bacterium, *Ideonella sakaiensis* 201-F6 (found near Sakai, Osaka), which can metabolize PET as its major energy and carbon source. When grown on PET, this strain produces two enzymes, PETase and MHETase, capable of hydrolyzing PET and the reaction intermediate, mono(2-hydroxyethyl) terephthalic acid (MHET). Both enzymes are required to enzymatically convert PET efficiently into its two environmentally benign monomers, terephthalic acid and ethylene glycol.

The researchers believe the biological route offers a viable PET-recycling alternative to existing thermal-degradation methods, which need more energy.

200°C by operating at a high pressure of 36 bars, instead of under 1 bar, as previously used. "Working at a constant temperature makes this a much easier process to implement in industry," says Patrick Tomkins, ETH Zurich master student and first author of the study, published in *Angewandte Chemie International*.

The researchers were also able to show that, at the atomic level, the reaction in the new low-temperature/high-pressure method takes place at different active sites of the copper-zeolite catalyst. Because a different reaction pathway is involved, the researchers are now investigating the possibility of performing the reaction using catalysts that had not been considered before.

CO_2 SCRUBBING

Linde Gases, a division of The Linde Group (Munich, Germay; www.linde.com), has launched a mobile technology to economically remove CO_2 from early flowback natural gas. The new mobile gas-cleanup unit (MGCU) uses an innovative membrane technology to remove up to 98% of the CO_2 in the production stream. It was designed to improve production-well economics, with an

(Continues on p. 11)

Design-of-experiments approach optimizes metal-grinding fluids

A design-of-experiments (DoE) approach has resulted in better-performing fluids for metal grinding, cutting and machining applications. These fluids serve to lubricate cutting surfaces, remove heat, prevent corrosion and carry away fine particulates that can distort machined surfaces. In recent years, machining practices have required higher-performance fluids that comply with stricter environmental, health and safety (EHS) mandates.

In an effort to meet the modern performance demands of metalworking fluids, Houghton International Inc. (Valley Forge, Pa.; www.houghton-intl.com) developed an optimization platform based on DoE that resulted in fluids with breakthrough performance in several key criteria for water-miscible metalworking fluids, the company says. "By optimizing the desirable properties in a systematic way, using DoE, we were able to arrive at metalworking fluids that outperform traditional fluids, which are usually built off of existing products," explains Dave Slinkman, senior vice president for global research and technology at Houghton.

Key criteria include lubricity profile, emulsion stability, anti-foaming qualities, corrosion-resistance and biostability (preventing odor issues and extending product life). In addition, Slinkman says, the fluids are optimized for EHS performance. They are free of potentially regulated substances, such as boron, formaldehyde-releasing agents, secondary amines, chlorine, phenols and nitrites.

In April, Houghton introduced its first product developed using the DoE platform. Known as Hocut 4440, the new fluid is designed for use with iron-based metals, including cast iron and steel. It is a semi-synthetic, water-miscible formulation and provides good lubrication and excellent cooling for titanium grinding operations, Houghton says.

Extremophilic algae selectively recovers precious metals from solution

The research group of Ayumi Minoda at the University of Tsukuba (Japan, plmet.biol.tsukuba.ac.jp) has discovered that the cellular surface layer of the sulfothermophilic red algae, *Galdieria sulphuraria*, can efficiently adsorb gold and palladium ions, even in highly acidic conditions.

G. sulphuraria lives on the rock surfaces of sulfate springs (such as those found in Kusatsu and Noboribetsu, Japan), under extreme conditions (low pH and temperatures up to 56°C). The researchers found that more than 90% of gold and palladium ions can be adsorbed by the algae from solutions with concentrations in the range of 0.5 parts per million (ppm) and strong acidic conditions (0.4 M HCl, with pH of 0.5). This low concentration is one order of magnitude lower than the 5–30 ppm concentration range that can be economically recovered by existing adsorption techniques, such as activated charcoal and ion-exchange resins.

The researchers confirmed that *G. sulphuraria* selectively recovers Au^{3+} and Pd^{2+} from 0.6 M nitrohydrochloric acid (royal water) waste-metal solution, which contains other metal ions (68 ppm $Fe^{2+/3+}$, 380 ppm Cu^{2+}, 6 ppm Pt^{4+}, 61 ppm Au^{3+}, 59 ppm Ni^{2+}, 7 ppm Sn^{2+}, 18 ppm Pd^{2+} and 12 ppm Zn^{2+}). The recovery efficiency is the same, even if dead algae cells are used. After the absorption step, the absorbed metals can be recovered from the algae as chloride complexes, by elution with NH_4Cl and NH_3. After 30 minutes, 48% of the gold and 77% of the palladium is recovered from the algae — a net recovery of 90% for both metals. The entire process of absorption and elution takes about 1 h.

With support from the New Energy and Industrial Science and Technology Organization (NEDO; Kawasaki, Japan; www.nedo.go.jp), under the authority of the Ministry of Economy, Trade and Industry (METI), the researchers plan to develop a low-cost algae system for industrial use.

emphasis on enhanced productivity or estimated ultimate recovery (EUR), reduced environmental footprint and improved economics in the field.

Natural gas typically contains trace amounts of CO_2. But when a well is fractured with energized fluids containing CO_2 to boost recovery, the early flowback gas may exceed pipeline specifications. The most common practice is to flare off the gas until the well cleans up enough to meet specifications.

"Our mobile gas cleanup unit scrubs CO_2, so producers can monetize early flowback natural gas while minimizing flaring and greenhouse gas emissions," says Robin Watts, program manager, Well Completions, Linde North America.

Mortimer Exploration Co. (San Antonio, Tex.) used the MGCU over a one-month deployment to clean up gas from one of their newly completed South Texas wells. "The results were way better than we had even hoped," says Glenn Mortimer, president of Mortimer Exploration Co. "Without the mobile gas cleanup unit, we

(Continues on p. 12)

would have incurred significant additional costs with alternative solutions and lost the revenue we were able to monetize by eliminating flaring and selling the gas into the pipeline."

MAKING H_2 IN NORWAY

NEL ASA (NEL; Oslo, Norway; www.nel-hydrogen.com) — together with Sintef, Statoil, Linde Kryotechnik, Mitsubishi Corp. Kawasaki Heavy Industries, NTNU and The Institute of Applied Energy, among others — has initiated the project "Hyper," a feasibility study of the potential for large-scale H_2 production in Norway for export to the European and Japanese markets. "We are looking at a scenario in which production of 225,000 tons of hydrogen could fuel as many as three million cars annually," says Bjørn Simonsen, market development director of NEL.

Sintef Energy Research (Trondheim, Norway; www.sintef.no) is the host organization and the lead research partner for Project Hyper. The project is planned and financed through 2019. The total project cost is estimated at NOK20 million. It is funded by a NOK14-million grant from the Research Council of Norway (ENERGIX), in addition to the contributions from the project partners.

Making PLGA by one-step fermentation

A Korean team, headed by professor Sang Yup Lee of the Korea Advanced Institute of Science and Technology (Daejeon, South Korea; www.kaist.ac.kr), has obtained various forms of PLGA [poly(lactate-co-glycolate)] from natural sources, allowing plastics to be made in an environmentally friendly manner.

PLGA is a copolymer of lactic and glycolic acid. It is biodegradable, biocompatible and non-toxic. It has been widely used for surgical sutures, prosthetic devices, and in drug delivery and tissue engineering. Up to now, PLGA has been synthesized by means of a catalytic ring-opening copolymerization of two different monomers, the cyclic dimers (1,4-dioxane-2,5-diones) of glycolic acid and lactic acid. In contrast, the Korean team is able to biologically produce PLGA (and several novel copolymers) from renewable biomass by a one-step, direct fermentation by metabolically engineered *Escherichia coli.*

Initially the researchers developed a method for producing PLGA in engineered *E. coli*. The process involved eliminating the genes responsible for byproducts formation and enhancing the expression of certain genes, thus achieving the effective production of certain target polymers. However, the team saw that it could not enhance the polymer content and glycolate fraction of PLGA via further engineering techniques. Therefore, they introduced a heterogeneous pathway to produce glycolate from xylose and succeeded in developing the recombinant *E. coli* that produce PLGA more efficiently.

PHA (polyhydroxyalkanoates) synthase was used to produce monomers inside the bacteria by metabolic engineering, and then copolymerize to improve the properties of PLGA. A variety of PLGA copolymers were produced, with varying monomer compositions approved by the U.S. Food and Drug Administration (FDA; Silver Spring, Md.; www.fda.gov). ■

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Plant Watch

TCV begins construction of new liquid polybutadiene plant in France

April 15, 2016 — Total Cray Valley (TCV; Paris, France; www.crayvalley.com) has begun construction of a new plant for liquid polybutadiene in Carling, north-east France. The plant will produce several thousand tons per year of polybutadiene, and is scheduled to start production in October 2016. It is TCV's fifth manufacturing plant for this product line.

Linde to build air separation unit in Sarawak, East Malaysia

April 14, 2016 — Linde Eastern Oxygen Sdn Bhd (Linde EOX), a subsidiary of Linde Malaysia Sdn Bhd (Bintulu; www.linde.com.my) will invest RM33 million (€7.4 million) to build an air separation unit (ASU) in Tanjung Kidurong, Sarawak, Malaysia. The new ASU will have a capacity of 33 metric tons per day (m.t./d) when it comes on stream in 2017.

Clariant expands bleaching earth capacity in Mexico

April 14, 2016 — Clariant (Muttenz, Switzerland; www.clariant.com) has announced a 30% increase in production capacity for natural molecular sieves at its Puebla mine in Mexico. This follows two years of engineering work and an investment in the mid-single-digit range of millions of Swiss francs (around $5 million). Clariant's Tonsil bleaching earths are used to treat edible oils, while Tonsil Coarse Optimized (CO) grades are used to purify petrochemical streams including aromatics and jet fuel.

Air Liquide to build air separation plant for Sinopec subsidiary

April 12, 2016 — Air Liquide (Paris, France; www.airliquide.com) signed a new long-term contract with Maoming Petrochemical Co. (MPCC), a subsidiary of China Petroleum & Chemical Corp. (Sinopec Corp.), to invest around €40 million in a new ASU with a total capacity of 850 m.t./d of oxygen. Located in Maoming City, Guangdong Province, the ASU will supply oxygen and nitrogen to two ethylene-oxide plants. It will be owned and operated by ALMPCC, a joint venture between Air Liquide China and MPCC.

Praxair signs contracts with glassmaker for energy savings and oxygen supply

April 12, 2016 — Praxair, Inc. (Danbury, Conn.; www.praxair.com) will supply its Optimelt thermochemical regenerator (TCR) system to Libbey, one of the world's largest manufacturers of glassware and tableware. Installed on a new glass furnace in Leerdam, the Netherlands, Optimelt will cut natural gas consumption and carbon dioxide emissions by approximately 20% by reacting natural gas with hot fluegas to produce syngas. Praxair also signed a long-term contract with Libbey to deliver 60 ton/d of oxygen through a non-cryogenic, vacuum pressure swing adsorption (VPSA) system at Leerdam. Both the Optimelt TCR system and the VPSA oxygen plant are scheduled to start up in 2017.

Vertellus completes expansion for DEET insect repellant

April 11, 2016 — Vertellus Specialties (Indianapolis, Ind.; www.vertellus.com) has expanded DEET (diethyl toluamide) production capacity at its Greensboro, N.C. site. From January 2016, DEET capacity has increased by 80%. DEET is widely used in mosquito and tick repellents, and Vertellus cites recent outbreaks of the mosquito-borne Zika virus as increasing the demand for DEET.

Startup of new purified terephthalic acid line in China

April 8, 2016 — Invista Performance Technologies (IPT; Shanghai, China; www.ipt.invista.com) and China Prosperity (Jiangyin) Petrochemical Company Limited (also referred to as Hanbang Petrochemical) announced successful startup of China Prosperity's second PTA (purified terephthalic acid) line. On-specification product was achieved within 24 hours of the March 14 start-up, the company says. The new line incorporates Invista's E2R, Solvent Interchange and R2R technologies.

Linde breaks ground for Bangladesh's largest cryogenic air separation plant

April 6, 2016 — Linde Bangladesh Ltd. (Dhaka; www.linde.com.bd), a member of the Linde Group's (Munich, Germany; www.linde.com) Gases Division, has begun construction of a BDT 1.2 billion (€14.6 million) ASU in Rupganj. The project was announced in November 2015. When completed in 2017, the Rupganj plant will produce approximately 100 m.t./d of liquefied gases, making it the largest liquid-producing ASU in Bangladesh.

Indian company SRF to set up pilot plant for new-generation auto refrigerant

April 4, 2016 — SRF Ltd. (Gurgaon, India; www.sfr.com) is to build a pilot plant to develop its own process to manufacture the next-generation refrigerant gas HFO-1234yf (2,3,3,3-tetrafluoropropene). This will make SRF the first company outside the U.S. and Europe to develop technology for HFO-1234yf, the company says. HFO-1234yf is expected to find increasing use in car air-conditioning systems because it has a lower global warming potential than HFC-134a. Honeywell and DuPont hold patents on HFO-1234yf.

Mergers & Acquisitions

Calgon Carbon to acquire activated carbon and filter aids from CECA of France

April 14, 2016 — Calgon Carbon Corp. (Pittsburgh, Pa.; www.calgoncarbon.com) has made a binding offer for the wood-based activated carbon, reactivation and mineral-based filtration media business of French company CECA, a member of the Arkema group. The deal is valued at €145.5 million ($160.1 million) and is anticipated to close in the fourth quarter of 2016.

Clariant partners with Korean firm BioSpectrum to source cosmetic ingredients from plants

April 12, 2016 — Clariant (Muttenz, Switzerland; www.clariant.com) will acquire a 17% share in BioSpectrum, Inc. (South Korea; www.biospectrum.com), which supplies plant-derived functional ingredients for cosmetics.

Jacobs Engineering acquires cybersecurity firm Van Dyke Technology

April 12, 2016 — Jacobs Engineering Group Inc. (Pasadena, Calif.; www.jacobs.com) has acquired Van Dyke Technology Group, Inc. (Van Dyke; Columbia, Md.; www.vdtg.com), a 180-person company specializing in identity and access management, threat mitigation and other cybersecurity solutions. Terms were not disclosed.

BOC gases and ITM Power sign hydrogen refueling agreement for U.K. vehicle network

April 11, 2016 — BOC (London, U.K.; www.boconline.com), a member of the Linde group, has signed an agreement with ITM Power, an energy storage and clean fuel company, to provide infrastructure for ITM Power's new hydrogen refueling stations for passenger cars. The announcement underpins ITM Power's plan to build a network of hydrogen refueling stations in the U.K. The stations will use ITM Power's proprietary electrolyzer technology, while BOC will contribute technology, including Linde liquid-piston compressors and hydrogen dispensers.

Hoerbiger strengthens safety portfolio with explosion venting specialist Brilex

April 5, 2016 — The Hoerbiger Group (Zug, Switzerland; www.hoerbiger.com) has acquired the privately held Brilex Gesellschaft für Explosionsschutz mbH (Brilon, Germany) for an undisclosed sum. Brilex is a leading provider of explosion-relief venting products. This is the third acquisition for Hoerbiger's new safety business, after IEP Technologies (Marlborough, Mass.), and Newson Gale (Nottingham, U.K.).

Archer Daniels Midland to sell its sugarcane ethanol operations in Brazil

April 1, 2016 — Archer Daniels Midland Co. (ADM; Chicago, Ill.; www.adm.com) has reached an agreement to sell its sugarcane ethanol operations in Limeira do Oeste, in the Brazilian state of Minas Gerais, to JFLim Participações S.A. The transaction includes a sugarcane plantation and an ethanol distillery, which is capable of crushing up to 1.5 million ton/yr of sugarcane and producing 37,000 gal/yr of ethanol. ■

Charles Butcher

New Developments Take Shape for U.S. Refiners

Process safety strategies, water use and alkylation technology were among the topics figuring prominently at the 2016 AFPM annual meeting

IN BRIEF

CURBING HUMAN ERRORS
AVOIDING ABNORMAL EVENTS
ALKYLATION TECHNOLOGY ADVANCES
SOLID-ACID CATALYSTS
UNIQUE ALKYLATION FEEDS
REFINERY WATER ISSUES
SELENIUM REMOVAL
CRUDE OIL TESTING PRODUCTS

An evolving set of issues facing petroleum refiners in the U.S. figured prominently at the annual meeting of the American Fuel and Petrochemical Manufacturers (AFPM; Washington, D.C.; www.afpm.org), held in March in San Francisco, Calif. Among wide-ranging sessions on topics such as crude-oil supply, regulatory and legislative issues, fluid catalytic-cracking-unit (FCCU) operations and others, the meeting featured presentations highlighting some of the many areas in which petroleum refiners are looking to adapt and improve.

One area of focus was process safety, where a number of new tools are emerging to help reduce human errors in refinery operations. Meanwhile, water issues are becoming more prominent for refineries, along with industry in general, and the AFPM meeting featured a session on that topic. In addition, several presentations reported progress in the area of alkylation technology.

Curbing human errors

In the process safety session, several presentations focused on strategies to reduce the possibility of human errors in petroleum refinery operations. Yokogawa Electric Corp.'s (Carrolton, Tex.; www.yokogawa.com/us) Thomas Fiske said data show that 42% of negative incidents in the process industries had human error as the major cause, and deficiencies with procedures and employee training were critical in the majority of those incidents. Fiske discussed a focus on procedures, the effective use of which can have a major positive impact on safe and reliable facility operations.

One error-reducing approach involves the automation of manual procedures, a technique pioneered by Yokogawa. Fiske said that modular procedure automation is becoming an increasingly popular method, not only to mitigate human errors that are associated with accidents, but also to help improve product quality, production efficiency, and capture best practices, especially in higher-risk operations, such as startups, shutdowns and transitions.

Procedural automation refers to the set of activities in which operator knowledge and best practices are captured and assembled into specific procedures that are then consistently followed to complete plant tasks. Automating certain procedures can help reduce operator workload and avoid human errors, Fiske said.

But since automating every procedure does not make practical or economic sense, Fiske discussed how best to determine which procedures should be automated. He suggested focusing on procedures associated with the operations most likely to lead to production disruptions, and then determining what type of procedure automation could mitigate the consequences of those events. Opportunities where procedural automation makes sense include low-frequency, high-consequence operations, such as startups and shutdowns, highly complex procedures, transitions and others, Fiske said.

Fiske also reported progress by a technical committee under the auspices of the International Society of Automation (ISA; Research Triangle Park, N.C.; www.isa.org) in formulating a consensus standard on procedure automation in continuous processes. The forthcoming ISA Standard 106 is in the planning stages currently, and the technical committee is now working on its second technical report. The committee has already published its first technical report: ISA-TR106.01 on Procedure Automation for Continuous Process Operations – Models and Terminology.

Avoiding abnormal events

Another approach for reducing process-operator errors discussed at the AFPM meeting focuses on predicting process faults more effectively to avoid abnormal process events. Thomas Kindervater, the solution support manager at the Center for Operator Performance (COP; Dayton, Ohio; www.operatorperformance.org), explained that while process faults are a significant concern in the chemical and petrochemical industries, the real problem is that "process operators typically become aware of process faults only after the problem has triggered an operating alarm, forcing the operator to react to the situation after it has caused a deviation of the process from desired operating conditions." The better alternative would be for the operator to proactively address a process fault before it causes an operational deviation that is sufficient to trigger an alarm, Kindervater said.

Kindervater discussed research commissioned by the COP and conducted by Michael Baldea and Ray Wang at the University of Texas at Austin (www.utexas.edu) that aimed to help identify ways to provide operators with advanced warning of pending abnormal events. The research developed a new fault-detection approach that employs geometric analysis of time-ordered radial plots. Radial plots depict multi-variable data samples using axes extending outward from a central point, while the time dimension is represented by stacking the data samples (Figure 1). The tool developed by the research group performed better than several other widely used data-analysis techniques, Kindervater said, with a very low rate of false positives.

The technique has been successfully applied in the detection of surge in a large, multistage compressor, where analysis of past surges helped identify event signatures as early as a few hours before surge onset, Kindervater explained. It has given equally impressive fault detection for distillation flooding events and for detecting precursors to flaring events, continuing to show a low false-positive rate, he says.

Alkylation technology advances

Meanwhile, within another session on gasoline production, AFPM attendees heard about progress on several unique alkylation installations.

Several presentations emphasized the rising importance of alkylation processes, which involve combining light olefins with isobutane to produce isomers of trimethylpentane, a liquid hydrocarbon known as alkylate that is used as a clean gasoline blendstock. Alkylate is a premium gasoline component because it provides high octane, low Reid vapor pressure, low sulfur and no aromatic compounds. The demand for alkylate is growing primarily as a result of gasoline demand from emerging economies, tighter government-mandated gasoline specifications, removal of high-octane components (such as aromatics and olefins) from the gasoline pool and higher-performance engine requirements.

Tightening restrictions on sulfur content in gasoline requires a greater level of hydrotreating, which reduces

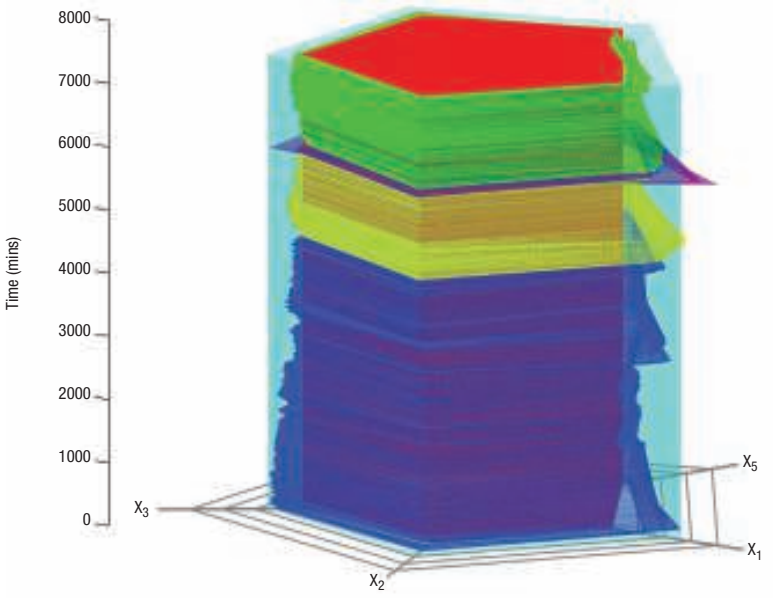

FIGURE 1. Radial plots depict multi-variable data samples using axes extending outward from a central point, while the time dimension is represented by stacking the data samples

octane number of resulting gasoline. Alkylate, a high-octane, low-sulfur blendstock, offers a way to raise octane numbers. Meanwhile, another factor is the availability of inexpensive butanes from shale deposits in the U.S., making for a potentially cheap feedstock for alkylation.

Solid-acid catalysts

The past several months have seen the culmination of years of development for solid-acid catalysts for alkylation that can replace liquid-acid catalyst systems using the hazardous and corrosive hydrofluoric and sulfuric acids as catalysts.

At the AFPM meeting, CB&I (The Woodlands, Tex.; www.cbi.com) discussed the progress of what is said to be the world's first commercial-scale, solid-acid-catalyst alkylation unit. The unit started up in August 2015 at Zibo Haiyi Fine Chemical Co., a subsidiary of Shandong Wonfull Petrochemical Group Co. The unit employs CB&I's AlkyClean technology, jointly developed by CB&I, Albemarle Corp. (Baton Rouge, La.; www.albemarle.com) and Neste Corp. (Espoo, Finland; www.neste.com). The unit has a capacity of 2,700 barrels per day of alkylate production (100,000 metric tons per year).

The unit, located in Shandong Province, China, has achieved all performance expectations thus far, CB&I says. Since the startup, the alkylate product has demonstrated excellent quality, the company points out, including an octane value (RON) between 96 and 98 — a considerably higher RON than typical alkylate products, according to CB&I. RON is considered an indicator of the alkylate's value as a gasoline blending component.

AlkyClean technology uses Albemarle's AlkyStar catalyst, a robust fixed-bed zeolite catalyst. By pairing this catalyst with CB&I's novel reactor scheme, the AlkyClean process is able to produce a high-quality alkylate product without the use of liquid-acid catalysts, which makes the process inherently safer. By eliminating the need for post-treatment, and waste streams of acid-soluble oils, the process offers an efficient alkylate-production technology. For more information on the CB&I solid-acid catalyst alkylation process, see *Chem. Eng.*, April 2013, p. 11.

In February 2016, KBR Inc. (Houston, Tex.; www.kbr.com) announced the first licensing contract for its K-SAAT Solid Acid Alkylation technology. The contract was awarded to KBR by Dong Ying Haike Ruilin Chemical Co. for use at a facility in Dong Ying City, China. KBR is supplying the technology know-how, basic process design, key equipment and catalyst. The Haike K-SAAT unit is anticipated to start up in Q1 2017, KBR says.

The K-SAAT process features a solid-acid catalyst, known as ExSact, which is based on modifications of commercially available zeolite catalysts, and is much less hazardous to both personnel and the environment than liquid-acid catalysts. These aspects and the lower installed cost for the K-SAAT process influenced Haike's decision to select the K-SAAT process over conventional sulfuric acid alkylation technologies. KBR's Gautham Krishnaiah, director, FCC & Alkylation Technologies, says the operating expenses for solid-acid catalyst systems for alkylation are also lowered because K-SAAT has lower maintenance costs and does not require refrigeration (unlike the sulfuric-acid-catalyzed alkylation process). In addition, liquid-acid regeneration and disposal of solid wastes (acid neutralization with caustic) are not required.

KBR has partnered with Exelus, Inc. (Livingston, N.J.; www.exelusinc.com), a developer of green chemical technologies, and now has an exclusive license for Exelus' ExSact catalyst. The K-SAAT process employs two reactors — one in the alkylation cycle and one in the regeneration cycle or on standby. The process uses hydrogen to completely regenerate the catalyst. During this regeneration, the soft coke (a combination of highly unsaturated hydrocarbons) and contaminants adsorbed on the catalyst are released and purged, KBR's Krishnaiah says.

The ExSact catalyst has been engineered to outperform liquid-acid catalysts and other solid-acid catalysts on multiple levels, says KBR's Krishnaiah. The catalyst acid sites and pore structure have been optimized to enhance product selectivity. The ExSact catalyst offers long alkylation cycles in comparison with other solid-acid-alkylation catalysts; a high degree of flexibility in terms of the feed sources and components (ethylene, propylene, butylenes and amylenes can be used as the olefins). In contrast, liquid-acid alkylation processes cannot alkylate ethylene, he says, since ethylene forms stable esters. In addition KBR's solid-acid process has a higher toler-

ance to feed contaminants, such as moisture, sulfur, dienes, oxygenates and nitriles. For more information on ExSact, see *Chem. Eng*. May 2011, pp. 17–22; and *Chem. Eng*. January 2007, p. 11.

Unique alkylation feeds

The emergence of commercial-scale solid-acid catalyst processes for alkylation has not eliminated innovative applications for liquid-acid catalyst units, however. DuPont (Wilmington, Del.; www.dupont.com) is applying its sulfuric-acid alkylation technology to unique alkylation feedstocks, and in March announced a contract to supply an alkylation unit to a Chinese refinery that is using a 100% butylene stream for its feedstock.

Jeannie Branzaru, global marketing manager for DuPont Clean Technologies says, "It's a new era of alkylation — the chemistry has been around for a long time, but the economic conditions are now favorable for butane-to-alkylate processing, or 'on-purpose alkylation.' The economics for this unique processing configuration have not been there before." Branzaru says companies are able to purchase low-value butane inexpensively on the open market, then process it in a dehydrogenation unit to make isobutylene, which is then sent to an alkylation unit to make high-value alkylate. "Our technology is not limited to butanes only, however. We are currently working on alkylation unit designs that process very high concentrations of propylene and 100% amylene (C5 olefin) feeds as well."

Hengli Petrochemical Co., based in Dalian, China, awarded DuPont a contract to supply the alkylation and spent acid regeneration (SAR) technologies for its new grassroots refinery in the Changxing Island Harbor Industrial Zone. Installation of the new units at Hengli is currently planned for 2018 with start-up anticipated in 2019. DuPont will employ its Stratco alkylation and MECS SAR technologies.

The inclusion of the DuPont technology to the refinery complex will allow Hengli to produce a high-quality alkylate product from a 100% isobutylene feed stream. "The unique feed stream available from the Hengli facility marks the beginning of a new era for alkylation in the gasoline market as the butane-to-alkylate movement grows around the world," says Kevin Bockwinkel, global business manager for the Stratco technology.

The alkylation unit at Hengli will utilize DuPont's patented XP2 technology in the Stratco Contactor reactor. The XP2 technology is designed to ensure the most effective and efficient use of the tube bundle heat-transfer area, providing significant process benefits resulting in improved alkylate product quality, Bockwinkel explains.

Petroleum refinery water issues

The AFPM meeting's second day featured a session on water issues, which have emerged as a major challenge for all industrial sectors. In petroleum refining, significant water use traditionally occurs with cooling towers, boilers and desalters. Although water use has decreased in the past few decades because of technology development, the need for water in petroleum refining remains.

"Water access issues, scarcity and competition occur at local, state, regional and national levels," said Larry Close, a process engineer at Burns & McDonnel, "And this has the potential to significantly affect the refining market."

Most people have heard of recent droughts in Texas and California, which contain the highest number of petroleum refineries by state. However, many organizations outside of those states are becoming equally concerned with looming water issues in the near future, said Close.

Close discussed opportunities for water reuse at petroleum refineries, including the treatment requirements for each use. The primary sources of reuse water are non-contaminated stormwater, stripped sour water, vacuum and crude-tower overhead water and wastewater (refinery and municipal sources), Close explained, while the primary reuse opportunities are the desalter, boiler feed water (BFW) and cooling tower makeup water (CTW).

"Identification of appropriate source water and reuse opportunity is based on many factors, including required

water treatment, interconnecting piping, reliability risk to refinery process units, and risk to the refinery wastewater-treatment plant," he said.

One approach that refineries have used to produce reuse-quality water from refinery wastewater is membrane bioreactor (MBR) technology. A presentation from GE Water & Process Technologies (Trevose, Pa.; www.ge.com) discussed progress in using MBRs with the company's MACarrier (membrane-accommodating carrier) technology, which is a specialized carbon-based biological carrier that promotes nitrification, and enhances the removal of recalcitrant chemical oxygen demand (COD) and other toxic compounds.

MACarrier provides a large, bacteria-friendly surface area where dense and strong biofilm is quickly formed, GE explains. It adsorbs and concentrates the problematic recalcitrant organic compounds where the biomass degrades the adsorbed compounds and regenerates the MACarrier.

GE conducted a pilot study at a southern Ontario refinery aimed at comparing the company's existing MBR system to an MBR system with MACarrier. Wastewater downstream of oil-water separator and dissolved air filtration units was treated by an MBR and an MBR with MACarrier. The study found that MBR with MACarrier "could achieve higher effluent quality in terms of acute toxicity and the effluent could be directly discharged," while the MBR [without MACarrier], even though providing higher effluent quality . . . "could not meet the toxicity requirements for discharge," says GE.

Selenium removal

Another petroleum refinery wastewater-treatment challenge comes from the selenium present in some crude oils. The element, in its several forms (selenite, selenate, selenocyanate), must be removed from refinery wastewater because while selenium is an essential trace nutrient, it can be toxic at high concentrations. Regulations on selenium-release limits have become more stringent in recent years.

Physical and chemical methods to remove selenium from refinery wastewater are difficult, so biological treatment has been explored as a means of achieving the low selenium levels. Biological treatment has the potential to convert various forms of selenium to elemental selenium, which is relatively non-toxic, and can be separated from the wastewater streams as an inert solid associated with the biomass that is present in the solids recovered from the treatment process.

In a paper presented by Lori Donovan, an account manager with UOP Industrial Wastewater Technologies (Des Plaines, Ill.; www.uop.com), a pilot study was discussed in which UOP's (Honeywell) XCeed SE Bioreactor was used to remove selenium from wastewater at a refinery in the western U.S.

Using UOP's immobilized-cell biological-treatment technology, XCeed consists of a series of bioreactors and UOP's proprietary biological growth media, and was set up as an onsite field trial. The system was inoculated using nitrate-reducing cultures that were developed during a previous laboratory study. Organic carbon and phosphoric acid were dosed to provide nutrients for biological growth.

In order to discharge to a local municipal treatment plant, the refinery needed to reduce the selenium present in its final water discharge from a level of approximately 200 µg/L to less than 50 µg/L. Donovan said the pilot testing successfully demonstrated that the XCeed SE biotreatment technology "can meet the total recoverable selenium target of 50 µg/L without the need for post-treatment, allowing the refinery to comply with local regulations." ■

Scott Jenkins

NEW PRODUCTS FOR TESTING CRUDE-OIL LAUNCHED

In a product launch timed to correspond with the AFPM annual meeting, GE Water & Process (Trevose, Pa.; www.ge.com) introduced new predictive-analytics software and laboratory equipment for the on-site testing of crude oil to determine how the oil might affect a petroleum refinery before processing begins.

GE's CrudePLUS reduces analysis time of crude oil and can lead to streamlined operations, less fouling and increased energy efficiency, the company says. GE's new digital solution uses predictive analytics to improve operation and reduce carbon dioxide emissions and costs. Data captured with CrudePLUS can lead to improved blending and desalter operations that result in reduced oil to the refinery's wastewater treatment plant.

"As the variability of crude oil increases and refineries adopt more aggressive blending strategies, there is tremendous value in rapid data and predictive analytics," says Amy Ericson, global leader, chemical and monitoring solutions for water and process technologies at GE Power.

GE also introduced its LoSALT Online and Onsite Amine Speciation software, an upgrade to its LoSALT simulator software. "Previously, refinery operators could only test on-site for a small number of amines and had to send samples away to a laboratory. GE's new LoSALT Online and Onsite Amine Speciation technology now offers refineries a more accurate, comprehensive and instantaneous method of testing and receiving critical data," says Ericson.

GE's LoSALT Online and Onsite Amine Speciation technology can increase protection of the crude overhead system by providing a more complete picture of the salting and corrosion potential than previously possible, says the company.

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IN BRIEF

HOW HACKERS GAIN ACCESS
IS THE CPI AT HIGHER RISK?
HOW TO PROTECT YOUR FACILITY
CYBERSECURITY SOLUTIONS
AN ONGOING PROCESS

In December 2015, 80,000 homes in the Ukraine were left without power when a cyber attack took down the electrical infrastructure. Investigations suggest that hackers used malware in conjunction with remote access to industrial control systems to directly interact with control systems, infect workstations and servers with malware, damage control-system hosts on workstations and servers, and block calls to customer call centers that would have alerted power companies to the outages.

A year prior, a German steel mill was the victim of a cyber attack. Investigations revealed that attackers used a spear phishing campaign — an email that appears to be from an individual or business known to the recipient, but isn't. Instead, it's from hackers who want financial, personal or login information found on that user's PC. The attack was aimed at particular individuals in the company to trick them into opening malicious links. The opening of the links provided hackers with login information that granted them access to the plant's network and control systems, resulting in failure of parts of the plant and the inability to properly shut down a blast furnace, causing "massive damage" to the equipment.

Clearly, as more industrial control systems connect to the Internet, they are becoming accessible to skilled hackers, resulting in an industrial landscape that is open to attack, an especially scary prospect for chemical processors.

How hackers gain access

"As we integrate more digitalization into our lives, we are increasing the attack surface available to hackers," says Andy Kling, director of cybersecurity and software practices with Schneider Electric (Andover, Mass.; www.schneider-electric.com). "The use of tablets, smart phones and cloud storage is expanding at an exponential rate and, as a result, cyber attacks are more likely to avoid traditional security tools and infiltrate the workplace. Industrial targets aren't necessarily secure on this fuzzy perimeter of our digital lives."

Honeywell

FIGURE 1. The Honeywell Industrial Cyber Security Risk Manager specifically proactively monitors, measures and manages cybersecurity risk for industrial plants and systems

As processors get smarter regarding cybersecurity, so too do hackers, who realize that the weakest link in the defense of industrial control systems is the humans who interact with them. "By tricking an employee into clicking on a link via a spear-phishing campaign, attackers can melt away defensive barriers, gain access to control systems and immediately take over the digital world of the plant," warns Kling. "Once they do that, all bets are off."

In addition, attackers can also enter a network via malicious links embedded in advertisements on websites where employees may browse, says Neil Peterson, director of DeltaV product marketing with Emerson Process Management (Austin, Tex.; www.emersonprocess.com). "Hackers can buy ad space on a reputable website and, embedded in that advertisement, can be malware. If an employee clicks the ad and your system is unpatched, hackers just injected malware onto your system and, from there, can begin to take control," he says.

Another common point of entry is universal serial bus (USB) sticks. "People use them and aren't aware that they contain malware. They plug [a USB stick] into their computer with the intention of moving data and acci-

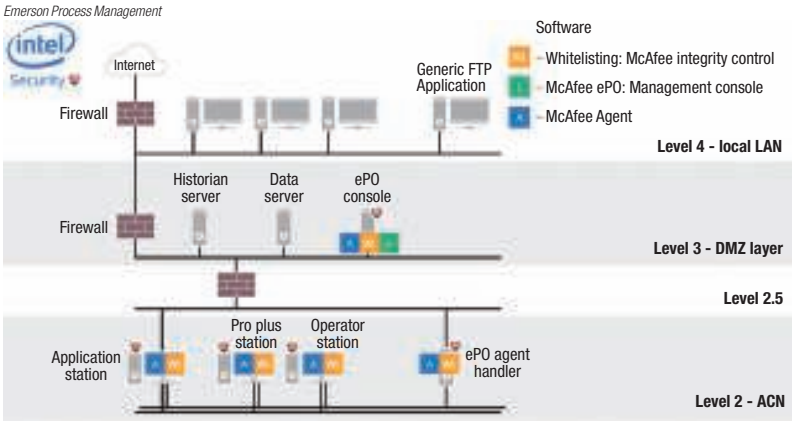

FIGURE 2. The DeltaV reference architecture includes the managed whitelisting protection based on the Intel Security Application Control for DeltaV workstations

dentally infect the control system," Peterson explains.

Adding to the complexity and severity of the situation, says Vincent Turmel, industrial cybersecurity consultant with Siemens Industry Services (Alpharetta, Ga.; www.siemens.com), is that it's often difficult to patch or upgrade the equipment found on the operations side. "On the plant floor, PCs are used for a long period of time, so you often end up with a lot of older systems and various levels of legacy products that have different protection requirements and a range of patches and protections in place," notes Turmel. "One of the greatest cybersecurity risks we encounter is trying to patch, maintain and defend the PCs on the plant floor. One size does not fit all when it comes to protecting PCs on the operations technology (OT) side."

In addition, equipment used for operations is often tied into a larger system where, if you upgrade one part of the system, you have to upgrade all of it, which then becomes a cost issue, Turmel continues. "What this means is that even a common virus that's been eradicated on the IT side, can wreak havoc on the OT side, due to the various ages of equipment and operating systems found on the plant floor."

"Sometimes it feels like the only way to secure a computer after it has been connected to the network is to unplug it and throw it into a lake," jokes Peterson. However, he is quick to add that cyber attacks on industrial facilities are no laughing matter as they may result in loss of assets and production dollars, theft of intellectual property or endanger the health and safety of employees and the environment.

Is the CPI at higher risk?

"We do see the risk for very specific attacks that can occur via PCs in today's automation space," agrees Anthony Baker, security leader with Rockwell Automation (Milwaukee, Wis.; www.rockwellautomation.com). "Many of those attacks leverage known vulnerabilities in industrial control systems where owners of the systems have not been able to patch and maintain the systems used in their production space," says Baker.

"When we talk to our customers about possible risks, we like to point out those concerning intellectual property because they are often not considered and are very applicable for the chemical industry in the form of recipes, process and information," says Baker. "However, the more significant concerns are related to the risks associated with the integrity of their operations. If an attacker decides to tamper with operations or equipment, it may cause critical damage that jeopardizes production availability. But the most significant and frightening issues include attacks that would impact the safety of personnel, people in the vicinity or the environment."

So, are the chemical process industries (CPI) at a greater risk for these types of targeted attacks than other industries? "While we can't know for sure how likely there is to be an attack on any given plant or what type of attack it might be, we do know

that there have been recent attacks on industrial control systems, so we know it's possible to gain access to an industrial facility via the control system and cause damage," notes Baker. "We also know that attacks on a chemical facility have the potential to affect the broad population."

For this reason, the U.S. Presidential Policy Directive on Critical Infrastructure Security and Resilience, which identified 16 critical infrastructure sectors in need of strengthening and protection, includes the chemical industry. "The chemical processing industry is listed as one — as a matter of fact it's first on the list — of the critical sectors of this country and, as such, we have to consider that it is likely to be part of any cyber attack that might take place. If, how and where such an attack would occur would depend upon the motivation of the attacker, but some type of attack is obviously a real risk," advises Schneider Electric's Kling.

How to protect your facility

"Today's digital culture of bring your own devices, higher connectivity between the IT and the OT networks and remote and cloud connections can significantly increase the risk of a cyber incident on an industrial control system," says Mike Baldi, chief cybersecurity architect with Honeywell Process Solutions (Houston, Tex.; www.honeywellprocess.com). "However, this risk can be managed by properly implementing new technologies on the industrial control system and integrating appropriate security controls with the new technologies."

Determining the specific threats is the first step to deciding which of these technologies should be implemented, according to the experts. "Every facility — chemical and otherwise — has its own target-rich environment," says Siemens' Turmel. Figuring out your facility's threat landscape includes trying to decipher who's likely to break in and what their intent might be."

Turmel calls this "threat-vectoring." "The first step in implementing a plan is to work with a cybersecurity service to determine the list of likely adversaries, how they would gain access and what they might be trying to accomplish," he says. "From there, you conduct a vulnerability assessment and threat modeling, which becomes a guide to creating a holistic plan that considers and protects against specific threats to your facility so you are sure you are implementing the right tools. Then, when you have everything in place, you do threat-vectoring again and begin to test your defenses. You continue to add tools until you are as strong as you choose to be."

Indegy

FIGURE 3. Indegy's cybersecurity solution comes in the form of a plug-and-play "box" that connects to a port on the network and, from there, provides monitoring and visibility of the controls and core technologies

The participation of industrial control-system suppliers, such as Siemens, in customer control system security continues to grow in importance. All industrial control-system owners should build a collaborative relationship with their supplier, including becoming familiar with the supplier's cybersecurity organization. "The key to finding a security service provider is to find one that knows the plant-floor space, as well as cybersecurity," notes Turmel. "They will coordinate activities, from assessments to implementation of managed services, to monitoring or patch management, to maintaining the infrastructure."

"Assessments should also review policies and practices concerning Internet access to the control system and the use of industrial control-system protection for removable media, such as USB sticks, on every control workstation," suggests Emerson's Peterson.

Tools that assist with risk assessment are also available. "We have developed our Honeywell Industrial Cyber Security Risk Manager (Figure 1) specifically to address cybersecurity risk on industrial control systems," says Baldi. "The product proactively monitors, measures and manages cybersecurity risk for industrial plants and systems. Through an interface, it allows users to prioritize and focus efforts on managing cybersecurity risks that are most important for reliable plant operations to provide an ongoing situation awareness of the cybersecurity posture of a control system."

Cybersecurity solutions

After the risk assessment, security tools should be implemented, but what types of solutions are being offered? "There's a whole portfolio of cybersecurity solutions and technologies available to protect industrial control systems, ranging from end-point protection to network protection," says Baldi. "The solutions portfolio includes both active and passive tools, tools based on known malware of cyber-attack signatures, tools that restrict the allowed operations and tools that are based upon cyber-attack behaviors."

Traditional tools. Traditional, signature-based tools such as antivirus solutions, firewalls and deep packet inspection are still viable and advisable, but with the shear number of attacks and new viruses created each year, experts suggest that these alone are no longer enough to protect an industrial control system. "If all you have is a signature-based approach, eventually the software isn't going to recognize a malicious signature and you'll be exposed to a cyber attack," says Kling. Instead, updated versions of these tools should be used in conjunction with other solutions to provide a holistic, proactive approach.

Whitelisting. Whitelisting, a newer signature-based solution, is currently being updated, improved and deployed for control systems, say the experts. Whitelisting is "superior to, but the opposite of antivirus technology," says Emerson's Peterson. "With antivirus tools, there are signatures that are discovered after viruses and malware become known. When antivirus software sees those signatures, the script is prevented from running. Whitelist-

Bedrock Automation

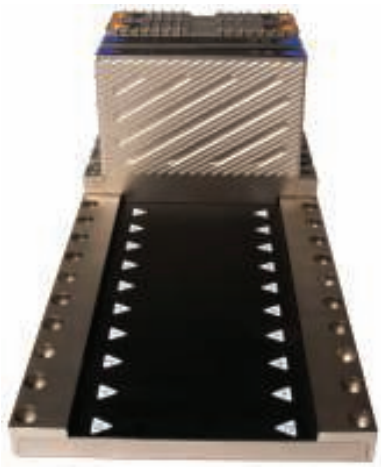

FIGURE 4. Bedrock Automation's industrial control system replaces pins with an electromagnetic backplane (shown here), microcontrollers that are secured with encrypted keys and TRNG embedded in all system modules including the controller, power supply and I/O

ing, however, assumes everything is bad, except the signatures the owner has deemed safe. This approach ensures that the file you are executing hasn't been tampered with."

In the past, he says, whitelisting required a lot of management because, if not properly deployed, it could prevent users from accessing their own system. However, Peterson says Emerson worked to improve and thoroughly test a new cybersecurity solution that includes whitelisting for its DeltaV control system that will provide high-level whitelisting protection without the high maintenance (Figure 2).

Authentication. Authentication and authorization tools are also an important piece of the puzzle, according to Clark Case, security leader with Rockwell Automation. "Some control products, such as our FactoryTalk-enabled software products, provide user authentication and authorization, a method for access-control policies," he says. Authentication and authorization technology provides secure access to the system, prevents unauthorized and unwanted changes from occurring in running processes or files and provides a documented audit trail of who made what changes and when.

Detect-and-respond. "Detect-and-respond" tools are another emerging solution. Rather than spotting malicious signatures, these solutions look for and recognize unusual behaviors taking place within the network (for example, excessive login attempts at the same workstation in a short window of time) and trigger an alarm. "This secondary class of tools is based upon artificial intelligence that has been available for years but is just now being applied to the security domain to recognize a pattern," says Kling. "We believe the future of cyber defense lies in this type of tool."

Experts now believe this type of visibility plays a big role in protection. So, a solution from cybersecurity start-up Indegy (Fort Worth, Tex.; www.indegy.com) monitors control-layer activity on PLCs via the network and on the actual controllers to detect cyber attacks before damage can occur. "Most solutions

focus on protecting the management software, but attackers can compromise these platforms to hide the changes and status of the industrial process controllers so that everything appears normal, but this new approach monitors and provides visibility into the critical control layer of operational technology networks to identify threats in real time that place the safety, reliability and security of industrial control systems at risk," says Dana Tamir, vice president of marketing with Indegy. The company's solution comes in the form of a plug-and-play "box" that connects to a port on the network and, from there, provides monitoring and visibility of the controls and core technologies (Figure 3).

Protection from inside. A different approach, which protects from the inside out, comes from Bedrock Automation (San Jose, Calif.; www.bedrockautomation.com), which offers an industrial control system in which pins are replaced with an electromagnetic backplane, microcontrollers are secured with encrypted keys and TRNG is embedded in all system modules including the controller, power supply and I/O (Figure 4). All modules are encased in anti-tamper metal that is impenetrable without metal cutting tools and authentication extends throughout the supply chain, including third-party software and applications. "Cybersecurity ultimately comes down to protecting the computer," says Albert Rooyakkers, founder, CTO and vice president of engineering, with Bedrock Automation. "You must solve the problem right at the submicron transistor level the same way you stop a viral contagion with a vaccine — from the inside out. So we've developed a cybersecurity solution where all the computing elements in the system are designed to be cyber hardened, from waking up with a secure boot to encryption keys that ensure that communications going in or out of the machine are authenticated. Traditional control systems have to wear armor to protect themselves, but we've built the protection right into the system," he says.

An ongoing process

"When it comes to cybersecurity, the right solution won't be a one-size-fits-all approach," says Rockwell Automation's Case. "The solution will depend upon the risk. Two facilities may have the same infrastructure but one produces distilled water and the other makes a dangerous chemical, so the required mitigations will vary greatly."

The key is to fully understand the process, the risks and the vulnerabilities, and, based upon those, to identify the specific combination of solutions needed to create a holistic, proactive solution. But it doesn't end there. Selected technologies must be installed and monitored and any internal, corporate cybersecurity policies needed to ensure proper use of the solutions must be enforced. However, since hackers never stop trying to find a way in, any protection must constantly be tested, updated and upgraded to thwart future methods of attack. Cybersecurity is not a "one-and-done" process. ■

Joy LePree

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Pipes, Tubes and Fittings

New Age Industries

Viega

Wieland-Werke AG

Applied Flow Technology

Antimicrobial tubing reduces the risk of bacterial transfer

Clearflo Ag-47 antimicrobial tubing (photo) is now available in an additional seven sizes, expanding its range up to 1-in. inner dia. The NSF-listed tubing protects liquids from harmful bacteria that can result in odors, taste transfer and illnesses, in numerous applications such as beverage and dairy transfer, food processing, water lines, medical devices and clean fluid transfer. Its antimicrobial properties exist throughout the tubing, not just on the inner surface, says the company, improving protection against bacteria such as *E. coli*, *listeria*, *Salmonella*, *Legionella*, *Campylobacter Pseudomonas* and others. The transparent tubing is said to be especially effective in applications where there is infrequent use of fluids in warm or humid conditions, preventing thorough drying between uses. It uses no phthalates, latex or animal-derived materials, and conforms to NSF-51. — *New Age Industries, Southhampton, Pa.*
www.newageindustries.com

Sorbent tubing aids in the analysis of trace organics

This company's PAH Tube is a thermal desorption tube that enables reliable analysis of polycyclic aromatic hydrocarbons (PAHs), to improve the detection of these trace organic compounds using the company's Unity or TD-100 gas-chromatography and mass-spectroscopy analytical systems. PAHs are subject to very low limits worldwide because of their carcinogenic properties, yet they tend to be very challenging analytes to accurately detect, says the company. Existing, solvent-based techniques that are used to analyze PAH levels in air are prone to loss of analytes, but the PAH thermal-desorption tubes are said to ensure the transfer of even the heaviest PAHs from the sorbent-sampling tube into the gas chromatography system. — *Markes International, Llantrisant, U.K.*
www.markes.com

Corrugated sleeving protects tubing

The ViegaPEX Ultra tubing has been expanded to include corrugated sleeving (photo) for hot and cold water applications where additional structural strength or protection is needed. ViegaPEX Ultra tubing carries the industry's highest rating for chlorine and ultraviolet resistance. In some applications, the corrugated sleeving allows the tubing to be protected in exposed locations, and thus is easily accessed for repairs or replacement without the need to excavate soil or chisel into concrete floors, says the company. The black corrugated sleeving is available with inserted red or blue ViegaPEX Ultra tubing in 300-ft coils. Ultra tubing is rated at 100 psi at 180°F, and 160 psi at 73°F, and comes with a 25-year limited warranty. — *Viega LLC, Wichita, Kan.*
www.viega.us

Tubing products serve heating, cooling and sanitary needs

This company offers a large family of tube-related products (photo), which are available for use in refrigeration, air conditioning, heating and sanitary applications. The product offerings include industrial tubes in copper and copper alloys, heat-transfer systems with finned tubes and heat exchangers, blank and coated cooling tubes, and semi-finished associated accessories (including turned parts, milled parts and forged parts). — *Wieland-Werke AG, Ulm, Germany*
www.wieland.de

Flow-modeling software addresses piping issues

The AFT Fathom modeling software provides incompressible pipe-flow-modeling analysis and system modeling (photo) to improve the design of piping and ducting systems. Dynamic simulation can be used to calculate pressure drop and flow distribution in piping and ducting systems handling liquids and low-velocity gases, including petroleum and refined products, chemicals, refrigerants and cryogens,

Note: For more information, circle the 3-digit number on p. 94, or use the website designation.

low-velocity gases, water and more. In particular, the software is used to size piping, pumps and control valves. The program's simulation capabilities help users to not only simulate system operation but evaluate heat transfer in pipes, to determine the cause of operational problems. — *Applied Flow Technology, Colorado Springs, Colo.*
www.aft.com

Resin enables piping to withstand many temperatures

Dow Packaging and Specialty Plastics

Piping made from this company's proprietary Hypertherm 2399 resins (photo) provides a lower-cost alternative to piping made from copper, steel, or rigid plastic, and benefits from the material's light weight, inherent flexibility, toughness and durability, corrosion resistance, and resistance to leakage. The resin is a certified Level 5 chlorine-resistant material (ASTMF2769, F2023) for use in piping carrying hot and cold water. And pipes made from Hypertherm resins are natural insulators, which can help to improve the energy efficiency of hot-water systems. — *Dow Packaging and Specialty Plastics, Midland, Mich.*
www.dow.com

Transition pieces ease pipe connections in dry processes

Roto-Disc.

This company offers a full range of process transitions to connect piping and other plant components that may have non-matching dimensions, in facilities processing dry materials (photo). Among the many piping, flange and duct transitions are round-to-square pipe transitions, adaptors and sanitary pipe/tube extenders with clamp ferrules. Transition pieces are available with flanges on one or both ends, as are flangeless/weld stub transitions. Custom shapes, such as offset/oblique, rectangular and double-cone types can also be provided upon request. Typical materials of construction include type 304 and type 316 stainless steel, abrasion-resistant steel, mild steel and Hastelloy, but many other materials are also available. Various finishes include mechanical and electropolish, nickel, chrome and tungsten hardfacing polymer coating and glass-bead blast. — *Roto-Disc., Erlanger, Ky.*
www.rotodisc.com

Tubing provides enhanced resistance to fatigue

Parker-Hannifin

Parprene tubing (photo) is constructed from a specially formulated thermoplastic elastomer. It is designed to withstand the rigors of peristaltic pump applications. It is extremely flexible, fatigue resistant and abrasion resistant, making it a good alternative to neoprene and rubber tubing, according to the company. It can handle temperatures up to 275°F (135°C), and provides a broader range of chemical compatibility than standard rubber and thermoplastic products, according to the company. Paraprene tubing is available in Series G for general industrial applications, and Series F for food, beverage and dairy applications. — *Parker-Hannifin Corp., Paraflex Div., Ravenna, Ohio*
www.parker.com

Sensor enclosure approved for piping in hazardous locations

This company's design-patented line of Explosion Proof (XP) connection heads (photo), are designed for use in chemical, petroleum refinery, power generation, pharmaceutical and other process-plant applications where potentially combustible or flammable conditions are present. The stainless-steel or aluminum heads are used as electrical enclosures where connecting instrumentation (such as a temperature sensor or a level sensor in a piping or tank application), transports the measuring signal from the process to the

Pyromation

Ametek Fluropolymer Products

Kalenborn Abresist

Schwarze-Robitec

control panel. The connection heads are designed for flexibility and ease of maintenance, says the company. — *Pyromation, Fort Wayne, Ind.*
www.pyromation.com

Piping is designed for ultra-high-purity chemical transport

The Fluor-X high-purity fluoropolymer pipe (photo) is available in a wide range of standard and custom lengths and diameters. The Schedule 40 and 80 pipe is available in a choice of fluorinated ethylene propylene (FEP), perfluoroalkoxy alkane (PFA) and ultrahigh-purity (UHP) resins. This high-purity pipe is manufactured from low-iron-extractable resins, and it offers excellent corrosion resistance for temperatures ranging from –100 to 400°F. The low extractable levels and chemically inert nature of the fluoropolymer piping make it ideal for high-purity acid and chemical-transport applications, especially in semiconductor wafer fabrication, says the company. — *Ametek Fluropolymer Products, Wilmington, Del.*
www.ametek.com

Corrosion-resistant coatings protect piping systems

Kalpoxy corrosion-resistant coatings (photo) are suitable for use in applications above and below water. It relies on a unique blend of liquid epoxy polymer and aliphatic polyamine curing agents, allowing them to displace water from wet surfaces, ensuring a permanent bond, says the company. They are solvent-free for safety, and incorporate Kevlar microfibers for reinforcement and viscosity management. — *Kalenborn Abresist Corp., Urbana, Ind.*
www.abresist.com

Tube-bending machines provide precise control

This company's tube-bending systems now include an advanced control system, the NxG 2.0 (photo), which is said to provide improved flexibility and increased production rates for bended products. The system allows operators to bend tubes of many materials into complex geometries. The control systems allows a variety of process parameters to be tracked, so that realtime data can be gathered and evaluated. For instance, integrated sensors provide information on wear values, the consumption of lubricants, the condition of the bending tools, the need for machine maintenance and more. The advanced software and icon interface provide intuitive operation and high process reality. — *Schwarze-Robitec GmbH, Cologne, Germany*
www.schwarze-robitec.com

Back-pressure regulator serves thermoplastic pipe

The Frank Series V86 back-pressure regulator (photo) is the latest addition to this company's Chem Proline Advanced PE piping system. Made from an advanced polyethylene resin, these pressure regulators have the same chemical resistance and stress-crack resistance as the Proline pipe and molded fittings, making them suitable for use in water treatment and chemical process applications handling a variety of chemicals, including sodium hydroxide, sodium hypochlorite, caustic soda and low-concentration acids. The V86 inline regulator is available in both inline and angled configurations, with either butt/IR or socket connections. — *Asahi/America, Lawrence, Mass.*
www.asahi-america.com

Single-use bioreactor tubing kits reduce contamination risk

The AdvantaPure Single-Use Bioreactor Tubing Kits (photo, p. 31) are built-to-order, single-use kits containing tubing, filters and connectors, for harvest, vent, sparge and addition lines used in benchtop bioreactors. The kits arrive with components preassembled to provide quicker turnaround time, and to ensure reduced chance of cross contamination. Platinum-cured silicone or AdvantaFlex TPI tubing may be selected as the tubing components in each kit. AdvantaFlex tubing is weldable and heat sealable. — *AdvantaPure, Southampton, Pa.*
www.advantapure.com

Pipeline connectors ease steam trap replacement

The PC3000 and PC40000 pipeline connectors, equipped with single or double isolation capabilities, allow steam trap assemblies to be installed or maintained without the need for process shutdown. These pipelines connectors are ideal for the petroleum, petrochemical and specialty

chemicals industry, and they are suitable for manifold applications where steam traps are used on tracing and line drainage. The connectors have an ASME 600-rated forged body that makes them suitable for use on lines up to 800°F, and a shrouded piston valve stem, which reduces the potential for corrosion. — *Spirax Sarco, Blythewood, S.C.*
www.advantapure.com

Dry-disconnect couplings improve product transfer

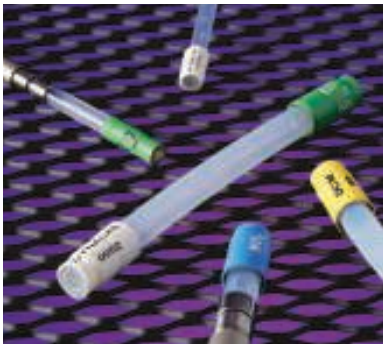
The Epsilon Dry-Disconnect Couplings provide a range of design and operational features that make them ideal for use in critical in-plant and railcar or tank-truck chemical-transfer operations in pharmaceutical applications. They allow safe, precise handling of volatile, hazardous and high-value pharmaceutical compounds during transfer operations. The design uses ball valves rather than poppets to facilitate the opening and closing of the coupling, resulting in a straight-through flow path that creates no areas where chemicals can nest, says the company. — *OPW Engineered Systems, Lebanon, Ohio*
www.opw-es.com

Permeation tubes are designed for gas calibration standards

During gas chromatography, calibration gas standards are used to establish a reference point for analysis verification. Dynacal Permeation Tubes (photo) are small, inert capsules containing a pure chemical compound in two-phase equilibrium between its gas phase and either its liquid or solid phase. At a constant temperature, the device emits the compound through its permeable portion, at a constant rate. Accurate, stable concentrations range from parts-per-billion to high parts-per million, says the company. Rates can be certified using standards traceable to NIST, using accurate laboratory procedures, says the company. — *VICI Metronics, Poulsbo, Wash.*
www.vici.com

Suzanne Shelley

AdvantaPure



VICI Metronics

New Products

Endress+Hauser

Radar measurement with 79 GHz technology

The Micropilot NMR81 (photo) utilizes 79 GHz technology to generate a narrow beam angle of 3 or 4 deg. Measurements are substantially more reliable, even in narrow tanks, because the radar beam avoids obstacles, such as baffles on the tank walls. Furthermore, measurements right to the bottom in very tall tanks are easier because the beam does not hit the tank walls prematurely. The technology permits very long measuring ranges of up to 70 m. In custody transfer, the instrument measures up to 30 m with an accuracy of ±0.5 mm, which surpasses the recommendations of the American Petroleum Institute (API) and the International Organization of Legal Metrology (OIML). Micropilot NMR81 easily fulfills all API and OIML requirements. — *Endress+Hauser, Inc., Greenwood, Ind.*
www.us.endress.com

Flottweg

This high-speed separator also discharges quietly

The AC separator (photo) is said to reach far higher speeds than other centrifuges, such as the decanter centrifuge. The special design of the separator permits the centrifuge to achieve gravitational (*g*) forces of up to 10,000 *g*. Moreover, disk inserts also provide a larger clarifying surface. The combination of an expanded clarifying surface and the high *g* forces make it possible to separate the finest of solid particles or liquid mixtures efficiently. A particular feature of the AC separator is the Soft Shot discharge mechanism. Unlike many discharge mechanisms in which the solids discharge is acoustically perceptible as a loud bang, the Soft Shot is silent. During discharge, part of the control water stays under the piston, which means that during ejection, the piston cannot strike the bottom of the bowl. The solid is ejected in a gentle, quiet manner. — *Flottweg SE, Vilsbiburg, Germany*
www.flottweg.com

Heinkel Drying and Separation Group

Laboratory dryer simulates production steps

The fully equipped laboratory dryer BS-miniDRY (photo) has a mobile and compact design. It is easy to install and enables "plug-and-play" operation. The BS-miniDRY can simulate complex processes and production steps, such as drying under vacuum. Because it is identically designed as a larger, production-scaled conical screw dryer, the BS-miniDRY is especially suitable for scaleup and processing of, for example, bulk solids and active pharmaceutical ingredients. It is characterized by gentle product handling, reliable operation, and works with very small amounts of product. — *Heinkel Drying and Separation Group, Besigheim, Germany*
www.heinkel.de

Lewa

A metering pump for low-pressure ranges

The Ecodos diaphragm metering pump (photo) is mechanically driven, rather than hydraulically driven. Due to its simple construction, it operates without hydraulic oil and can also be used for sensitive applications in the pharmaceutical field. Fluids that would react with hydraulic oil can be metered just as safely. In principle, it is suitable for virtually all metering and pumping tasks in the low-pressure range. The Ecodos, as a single-drive unit with a space-saving, vertically attached motor, delivers a flowrate of 0.4 to 1,500 L/h per pump head and a maximum discharge pressure of 20 bars. Its multiplex capability also enables additional areas of application, for which multiple drive units with identical or different output capacities are ideally suited, particularly for low-pulsation pumping, recipe metering and mixing tasks. — *Lewa GmbH, Leonberg, Germany*
www.lewa.de

Mixing, coating and drying with high-performance mixers

When surfaces of inorganic components have to be homogeneously and reproducibly coated with functional coatings in batch processes, high-performance universal mixers of the Uni tec series (photo, p. 33) are said to offer significant advantages over conventional systems. The Uni tec mixers produce a 3-D mixing vortex without any dead spots in which the entire material to be mixed is fluidized. The result is maximum homogeniza-

MTI Mischtechnik International

tion with minimum time and energy consumption. All Uni tec mixers are suitable for vacuum operation, which makes it possible to perform complex processes, such as vacuum drying after coating, in a single machine. An optional chopper avoids the formation of lumps. Options include spray systems for adding fluids, double-jackets for temperature control, electrically heated lids and surfaces, and more. — *MTI Mischtechnik International GmbH, Detmold, Germany*
www.mti-mixer.de

Tableting technology debuts in North America

This company's "next-generation" tableting technology will be showcased at Interphex (April 26–28; New York, N.Y.). Launched last year at Achema 2015, the Modul Q rotary tablet press (photo) features the company's Exchangeable Compression Module (ECM). The new version of the ECM is even more convenient to use and offers a higher level of containment performance. With easier access for cleaning and set-up operations and improved functionality, the Modul Q also incorporates the Exchangeable Die Disc, which was only previously available on the Performa P press. Operationally, the Modul Q has a bigger pitch diameter and, in terms of size, will be positioned between the Modul P and Modul S. The use of A-type tooling is now possible, which allows 51 punch stations to be incorporated and an output of up to 367,200 tablets per hour to be achieved. — *GEA Group AG, Düsseldorf, Germany*
www.gea.com

GEA Group

Detect thunderstorms well before the first lightning strikes

Biral

For many manufacturing facilities, thunderstorms can play a significant role in disrupting operations from an increased risk of ignition due to static electricity, as well as lightning strikes to the plant and process equipment. Many manufacturing and storage-transfer processes have to be made safe or halted completely when a thunderstorm is in the vicinity as part of the risk mitigation and safety protocols onsite. Both cause loss of productivity and efficiency for the plant operators. The new BTD-300

Wanner Engineering

Pope Scientific

Flexicon

thunderstorm detector (photo, p. 33) can provide early warning of a nearby thunderstorm and so ensure the safety of operating personnel while minimizing downtime. While there are existing lightning systems available, these only alert after the strikes have begun, whereas the BTD-300 uses a quasi-electrostatic operating principle that gives early warnings of overhead lightning risk and detects strikes as far as 83 km away, says the company. In addition to lightning detection, the BTD-300 has the ability to detect the presence of electrically charged precipitation and strong electric fields. The Biral BTD-300 is virtually immune to all forms of human-made radio frequency interference so false alarms are minimized. — *Biral, Bristol, U.K.*
www.biral.com

Metering pumps with brass manifolds and Aflas diaphragms

Since March, the Hydra-Cell Metering Solutions pumps (photo) are available with Alfas diaphragms as well as brass manifolds. Aflas is a copolymer elastomer that is resistant to extreme heat, acids and alkalis. It is appropriate for use when pumping water or alcohol, and in various chemical environments. Brass provides a lower-cost alternative to stainless steel and Hastelloy when the higher discharge pressures of a metallic pump head are required, the company says. The Hydra-Cell Metering Solutions line includes six models with maximum flow capacities from 26.5 to 894.6 gal/h and maximum pressure ratings from 1,000 to 2,500 psi. — *Wanner Engineering, Inc., Minneapolis, Minn.*
www.hydra-cell.com

A new flowmeter with entrained-gas management and more

The Optimass 6400 is said to be the first Coriolis mass flowmeter in the world to feature advanced entrained gas management (EGM), with no loss of measurement with gas entrainment up to 100 vol.%. Unlike other mass flowmeters, where relative movement between gas and fluid dampens the amplitude of the measuring tube and interferes with the electronics' capability to determine the actual resonant frequency, the Optimass 6400 with EGM can follow and correct for the varying amplitudes. EGM continues to present an actual measured reading, together with an indication or configurable alarm that improves processes by identifying transient gas entrainments. The flowmeter is equipped with a new signal converter that features advanced device and process diagnostics, compliant to Namur recommendation NE 107. It is available in a range of sizes from DN 08 to 250, and is offered in stainless steel 316L, Hastelloy C22 and Duplex steel UNS S31803. The Optimass 6400 operates in temperatures from –200 to 400°C, and handles pressures up to 200 bars. — *Krohne, Inc., Peabody, Mass.*
www.us.krohne.com

Customized process vessels and mixing systems

This company's pressure vessels and integrated mixing/processing systems (photo) are used in production, pilot plants and laboratories for processing, reacting or blending specialty chemicals, adhesives, coatings, biomaterials recycling and more. High-quality materials, welding and finishing assure integrity and validation in sanitary, ultra-high purity and hazardous applications. ASME stamping is standard; CE/PED and other certifications available. Options may include various mixer types, pumps, plumbing and valve manifolds, instrumentation, controls, filters, lifts, heating/cooling systems, skid mounting and other features. They are fabricated with 316L stainless steel; other alloys, such as Hastelloy, finishing levels and coatings are also available. Custom designed complete turnkey skid-mounted systems, from 1 to 1,000 L, are offered. — *Pope Scientific, Inc., Saukville, Wis.*
www.popeinc.com

This drum dumper is dust tight

A new Tip-Tite Mobile Drum Dumper (photo) allows dust-free transfer of bulk materials from drums into process equipment and storage vessels. It is mounted on a mobile frame with quick-action floor jacks for stable operation anywhere in the plant. A hydraulic cylinder raises the drum carriage which seals the drum rim against a discharge cone, after which a second hydraulic cylinder tips the carriage-hood assembly and drum,

stopping at a predetermined dump angle of either 45, 60 or 90 deg with a motion-dampening feature. As the assembly approaches its fully-tipped position, the outlet of the discharge cone mates with a gasketed receiving-ring inlet fitted to existing process equipment or to the lid of an optional hopper with integral pneumatic, tubular cable or flexible screw conveyor, creating a dust-tight seal. Once the discharge cone is seated against the gasket, a pneumatically-actuated slide gate valve opens, allowing material to enter the receiving vessel. The unit accommodates drums from 30 to 55 gal, weighing up to 750 lb. — *Flexicon Corp., Bethlehem, Pa.*

www.flexicon.com

Realtime monitoring of water-solvent drying

This company has demonstrated that tunable diode-laser absorption spectroscopy (TDLAS) can provide the advantages of continuous process control of pharmaceutical drying to manufacturers using water as their primary solvent. Working with a pharmaceutical manufacturer, this company carried out a production trial using its Model 5100 HD analyzer (photo) to monitor the batch production of a widely prescribed medication whose synthesis involves the use of water as the final rinse agent. The trial demonstrated that TDLAS techniques can be used to continuously monitor and control the solvent drying process online, in realtime, without operator intervention or process interruption. The Model 5100 analyzer can provide online, realtime process control of moisture over a wide range of levels down to 4 parts per million (ppm), or 2%, of the reading, whichever is greater. — *Ametek Process Instruments, Inc., Newark, Del.*

Ametek Process Instruments

www.ametekpi.com

A peristaltic pump for metering and transfer applications

The new 530 peristaltic cased pump (photo) handles metering and transfer applications, such as surface coating, printing and lime addition. The cost-effective pump is said to offer easier operation and greater versatility coupled with high levels of accuracy. The new 530 models meet the demands of rugged and often remote environments, and are built to operate 24/7 without interruption. The versatile 530 range of process pumps offers four drive options and nine pumphead variants. The pumps

Watson-Marlow Fluid Technology Group

Emerson Process Management

deliver flowrates from 0.000026 to 0.92 gal/min. The pumps can be fitted with either continuous tubing pumpheads, or with LoadSure tube element pumpheads for pressures up to 101.5 psi. — *Watson-Marlow Fluid Technology Group, Falmouth, U.K.*
www.watson-marlow.com

Safe combustible-dust explosion isolation with this system

Tanks, silos and equipment are usually connected by pipelines through which, if an explosion occurs, fire and the pressure spread very rapidly. In addition, the intensity of the explosion in connected containers is increased by pressure piling and flame jet ignition. This sequence of events can be prevented by the Exkop isolation system, consisting of a control panel and one or more quench valves. The integrated elastomer seal within the quench valve closes within a few milliseconds, triggered by a signal from the company's Explosion Panel, Q-Rohr-3, Q-Box II, an infrared signal, or pressure or temperature sensors. The quench valve can be safely put back into operation again at the press of a button. The company recently introduced the new and improved Exkop isolation system, which expands to range of applications of its predecessors to include ST 2 dusts, reduced explosion pressures of up to 2 bars and larger diameters. — *Rembe, Inc., Charlotte, N.C.*
www.rembe.us

Balluff

Measure process temperatures without a thermowell

The Rosemount X-well Technology (photo) is a surface-sensing temperature-measurement solution that eliminates the need for thermowell process penetration when measuring process temperatures in pipe applications. This device provides an accurate and repeatable internal process temperature measurement, while eliminating possible leak points and simplifying specification, installation and maintenance. Rosemount X-well Technology is available in the Rosemount 648 Wireless Temperature Transmitter and Rosemount 0085 Pipe Clamp Sensor Assembly. These components work together to calculate process temperature via the transmitter's thermal conductivity algorithm. — *Emerson Process Management, Austin, Tex.*
www.emersonprocess.com

A smart capacitance sensor for level control

The Advanced SmartLevel capacitive sensor (photo) combines standard capacitive sensing technology and the patented SmartLevel technology, enabling the ability to sense solids and highly conductive acids and bases with the utmost reliability. The Advanced SmartLevel is housed in 316 stainless steel, and the PEEK sensing nose provides protection against sticky and adhesive materials. This combination of housing materials gives the sensor an IP69 rating, and is suitable for use in autoclaves for one hour. When used with the proper mounting accessories, the sensor can be used in hygienic applications. Integration into control systems is fast and flexible with either discrete outputs or with IO-Link communication. — *Balluff, Inc., Florence, Ky.*
www.balluff.com

A sanitary cone mill for sticky, fragile materials

The Model CM540 Sanitary Cone Mill (photo) delivers gentle, low-energy size reduction while achieving even particle distribution with minimal fines. It is suitable for de-lumping of dried or hygroscopic materials that have agglomerated due to dampness or compaction, for intermediate sizing of "wet mass" product for improved drying and granulation prior to tableting, and for regrinding of out-of-spec tablets to be reintroduced to the tableting process. Its smooth, moderate action alleviates traditional milling problems of product build-up, dust and heat generation, enabling it to process fatty, heat-sensitive, sticky, moist or fragile products. Conical screens can be changed rapidly, and are offered with apertures from 150 micron for fine/dry de-agglomeration, up to 25 mm, including square and rectangular perforations for wet granulation. — *Kason Corp., Millburn, N.J.*
www.kasonkekgardner.com ■

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Insulating Heat-Transfer-Fluid Piping

Department Editor: Scott Jenkins

Heat-transfer-fluid (HTF) system piping is insulated to reduce heat loss and prevent worker contact with hot surfaces. Insulated piping minimizes the effects of changes in ambient temperature to help ensure precise control of process temperature. Proper design of the HTF system and its insulation is required to reduce the risk of fire as a result of fluid leakage into insulation.

Types of insulation

The main insulation materials used for HTF system piping are fiberglass, mineral wool, calcium silicate and cellular glass. Table 1 lists some important properties to consider when choosing insulation.

Fiberglass and mineral wool are fibrous materials produced in similar processes. Thermal conductivity is similarly low for both materials. Calcium silicate insulation is formed by drying a calcium silicate slurry in a mold, yielding a material with a slightly higher thermal conductivity than fiberglass or mineral wool. These three materials have open, air-filled channels, which can wick leaking fluid into the insulation.

Cellular glass insulation is formed by heating a glass powder mixture, which melts and expands, leaving tiny, sealed glass cells throughout the material. It is impermeable to leaking fluid and has a thermal conductivity similar to calcium silicate.

Insulation design

Insulation should be installed to cover all piping and other exposed surfaces of the HTF system where heat loss can occur. Free online calculators can be used to determine required insulation thickness for most processes.

Fire safety

Fires have occurred in insulation materials that have been soaked with organic heating fluids at apparent temperatures of 500 to 600°F, which is well below the autoignition temperature of most commercial HTFs. While the exact mechanism by which such fires occur is not fully understood, the most probable explanation is that a slow exothermic oxidation reaction between hydrocarbon-type heating fluids and the air inside the voids of the insulation starts at about 500°F. Such a reaction is believed to occur for the following reasons:

- A large heating surface area exists within the insulation
- Formation of low-flash-point oxidation products, resulting from exposure to air
- Temperatures can rise within the saturated insulation mass due to poor heat dissipation conditions

Tests indicate that fiberglass, mineral wool and calcium silicate insulations are more subject to this problem, since they can absorb large amounts of leaking fluid with greater surface area of liquid-air contact.

Cellular glass insulation resists saturation by heat transfer fluid and, therefore, may be a safer insulation to use. Cellular glass normally is more costly for most applications because of its higher installation cost and its tendency to crack when thermally shocked. Cellular glass is suggested for use around flanges and other areas where leaks are likely to occur, while lower-cost insulation materials may be used for pipe racks and all-welded runs of piping.

Tips to reduce risk of fire

Install and maintain a leak-free piping system when combustible heat-transfer fluids are being used. Reduce the number of flanges and incorporate adequate flexibility of piping. Use suggested piping specifications. If a leak develops, remove the insulation and contain and control the HTF until the leak can be repaired.

On horizontal runs of pipe with welded joints and proper flange fittings, the standard high-temperature insulation, such as calcium silicate or fiberglass and so on, may be used.

On vertical runs of lines of pipe where occasional sources of leaks can develop at flanges and valves, install protective, tight-fitting caps below flanges and valves to divert any fluid leakage to the outside of the insulation.

Install valve stems horizontally to help avoid stem leakage from entering the insulation.

On those sections of lines where greater numbers of control valves and instrument fittings present higher leakage risk, install cellular glass insulation or metal-shielded insulation to minimize or eliminate any fluid saturation of the insulation system.

Consult your company's insulation supplier and insurance company for additional suggestions on reducing fire hazards. ■

TABLE 1. KEY PROPERTIES OF COMMON PIPING INSULATION TYPES

Insulation type	Temperature use range	Absorbent?	Price
Fiberglass	0 to 1,000°F (–18 to 538°C)	Yes	Low
Mineral wool	0 to 1,400°F (–18 to 760°C)	Yes	Low
Calcium silicate	80 to 1200°F (27 to 650°C)	Yes	Medium
Cellular glass	–450 to 800°F (–268 to 427°C)	No	Medium

References

1. "Systems Design Data," Publication No. 7239193C, Solutia Inc., subsidiary of Eastman Chemical Co., September 2002.
2. "Liquid Phase Design Guide," Publication No. TF-04, 5/14, Eastman Chemical Co.
3. Controls Southeast Inc., "Insulation," from www.csiheat.com/csi_university/insulation.aspx, accessed January 2016.

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Styrene-Butadiene Rubber via an Emulsion Process

By Intratec Solutions

Styrene-butadiene rubber (SBR) is an elastomer that was originally developed prior to World War II as a replacement for natural rubber. SBR is used for manufacturing vehicle tires, but is also used in other applications, such as: adhesives, flow modifiers for other elastomers, footwear, pharmaceutical and food-contact articles, and even chewing gums.

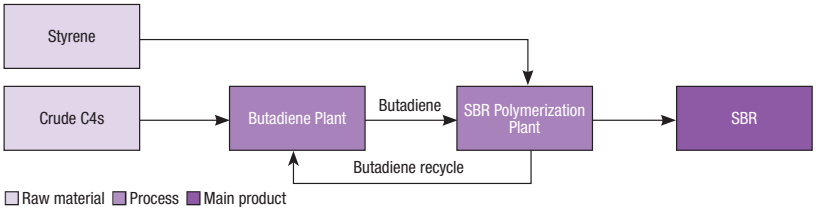

FIGURE 2. This figure shows an integrated industrial complex, including a butadiene plant and an SBR plant

The process

The following paragraphs describe a cold emulsion-polymerization process for SBR production from butadiene and styrene. SBR grades generated in this type of process are usually referred to as emulsion SBR (eSBR). Figure 1 presents a simplified flow diagram of the process, showing the main pieces of equipment.

Polymerization. Styrene and butadiene are mixed with an emulsifier and demineralized water to form the emulsion that will be fed to the polymerization reactors. The polymerization occurs in a connected series of continuously stirred, jacketed tank reactors. To maintain a low reaction temperature, all reactors are cooled using ammonia refrigeration.

Downstream, a "shortstop" agent is mixed with the emulsion to stop the reaction at the desired conversion stage and avoid gel formation. The shortstopped latex is transferred to the monomer-recovery section.

Monomer recovery. The latex generated in the polymerization reactors is directed to blowdown tanks and subsequently flashed to recover unreacted butadiene. Residual butadiene vapors are sent to a butadiene-recovery step, while the degassed latex is pumped to a steam-stripping column.

In butadiene recovery, water is removed from the stream and recovered butadiene is recycled to the butadiene plant. In the butadiene plant, butenes are separated, so the recovered butadiene can be reused in the eSBR plant.

In the steam-stripping column, residual styrene monomer is stripped by contacting the latex with steam entering the bottom of the column. Stripped styrene is recycled to the polymerization, while the latex is transferred to the coagulation section of the process.

Coagulation, drying and finishing. In the coagulation step, the latex coagulates and becomes small crumbs suspended in water. The coagulated crumbs are then sent to a drying stage, where they are dewatered. The resulting crumb stream, containing less than 10 wt.% moisture, is dried with continuous belt dryers. After drying, the rubber is pressed into bales, weighed, film-wrapped and boxed.

Economic performance

An economic evaluation of the process described was conducted based on data from the first quarter of 2014. The scope of this analysis assumes an eSBR plant located inside a petrochemical complex that also contains a butadiene plant (Figure 2).

The total capital investment estimated to construct a plant in the U.S. with the capacity to produce 140,000 metric ton per year (m.t./yr) of eSBR is about $230 million. The capital investment includes fixed capital, working capital and additional capital requirements. The production costs (costs associated with plant operation, product sales, administration, R&D activities and depreciation) are about $2,700/m.t. of eSBR produced.

This column is based on "Styrene-Butadiene Rubber Production: Cost Analysis," a report published by Intratec Solutions that can be found at: www.intratec.us/analysis/styrene-butadiene-rubber-production-cost. ■

Edited by Scott Jenkins

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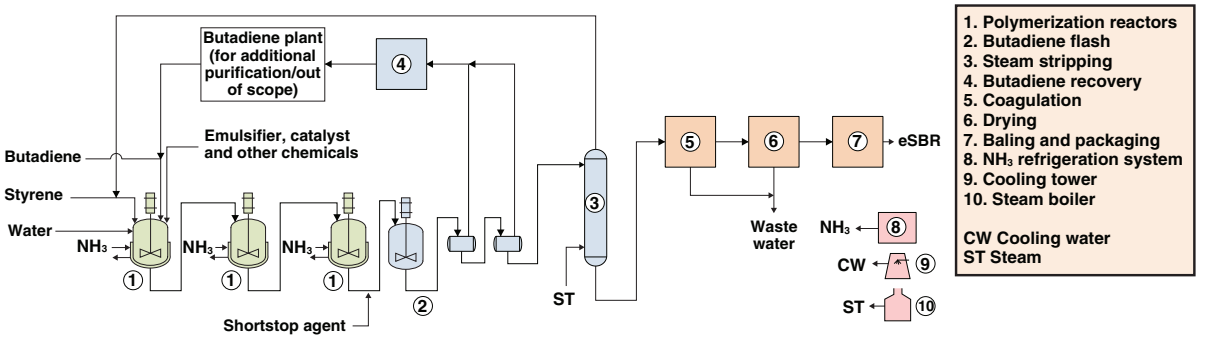

FIGURE 1. This figure shows a diagram of SBR production from styrene and butadiene via a cold emulsion process

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Mixers: Four Innovations Worth a Closer Look

Many factors can impact the success of mixing in chemical process operations. The design breakthroughs profiled here address some of the most commonly encountered issues

Christine Banaszek
Charles Ross & Son Company

IN BRIEF

FOUR RECENT ADVANCES IN MIXER DESIGN
PLANETARY DISPERSERS
POWDER-INDUCTION MIXERS
ULTRA-HIGH-SHEAR ROTOR-STATOR MIXERS
VERTICAL BLENDER-DRYERS
CLOSING THOUGHTS

All photos provided by Charles Ross & Son Company

FIGURE 1. This planetary disperser is equipped with two helical, planetary stirrers, four saw-tooth blades (two on each high-speed shaft), a removable sidewall scraper arm, and a bottom scraper (attached to one of the stirrers)

The last few decades have not lacked for innovations in mixing technology. As the chemical process industries (CPI) have made great strides in developing novel raw materials, enhanced value-added formulations and improved processes — in response to ever-changing consumer preferences and legislation — the science and art of mixing has continued to evolve, too, to meet the demands of modern production.

Mixer manufacturers have needed to quickly adapt and respond to real issues that are encountered, from research and development (R&D) all the way through scaleup and commercial production. While many of the solutions commonly take the form of strategic modifications applied to prevailing technologies, there are others that ultimately give rise to more drastic innovations and thus become a new mixer category all their own.

As with most novel devices and ideas, mixing innovations do take time to spread and gain widespread usage, some more than others. In this article, we review four specialty equipment designs that provide a range of

processing and operational advantages over traditional mixers. While they may not yet be considered standard workhorses (and are often are known only within specific industry sectors), they are worth a closer look by most CPI operators, because of the universal benefits they offer.

Four recent advances in mixer designs

1. Planetary dispersers. The classic high-speed disperser, also sometimes called a dissolver, is a popular mixing tool used in the manufacture of paints, inks, coatings, adhesives, plastics and other applications. It is economical, simple to operate and usually equipped with a saw-tooth blade, which works well for straightforward, powder wet-out and dispersion applications. However, its efficacy is significantly diminished once the product viscosity exceeds 50,000 centipoise (cP).

And, a high-speed disperser can easily raise product temperature due to frictional heat. In a viscous batch, when not enough material is able to flow toward the blade, localized heating sets in. Eventually, colder materials near the vessel periphery can become stagnant. This further contributes to poor mixing, and increases the risk of product degradation due to overheating in the vicinity of the high-speed blade.

The addition of an anchor agitator, designed to sweep the vessel walls and promote bulk flow, can improve the disperser's rheological limitation, but only to a certain extent. As viscosity climbs to around 500,000 cP and higher, such a multi-shaft mixer configuration — one that combines a disperser and an anchor — will ultimately begin to suffer, as a result of inadequate product turnover and uneven heating.

Manufacturers familiar with the above scenarios could learn from the battery industry, where many producers have standardized their operations using planetary dispersers for producing viscous, electrode pastes and similar materials with high solids content. These are hybrid mixers that deliver simultaneous planetary agitation and high-shear dispersion.

Planetary dispersers are highly efficient at incorporating large amounts of dry ingredients into a liquid, even if the fluid is thick or tacky to begin with. The most robust configuration of this style of mixer consists of two low-speed planetary stirrers, and two high-speed shafts, each equipped with multiple, saw-tooth disperser blades (Figure 1). All four agitators rotate on their own axes, while revolving around the vessel. A more basic version, with just one planetary stirrer and one disperser, can be considered, as well.

FIGURE 2. The agitators in this 300-gal planetary disperser are lifted out of the vessel via a dual-post hydraulic lift, allowing complete access for cleaning and maintenance

Both sets of agitators are independently controlled, so flow patterns and shear rates can be fine-tuned as the product undergoes changes in rheology and other physical characteristics throughout the mixing cycle. In a planetary disperser, the concern of localized overheating is reduced to a large extent, because the sawtooth blades do not turn from a fixed location. Just as importantly, two other agitators are essentially "feeding" the dispersers with product from all other areas of the vessel. Polytetrafluoroethylene (PTFE) scrapers can be added for the sidewalls and tank bottom, as well, for even tighter temperature control.

Compared to double planetary mixers and sigma-blade mixers — which apply a lower-speed kneading action and thus rely on elevated viscosity in order to effectively disperse agglomerates — planetary dispersers deliver very high levels of shear over a wider viscosity range and are better

FIGURE 3. This illustration shows how a powder-induction mixer works. The liquid stream (blue) enters the mixer and immediately encounters the powder addition. Drawn by a powerful vacuum, free-flowing powders (yellow) are injected into the liquid and instantaneously mixed under high shear. The resulting dispersion (green) is expelled centrifugally through the stator openings at high velocity

able to accommodate extreme fluctuations in consistency.

Adding to their functionality and efficiency, the "change can" design of planetary dispersers allow the use of multiple vessels for semi-continuous production. Upon completion of a mix cycle, the agitators are lifted completely out of the finished product so the vessel can be wheeled away to a discharge station (Figure 2). Another vessel is then rolled into position under the mixer to immediately begin the next batch.

Case history snapshot 1. A manufacturer of structural adhesives was previously batching one of its formulations in open vessels equipped with high-speed dispersers. After mixing, the product required further processing in a three-roll mill, to achieve a 6 Hegman grind.[1]

Testing revealed that vacuum mixing in a planetary disperser produces a superior finished product, which no longer requires additional milling. The much-improved material turnover throughout the mixing cycle, coupled with vacuum conditions, consistently results in a final product with a 7–8 Hegman grind.

The company has since installed 40- and 100-gallon planetary dispersers with interchangeable vessels and accompanying discharge systems. The new production method is essentially a "one-pot" process, which is more streamlined and capable of significantly greater output in less time, compared to the former approach.

2. Powder-induction mixers. As many process engineers and operators can attest, poor-quality dispersions occur even when the application has a relatively low viscosity and is relatively easy to agitate. Stubborn agglomerates, "fish eyes" (that is, partially hydrated clumps of powder characterized by a tough outer layer that prevents the complete wetting of particles within the interior portion), and floating powders are a frustrating sight that can take several hours of mixing to remedy. Unfortunately, it does not take a large amount of solids to create this type of bottleneck.

Consider the case of fumed silica, carbomers, cellulose gum (CMC), starch, alginates, pectin, xanthan gum, carbon black and other hydrophobic or low-surface-energy solids. Dispersing powders like these into water, solvent, resin or other liquids is typically time- and energy-consuming. To aid wetting, chemical surfactants and dispersants are typically utilized, allowing manufacturers to continue relying on existing and legacy mixing equipment with reasonable success. However, the option to upgrade to a better method of powder dispersion should not be overlooked as an opportunity to sharpen competitive advantage.

Thanks to innovations in rotor-stator technology, sub-surface induction has become arguably the best technique for handling hard-to-disperse powders — provided the dispersion has a maximum viscosity no greater than 10,000 cP (Figure 4). Today's powder-induction mixers are capable of pumping liquid while simultaneously drawing powders and dispersing them into the fluid stream (Figure 3). After inducting all of the dry ingredients, the mixer continues to recirculate the product until the desired level of dispersion or dissolution has been achieved, usually in just a few tank turnovers.

When used in conjunction with, or in lieu of, top-entering agitators like propellers, turbines, paddles or anchors, a powder-induction mixer virtually eliminates the occurrence of floating powders, excessive dusting and

1. A Hegman grind gage is one method for determining the presence of coarse particles or agglomerates in a dispersion. The gage resembles a flat block of steel with grooves machined into it, decreasing in depth from one end of the block to the other. The Hegman scale ranges from 0 to 8, with numbers increasing as the particle size decreases. A value of 0 Hegman correlates to approximately 100 microns, while a value of 8 Hegman is equivalent to 0 microns.

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FIGURE 4 (above). Combining this powder-induction mixer with a work bench eases material handling. This mobile system pumps liquid from a tank, while simultaneously drawing powders from a built-in hopper. The resulting mixture is pumped by the mixer back into the tank and recirculated until dispersion is complete

persistent fish eyes. Other processing advantages include greatly reduced mixing times, less rework and waste, and increased operator safety.

The design breakthrough of today's newer powder-induction mixers is particularly valuable because it has removed the need for eductors and auxiliary pumps. In earlier designs, solids were combined with the moving liquid stream in an eductor by means of the Venturi effect, and then mixed further down the line. These systems worked to some extent but were often temperamental and prone to clogging. They also required constant attention by an experienced operator in order to maintain a careful balance between the pump, eductor and mixer.

The latest iteration of the powder-induction mixer utilizes a modified rotor-stator that creates a powerful vacuum, which draws powders directly into the high-shear zone, where they are instantaneously dispersed into the liquid stream. In essence, the rotor-stator generator assumes all three functions of the pump, eductor and mixer in a compact machine that is simpler to use and far more reliable than the prior approach.

Case history snapshot 2. At a chemical plant, fumed silica dispersions were being made in a 4,000-gal tank equipped with a propeller agitator vessel and a rotor-stator mixer in the recirculation line. An oily liquid with surfactant was charged into the tank and heated to 110°F, followed by fumed silica powders, which were added slowly and deliberately, one bag at a time. The batch took several hours to complete, even with the recirculation mixer providing some level of shear.

By simply swapping its regular, inline rotor-stator mixer with a newer model capable of powder induction, the company was able to cut down the cycle time to under two hours, and reduce operator exposure to airborne particles. The powder-addition step is especially more convenient — operators no longer have to climb the mezzanine carrying bags of fumed silica.

3. Ultra-high shear rotor/stator mixers. Ultra-high-shear mixers are super-close-tolerance rotor-stator devices (Figure 5) designed for very high tip speeds (upwards of 11,000 ft/min, which is three to four times that of conventional rotor/stators). What makes them an essential innovation is their ability to produce very fine dispersions and emulsions, which previously could only be made in colloid mills, media mills and high-pressure homogenizers. Such machines are popular in certain industries, but are known for their notoriously low throughput, high energy consumption, costly maintenance and long downtimes.

Many of the companies currently using ultra-high-shear mixers have switched to this technology because of applications that require intense mixing, but

FIGURE 5 (below). Shown here are some examples of the rotor-stators used in modern ultra-high shear mixers. The combination of high tip speed and extremely close tolerances between the interlocking channels subjects the product to intense shear in a single pass. The gap between adjacent surfaces of the rotor and stator is adjustable, allowing operators to fine-tune shear levels and flowrates

actually tend to degrade when exposed to excessive shear. In other words, ultra-high-shear mixers offer a "sweet spot" of intensity necessary for particle- or droplet-size reduction beyond what regular single- and multi-stage rotor-stator mixers can deliver.

At the same time, they are not exact drop-in replacements for high-pressure homogenizers, but offer an alternative strategy for certain applications, including pharmaceutical, cosmetic and food emulsions, fine pigment dispersions, electronic inks and specialty coatings, to name a few. Manufacturers reap the advantages of lower equipment cost, significantly higher production capacity, faster changeover and easier maintenance. Sanitary models, which can be cleaned and sanitized in place, also make ultra-high shear mixers a very practical option for sensitive applications.

Case history snapshot 3. A pharmaceutical company uses several ultra-high-shear mixers to produce a topical emulsion made up of a slightly thickened aqueous phase and a smaller-quantity oil phase. The aqueous phase is charged into a recirculation vessel and the mixer is started up. Once the mixer has ramped up to the operating speed, the oil phase is added to the tank at a controlled rate, as the emulsion recirculates with the aid of a pump. Within minutes, a tight distribution with submicron median droplet size is achieved.

4. Vertical blender/dryers. When drying to very low moisture levels, conventional ovens and tray dryers are often left to run continuously for many hours, perhaps even overnight. Vacuum ovens and tray dryers offer better drying rates compared to their atmospheric counterparts, but agitated vacuum dryers can be even more efficient. In fact, combining mixing and drying in a single simultaneous operation may offer substantial improvements to production rate and energy consumption.

Recognizing the potential savings from lower operating costs and faster drying, more and more manufacturers throughout the CPI are upgrading to agitated vacuum dryers. One of the most reliable systems available is the vertical blender/dryer, which features a slow-turning auger screw and a conical vessel (Figure 6). The motion of the auger screw gently lifts materials upward and reintroduces them to the center of the batch. As it orbits around the vessel, the screw also nudges product near the top to cascade slowly back down. The combination of thorough mixing, deep vacuum and low horsepower makes the vertical blender an extremely efficient dryer. With a very low footprint requirement, the vertical blender/dryer is especially practical for large batch volumes up to 500 ft^3 or even larger, as long as the plant has enough ceiling height.

FIGURE 6. The agitator movement and material flow pattern shown here for a vertical blender-dryer provides favorable results for many applications. Product is heated through contact with the jacketed sidewalls. The vacuum-rated cover may also be jacketed to avoid condensation

As opposed to ovens and tray dryers where product is stationary and relies on convection for heat transfer, the materials inside a vertical blender are heated via conduction. The layer of product in direct contact with the heated sidewalls is constantly renewed, and under vacuum conditions, this continuous but gentle turnover of materials accelerates drying without affecting bulk density or generating an excessive amount of fines.

Another great benefit of the vertical blender is that it can accommodate a wide range of feed forms, from free-flowing powders and pellets to wet granules and paste-like materials. The low-impact blending mechanism also makes it well-suited for delicate, abrasive and high-purity applications.

One particular innovation that is an essential feature of the modern vertical blender is the fully top-supported screw agitator. With-

FIGURE 7. Vertical blenders are easily scalable and available in many standard sizes from 1 to 500 ft^3. Shown here is a 350-ft^3 model, with a cone height measuring 14.5 ft

out a bottom support bearing to get in the way, finished product is quickly and completely discharged out of the steeply angled conical vessel. The blender requires very little maintenance as there is no packing gland in the product zone, which also simplifies cleanup.

Among agitated dryers, the vertical blender is one of the most economical because of its low horsepower-to-volume ratio. For instance, it consumes up to 50% less power than a comparable ribbon blender. It is also the most flexible in terms of batch size. Given the geometry of the cone, the vertical blender can operate efficiently with batches as small as 10% of the maximum capacity, whereas a blender with a horizontal trough generally needs to be at least 30–40% full in order to mix properly. Furthermore, the vertical blender is not sensitive to the order of addition and positioning of raw materials (Figure 7).

Case history snapshot 4. A plastic manufacturer used to dry thermoplastic resin powders (reducing moisture from 35% to less than 1%) in a V-cone tumble blender and transfer them to trays for curing in an oven. The powders were then milled to disperse agglomerates that re-formed during curing. This three-step process took 24 hours to complete.

Simulation trials confirmed that the drying and curing stages could be done in a vacuum-rated, vertical blender/dryer. Temperature at each stage is easy to control and maintain accurately, while the constant agitation prevents agglomerates from forming, therefore eliminating the downstream milling step.

The company ultimately installed a vertical blender/dryer designed for 29.5 in. Hg vacuum and operating temperatures up to 500°F. Heating oil is circulated through a 100-psig stainless steel jacket around the vessel and cover.

Closing thoughts

Innovations in mixing and blending will continue to emerge as long as users and equipment manufacturers remain open to new and unconventional solutions. There is certainly room to grow considering the many processing objectives that mixing accomplishes throughout the CPI — from simple dissolution, suspension and particle-size reduction, to homogenization, emulsification, drying and a host of chemical reactions.

Mixing is a very application-specific operation that should be approached empirically, because the raw materials and their interactions under certain operating conditions affect mixing performance. Hence, the most successful mixing strategies are often those that were grounded on practical experience — and not just theoretical calculations. Process engineers, R&D scientists and managers are encouraged to take advantage of testing opportunities, whether through in-house trials using rental equipment, or spending a day or two at a mixing laboratory. By partnering with a reputable mixer manufacturer, companies from any field can leverage decades of industry experience to solve their operating issues and fuel their own innovations. ■

Edited by Suzanne Shelley

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Reliable Operation and Sealing of Agitators

Mechanical seals, as required by most vessel agitators, are systems sufficiently complex to warrant a good understanding by engineers and appropriate training for operators

Bernd Reichert
EKATO

IN BRIEF

AGITATOR SEAL SYSTEMS COMPARED
BASICS OF MECHANICAL SEALS
BARRIER FLUIDS
MATERIALS OF CONSTRUCTION
SUPPLY SYSTEMS
CONTINUOUS FLOW SYSTEMS
PRESSURE COMPENSATORS

To ensure safe and reliable agitator operation, the sealing of the rotating shaft is of fundamental importance. Depending on the operating conditions — such as pressure, temperature and speed — various sealing principles may be used. A comparison of their characteristics with the requirements for mixing shows that mechanical seal technology offers many advantages over other sealing methods. In particular, when hazardous substances are being mixed or an explosive atmosphere is present, the use of a mechanical sealing system is almost mandatory, especially if the mixing vessel operates at elevated pressure and temperature.

Agitator seal systems compared

A reliable mechanical design for an agitator (Figure 1) must take into account the hydraulic loads on the impellers, which in turn create the torques and bending moments that exert mechanical loads on agitator components such as the shaft, bearing and gearbox. Secondary loads, such as oscillations, vibrations and noise emissions also play important roles.

Shaft seals can be divided into two main groups: radial and axial seals. The main difference between these two groups is the direction in which the contact forces act.

Typical types of radial shaft seals include radial sealing rings, lip seals and stuffing boxes. Here, the sealing effect is provided by radial forces, and the length of the cylindrical sealing gap is in the axial direction. Although radial seals are relatively insensitive to axial displacement, radial shaft deflections lead to higher sealing forces on one side, which may cause leakage and accelerate wear.

In contrast, the sealing forces in axial shaft seals act in the axial direction. This results in a horizontal sealing surface with a concentric circular cross-section. Owing to their design, axial shaft seals are relatively insensitive to radial shaft deflections and are thus very suitable for agitator applications. Axial displacements have to be compensated with elastic elements. Mechanical seals belong to the group of axial shaft seals. Below, some examples of each type of seal are discussed in more detail (see also Figure 2).

FIGURE 1. The forces on the components of an agitator — including the seal — result mainly from the hydraulic loads on the impellers

Stuffing boxes. Historically, stuffing-box packings are the oldest type of sealing element. The term "stuffing box" originates from early steam ship construction. The passage for the shaft through the hull was sealed with oil-soaked rags that were stuffed into the gap between the shaft tube and the housing. The first mixing vessels were often equipped with a stuffing box.

Lip seals. In mixing applications, the working principle of lip seals can be in either the radial

or the axial direction. Cup collars, which provide axial sealing, can be shifted to different positions along the shaft. A cup collar whose lip runs along the surface of the mounting flange can protect surrounding equipment from steam or other vapors inside the mixing vessel, though it works only for vessels operating at atmospheric pressure. Radially acting lips — usually made from a modified polytetrafluoroethylene (PTFE) material — are also used to seal mixing vessels. These shaft lip seals, however, must be equipped with relatively complicated bearings to limit shaft deflections within the seal housing to about 0.01 mm. This is the only way to operate the lips reliably at pressures of up to 6 bars.

Hermetic seals. To hermetically seal a mixing vessel using only static seals, the mechanical energy required at the impellers must be transmitted through the wall of the closed vessel. The input torque of a magnetic drive is transmitted to the shaft through a canister using permanent magnets.

Mechanical seals. Mechanical seals with dynamic sealing elements are regarded as technically tight when pressurization of the seal liquid is able to maintain a positive pressure gradient between the seal liquid chamber of the mechanical seal and the product in the vessel. Most mechanical seals used with agitators have two pairs of sealing rings: two rotating and two stationary rings (Figure 3). These pairs of rings form an enclosed space — the seal chamber — that can be filled with seal liquid. The contents of the vessel can be reliably sealed against the surroundings by applying pressure to the seal liquid.

If the seal-chamber pressure is controlled so that it is always higher than that inside the vessel, the product inside the vessel cannot get past the mechanical seal. However, the unavoidable leakage of seal liquid past the inboard sealing rings will enter the vessel, while leakage past the outboard pair of sealing rings will enter the surroundings.

The design principles of mechanical seals can be divided into single- and double-acting seals. Another differentiating feature is the type of seal-ring lubrication: dry-running, gas-lubricated or liquid-lubricated.

Single-acting mechanical seals. The key design feature of single-acting mechanical seals is that they have only two seal rings. This means they have only one interface and no seal-liquid chamber. A key characteristic of single-acting mechanical seals is that they can leak into the surroundings of the vessel. The leakage rates are generally not high: about 10–100 mL/hr of gas for dry-running seals and 10–50 mL/d of liquid for side-entry mechanical seals. This means that the vessel is not technically tight, in contrast to double-acting mechanical seals. Therefore, this seal design cannot be used when hazardous materials are to be mixed.

Although dry-running mechanical seals do not need seal-liquid supply systems and their corresponding monitoring devices, the seal rings are subject to relatively high wear. The service life is therefore much lower than that for liquid-lubricated mechanical seals. Nevertheless, dry-running mechanical seals

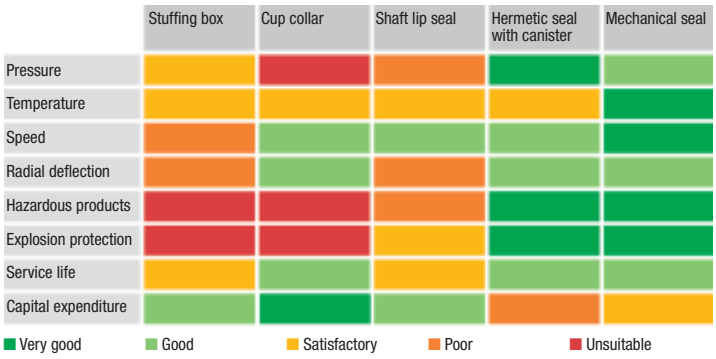

FIGURE 2. Of the various technologies used for agitator sealing, mechanical seals typically score best in terms of the balance of process and economic factors

can achieve service lives of a year or more under appropriate operating conditions.

Liquid-lubricated single-acting mechanical seals can achieve much longer service lives, where the nature of the product allows them to be used. Many applications involve suspended solid particles that — depending on their hardness and particle-size distribution — can greatly influence the service life of the seal rings. These seals are generally equipped with two seal rings made from abrasion-resistant silicon carbide (SiC). However, the use of two hard materials is not ideal with respect to sliding friction. In this case, it is usually better to use a softer material for one of the faces, accepting higher wear in return for lower friction.

Double-acting mechanical seals. Double-acting liquid-lubricated mechanical seals are the most common type for mixing applications, where they can be used under nearly all operating conditions. They are also available in gas-lubricated variants, in which a continuous supply of gas into the seal chamber maintains a seal gap of a few micrometers, thus preventing wear of the seal rings. The characteristic feature of a double-acting mechanical seal is its seal-fluid chamber that can be filled with seal liquid or gas, thus separating the interior of the vessel from its surroundings.

Figure 2 shows how the various types of seals discussed above score against process parameters such as temperature and pressure, plus broader criteria like cost and service life. It is obvious that mechanical seals offer many advantages over the other types. Particularly if hazardous or explosive materials are being mixed, a mechanical seal is practically mandatory. A hermetic seal with a canister in combination with a mechanical seal is used for applications requiring the highest safety, such as hydrogenation or phosgenation reactions.

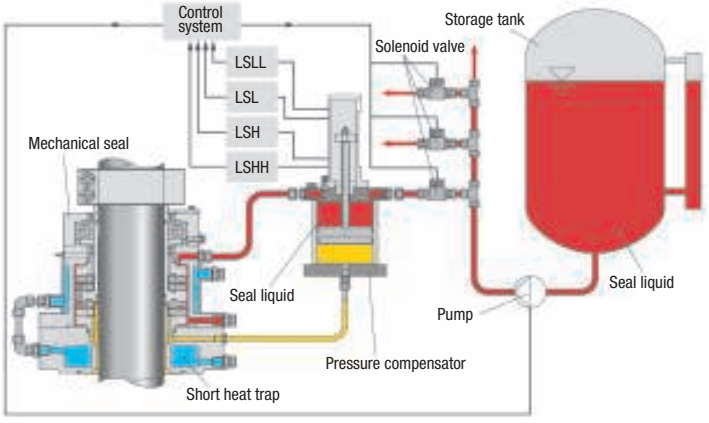

FIGURE 3. A complete mechanical seal system typically includes the seal cartridge itself, a seal liquid supply tank and pump, a pressure compensator with position sensors to monitor leakage, and automated isolation valves

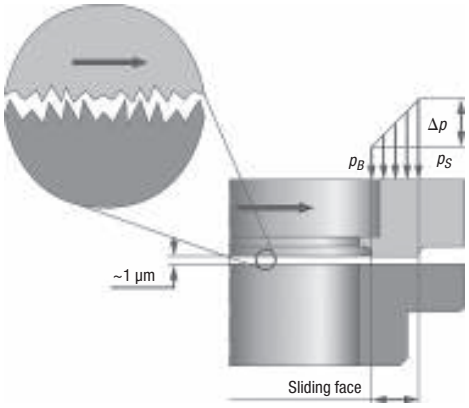

FIGURE 4. As the seal fluid cools and lubricates the seal faces, it creates a hydraulic force that tends to open the gap

Basics of mechanical seals

A mechanical seal system, as shown in Figure 3, has several components. Alongside the mechanical seal cartridge itself are the hydraulic components (such as a pressure compensator), and the rest of the installation, comprising the pipework, instrumentation and mountings. Some applications also include a seal-liquid refilling system. As a consequence, in most mixing systems, reliable sealing depends on the complete mechanical seal system. Careful selection of suitable hydraulics and installation components is just as important as the design of the mechanical seal itself.

The function of a mechanical seal is essentially governed by the mechanisms taking place in the gap between the rotating and the stationary seal rings. As Figure 4 shows, the seal interface can be imagined as a very narrow annular gap across which the seal faces are in partial contact. Full solid contact would be ideal from the perspective of avoiding leakage. On the other hand, a pure fluid film — with no solid contact — minimizes frictional forces, wear and heat generation. The design of the seal ring must therefore take into account both aspects, and thus always represents a compromise. This condition is known as mixed friction: the seal faces are in partial contact, yet thanks to lubrication they also are able to slide over each other.

The physical and chemical processes taking place within the sealing gap of a mechanical seal are difficult to describe theoretically. Some processes, such as blistering on seal faces, are not yet completely understood because it is hard to take measurements at the seal interface. The key variables influencing the sealing and frictional characteristics of seal rings are the various

axial forces, which operate in both the opening and closing directions. As Figure 4 shows, the pressure between the seal faces pushes the seal rings apart, whereas the hydraulic pressure on the rings (Figure 5) pushes them together. The ratio of these forces governs the efficiency of the sealing function and how easily the seal rotates. The closing forces must be slightly higher than the opening forces; otherwise, there is a risk that the gap will open suddenly and the seal will start to leak.

The ratio between the closing forces and the opening forces is described mathematically by the hydraulic balance ratio K (Figure 5):

$$K = \frac{\text{hydraulic loading area}}{\text{sealing interface area}} = \frac{A_2}{A_1} \qquad (1)$$

With the assumption of a linear pressure drop across the sealing interface (Figure 4), the closing and opening forces will balance when $K = 0.5$. In practice, optimum performance is obtained when the value of K lies between 0.6 and 0.9.

The hydraulic balance ratio K is also used to characterize mechanical seals as unbalanced or balanced. Unbalanced mechanical seals have $K > 1$, whereas balanced seals have $K < 1$. Unbalanced seals are expedient for simple operating conditions, such as low pressures and low agitator speeds. Here, the high hydraulic balance ratio, with closing forces dominant, provides good sealing efficiency without thermally overloading the mechanical seal. In more-difficult operating conditions, such as high pressures and high agitator speeds, only balanced mechanical seals can be used.

So far we have ignored the closing force contributed by the springs that form part of every mechanical seal. This force is generally equivalent to a pressure of 1–2 bars. This is important at low operating pressures, but can confidently be neglected at vessel pressures above 10 bars. Nevertheless, even high-pressure mechanical seals require springs to keep them closed while they are unpressurized.

Barrier fluids

Another essential factor influencing the function of a mechanical seal is the choice of barrier fluid. This liquid has three main functions: lubrication, cooling and sealing. It must also meet certain secondary conditions, such as compatibility with the product and, if necessary, conformity with the specifications of the U.S. Food and Drug Administration (FDA).

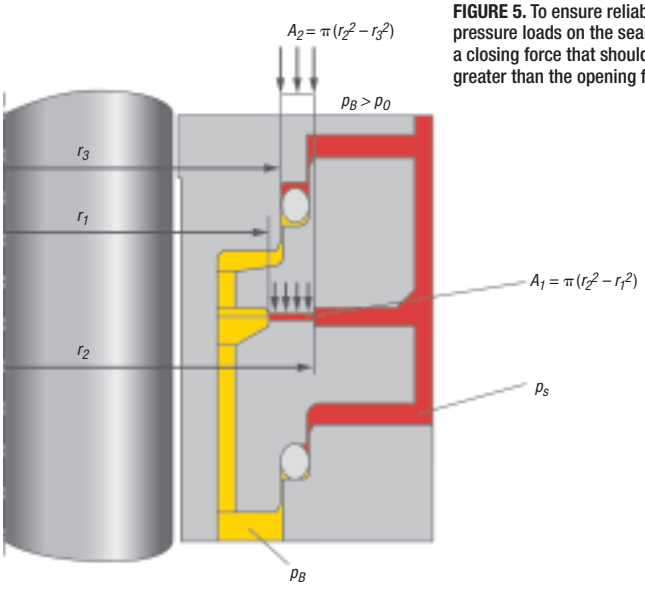

FIGURE 5. To ensure reliable operation, pressure loads on the seal rings create a closing force that should be somewhat greater than the opening force

Figure 6 compares barrier fluids used in mixing applications with respect to their suitability for various tasks. It is clear that the demands of lubrication and cooling may conflict. Water cools efficiently, but lubricates poorly, whereas the reverse is true for mineral oils and pure glycerin. A mixture of glycerin and water can be a successful compromise: the glycerin lubricates, while the water phase cools. For this reason, glycerin/water mixtures should always be used if possible. Unfortunately, not all products tolerate a glycerin in-leakage of several milliliters per day, though it is technically possible to collect the leaked barrier fluid and keep it away from the product.

Especially when water or organic solvents are used as barrier fluids, special

Barrier fluid	Lubrication	Cooling	Circulation	Product compatibility	FDA compliance
Water					
Mineral oil 20 cSt					
Glycerin 100%					
Glycerin/water					
Synthetic oil					

Very good · Good · Satisfactory · Poor · Unsuitable

FIGURE 6. For many applications, a mixture of glycerin and water yields the preferred balance of properties for the barrier fluid

Modules / Application criteria	Pressure compensator	Refilling unit	Cooling	Emergency supply	Flushing system	Thermo-siphon	Forced circulation
High pressure							
High temperature							
High agitator speed							
Many agitators or vessels							
Fluctuating pressure							
Unreliable cooling water supply							
Corrosive products							
Incrustations							
Toxic products							
Long shutdown time							
Unqualified personnel							

Particularly advantageous · Possible
Generally used · Not Recommended

FIGURE 7. This matrix aids the choice of the various modules typically associated with seal-liquid supply systems, according to their suitability for different applications

cooling measures may be necessary to dissipate the greater frictional heat. Compromises of this kind in the choice of barrier fluid generally shorten the service life of the seal rings.

Materials of construction

Modern seal rings made of SiC, graphite, or SiC/carbon graphite composites can handle nearly all sealing tasks. O-rings are nearly always made of fluorocarbon (FKM/FPM) rubber such as Viton, which withstands a wide range of temperatures and chemical environments. The most demanding requirements for chemical resistance require perfluoroelastomers (FFKM). Most of the other components of mechanical seals are made of stainless steel.

Supply systems

Supply systems ensure that the mechanical seal operates safely and reliably. A mechanical seal is regarded as being technically tight when the pressure in the seal chamber is always higher than the vessel pressure. The supply of seal liquid is thus of primary importance to safety. The seal liquid also lubricates the seal interface. The tasks required of the supply system include:

Pressure maintenance. Alternatives for pressure maintenance are continuous flow systems and pressure compensator arrangements (discussed further below).

Cooling. The physical processes taking place in the seal interface and at the seal faces are very sensitive to high temperatures. If critical values are exceeded, this may cause localized areas to dry out, resulting in hotspots and greater shear stresses on the surfaces of the seal rings. The sealing function is compromised as soon as the surface structure has been destroyed (blistering). Heat conducted to the seal from the vessel, and generated by friction at the seal interface, must therefore be continuously removed. Continuously operating cooling systems are extremely important for reliable operation. Cooling systems for mechanical seals must be designed so that the seal rings, O-rings and barrier fluid are not thermally overloaded. The weakest link in this chain is usually the barrier fluid, because it evaporates if the temperature of the seal faces is too high. Without the cooling and lubrication provided by the barrier fluid, the seal faces will rapidly suffer damage and drastically reduced service life. Long-standing experience at EKATO indicates that, irrespective of the type of barrier fluid, the temperature should not exceed 80°C.

Flushing. In many processes, corrosive or abrasive substances contaminate the surfaces of the seal rings. To protect them, the rings can be flushed with a compatible liquid.

Emergency supply. In the event of an unexpected increase in the leakage rate due to damaged seal rings, the normal system may not be able to supply enough barrier fluid to keep the seal rings cooled and lubricated. To maintain the positive pressure difference between the mechanical seal and the vessel, and thus maintain the lubrication function, a backup seal liquid (often water) is circulated through the mechanical seal at a higher flowrate. This allows the reactor to continue operating for a certain time after leakage has increased.

Seal liquid refill system. An outstanding characteristic of mechanical seals is their very small leakage rate, even at elevated vessel pressures. A leakage rate of only 20–50 mL/d

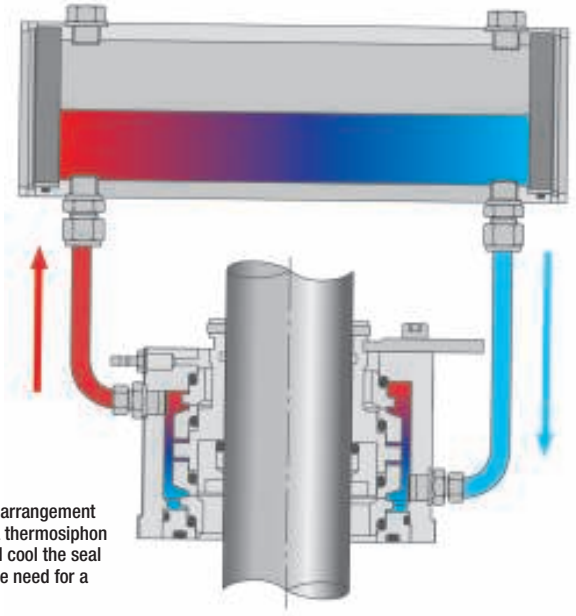

FIGURE 8. This arrangement makes use of a thermosiphon to circulate and cool the seal fluid without the need for a pump

can be expected during normal agitator operation at vessel pressures up to 70 bars. Nevertheless, it is advisable to monitor the leakage rate continuously and refill the system automatically when needed. This is especially important in continuous mixing processes.

Figure 7 shows the support systems recommended for various operating conditions.

Continuous flow systems

Water cooling systems and circulation pumps are not very popular because the necessary pipework and pumps increase the capital outlay. They also consume water and electricity, and require extra maintenance.

Fortunately, simple sealing tasks do not require these additional elements if we exploit the thermosiphon effect to circulate the seal liquid, and natural convection in the surrounding air for cooling (Figure 8). Hot liquid has a lower density than cold liquid, so it rises into a storage vessel mounted above the seal. Natural cooling of the liquid storage vessel then sets up a circulation through the seal. The storage vessel can also be cooled with a water jacket instead of air. A supply of compressed gas is required to pressurize the storage vessel.

FIGURE 9. Shown here is a forced-circulation system serving several mechanical seals

If the thermosiphon effect is insufficient to remove the generated heat quickly enough, the seal liquid must be circulated with a pump. Natural convection cooling with air must also be replaced or supplemented by forced cooling with liquid, for instance cooling coils in the storage vessel.

The resulting forced circulation cooling system (Figure 9) can only operate reli-

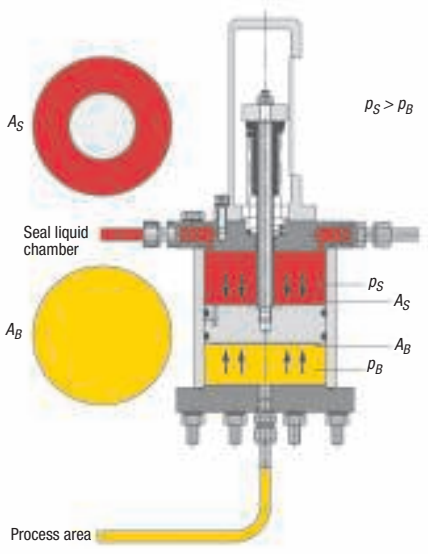

FIGURE 10. A pressure compensator allows the seal-liquid pressure to track just above the vessel pressure

ably if it is equipped with suitable monitoring instruments, such as flowmeters and temperature sensors. The most important component in terms of safety is the pressure control valve. This ensures that the pressure in the seal-liquid circuit is always greater than the vessel pressure. The usual arrangement is to set the seal-liquid pressure at a fixed value 10% above that of the maximum vessel pressure.

Also important to safety is an accumulator. If the circulation pumps should fail, for instance following a power failure, the high pressure in the seals is maintained by valves. During this time, the accumulator ensures that the pressure in the seal-liquid circuit remains higher than in the vessel, and also supplies more seal liquid to replenish leakage.

Pressure compensators

An alternative to setting the seal-liquid pressure at a fixed value is to use a pressure compensator. This allows the seal-liquid pressure to follow the vessel pressure. A pressure compensator is a hydraulic cylinder in which a piston acts as a divider between two fluid chambers (Figure 10). The lower face of the piston is subjected to the vessel pressure p_B, while the seal-liquid pressure p_S acts on the upper face. The area of the lower face (A_B) is shown by the yellow circle in Figure 10; the upper face has a smaller area (A_S) because the piston rod occupies some of the top surface, as the red "dougnut" in Figure 10 shows. The force balance is:

$$p_B \times A_B = p_S \times A_S \quad (2)$$

Because $A_B/A_S > 1$, $p_S > p_B$. The area of the piston rod is arranged so that the pressure in the seal liquid is always higher than the vessel pressure by the required differential.

As Figure 3 shows, the lower chamber of the pressure compensator is connected to the headspace of the vessel via the seal flange. The upper chamber is connected to the seal-liquid chamber. This arrangement ensures that the pressure in the seal-liquid chamber automatically follows the vessel pressure (Figure 11).

The inboard pair of seal rings is generally regarded as particularly critical because these rings are directly exposed to the process, and so bear the brunt of corrosion, erosion and high temperatures. Under varying operating conditions, such as those found in batch processes or during commissioning, a pressure compensator can reduce wear on these rings by dropping the seal-liquid pressure to the minimum safe value.

Pressure compensator systems are generally equipped with a manually controlled pump for refilling. An automatic refill system is recommended if there is more than one agitator (Figure 12) to exclude possible errors by operating personnel. Position monitoring of the pressure-compensator piston (Figure 3) provides very sensitive monitoring of the leakage behavior of each individual seal. This enables countermeasures to be started in good time if premature failure of the seal is imminent.

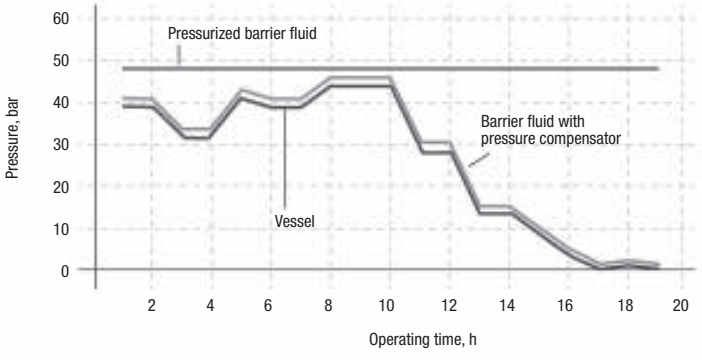

FIGURE 11. Shown here is a comparison between pressure correction via a pressure compensator, and constant pressurization with a continuous flow system

Summary

In most mixing systems, reliable agitator sealing requires a complete mechanical sealing system. As well as the mechanical seal itself, auxiliary equipment is needed to maintain an adequate flow of fluid at the correct temperature and pressure to cool

FIGURE 12. This automatic refill system serves 24 mechanical seals

and lubricate the seal faces. Careful selection of hydraulic and other components is thus just as important as the reliable design of the mechanical seal itself. The sealing function of the vessel can only be guaranteed and maintained if the complete system is correctly selected, installed and maintained.

When a mixing system is being commissioned, support and training for the equipment operators are very important to allow work to proceed rapidly and without problems. Once the plant is up and running, training and support are often the cornerstones needed to ensure high availability of the complete mixing system. ■

Edited by Charles Butcher

References

EKATO the Book (2012): Handbook of Mixing Technology, 3rd edition, EKATO GmbH, ISBN 978–3-00–038660–2.

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Performance Trends of Top Performers in the CPI

Focusing on a 'reliability culture,' mechanical availability and optimum costs leads to top performance

Jeff Dudley
HSB Solomon Associates

IN BRIEF

CULTURE CONTINUUM
CULTURAL PRACTICES AT THE TOP
MECHANICAL AVAILABILITY
MAINTENANCE COSTS
REDUCED HUMAN & BUSINESS RISK

Three factors drive manufacturing performance in the chemical process industries (CPI). These factors establish an operational culture that creates maximum availability of assets (mechanical availability) at an optimum cost. Results from the "International Study of Plant Reliability and Maintenance Effectiveness" (RAM Study), conducted by the author's employer [*1*], show that top performers focus on all three of the following factors:

- A reliability culture
- Mechanical availability
- Optimum cost

The RAM Study uses an overall metric that incorporates the impact of all three factors and is known as the RAM Effectiveness Index (RAM EI).* Organizations with top-quartile (Q1) RAM EIs (referred to here as top performers) have many common traits, no matter what product they are producing and regardless of the scale of their production operations or the age of their facilities. Industry trends show that top performers come from all sectors of the CPI: They include users of continuous and batch processes, manufacturers of commodity and specialty products, and organizations both large and small. The same is true for second-, third-, and fourth-quartile RAM EI organizations (called "other performers" here, or Q2, Q3 and Q4) — these also exhibit a mix of processes, products and sizes.

The study clearly shows that neither process, nor product, nor age correlates with top performance. So what does? The answer is the three attributes mentioned earlier — a reliability culture, mechanical availability, and optimum cost. Of these three attributes, one is by far the least understood — and most rarely achieved — but in reality has the most dramatic and lasting impact: a reliability culture.

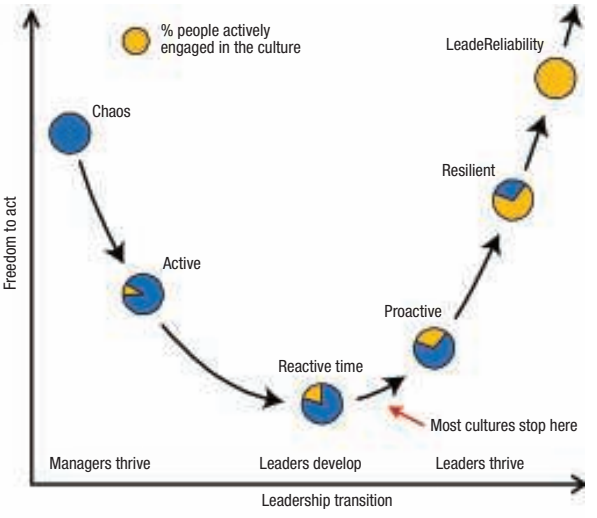


FIGURE 1. This graph of the "culture continuum" shows that, as managers shift to a leadership style, freedom to act and reliability are positively impacted

Culture continuum

It is interesting to examine the dynamic between freedom to act and reliability as an organization moves from left to right along the culture continuum (Figure 1). The RAM Study has shown that, as top-performing organizations move to the right on this continuum, they increase their profitability as they become more reliable. Creating a "LeadeReliability" culture (the culture farthest to the right) has the greatest impact on performance and can ultimately drive top performance in the other two areas.

Culture, in this context, is defined as the behaviors and processes an organization practices and the extent to which they are prevalent throughout the organization as a whole. Based on my personal observation, the types of cultures in the industry today span a wide continuum. Inside each different facet of the continuum are prevalent

* The RAM Effectiveness Index is a measure of the dollar value lost because of unreliability and inefficiency. A RAM EI of 5 says that you are losing 5% of your plant replacement value (PRV) due to lack of plant availability and are either under- or over-spending to provide that availability.

behaviors and work processes that define the segment. These varying behaviors and work processes have a dramatic impact on the overall performance and reliability of the organization and impact bottom-line performance in a significant way. Observations from the study show that unless the culture is developing behaviors and work practices commonly found in the mature proactive or early resilient culture (see Figure 1), top performance is unachievable.

Cultural practices at the top

What are some of the behaviors and practices top performers display on a daily basis to drive top performance?

Proactive. The organizations are, first, intentionally proactive in much of what they do. They are focused on leading indicators, they use foresight to analyze data, and they use their analyses to predict outcomes. Once they have predicted an outcome, they focus on anything that would appear to be abnormal — in other words, anything that could change the expected or predicted outcome. When abnormalities are detected, action is taken to understand why these abnormalities have occurred. This new information is then used to remedy the situation and drive it back to normal or to adjust the predicted outcome. The culture is always encouraging employees to learn from experience and then use the knowledge gained to improve performance.

Maintenance abnormalities. Top performers use key process variables to monitor, with foresight, any abnormalities that occur in the process, and they use key process indicators to ensure they are staying on track over the long term. Both short- and long-term performance are important to the delivered results. Top performers are not short-sighted and do not make decisions that could negatively impact the future performance of their assets.

When particular abnormalities can't be remedied, proactive plans are made to address the abnormal state as a whole in order to bring it back to normal. Abnormalities are not ignored and then allowed to become normal, which is a trait of non-top-performing organizations.

Planning. The vast majority of work is planned, scheduled and completed to plan, at a very high frequency. Many of the jobs that are planned and scheduled, if they've been done before or are part of an equipment strategy, can be found in a pre-planned job library. Preparation for work is detailed. Often, the materials needed to complete a job are delivered to the jobsite before the craftsperson arrives and work begins. These planned and scheduled jobs are typically completed as planned. Any deviations from the plan or schedule are treated as an unplanned event and are investigated, with the results of the investigation being used to prevent recurrence.

Reliability. The most significant thing top-performing organizations have discovered is that asset and equipment reliability are an outcome of the true driver of reliability. They understand that total reliability is driven by the way people in the organization perform their work, and that this performance has an impact on all other things. Reliability is not an asset issue, but instead is the result of people's behaviors. Individuals create reliability or the lack of it. The focus of top-performing organizations is on training and educating each member of the organization and ensuring that everyone understands the need to constantly and consistently meet their commitments. When this is accomplished, reliability is achieved.

Reliability is not an asset issue, but instead is the result of people's behaviors. Individuals create reliability or the lack of it.

The results. When this type of culture is put into place, the final result in a top-performing organization is the following:

- High customer loyalty
- Engaged employees
- An improved level of profitability

The entire focus is on minimizing the impact of unplanned events by detecting abnormal situations proactively and addressing them before disruption can occur.

While the existence of these behaviors and work processes is the leading indicator of top performance, this softer side of culture and leadership is hard for non-top-performing organizations to grasp. These non-top-performing organizations want the same high mechanical availability top performers enjoy, but are often looking for the "silver bullet" that allows delivery of that performance. Their understanding of what it takes to generate this outcome is centered on cost, and they assume that the right cost structure will result in high mechanical availability. Top-performing organizations realize that high mechanical availability and low cost are lagging indicators that result from their efforts to establish a reliability culture.

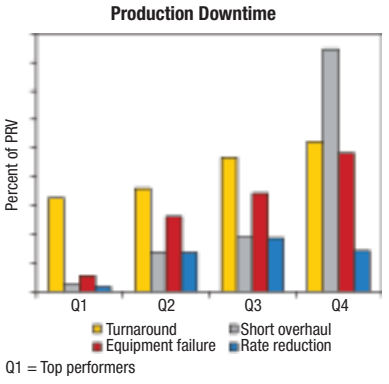
The following discussion will examine industry trends resulting from organizations focusing first on creating top-performing cultures.

Mechanical availability

Loss of mechanical availability (that is, downtime) in production facilities can generally be categorized into six distinct groups. Some downtimes are proactive in nature, while others are reactive. The six common causes of downtime are as follows:

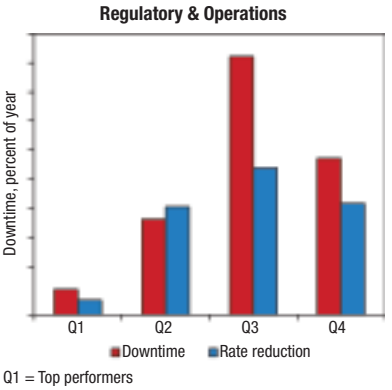
- Routine maintenance (both planned and unplanned)
- Turnarounds (extended downtimes that are scheduled at least a year in advance)
- Short overhauls (a short production outage, typically less than a week in length, that occurs with some level of planning done less than a year in advance)
- Rate-reduced operation (running an asset at less than its 30-day maximum rate due to a mechanical, instrument or electrical issue)
- Regulatory (running at reduced rates or total outage due to regulatory issues)
- Operations (running at reduced rates or loss of production due to an operations or process issue)

All of these categories prevent the asset from running at optimum



Q1 = Top performers

FIGURE 2. This plot of the average mechanical downtime (by cause) shows an increase in downtime in all areas as overall reliability performance decreases (PRV = plant replacement value)



Q1 = Top performers

FIGURE 3. This graph of the average operations downtime (by cause) shows an increase in downtime in rate reduction and shutdowns as overall reliability performance decreases

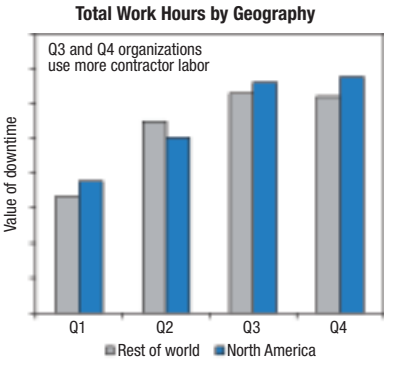


FIGURE 4. This graph of the average total work hours (by geography) shows that there is geographic similarity and downtime increases as overall reliability performance decreases

performance or from running at all, but the quantities of downtime in each category provide a window into the performance and culture of the organization.

For example, top performers (Q1) use turnarounds and short overhauls to do a large majority of their work. All turnarounds and most short overhauls can be scheduled, planned and executed, and are therefore proactive in nature. The degree of planning and scheduling and the type of execution reflects the culture of the organization. And the amount and type of work done during these outages also tells the culture story (Figure 2). In almost all cases, top performers use proactive outages as an insurance policy for when they are in normal operation. Because they see the work as an "insurance policy," they rarely limit the scope and level of work they perform during these outages.

The main focus of top performers during outages is to perform the work necessary to allow all of the assets to operate from startup until the next planned outage. The focus, in other words, is on proactively limiting the number of unplanned events. As a result of this focus, top performers (Q1) have much lower rates of downtime in the areas of mechanical failure, rate reduction, and regulatory and operations-related downtime (Figure 3). Figure 4 shows the significant reduction in downtime top performers (Q1) experience both in North America and the rest of the world.

So a combination of significantly fewer hours worked and a high level of proactive work gives top performers a distinct advantage. Other indications of proactive work performed tell even more about why top performers perform as well as they do.

As mentioned, turnarounds and short overhauls are typically planned. For top performers, the majority of their reactive downtime is planned as well. Other performers, in contrast, spend many hours on routine, rate-reduced, regulatory, and operations-related downtime. Even the maintenance performed during downtimes by these other performers is done in a much more reactive fashion.

Top performers use planning and scheduling for the majority of their work. Because of the proactive work they have done during their extended outages, they have much less emergency work to do in addition to their routine maintenance work. Routine maintenance is something that occurs in all organizations, but how it is handled is a strong indication of the culture of the organization. Seventy percent of the work done by top performers (Q1) is planned and scheduled — and only a small percentage is done as emergency work (Figure 5).

Another interesting trend is apparent when it comes to the type of equipment top performers use to do their work. There are three types of equipment families in most manufacturing facilities, namely:

- Rotating
- Fixed
- Instrumentation & electrical (I&E)

Not only is the total work of top performers lower on all types of equipment than for other performers but, as shown in Figure 6, the percentage of emergency work is lower for all three types and, for fixed equipment, much lower. Why would this be? In many facilities, affixed equipment is treated differently than rotating and I&E equipment. Often, fixed equipment is installed and then left as a utility. By "left as a utility" I mean that, after installation of the fixed equipment, which in many cases occurred years in the past, the equipment is essentially forgotten although, when needed, it is expected to function as it did when installed. For many organizations, this expectation is not backed up by robust maintenance of the equipment. As a result, vibration, corrosion, erosion and other mechanisms cause unexpected failures that require emergency work. Top performers experience these types of failure on fixed equipment less frequently because they have robust methods for ensuring their fixed equipment is well maintained and functions as expected for long periods of time.

The following methods of non-destructive testing are often used:

- Predictive inspection
- Painting programs
- Use of non-invasive inspection techniques (thermography, sonic and so on)
- Corrosion under insulation (CUI) programs
- Use of non-insulation alternative heat shielding

These methods also allow foresight into predictive failure modes and are used to allow proactive replacement of potentially faulty equipment on a planned basis if it is discovered.

These are some of the trends that

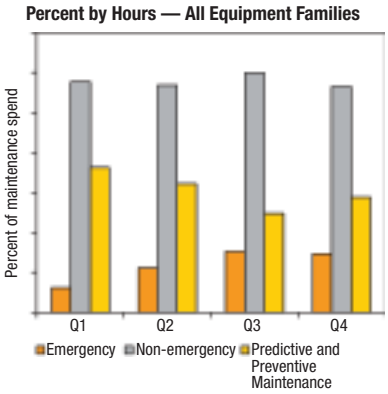


FIGURE 5. This graph of percent of maintenance spend by work order type shows that, while non-emergency work percentage is relatively flat throughout the industry, top performers (Q1) do a lower percentage of emergency work and a higher percentage of predictive and preventative work

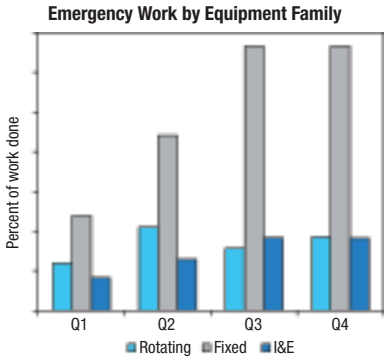


FIGURE 6. This graph of percent of emergency work by equipment family for all quartiles shows that top performers (Q1) have a lower percentage of work in all equipment categories than other performers

are present in the industry when it comes to production downtime; now let us look at the trends regarding maintenance costs of top performers.

Maintenance costs

It is easy to see how planned work and many fewer hours of total work allow top performers to reach optimum cost performance. It is important to use the phrase "optimum cost performance," because cost is the result and not the driver. Top performers, as stated above, do not minimize the quantity of work based on cost, and they do not overspend to get some incremental perceived improvement in mechanical availability. They spend the exact amount necessary to achieve the desired level of mechanical availability. Since their culture drives planning, scheduling and permanently solving problems rather than just repairing them, they drive their cost to a low level.

It is true that cost and mechanical reliability are related, but if cost is used as the driver, the long-term reliability of the assets will suffer and maintenance costs will go up (Figure 7).

Top performers are not the organizations with the lowest maintenance spending; the lowest-spending organizations are RAM EI performers that may have reached Q2 but are typically found in Q3 or Q4 because their cost-focus-only mentality has negatively impacted their mechanical availability.

Figure 8 shows that the area with the greatest difference in spending for top performers compared to other performers is routine maintenance. This is of course expected, as indicated in the discussion above. Top performers work many fewer hours than other performers, and as a result, also spend much less on materials. Since their routine maintenance work is typically planned and not emergency work, one would expect

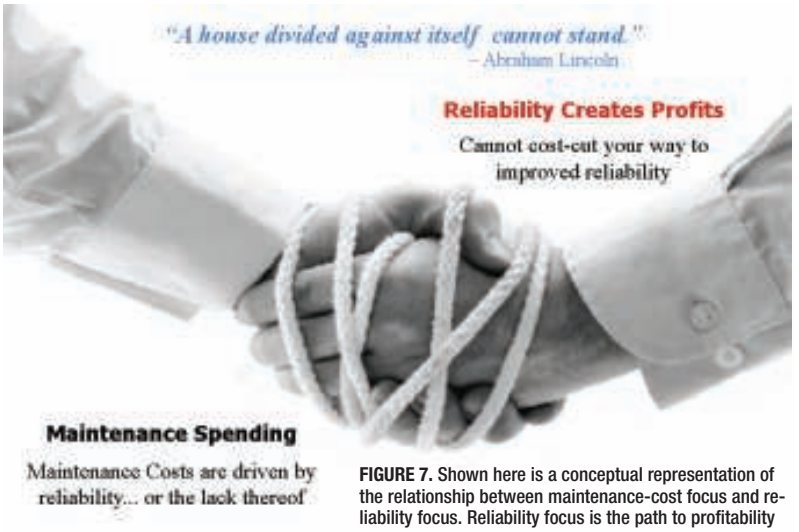


FIGURE 7. Shown here is a conceptual representation of the relationship between maintenance-cost focus and reliability focus. Reliability focus is the path to profitability

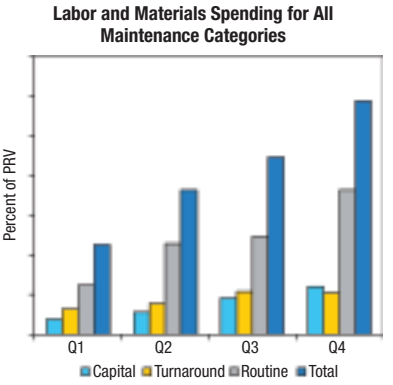


FIGURE 8. This graph of labor and materials spend for all maintenance-spending categories shows that top performers (Q1) spend the least amount in all categories

their spending in this area to be lower and, as discussed further below, it is.

We also can surmise from what we said about mechanical availability that top performers have less fixed equipment cost than other performers and that they spend less money on reactive work.

The RAM Study annualizes turnaround costs, and while on an annualized basis, those costs are the second most significant cost, they are still lowest for top performers. Even though this is the case, top performers do not predetermine the amount they will spend on each turnaround prior to understanding what needs to be done. The low annualized turnaround cost is due to the sustainability of the top-performing culture. Top-performing organizations are not afraid to spend significantly more on a specific turnaround than the average — if it is needed to minimize unplanned events before the next scheduled downtime. They also do not overspend in the areas of inspection and testing, because their ongoing data collection and proactive inspection techniques keep them informed both before and after turnarounds. Top performers are also constantly updating the schedule and plan during the turnaround to create the most efficient work flow and work plan while taking into account the resources available.

Many who are reading this article are probably wondering why this section on costs is so short. Well, it was delivered that way deliberately to drive home the point that cost for top performers is truly a result of their cultural approach to their work. Their focus on reliability drives mechanical availability, which determines how much they spend.

Reduced human & business risk

Data from the RAM Study also point to two significant areas of importance for any organization: Human risk and business risk.

Limiting human risk. The interesting thing about human risk — how safe your employees are — is that it actually could be called human reliability. If the employees of an organization are safe, then they are demonstrating human reliability because they are practicing the appropriate behaviors to keep themselves safe on a continuous basis. If you think about employee safety in relation to the top performers' definition of reliability, you will realize that reliability, like safety, is generated by an organization's people. If employees constantly and consistently meet their commitments, they're reliable, and if one of those commitments is to comply with all of the safety rules, then those employees will not be injured — they will be safe. So employee safety truly is an aspect of human reliability.

Total maintenance work hours limits risk, and planned work is much safer than reactive work; these two facts alone tell us why anyone doing maintenance work for a top-performing organization is much more likely to do that work safely or at least under circumstances that lead to safe work.

Let's take a look at the data revealed earlier in this article to see why top performers are generally also the safest, most reliable and even the most environmentally reliable performers.

RAM EI Q4 performers can be characterized as follows:

- They work twice as many hours as top performers
- They work at least double the percentage of unplanned work
- They have a percentage of emergency work 2.5 times higher than that of top performers

Considering all of these high-risk activities together, one can see how Q4 performers potentially have much higher human risk. Q2 and Q3 performers also work more hours, perform less planned work, and have a higher percentage of emergency work than top performers — so they too see higher human risk. Safe work and planned work correlate to injury-free work and lower human risk.

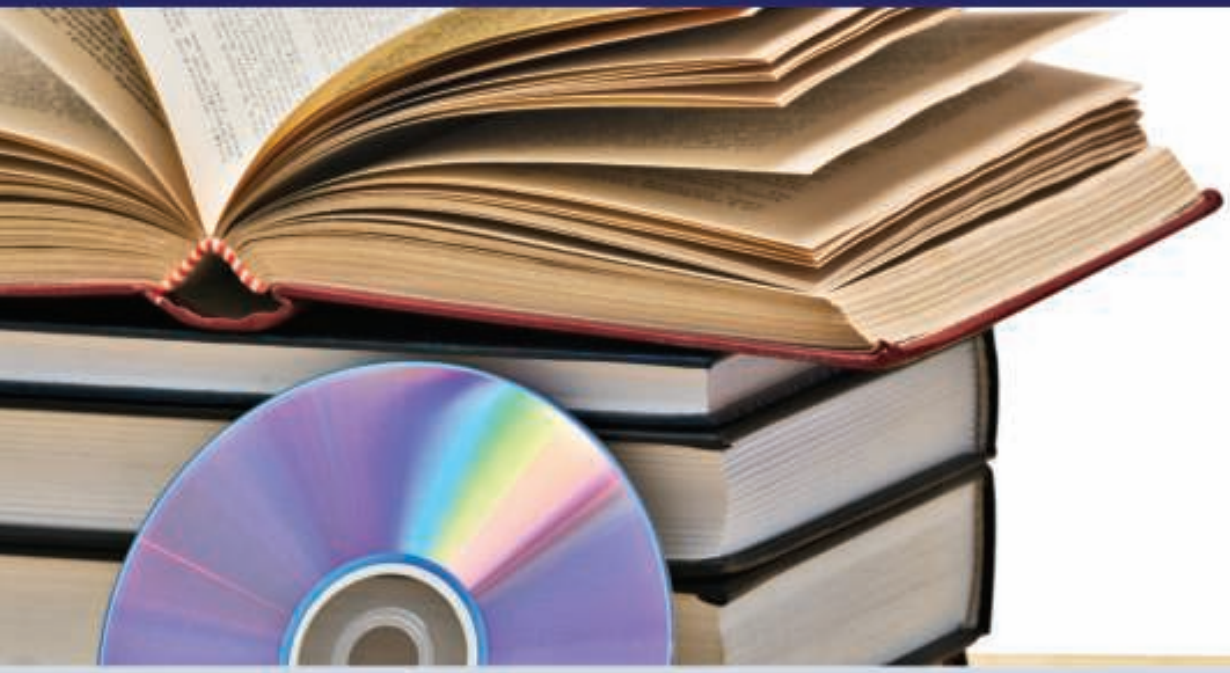
Limiting business risk. What creates business risk in a manufacturing organization? The following are signs of business risk from a purely financial viewpoint:

- Loss of sales
- Financial retribution for poor service
- The customer moving to another supplier

Signs of business risk from a purely business standpoint are:

- Poor quality
- Environmental issues
- Regulatory issues

The *Chemical Engineering* store offers a variety of industry topics you will come to rely on.



Environmental Management: Air-Pollution Control

Includes articles on technologies for managing gaseous emissions, NOx, SOx, particulate matter, and other airborne industrial pollutants, design tips for thermal and catalytic oxidation systems, emissions monitoring, relevant data and calculation methods, and more (300 pages)

Environmental Management: Wastewater and Groundwater Treatment

Includes articles on chemical, biological and physical treatment systems, and emissions-monitoring techniques, for industrial wastewater and groundwater; technologies include membrane systems, reverse osmosis, filtration, carbon-based adsorption, evaporation, aerobic and anaerobic digestion, and more (360 pages)

Fluid Handling

Includes articles on specifying, operating and maintaining pumps, valves, and flowmeters, coping with troublesome fluids and flow problems, pipeline issues, modeling, and more (350 pages)

Gas-Solid and Liquid-Solid Separation

Includes articles on particle separation using filters, cyclones, hydrocyclones, centrifuges, baghouses and electrostatic precipitators, drying systems and more (220 pages)

Liquid-Liquid and Gas-Liquid Separation

Includes articles on distillation, adsorption, absorption, stripping, liquid-liquid extraction, membrane separation, ion exchange, crystallization, evaporation, and more. (250 pages)

Managing Bulk Solids

Includes articles on storage, weighing and feeding of bulk solids, particle characterization, separation and classification, pneumatic conveying, drying, managing dust emissions and electrostatic hazards, and more (285 pages)

Each one of these issues can negatively impact a business and put it at risk. All of these can have one common cause: assets not running as designed, or not running reliably. Under these circumstances, a customer may not get their product on time, and when that happens, the customer's decision about what to do next is often not in your hands. When lack of reliability leads to equipment malfunctions and poor quality, environmental and regulatory issues are likely to arise. Think about when manufacturing facilities make the news — more often than not it is when some part of the process is in a risky condition.

Another interesting factor, one that is related to equipment reliability and is often overlooked from a financial performance standpoint, is how much inventory needs to be carried by an organization. Let's put this in the simplest of terms. The more reliable a manufacturing organization is, the lower the inventory of all products it has to carry and therefore the less capital burden it has to carry. If you are examining the entire supply chain from sales to manufacturing and the manufacturing assets are completely reliable, then, assuming good communication between sales, supply chain and manufacturing, you can carry the optimal inventory and always meet the customer's needs. This leads to customer loyalty and maximum profitability, two of the three outcomes of reliability.

Assets that function reliably and are led by a culture of proactive employees are one key to reducing unnecessary business risk and ensuring delivery of desired performance to all stakeholders.

Top performers focus on culture, mechanical availability, and the cost to achieve that mechanical availability. They also know that their mechanical availability is an outcome of their culture and their cost is an outcome of their mechanical availability. They never confuse the order or priority of these three. As a result, they provide all their stakeholders with exactly what they are looking for: customer loyalty, employee engagement and maximized profitability. ■

Edited by Gerald Ondrey

Reference

1. The Solomon International Reliability and Maintenance Benchmarking Study is a granular analysis of the overall reliability of an organization and the maintenance dollars that are spent to achieve that level of reliability. Details about the study can be found at www.solomononline.com.

Author

Jeff Dudley is a senior consultant for Solomon Associates (One Lincoln Center, 5400 LBJ Freeway, Suite 1400, Dallas, TX 75240; Phone: +1-989-430-1521; Fax: +1-972-726-9999; Email: Jeff.dudley@solomononline.com), where he is project director for The Solomon Reliability and Maintenance Benchmarking Study. He also leads Solomon's LeadeReliability Workshop. Dudley is an experienced chemical manufacturing and operations leader and recognized practitioner of developing reliability-based cultures. He has 36 years of experience in the chemical industry. Prior to joining Solomon in 2014, Dudley was corporate director of Maintenance and Reliability for The Dow Chemical Company. He also held numerous global business operations roles. He is the author of LeadeReliability, and is an internationally recognized thought leader in reliability and leadership. He has published numerous articles on both topics and has delivered many conference addresses on the subjects. Dudley has a B.S.Ch.E. degree from Carnegie Mellon University, and is a member of the SMRP Best Practices Committee and AFPM.

Show Preview

More than 3,000 exhibitors are projected to participate in IFAT 2016 — the International Trade Fair for Water, Sewage, Waste and Raw Materials Management (May 30–June 3; Munich, Germany). Celebrating its 50th year, IFAT has grown tremendously in all sections — including in the recently added sections on water supply, recycling and technology for municipal services.

IFAT occupies all 16 halls — a total of 230,000 m^2 of exhibition space —and parts of the outdoor exhibition area of the Messe München exhibition center. More than 135,000 visitors from all over the world are expected to attend.

A small selection of products and services that will be exhibited at IFAT 2016 is presented below.

Submersible motor pumps for a broad range of applications

This company is showcasing the youngest generation of its Amarex KRT submersible motor pumps (photo) for the first time in Germany. This pump type is used for handling all kinds of municipal and industrial wastewater. Its maximum flowrate is 10,080 m^3/h and its highest head is 20 m. With 850 kW, it offers the highest motor power available on the market as standard. To support as broad a range of applications as possible, the new submersible motor pumps are available with four different improved impeller types. Depending on the system's load profile, operators can choose a highly efficient motor variant, which corresponds to the IE3 efficiency level for standardized motors, in accordance with the IEC-60034-30 standard. Two bi-directional mechanical seals reliably protect the motor space against ingress of water. Hall A6, Stand 327/426 — *KSB AG, Frankenthal, Germany*
www.ksb.com

This online analysis system cleans itself

The Type 8905 Online Analysis System (photo) supports waterworks in monitoring of the most important water parameters and compliance with all directives. Now, the analysis device can also be cleaned automatically. The Type MZ20 cleaning module can be connected as an add-on module upstream of the measurement system for dosing of cleaning solutions. The module normally executes the cleaning process on a time-controlled basis, but can also be programmed individually to clean when certain measurement constellations of the connected sensor cubes exist. Based on the changes in the measured values, the system tests whether the cleaning was successful and repeats the process, if necessary. The cleaning system automatically carries out all relevant functions, such as water sample shut-off, solution dosing and condition signaling via the CANopen-based Bürkert system bus. Hall A5, Stand 433/532 — *Bürkert Fluid Control Systems, Ingelfingen, Germany*
www.burkert.com

Filtration systems featuring automatic backwashing

This company develops and manufactures high-quality automatic filtration devices for solid-liquid separation. Coming from the technology of filtering high-viscosity spinning solutions in the synthetic fiber industry, the product portfolio has been continuously extended over the last 40 years. It ranges from automatic backwash filters for low- to high-viscosity media and cake-building pressure filters to disposable filtration systems. One of the main benefits of the company's filtration systems is the unique, patented regeneration system, ensuring efficient filtration, even with the finest filter materials (down to 1 µm). One example is the OptiFil (photo) for fine and microfiltration, which handles throughputs up to 700 m^3/h. Hall A3, Stand 549 — *Lenzing Technik GmbH, Lenzing, Austria*
www.lenzing-technik.com

Increase settling performance with these lamella separators

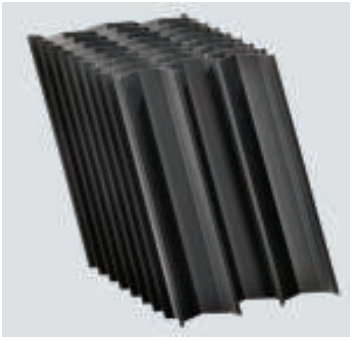
The use of 2H TUBEdek parallel-plate separators (photo, p. I-2) enables considerable increases in the performance of rainwater overflow basins, says the manufacturer. The separators provide multiple settling planes, in an inclined configuration. As a result,

KSB

Bürkert Fluid Control Systems

Lenzing Technik

Enexio Water Technologies

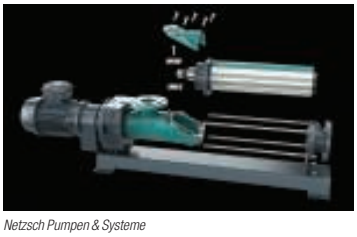


the previous performance can be more than doubled — when incoming and outgoing flows are correctly designed. This solution offers an increase in the capacity of existing overflow plants, simpler integration of smaller-sized new basins in existing structures, and more effective use of available land area. The relatively small requirement for space is especially beneficial in densely populated areas. The application of TUBEdek separators in rainwater settling tanks with throughput of up to 2 m^3/s has proven effective in past years; users profit from greater throughputs with the same or improved treatment performance, says the company. Hall A1, Stand 527 — *Enexio Water Technologies GmbH, Herne, Germany*
www.enexio.com

Vega Grieshaber

The first radar level sensor for liquids with 80 GHz technology

Measuring the level of liquids with 80 GHz allows considerably better focusing of the radar beam, even under difficult conditions, such as tanks fitted with heating coils, baffles or agitators. Levels can now be measured in applications where the process or structural conditions were previously not suitable for radar. The new level radar sensor Vegapuls 64 (photo) has a beam angle of only 3 deg. Until now, a radar sensor with a transmission frequency of 26 GHz and an 80 mm-diameter antenna had a beam angle of approximately 10 deg. The antenna — said to be the smallest of its kind — is encapsulated in PTFE or PEEK, so there are no cavities or crevices in which product can accumulate. In addition, special software algorithms filter out interference caused by buildup on the antenna system. With the high dynamic range of the sensor, signal attenuation caused by deposits is largely compensated. This allows the level to be reliably detected, even with contamination on the sensor. Hall 5, Stand 239/338 — *Vega Grieshaber KG, Schiltach, Germany*
www.vega.com/radar



Netzsch Pumpen & Systeme

This rotary lobe pump is maintenance-friendly

In addition to its Tornado rotary-lobe pumps and shredders, this company is introducing its new NEMO progressing cavity pumps with the maintenance-friendly FSIP (full service in place) design (photo). The FSIP pump is designed in a way that the housing itself functions as support and orientation guideline. The special design enables that each part automatically fits into its place. Positioning is done automatically without further adjustments. Therefore, the change of all wear parts takes less than half of the time normally required. NEMO pumps with FSIP design can be used in industrial applications where a great variety of different substances must be pumped or precisely dosed. The FSIP concept is especially interesting where pumps are installed in wear-intensive applications requiring more service and maintenance work. Hall A6, Stand 151/250 — *Netzsch Pumpen & Systeme GmbH, Waldkraiburg, Germany*
www.netzsch.com

CUT Membrane Technology

These membrane modules handle the challenges of landfill leachate

The new T-CUT tubular modules (photo) with membranes made from PVDF and PES expands this company's family of products by another robust tubular module. The special stability of the membranes together with the possibility of chemical cleaning means that T-CUT tubular modules can be used in challenging applications, such as those found in the metal-processing industry and for treating landfill leachate. For example, two landfill-leachate water-treatment plants in Portugal have been running successfully since the beginning of 2015. Each of the installed T-CUT tubular modules handles approximately 12 m^3/h of raw water, and generates around 3 m^3/h of dischargeable permeate. The peak flux is 120 $L/(m^2 \cdot h)$ with a particle content of approximately 3.0 g/L. Hall A2, Stand 519 — *CUT Membrane Technology GmbH, a subsidiary of the Bürkert Group, Erkrath, Germany*
www.burkert.com

High-performance screw technology for blower air

This company is showcasing its high-efficiency screw blowers, with power ratings from 15 kW for low rates from 8 to 22 m^3/min. Like its larger counterparts, the EBS and FBS, the new DBS screw blowers (photo, I-3) are

Kaeser Kompressoren

significantly more efficient than conventional rotary blowers and also provide substantial energy savings compared with many competing rotary and turbo blowers. These screw blowers are especially well suited to municipal and industrial water-treatment applications. Two different versions are available to meet the needs of water-treatment plants requiring pressures of 400 or 650 mbar. The new blowers are exceptionally quiet, with sound levels in primary applications not exceeding 72 dB. They are designed for use over long duty cycles, including continuous operation, require little maintenance, and can be installed side by side, or even next to a wall. Hall A1, Stand 143/242 — *Kaeser Kompressoren SE, Coburg, Germany*
www.kaeser.com

A cost-effective electrochemical water-treatment system

Outotec

Combining its unique understanding of water treatment, process design, electrolysis and hydrometallurgy, this company has developed EWT-40 (photo) — a single modular electrochemical water treatment system. With EWT-40, purification of wastewater is based solely on electricity and the right combination of electrode materials, so there is no need for chemicals. The EWT-40 module can treat between 5 and 40 m^3/h of water, depending on the application. EWT-40 can be utilized to treat a wide range of wastewaters, removing various impurities, such as: arsenic, selenium, antimony and other metals; thiocyanate; thiosulfate; phenol; and organic residues. The system is cost-effective because no chemicals are required, and treatment is faster than conventional precipitation processes. Hall B3, Stand 416 — *Outotec Oy, Espoo, Finland*
www.outotec.com

A new member added to this family of MBR modules

Prior to 2014, the Bio-Cel submerged membrane bioreactor membrane (MBR) module has been available with membrane areas of 10, 50, 100 and 416 m^2. With the increasing acceptance of MBR technology, the world market not only grew, but the demand for large-scale projects (with feedrates of more than 10,000 m^3/d) increased. The meet these demands, this company introduced (at IFAT 2014) the Bio-Cel XL module, with 1,920 m^2 in membrane area. At this year's IFAT, the company is introducing the new Bio-Cel L — the successor to the Bio-Cel BC 416. That means the smart-design features of the Bio-Cel XL will now be available with 480 m^2 of membrane area per module. The membranes are enclosed in a stainless-steel housing for maximum stability, and are said to offer a 20% higher packing density than the predecessor. The BioCel membrane laminate technology, which combines the advantages of hollow-fiber and plate membranes into a hollow-sheet design, is equipped with a self-healing mechanism that allows the laminate to "heal" itself in less than 2 minutes. This results in constantly high effluent qualities even in case of damage caused to the membrane. Hall A2, Stand 227 — *Microdyn-Nadir GmbH, Wiesbaden, Germany*
www.microdyn-nadir.com

AGRU Kunstofftechnik

VAG-Armaturen

Alfa Laval

Double-containment pipe system ensures safe processing

The complex production processes in the field of chemical engineering require flexible, reliable and safe piping systems. The Poly-Flo double piping system (photo) offers security and full pressure resistance. Fast and simple welding possibilities enable uncomplicated installation. For leak detection in the double-containment piping system, different leak detection methods can be installed in the space between inner and out pipe. This innovative system provides optimal space management, as well as a cost-efficient solution. The company also offers a wide range of pipes, fittings, valves and special components for the transport of aggressive media, in a number of different materials, including PE, PP, PVDF and ECTFE. Hall B6, Stand 217 — *AGRU Kunstofftechnik GmbH, Bad Hall, Austria*
www.agru.at

A new product structure for this butterfly valve series

At IFAT, this company is introducing a new product structure for its EKN butterfly valve series. The valve series is now subdivided into an H, M and B series. The H Series (photo) stands for high performance, and this subdivision is also one of the innovations being presented at IFAT. This series features a new design with a patented hydrodynamic disc, an expanded inner diameter and patented pressure-equalization channels. These features combine to minimize pressure drop and reduce turbulence near the outlet, which results in energy savings. Other features, such as even more efficient corrosion protection, extend the life of the valves, making them suitable for applications in water treatment, water distribution, power stations and dams. The M-series of EKN butterfly valves offer added corrosion protection, a wear-resistant housing seat, an automatic and flow-independent sealing system, a distinctive sealing profile, as well as a double eccentric bearing. Finally, the newly created B (base) version is specifically used only for water treatment and water distribution. Hall A4, Stand 151/250 — *VAG-Armaturen GmbH, Mannheim, Germany*
www.vag-group.com

A complete spectrum of solutions for waste and water treatment

This company is presenting its complete spectrum of innovative and sustainable solutions for the treatment of water and waste, including screw and plate presses, decanters, evaporators and crystallizers, and more. For example, the all-in-one membrane bioreactor module and its AS-H Iso-Disc Cloth Media Tertiary Filter will be exhibited. Both modules are compact, gravity-driven and operator friendly, delivering superior effluent quality immediately suitable for reuse, for example, for irrigation, cooling towers and lakes. Also featured are membranes for ultrafiltration and reverse osmosis for final polishing that enable reuse for potable water. Also on hand are zero-liquid-discharge systems — evaporators and crystallizers based on the company's recently launched WideGap 100 (photo), as well as the AlfaVap heat exchangers, are ideal for effluent concentration, waste reduction and product recovery plus water reuse in many industries. Examples include effluents containing anaerobic and salty chemicals, oilfield produced water, reverse osmosis reject, and power plant applications. Hall A1, Stand 251 and Hall 01A, Stand 11 — *Alfa Laval AB, Lund, Sweden*
www.alfalaval.com

Less energy is required by these blowers

The ZS screw blowers are available in the power range from 18.5 to 315 kW, with and without speed control. The variable-speed machines match their flow directly to the actual air-demand of the clarifier, depending on current biological requirements. This reduces energy consumption considerably; the energy requirement for the ZS blower is about one third that of conventional positive-displacement blowers, says the company. At IFAT, the company is showing the ZS 75, which produces certified oil-free air to Class 0, according to ISO 8573-1 with flowrates from 800 to 11,000 m^3/h. Hall A3, Stand 343 — *Atlas Copco Kompressoren und Drucklufttechnik GmbH, Essen, Germany*
www.atlascopco.de ■

Gerald Ondrey

Integrated Risk-Management Matrices

An overview of the tools available to reliability professionals for making their organization the best-in-class

IN BRIEF

RELIABILITY, HISTORICALLY
RELIABILITY, TODAY
RISK-MITIGATION APPROACHES
HOW DO WE MEASURE RISK?
KPIS AND RISK

Nathanael Ince
PinnacleART

Since the 1960s, process facility operators have made concerted efforts to improve the overall reliability and availability of their plants. From reliability theory to practical advancements in non-destructive examination and condition-monitoring techniques, the industry has significantly evolved and left key operations personnel with more tools at their disposal than ever before. However, this deeper arsenal of tools, coupled with more stringent regulatory scrutiny and internal business pressure, introduces a heightened expectation of performance. Now, more than ever, companies recognize that best-in-class reliability programs not only save lives but increase the bottom line. These programs are also one of the foremost "levers" for C-level personnel to pull when trying to contend in a competitive environment.

With this in mind, a best-in-class reliability organization combines state-of-the-art theory, software and condition-monitoring techniques with a strong collaboration of departments and associated personnel. An independent risk-based inspection (RBI) program or reliability-centered maintenance (RCM) program no longer suffices as cutting-edge. Rather, the inspection department (power users of RBI) and maintenance department (power users of RCM) are integrating with process, operations, capital projects and other teams to form an overall reliability work process for the success of the plant.

To highlight reliability's growing prominence within process facilities, this article addresses the following:

- A brief history of reliability practices in the 20th and 21st centuries
- Examples of current reliability program tools
- A characterization of three different

TABLE 1. EXAMPLE MECHANICAL-INTEGRITY AND MAINTENANCE-PROGRAM IMPROVEMENTS

Mechanical integrity improvements	Maintenance/reliability improvements
Assessments and audits	Assessments and audits
Damage/corrosion modeling	Preventive and predictive maintenance
Risk-based inspection	Equipment hierarchies and data cleanup
Inspection data management and trending	Operator-driven reliability (rounds)
Piping circuitization	Mobile platforms
Integrity operating windows	Reliability operating windows
Corrosion monitoring locations (CML) and thickness management locations (TML) optimization	Maintenance data/order management (computerized maintenance-management system; CMMS)
Asset retirement calculation	Spare parts optimization
Corrosion under insulation (CUI) program	Reliability-centered maintenance
Utilizing advanced non-destructive evaluation	Reliability-centered design
Continuous condition monitoring	Repair procedures

risk-mitigation applications that are currently applied in process facilities
- The case for ensuring these risk mitigation frameworks are working together
- The value of key performance indicators (KPIs) in providing transparency and accountability to the effectiveness of these risk mitigation frameworks

Reliability, historically

When one thinks about process reliability, a variety of definitions come to mind. However, it has come a long way since the early 20th century. From the 1920s to the 1950s, reliability went from being classified as "repeatability" (how many times could the same results repeat) to dependability (hours of flight time for an engine), to a specific, repeatable result expected for a duration of time.

Through the 1950's age of industrialization, reliability's evolving definition was still very much focused on design and not as much on operations or maintenance. Then in the 1960s, the airline industry introduced the concept of reliability centered maintenance (RCM), pushing the idea that the overall reliability of a system included not only the design, but also the operations and maintenance of that system. In other words, reliability engineering was now stretching into other departments, mandating that the overall risk of failure was tied to multiple aspects of the asset's lifecycle. As a result, several different departments and individuals cooperated to ensure they attained reliability.

The concept of RCM pushed through some industries quicker than others. While it started with the airlines, it flowed quickly into power generation, petrochemical and petroleum-refining operations thereafter.

Fast-forward to 1992, and another facet, called process-safety management (PSM), was introduced into the reliability picture. In response to a growing perception of risk related to hazardous processes, the Occupational Safety and Health Administration (OSHA) issued the Process Safety Standard, OSHA 1910.119, which includes the following 14 required elements:
- Process-safety information
- Process hazard analysis
- Operating procedures
- Training
- Contractors
- Mechanical integrity
- Hot work
- Management of change
- Incident investigation
- Compliance audits
- Trade secrets
- Employee participation
- Pre-startup safety review
- Emergency planning & response

The intent of the regulation was to limit the overall risk related to dangerous processes, and "raise the bar" for compliance expectation for facilities with these "covered" processes. At that point, it became law to fulfill these 14 elements, and to ignore them, or to show negligence to these steps in the event of a release, implied the possibility of criminal activity. In other words, if those responsible in the event of a release were found to be negligent in these items, they could go to jail. The other business implication of this standard was that it meant that other individuals, and departments, now had a part to play in reliability and overall process safety.

While reliability was confined to designing equipment that could last a certain time and coupling it with a non-certified inspector to make general observations in the 1950s, by the mid-1990s, reliability had become a much more complex, integrated and accelerated science.

Reliability today

With the greater expectation on today's programs, department managers (including reliability, mechanical-integrity or maintenance managers) face a powerful, but often intimidating array of tools available to them for improving their reliability programs. Examples are listed in Table 1.

While this only represents a subset of the options available to the manager, all of these activities aim at doing the following:
1. Reducing the risk of unplanned downtime.
2. Limiting safety and environmental risk.
3. Ensuring compliance with regulatory standards.
4. Doing steps one through three for the least cost possible.

To summarize, the goal of these managers is to put a plan in place and execute a plan that identifies and mitigates risks as efficiently as possible. To do that, one has to systematically identify those risks in addition to the level to which those risks must be mitigated. If this is done correctly, the design, inspections, preventative maintenance, operational strategies, and other program facets should all be aligned in attaining steps one through four.

Risk-mitigation approaches

Since the 1960s, there have been substantial efforts on figuring out how to best characterize both downtime and loss-of-containment

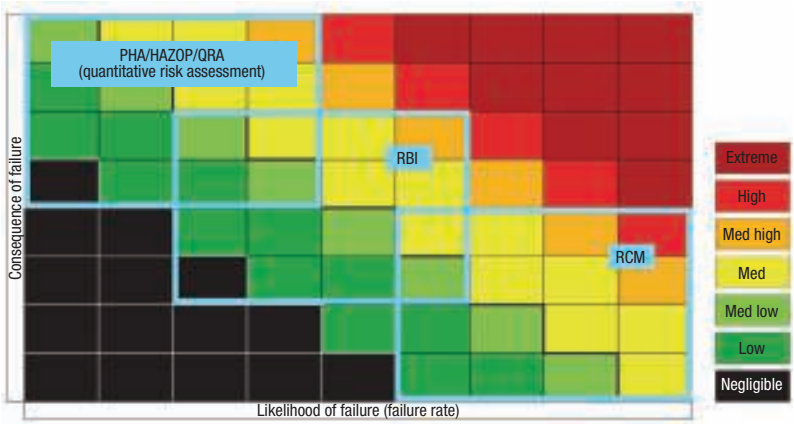


FIGURE 1. This graphical "consequence-of-failure" risk matrix shows the areas covered by process hazard analysis (PHA), risk-based inspection (RBI) and reliability centered maintenance (RCM)

risk in a facility so that appropriate and targeted mitigation actions can be taken at the right time. That being said, there are three common risk identification and mitigation frameworks that are currently being used in process facilities today. These include process hazard analysis (PHA), risk-based inspection (RBI), and reliability-centered maintenance (RCM). Let's briefly characterize each.

PHA. The PHA came out of OSHA's PSM standard and is one of the 14 elements listed above. Every five years, subject matter experts come together for a couple of weeks and identify the major events that could happen at different "nodes" in a unit. The general idea is to use guidewords to systematically focus the team on the identification of process deviations that can lead to undesirable consequences, the risk ranking of those deviations, and the assignment of actions to either lower the probability of those failures or the consequence if the failures do occur. While a PHA would not identify maintenance strategies or detailed corrosion mitigation or identification strategies, it focuses on safety and not unit reliability. In the end, the major deliverable is a set of actions that have to be closed out to ensure compliance with the PSM standard. Typically, this process is owned and facilitated by the PSM manager or department.

RBI. RBI arose from an industry study in the 1990s that produced API (American Petroleum Institute) 580 and 581, which describe a systematic risk identification and mitigation framework that focuses only on loss of containment. For this reason, when an equipment item or piping segment (typically called "piping circuit") is evaluated, the only failure that is of concern to the facility is the

breach of the pressure boundary.

As an example, the only failure mode evaluated on a pump would typically be a leak in the casing or the seal. The consequence of those losses can be business, safety or environmental, and while a variety of software packages and spreadsheets can be used to accomplish the exercise, the deliverable is an RBI plan targeting the mitigation of loss-of-containment events.

In addition, a best-in-class RBI program will not just be a systematic re-evaluation of that plan every five or ten years, but an ongoing management strategy that updates the framework whenever, the risk factors change. Therefore, if an equipment's material of construction was changed, insulation was added to an asset, or a piece of equipment was moved to a different location, a re-evaluation of the asset loss-of-containment risk and an associated update of the RBI plan would be appropriate. Typically, this process is owned and facilitated by the inspection or mechanical integrity manager or department.

RCM. As mentioned earlier, RCM was spawned out of the aviation industry, but the focus was to identify a proactive maintenance strategy that would ensure reliability and that performance goals were met. While this has been loosely codified in SAE (Society of Automobile Engineers) JA1011, there are a variety of methods and approaches and therefore RCM isn't as controlled as RBI.

However, much like RBI, the RCM study itself aims at identifying the different failure modes of an asset, the effects of those failure modes, and the probabilities of those failure modes occurring at any given time. Once the potential failure causes are identified, strategies are recommended that mitigate the failure mode to acceptable levels. Unlike RBI, RCM accounts for all failure modes relating to loss of function, including loss of containment (although it typically outsources this exercise to the RBI study), and the end deliverable is a set of predictive maintenance, preventative maintenance, and operator activities that lower loss-of-function risks to acceptable levels. Typically, this process is owned and facilitated by the maintenance or reliability manager or department.

How do we measure risk?

While it's not uncommon for a single facility to run PHA, RBI and RCM at once, it begs the question, which one is right? To find the answer, let's briefly discuss risk matrices. A risk matrix is a tool that allows one to associate individual assets, failure modes or situations with specific levels of risk. There is both a probability of an asset failing and a consequence of an asset failing, and each is represented by one axis on the matrix. The multiplication of both probability of failure and consequence of failure (represented by the actual location of the asset on the matrix) equals risk. What's interesting is that many facilities that are utilizing multiple-risk frameworks in their facility are utilizing multiple-risk matrices. This again begs the question, which one is right?

Figure 1 is a risk matrix that is much larger than the typical 4×4 or 5×5 risk matrix, but it shows each of the previously discussed risk frameworks on one larger matrix. The probability of failure is on the horizontal axis, and the consequence of failure is shown on the vertical axis.

As shown, the frameworks reveal the following characterization for each of the three covered risk mitigation frameworks:

- *PHA* — High consequence of failure events but lower probability that they will happen (an example would be an overpressure on a column with insufficient relief-systems capacity)
- *RBI* — Medium consequence of failure events (loss of containment) and a medium probability that they will happen (an example would be a two-inch diameter leak of a flammable fluid from a drum)
- *RCM* — Low consequence of failure events (loss of function) but a higher probability that they will happen (an example would be a rotor failure on a pump)

While each of these frameworks generally operate in different areas on the matrix, they are still standardized to a consistent amount of risk. The need to include all three risk-management tools into one standard matrix is twofold:

1. Making sure the data, calculations and actions coming from one study are properly informing the other studies.
2. Insuring that the actions being produced by each framework are being prioritized appropriately, as determined by their risk.

Making sure each of the three frameworks is communicating with one another is a common omission in facilities and programs. Many times, facilities spend millions of dollars building out and managing these frameworks, but there is often overlap between them and data gathered for one framework could be utilized for another framework. As an example, an inspection department representative should be present to ensure the RBI study is aiding the PHA effort.

In addition, prioritizing risk between each framework is another challenge. A plant manager is not wholly concerned about each individual risk framework but rather a prioritized list of actions with those action's projected return-on-investment (whether it is reduction of risk, a reduction of cost, or a reduction of compliance

fines). The objective of the integrated and organization-wide risk mitigation system should be that all possible failures must be identified, assessed, properly mitigated (whether through design, maintenance, inspection, or operations) and monitored in order of priority with an expected amount of return. If a consistent risk matrix is used effectively, this can inform single asset or system decisions and continue to ensure reliability value is being driven consistently across the facility.

KPIs and risk

A good set of key performance indicators (KPIs) is needed as well to help identify root causes and guide programmatic decisions. Once systematic risk management, production loss, and enterprise-resource-planning (ERP) systems are properly setup, roll-up KPIs can be reported regularly that reveal the overall trending of the reliability program and drive specific initiatives with targeted results (risk reduction, cost reduction or compliance satisfaction).

For example, at any point in time, the plant (or group of plants) could see the total risk of loss-of-containment or loss-of-function events across their units and assets, the total risk of loss of function events across its units and assets, the total planned and unplanned downtime across the plant with associated causes, and the total cost associated with running those programs broken out by activity, area and other helpful specifics. When one or many of those rollout KPIs reveal concerns, sub KPIs should be accessible to explore the root cause of those risks, downtime or costs. It's from this KPI drill-down, empowered by synthesized risk frameworks, that targeted initiatives and actions can be driven.

Summary

Reliability programs have come a long way in 100 years, and reliability professionals have more tools than ever at their disposal to increase overall plant availability and process safety. To drive systematic improvements in plant reliability with all these different tools, it is essential for facilities to get the data-management strategy right, to synthesize one's approach to measuring, reporting and mitigating risk, and to roll it up in a KPI framework that combines risk, cost and compliance reports. ■

Edited by Gerald Ondrey

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Monitoring Flame Hazards In Chemical Plants

The numerous flame sources in CPI facilities necessitate the installation of advanced flame-detection technologies

Ardem Antabian
MSA — The Safety Company

Fire is a primary and very real threat to people, equipment and facilities in the chemical process industries (CPI), especially in the refining and storage of petrochemicals. The consequences of failing to detect flames, combustible gas leaks or flammable chemical spills can have dire consequences, including loss of life and catastrophic plant damage.

The monitoring of flame hazards is mandated by the U.S. Occupational Safety and Health Administration (OSHA; Washington, D.C.; www.osha.gov) through its comprehensive Process Safety Management (PSM) federal regulation. Internationally, the European Union (E.U.) splits gas and flame safety responsibilities between E.U. directives and European standards organizations, including the European Committee for Electrotechnical Standardization (Cenelec; Brussels, Belgium; www.cenelec.eu), the International Electrotechnical Commission (IEC; Geneva, Switzerland; www.iec.ch) and several other bodies.

Many accidents are the result of either failing to implement these standards properly with suitable flame-detection equipment or the failure to train employees to follow related safety procedures consistently. In either case, it is important to understand the many different sources of flame hazards, the detection sensor technologies that can warn of imminent danger and the proper location of flame detectors in today's complex chemical plants.

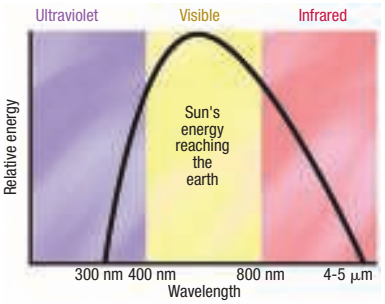

FIGURE 1. Flame detectors can detect light emissions at specific wavelengths across the UV, visible and IR spectrum to distinguish between actual flames and false alarm sources

FIGURE 2. Flame detectors, such as those shown here, implement ultraviolet and infrared detection technologies

In the petrochemical plant environment, the range of potential flammable hazards is expansive and growing as materials and processes become more complex. These hazards have led to the development of more sophisticated combustible-gas and flame-sensing technologies with embedded intelligence that can better detect the most common industrial fire sources, some of which are listed in Table 1.

Principles of flame detection

Industrial process flame detectors detect flames by optical methods, including ultraviolet (UV) and infrared (IR) spectroscopy and visual flame imaging. The source of flames in CPI plants is typically fueled by hydrocarbons, which when supplied with oxygen and an ignition source, produce heat, carbon dioxide and other products of combustion. Intense flames emit visible, UV, and IR radiation (Figure 1). Flame detectors are designed to detect the emission of light at specific wavelengths, allowing them to discriminate between flames and false alarm sources.

Flame-sensing technologies

The flame safety industry has developed four primary optical flame-sensing technologies: UV, UV/IR, multi-spectrum infrared (MSIR), and visual flame imaging (Figure 2). These sensing technologies are all based on line-of-sight detection of radiation emitted by flames in the

TABLE 1. COMMON INDUSTRIAL FIRE SOURCES	
Alcohols	Liquefied natural gas (LNG)
Diesel fuels	Liquefied petroleum gas (LPG)
Gasoline	Paper
Kerosene	Textiles
Jet fuels	Solvents
Ethylene	Sulfur
Hydrogen	Wood

UV, visible and IR spectral bands. Process, safety and plant engineers must choose from among these technologies to find the device that is best suited to their individual plant's requirements for flame monitoring by deciding upon the importance of the detection range, field of view, response time and immunity against certain false alarm sources.

Ultraviolet/infrared (UV/IR). By integrating a UV optical sensor with an IR sensor, a dual-band flame detector is created that is sensitive to the UV and IR radiation emitted by a flame. The resulting UV/IR flame detector offers increased immunity over a UV-only detector, operates at moderate speeds of response, and is suited for both indoor and outdoor use.

Multispectral infrared (MSIR). Advanced MSIR flame detectors combine multiple IR detector arrays with neural network intelligence (NNT). They provide pattern-recognition capabilities that are based on training to differentiate between real threats and normal events, thus reducing false alarms. MSIR technology allows area coverage up to six times greater than that of more conventional UV/IR flame detectors.

NNT is based on the concept of artificial neural networks (ANNs), which are mathematical models based on the study of biological neural networks. A group of artificial neurons in an ANN process information and actually change structure during a learning phase. This learning phase allows ANNs to model complex relationships in the data delivered by sensors in a quick search for patterns that results in pattern recognition (Figure 3).

Flame detectors with NNT operate similarly to the human brain; they have thousands of pieces of data stored in their memories from hundreds of flame and non-flame events observed in the past. These detectors have been trained through NNT intelligence to recognize flames based upon those data, and determine if they are real events or potential false alarm sources.

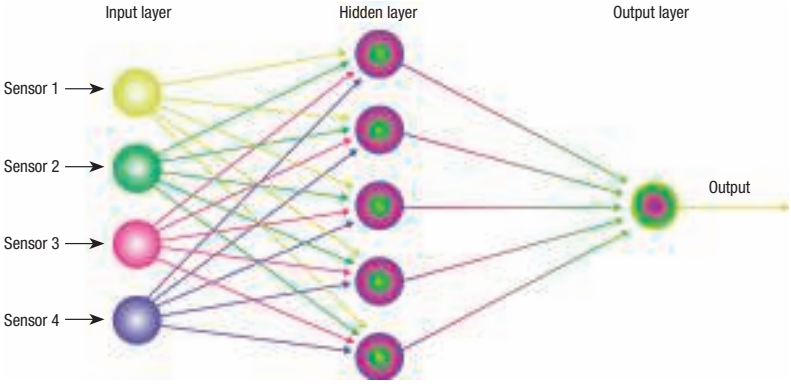

FIGURE 3. Many flame detectors employ technology based on artificial neural networks (ANNs) to more accurately analyze flames

Visual flame-imaging flame detectors. The design of visual flame detectors relies on standard charge-couple-device (CCD) image sensors, commonly used in closed-circuit television cameras, and flame-detection algorithms to establish the presence of fires. The imaging algorithms process the live video image from the CCD array and analyze the shape and progression of would-be fires to discriminate between flame and non-flame sources.

Visual flame detectors with CCD arrays do not depend on emissions from carbon dioxide, water and other products of combustion to detect fires, nor are they influenced by fire's radiant intensity. As a result, they are commonly found in installations where flame detectors are required to discriminate between process fires and fires resulting from an accidental release of combustible material.

Visual flame detectors, despite their many advantages, cannot detect flames that are invisible to the naked eye, such as hydrogen flames. Heavy smoke also impairs the detector's capacity to detect fire, since visible radiation from the fire is one of the technology's fundamental parameters.

Flame detection requirements

When configuring a flame-detection system and evaluating the available technology alternatives, there are many performance criteria that must be considered. The following sections outline some of these important detector criteria.

False alarm immunity. False alarm rejection is one of the most important considerations for the selection of flame detectors. False alarms are more than a nuisance — they are both productivity and cost issues. It is therefore essential that flame detectors discriminate between actual flames and benign radiation sources, such as sunlight, lighting fixtures, arc welding, hot objects and other non-flame sources.

Detection range and response time. A flame detector's most basic performance criteria are detection range and response time. Depending on a specific plant-application environment, each of the alternative flame-detection technologies recognizes a flame within a certain distance and a distribution of response times. Typically, the greater the distance and the shorter the time that a given flame-sensing technology requires to detect a flame, the more effective it is at supplying early warning against fires and detonations.

Field of view (FOV). Detection range and FOV define area coverage per device. Like a wide-angle lens, a flame detector with a large field of view can take in a broader scene, which may help reduce the number of flame detectors required for certain installations. Most of today's flame detector models offer fields of view of about 90 to 120 deg (Figure 4).

Self diagnostics. To meet the high-

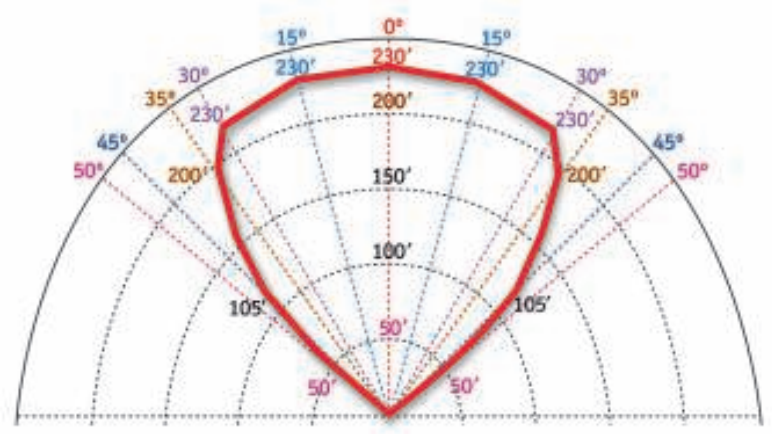

FIGURE 4. Field of view is an important factor to consider in the installation of flame-detection equipment. This diagram shows the distance a flame can be detected at various angles. For example, at 0 deg, a flame can be detected at 230 ft, and at a 50-deg angle, it can be detected at 50 ft (in this figure, the degree symbol ° is used for angle degrees, and the prime symbol ′ is used for feet)

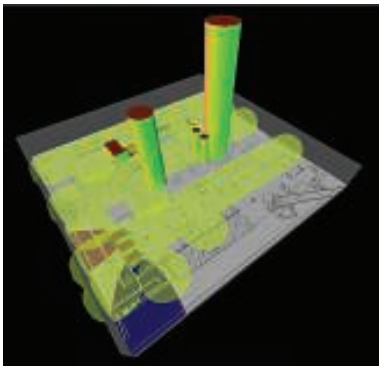

FIGURE 5. Three-dimensional mapping of a facility is useful in determining the most appropriate installation locations for flame detectors

est reliability standards, continuous optical-path monitoring (COPM) diagnostics are often built into optical flame detectors. The self-check procedure is designed to ensure that the optical path is clear, the detectors are functioning, and additionally, that the electronic circuitry is operational.

Self-check routines are programmed into the flame detector's control circuitry to activate about once every minute. If the same fault occurs twice in a row, then a fault is indicated via a 0–20-mA output or a digital communications protocol, such as HART or Modbus.

SIL/SIS standards. When plant safety engineers choose detectors certified to safety integrity levels (SIL) and properly integrate them into safety-instrumented systems (SIS), they have again added another layer of safety. Certification to these standards plays a valuable role in effective industrial gas and flame detection.

Normative standards establish minimum requirements for the design, fabrication and performance of flame detectors and other safety devices as necessary to maintain protection of personnel and property. The ANSI/ISA S84.00.01 standard was enacted to drive the classification of SIS for the process industries within the U.S., as well as the norms introduced by the IEC (IEC 61508 and IEC 61511).

Together, these standards have introduced several specifications that address safety and reliability based on optimizing processes for risk. The IEC 61508 standard is a risk-based approach for determining the SIL of safety-instrumented functions. Unlike other international standards, IEC 61508 takes a holistic approach when quantifying the safety performance of electrical control systems — the design concept, the management of the design process and the operations and maintenance of the system throughout its lifecycle are within the scope.

Location and installation

A variety of processes and sources within the plant environment can lead to flame and fire incidents, including leaking tanks, pipes, valves, pumps and so on. Accurate detection while avoiding false alarms is also important because false alarms result in unnecessary process or plant shutdowns, slowing production and requiring time-consuming reviews, paperwork and reporting.

False alarms can, over time, provide a false sense of security, because employees can become complacent if alarms go off frequently for no apparent reason and are continually ignored. The problem is that personnel alone cannot really determine the difference between a false alarm and a serious accident that is about to happen.

Fixed flame- and gas-detector systems are designed and installed to protect large and complex areas filled with process equipment from the risks of flames, explosions and toxic gases. For these systems to be effective, their location and installation are important so that they offer a high likelihood of detecting flame and gas hazards within monitored process areas.

Three-dimensional mapping. Determining the optimal quantity and location of flame and gas detectors is therefore critical to ensure the detection system's effectiveness. Flame and gas three-dimensional mapping is a solution that assists in the evaluation of flame and gas risks within a process facility and also reduces these risks toward an acceptable risk profile. Flame and gas mapping includes the placement of detectors in appropriate locations to achieve the best possible detection coverage (Figure 5).

The use of three-dimensional flame and gas mapping helps plant, process and safety engineers in a number of ways. First, mapping helps to increase plant safety by improving the likelihood of detecting flame and gas hazards. Also, it allows facilities to quantify their risk of a fire or a gas leak, and then assess the overall effectiveness of their flame- and gas-detection coverage. For new installations, mapping can help improve the design of new fire and gas systems to mitigate risks from accidental gas releases or fires. For existing installations, mapping provides a method for assessing the risk-reduction performance of existing fire- and gas-detector

systems and recommends ways to improve coverage.

Mapping assists facilities in understanding their risk of a fire or a gas leak, and then allows them to optimize their flame- and gas-detection protection layout by recommending the appropriate detector technologies, detector locations and quantities. Mapping also equips the engineer with the means to measure detection improvements when small incremental design changes are made. Mapping can therefore help to minimize overall system costs.

With mapping, determining detector layouts becomes much simpler, because mapping provides a methodical and systematic approach for determining the areas with the highest likelihood of flame and gas risks. Understanding the locations and likelihood of risks will help remove guesswork and uncertainties from engineering.

Once the optimal locations are determined for the placement of the flame detectors, then installation depends on the type of flame detector chosen. Most optical-type flame detectors are placed high and are pointed downward either inside or outside buildings or structures to monitor tanks and pipelines running throughout the plant.

Wrapping up

In order to protect chemical processes and plants from flame hazards, it is important to understand the basic detection sensor technologies and their limitations. Defining the type of potential hazard fuels, the minimum fire size to be detected and the configuration of the space to be monitored through three-dimensional hazard mapping can influence the choice of instrument.

When reviewing a plant's flame-safety protection level, be sure to ask for assistance from any of the flame detection equipment manufacturers. They have seen hundreds, if not thousands, of plants and their unique layouts, which makes them experts in helping to identify potential hazards and the best way to prevent accidents.

Remember, too, that no single flame-detection sensing technology is right for every potential plant layout and hazard. For this reason, adding multiple layers of flame- and gas-detection technology provides a multi-sensory approach that increases detection reliability and also can prevent false alarms. ■

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NFPA 652: Standardizing Combustible Dust Standards

The latest NFPA standard applies to many industry sectors, and aims to address the fragmented nature of the industry-specific standards currently in place

Christopher Frendahl, Brian Edwards and Jeff Davis
Conversion Technology, Inc.

On September 7, 2015, the National Fire Protection Association (NFPA; Quincy, Mass.; www.nfpa.org) issued NFPA 652 (Standard on the Fundamentals of Combustible Dust) [*1*]. There were already several industry-specific NFPA standards for minimizing hazards associated with the handling of potentially combustible dust and fine particulate materials. However, these individual standards do not always align, and the presence of numerous, competing standards creates confusion among operators, and increases risk at chemical process industries (CPI) facilities.

The publication of NFPA 652 is the first step toward creating a single, unified combustible-dust standard that would apply to all facilities that handle potentially explosive dusts (Figure 1). In addition, NFPA has also stated that, through its Combustible Dust Correlation Committee, the group plans to reformat some of the current NFPA standards so they become more aligned with NFPA 652.

NFPA 652 is still in its infancy, and as with all NFPA standards, it will continue to be improved and developed during future revision cycles. This article provides an update on the ongoing activities by NFPA, and discusses what is currently included in the new NFPA 652 Standard.

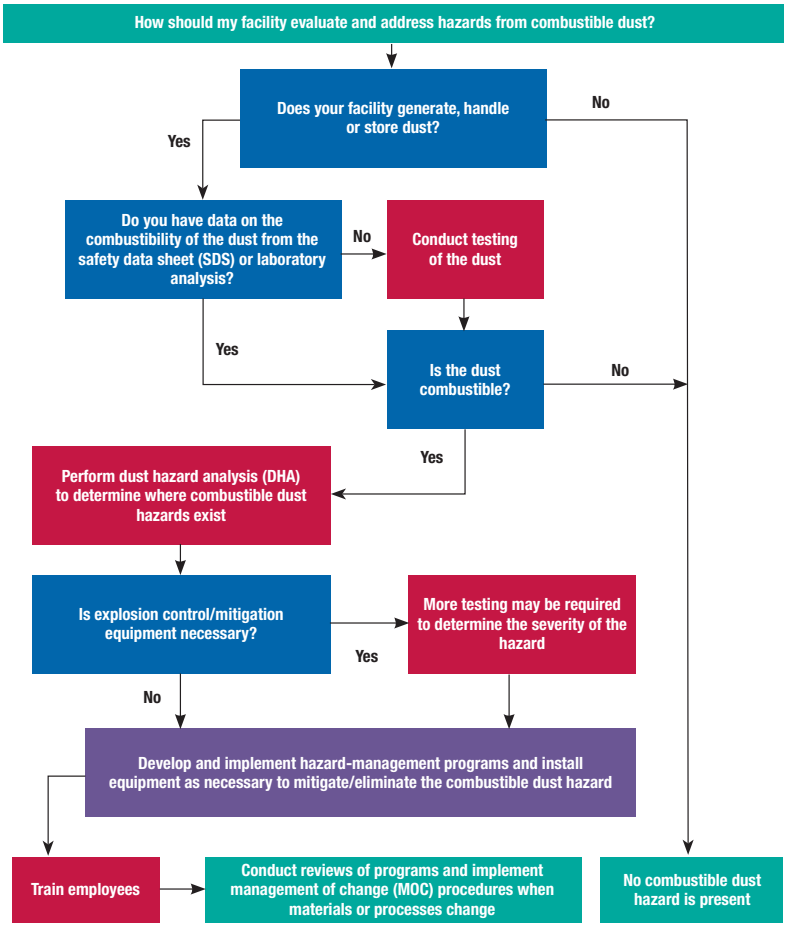

FIGURE 1. This decision-tree flowchart provides guidance for faciity operators, as they assess potential hazards associated with the handling or production of powdered materials that could be potentially flammable or hazardous under the right conditions

Fundamentals of dust hazards

Flash fires and explosions resulting from potentially combustible dust are responsible for a significant number of industrial accidents. However, the potential for dust-related flash fires or explosions is often overlooked. The serious hazards associated with handling fine dusts and powdered materials may be overlooked by many plant personnel because they are not fully understood.

The Occupational Health and Safety Administration (OSHA; Washington, D.C.; www.osha.gov) has begun to increase awareness of the hazards associated with cobustible dust through its National Emphasis Program (NEP) [*2*]. The NEP often cites NFPA standards for combustible dust, as the NFPA standards have been written explicitly to both reduce the risk of a combustible dust incident, and minimize the hazards in the event of a flash fire or explosion. However, as noted, many of NFPA's existing standards related

to dust-explosion hazards are industry-specific. For example, wood processing and woodworking facilities would refer to NFPA 664, while food-processing plants that handle flour and sugar (both of which are potentially combustible solids under the right conditions), would refer to NFPA 61. Often, the different NFPA standards directed at specific industry segments do not align with each other, creating confusion.

NFPA 652 aims to consolidate all of the various combustible dust standards, in order to create a single, overarching standard that addresses fire and explosion hazards associated with combustible dust of all types, in all industries. NFPA 652 lays the groundwork for a standardized format that all NFPA regulations relating to combustible dust will use. The new standard also implements methods that all facilities can use to evaluate and control hazards associated with potentially combustible dust. During the transition period (while NFPA is working on updating some of the current standards to align with NFPA 652), facilities should ensure that they are in compliance with both NFPA 652 and any applicable industry-specific NFPA regulations that pertain to their operations.

FIGURE 2. As part of the dust-sampling and hazard-assessment plan, it is important to collect representative samples of fine powdered materials that may be present in the facility. Keep in mind that fine particles are often found in elevated locations, such as ceilings, walls and ledges

What is included in NFPA 652?

NFPA 652 was created to apply to "all facilities and operations that manufacture, process, blend, convey, repackage, generate, or handle combustible dusts or combustible particulate solids" [*1*]. In addition to the general requirements listed in the standard, NFPA 652 also directs you to any applicable industry-specific

FIGURE 3. While housekeeping is important, facilities should focus on containing and collecting potentially flammable or explosive dust from the processes that handle or generate fine powdered materials. These include such common, seemingly innocuous materials, such as sugar, flour and sawdust

standards that would apply to different facilities. Over time these earlier, industry-specific standards will become more aligned with NFPA 652.

The primary focus of NFPA 652 is to help all facilities to identify where hazards exist due to the presence or handling of combustible or potentially explosive materials. In order to do this, a qualified person will need to conduct a dust hazard analysis (DHA). To conduct a DHA, a facility will need to develop a sampling plan to coordinate the collection and analysis of dust samples throughout the facility. This will allow the facility to identify and evaluate areas where combustible dust hazards exist.

Once all potentially hazardous areas and process equipment have been identified and a DHA has been completed, the facility should work to reduce the likelihood of a flash fire or explosion from occurring. It should also implement procedures or equipment to mitigate the hazards associated with a combustible dust fire or explosion.

If possible, the facility should work to contain and collect combustible dust, by both preventing fugitive dust from being discharged from equipment and by installing an effective dust-collection system throughout the process areas that handle combustible dust. The facility should develop a management system that monitors how hazards relating to combustible dust are being controlled.

Facilities should also provide training to employees and contractors. Such training should focus on both general safety regarding the hazards associated with combustible dusts, and on any job-specific training relating to their specific work environments.

Hazard identification and DHA

NFPA 652 includes procedures that all facilities can follow in order to identify areas where potential combustible-dust hazards exist. Dust samples should be collected from throughout the facility (Figure 2), in order to determine the combustible or potentially explosive qualities of the dust. To carry out such sampling, all facilities are required to create a plan that should include the following [*1*]:

- Identification of locations where fine particulate materials and dusts are present
- Collection of representative samples
- Methods to ensure preservation of sample integrity
- Communication with the test laboratory regarding proper sample-handling procedures
- Documentation of samples taken
- Safe sample-collection practices

Following a rigorous sampling plan will help facility operators to ensure that the dust samples are accurately analyzed to determine if they are combustible or potentially explosive.

Once dust samples have been collected and tested, if any of the materials are identified as being combustible or potentially explosive, the facility should then complete a DHA, to identify and evaluate the potential hazards associated with a fire or explosion due to the combustible materials handled throughout the facility. Inspections of areas where combustible dust is handled also allow facility operators to develop recommendations to minimize the risks of a combustible-dust incident.

Specifically, a DHA should include the following [*1*]:

- Identification and evaluation of locations or processes throughout the facility where hazards resulting from a potential fire, flash fire or explosion exist
- Identification and evaluation of specific fire and deflagration scenarios where fire and explosion hazards exist
- Identification of safe operating ranges
- Identification of any safeguards that are in place to mitigate the hazards of a fire or explosion
- Recommendations for additional safeguards, where needed

The DHA must be completed or led by a qualified person who has demonstrated the ability to understand combustible dust and associated hazards through education or experience [*1*]. This qualified person should inspect all buildings and processes to determine the potential likelihood of a fire or explosion due to the presence of combustible dust. This is determined by understanding the properties associated with the potentially combustible dusts that are handled in the building or process, identifying all potential ignition sources, and evaluating the effectiveness of any deflagration-suppression or protection systems that are currently in place.

Mitigating hazards

Once a DHA has been completed by a qualified person, the facility should begin to implement any recommendations made, to prevent or minimize the hazards. Often times, updated housekeeping procedures are the first actions facilities can take — for instance, to remove excessive dust accumulation in rooms and buildings (Figure 3). However, this requires extra labor and is often not as effective as expected.

For example, certain inaccessible

areas (such as upper levels, rafters, beams and roofs) may not be inspected or cleaned often enough. Additionally, some housekeeping activities, such as cleaning dusty areas with compressed air, may pose additional (sometimes significant) hazards, as potentially combustible dust clouds are able to form in the areas that are being cleaned. Finally, housekeeping activities are often reduced or overlooked during periods of increased production or decreases in staffing.

Perhaps more importantly, facilities should make it a priority to take steps to contain and collect dust and powdered materials from the processes that handle or generate them. While conducting the DHA, facilities should try to identify any equipment where fugitive dust is being released into the work environment. Particular focus should be put on such systems and components as pneumatic and mechanical conveyance lines, sifters and screeners, bins and silos, dryers and cyclones, hammer mills and grinders, and unloading bins and stations. Once the leaks have been identified, plant engineers should work to repair the equipment — to prevent fugitive dust from escaping from these systems and accumulating inside the facility.

Prevention and capture

It is not always feasible to prevent the discharge of fugitive dust into a room or building, so other means of protection or hazard mitigation should also be implemented to reduce hazards and mitigate the risk of fire and explosion. Specifically, NFPA 652 states that any building or room where a dust deflagration hazard exists should be protected using venting systems that comply with NFPA 68. Also, pneumatic conveyance systems must be equipped with deflagration protection or suppression systems that will prevent a flash fire from traveling throughout the conveyance system and connected equipment; details are spelled out in NFPA 69.

Exhaust air from equipment should only be directed outside and not into the room unless specific guidelines are met. Facilities should also ensure that all central vacuum systems are equipped with tools and attachments that are constructed of metal or static-dissipative materials, and that all vacuum hoses are properly grounded.

While facilities should focus on prioritizing dust collection and containment from their processes, it is also important to implement safe housekeeping procedures in areas where dust accumulation cannot be avoided. Sweeping and water washdown are allowed under NFPA 652, but compressed air cleaning should only be used if certain requirements are met (NFPA 652, Chapter 8.4.2.6), such as the use of pressure-reducing nozzles and ensuring that no ignition sources are present in the area.

All housekeeping procedures implemented by the facility should be documented, and all employees and contractors should be trained on these procedures. Employee training should also include information regarding required personal protective equipment

(PPE) to be worn during housekeeping operations, as well as instructions and training on how to properly use all equipment. In addition, the facility should ensure that all hot work being done onsite complies with NFPA 51B. The areas where hot work is being done must be cleaned before beginning the hot work, and all equipment in the area should be shut down.

NFPA 652 also states that facilities should conduct an assessment of workplace hazards, according to NFPA 2113, in order to determine if flame-resistant (FR) clothing is required. FR clothing is designed to not ignite when it comes into contact with a flame. If the assessment indicates that FR clothing is required, the facility must offer appropriate FR clothing to all affected employees.

Closing thoughts

NFPA 652 is the first step of many to consolidate and integrate a variety of NFPA standards that are intended to help reduce the risks for facilities producing or handling potentially combustible dusts and fine powdered materials. This new standard requires that all facilities create a sampling plan to test fine powdered materials from different locations and equipment, in order to determine if it is combustible or potentially explosive. If any of the dust samples pose a combustible dust hazard, a qualified person must conduct a DHA to determine how likely it is that a combustible dust incident will occur in a room or piece of equipment by evaluating the dust. Hazards assessments such as this are carried out by identifying any ignition sources, and evaluating any protection or suppression systems that have been implemented. Once the DHA has been completed, the facility should work to prevent or minimize the hazards. The facility should repair any leaks in equipment where fugitive dust is released into the work environment, and deflagration protection or suppression systems should be installed on at-risk equipment. Safe housekeeping procedures should be developed, and the facility should ensure that all employees and contractors have been trained.

While there is still a lot of work to be done by the NFPA dust standards committees, facilities throughout the CPI should begin to familiarize themselves with the new NFPA 652 standard, to be in compliance with the new standard. It cannot be stated strongly enough that CPI facilities must work aggressively and consistently toward minimizing the risk of combustible dust fires and explosions wherever fine, powdered materials are produced or handled.■

Edited by Suzanne Shelley

References

1. National Fire Protection Association, "NFPA 652: Standard on the Fundamentals of Combustible Dust – 2016 Ed.," Sept. 7, 2015; Accessed at: www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=652
2. Occupational Safety and Health Association (OSHA), "Combustible Dust National Emphasis Program (Reissued)," March 11, 2008; Accessed at: www.osha.gov/OshDoc/Directive_pdf/CPL_03-00-008.pdf

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This liquid level transmitter is smart and easy to use

Orion Instruments launches its next-gen magnetostrictive level transmitter

Orion Instruments, a global leader in high-performance level control instrumentation, is proud to announce the release of the JUPITER Model JM4 magnetostrictive level transmitter, its newest and most advanced level instrument to date. The JM4 is available as a direct insertion option, as well as an external mount on any Orion magnetic level indicator (MLI) (photo, left) or modular instrumentation bridle. With an improved design, unparalleled performance, and a collection of new and innovative features, the JM4 provides safer, simpler, and smarter measurement in total and interface level applications.

The JM4 is engineered to be the smartest, most innovative magnetostrictive transmitter available. To this end, Orion Instruments has introduced numerous enhancements, including greater signal-to-noise ratio (SNR), a full graphic local user interface, HART 7.0 (Foundation Fieldbus available), local waveform capture, and a more intuitive device type manager (DTM) allowing for remote configuration, trending, and diagnostics.

The JM4 is the first magnetostrictive transmitter in the industry to offer a field-removable and rotatable head. The removable head allows for simpler transmitter maintenance and troubleshooting without disrupting the process. 310° of head rotation provides users with greater accessibility to operate the JM4's on-board graphical interface.

To further enhance the removable head, the JUPITER Model JM4 also features Smart Probe technology. When any JM4 transmitter head is attached to a probe, a single push of a button imports factory configuration settings into the head, and in seconds the transmitter is ready for operation.

JUPITER now also offers a remote mount option. Available in lengths of 3 ft and 12 ft, the transmitter head attaches to the probe via a flexible cable to allow for easier viewing under various spatial constraints.

Orion Instruments is a globally recognized leader in the design and manufacturing of magnetic-based level technologies. Based in Baton Rouge, LA, Orion offers an extensive product line of custom level measurement solutions with the broadest range of options to solve the most difficult industry applications. Orion Instruments is a proven and innovative leader in the level monitoring and control world with solutions provided in every major industrial sector. With over 200 representative partners and multiple direct offices located around the world, Orion is positioned to service clients on a global scale. **www.orioninstruments.com**

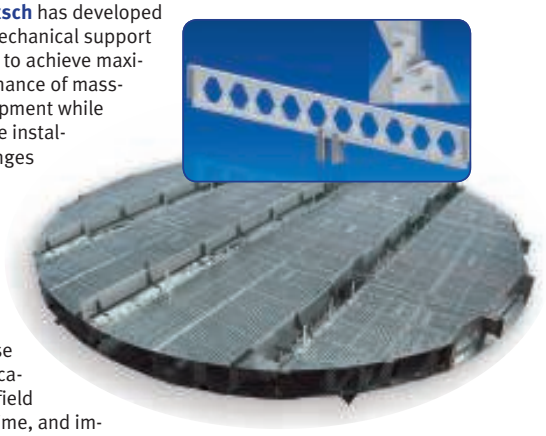
Innovative designs for large columns

Koch-Glitsch solves installation challenges and boosts mass transfer performance

To meet the growing global demand, the hydrocarbon industry is expanding plant sizes and installing larger-diameter columns to handle the increased production.

When evaluating the overall cost of a new large-diameter fractionation vessel, it is important to consider the structural support method for the mass transfer internals. Traditional structural beams are heavy, complex, and can significantly affect the total installed cost. When revamping towers where structural beams require replacement, traditional beams may require significant amounts of field welding that can increase installation time and costs. The size and weight of traditional beams also make them challenging to install through vessel access hatches.

Koch-Glitsch has developed innovative mechanical support technologies to achieve maximum performance of mass-transfer equipment while mitigating the installation challenges commonly found in large towers. The new designs reduce material use, increase the use of shop fabrication, reduce field installation time, and improve resistance to damage caused by process upsets or harmonic vibration. The improved efficiencies of these designs provide significant time and cost savings, the company says. While frequently used with distillation trays, the support technologies are also well suited for other column internals, such as collector trays and support grids for random and structured packed beds.



Koch-Glitsch SUPERFRAC tray and (inset) innovative support system

Recently, the new mechanical support technologies were used in an installation of SUPERFRAC trays in a 33.5 ft (10 m) propane/propylene splitter. The trays are in now operation and meeting all their performance objectives.

The patented technologies used in the SUPERFRAC tray are the culmination of over 25 years of comprehensive tray development work. With more than 2,000 successful installations, SUPERFRAC tray performance has been validated in both new tower designs and revamps of existing trays. Suitable for all tray operating regimes, the SUPERFRAC tray is especially beneficial in applications requiring a large number of mass transfer stages, or where mass transfer efficiency is critical to the economics of the operation, such as superfractionators and chemical and petrochemical splitters.

The SUPERFRAC tray gives high economic benefit to operators of distillation columns seeking solutions for both new construction and revamp projects. When optimized for efficiency and capacity, SUPERFRAC trays can yield a valuable reduction in energy consumption and increase in throughput. **www.kochglitsch.com**

Over six decades of experience in exhaust gas cleaning

CR Clean Air specializes in wet scrubbing systems, offering a wide range of designs and chemical reagents to suit equally diverse applications

CR Clean Air has been providing wet scrubbing systems to the chemical process industries for almost 70 years. From the initial venturi fume scrubbers developed in the 1950s to the fully skidded packages it offers today, CR Clean Air has always been driven by the need to engineer the best possible solution for each plant's emission control needs. Experienced in a wide range of applications, from handling acid gases such as HCl and SO_2 to the removal of fine and submicron particulates from contaminated vapor streams, CR Clean Air's depth and breadth of experience is unmatched. As a leader in clean air technology, the company has been at the forefront of dealing with many complex chemistries and challenging pollutants, from ethylene oxide mitigation to NOx emissions.

CR Clean Air's offerings include jet venturi fume scrubbers with integral separator tanks for bulk removal of pollutants and larger particles; high-energy jet venturis with cyclonic separators for sub-micron particles; and packed tower designs for the many situations in which higher removal efficiencies are required to meet ever more stringent emissions limits.

CR Clean Air has the experience to engineer a system that will work the first time, while its commitment to quality ensures that the equipment will continue to work for decades to come – be it a standby scrubber to handle an emergency release of toxic vapor, or an odor control unit that needs to run 24/7. From small manually controlled units to large fully automated systems with complex instrumentation and built-in redundancy, CR Clean Air's team of electrical, chemical and mechanical engineers can assist in developing customized solutions. Additionally, their offerings are available in a wide range of materials, both metal and non-metal, including carbon steel, stainless steel, corrosion-resistant alloys, FRP, polypropylene, PVDF and dual laminates.

CR Clean Air has systems installed across a wide range of industries: aerospace, chemicals, fibers, food, pharmaceuticals, pulp and paper, and semiconductor, just to name a few. The range of pollutants is just as varied, including HF, HBR, NH_3, silicates, dust, and VOCs. CR Clean Air has a range of approaches in its arsenal, including straightforward once-through water systems to chemically scrubbed systems with recirculated caustic or other reagent to neutralize contaminants.

From arsenic to zirconium tetrachloride, CR Clean Air scrubs gases that other systems won't touch.

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A combined venturi/tower is one of the many types of wet scrubbers offered by CR Clean Air

Rapid growth for communications and blinds provider

Service Radio-Industrial Blind Solutions committed millions of dollars of additional inventory to its new Houston location for industrial blinds and communication products

Service Radio-Industrial Blind Solutions (IBS) is a premier supplier of two-way radios and industrial blind products to the industrial maintenance and construction industries. Thanks to its rapid growth, geographic coverage, state-of-the-art technology infrastructure, and commitment to service, Service Radio-IBS is able to respond swiftly to customer service and equipment needs. By employing the right people, training those people, operating as a team, and positioning the company strategically throughout the marketplace, Service Radio-IBS is able to provide an extremely high level of service.

What sets Service Radio-IBS apart in terms of communication technology is the fact that the company provides solutions to communications problems within industrial environments, not just the equipment needed to talk.

Everything the company does is built around the needs of industrial plants and contractors. Time is money to these customers, so the service component is critical. With the expansion of its inventories and locations, Service Radio-IBS now has close to 11,000 radios coast to coast. It also has the largest inventory of industrial blinds in the U.S., representing nearly 50,000 units strategically located in Louisiana, Los Angeles and Houston. The company also manufactures custom blinds for specific needs.

Utilizing Service Radio-IBS' products and services allows customers to finish projects on time, run their businesses effectively and save millions, the company says.

From its headquarters in Houston, Texas, Service Radio-IBS operates throughout the Gulf Coast and far beyond

www.srr-ibs.com

A classic mixing tool for the petroleum industry

Ross LPD Static Mixers are rugged, reliable devices that combine excellent inline mixing with minimal pressure loss

Ross Low Pressure Drop (LPD) Static Mixers are used throughout the oil and gas industry for turbulent-flow mixing applications.

Shown are removable LPD mixing elements supplied with retainer ring and flanged housing

These heavy-duty low-maintenance devices serve in continuous operations where high performance and accuracy are required, such as on-line water determination of crude oil; dosing of various additives into gasoline; blending different kinds of fuel oils; gas-gas blending; and pipeline reactions, among others.

Static mixers have no moving parts and the energy for mixing is available in the form of pressure. Pressure loss – a natural consequence of static mixing – sometimes becomes the deciding factor in mixer selection. The LPD Static Mixer remains a classic choice for many inline blending requirements due to its simple and durable design capable of uniform mixing with little pressure loss. The mixer elements consist of semi-elliptical plates carefully positioned in series to split and rotate the product 90 deg. in alternating clockwise and counterclockwise directions.

LPD mixers in diameters from 1 in. through 2.5 in. are welded to a central rod, while larger elements are welded to four outside support rods for maximum rigidity and stability. Units as large as 48 in. diameter can be supplied as stand-alone mixer elements or as modules complete with a mixer housing and injection ports.

Established in 1842, Ross is one of the oldest and largest mixing equipment companies in the world. Ross mixing, blending, drying and dispersion equipment is used throughout many industries in the manufacture of foods, adhesives, electronics, coatings, cosmetics, pharmaceuticals, plastics and composites.

www.staticmixers.com

Turbine flow meters are accurate yet cost-effective

New Blancett B1500 Series turbine flow meters from Badger Meter combine accuracy and reliability with powerful display options

The **Badger Meter** Blancett B1500 Series Turbine Flow Meter is specifically designed to perform in harsh environments found in the oil, gas, and petrochemical industries. A cost-effective option for highly accurate and reliable flow measurement, B1500 flow meters are an ideal solution for standard clean, filtered liquid flow applications in precision industrial processes, such as batching, blending, filling, or general flow measurement.

B1500 Series turbine flow meters feature exceptional mechanical linearity, which increases usable flow range and helps mitigate output variance caused by viscosity fluctuations due to changes in fluid temperature. Using a helical rotor design with high-performance ceramic ball bearings, B1500 meters are able to achieve exceptional speed-of-response and minimal pressure drop. Ceramic bearings are also lighter, more tolerant to extreme temperatures and produce less friction than stainless steel ball bearings, which are commonly found in other turbine meters.

As an added benefit, B1500 flow meters are easily coupled with B3000 flow monitors to provide an economical, robust flow metering solution, with multiple local read and system integration options. Flow rates and totals are presented simultaneously via a crisp dot-matrix LCD display and/or transmitted to a user interface via Modbus RTU, a 4–20 mA analog output or totalizing pulse output. Basic, advanced and solar-powered configurations provide users with flexibility to meet the needs of unique applications.

B1500 Series meters are available in nominal line sizes of 0.25–2 in. with an accuracy rating of ±0.25% of reading, when linearized with a B3000 flow monitor, and repeatability of ±0.02% of reading. Ideal flow ranges vary from 0.25 to 250 gallons per minute depending on line size. The B1500 Series meter is constructed of 316 stainless steel and is available with either ANSI flange or NPT end fittings.

The Badger Meter Blancett B1500 Series is available in a wide range of sizes and fittings

B1500 Series turbine flow meters come calibrated and traceable to NIST standards, are in stock and ready to ship. With quick product availability and advanced electronic integration options, backed by experienced application support personnel, the Badger Meter Blancett B1500 Series is an ideal solution for critical flow measurement needs.

www.badgermeter.com

Should you buy or rent your lifting gear?

Owning hoists and other necessities for moving process equipment may carry hidden costs for maintenance and certification, says Lifting Gear Hire

Some of the more than 50,000 pieces of equipment that Lifting Gear Hire offers

Difficult assembly and restricted working spaces are among the challenges associated with moving equipment in petrochemical and pharmaceutical plants. Whether the job is to build a new plant or maintain an existing one, it is essential to handle sensitive components safely and gently. Failure to do so can result in expensive downtime, personal injuries, and damage to the environment. So, you are going to need the right tools for lifting and assembling the heaviest of loads, even in critical environments and under cramped conditions. The question is, should you buy or rent your equipment? There are a few factors to consider.

First off, can you handle repairs and certifications in-house? One poorly maintained hoist could break and cause whatever you are lifting to fall. So, not only is it best to anticipate mishaps, but you also need to consider whether you can repair the equipment on your own or if you will have to outsource the repairs to another company.

Turning to the lifting gear itself, remember that hard costs such as rental fees and lease payments are only a small part of total costs. Among the most frequently overlooked costs are those of maintenance and certifications. All equipment eventually requires maintenance, so if you are looking to buy, make sure you have access to the specialized labor and testing equipment you will need to repair your equipment.

Another question is whether the equipment will remain in one location or be repositioned around the country. The answer to this largely depends on whether you are a regionally-focused company or if you have a geographically distributed customer base. A regionally focused company has little need to transport equipment, and has an on-going need for the equipment, which makes owning more sensible.

Weigh the long-term needs of your company to understand what makes the most sense. There are many factors to consider, and no one-size-fits-all answer. Careful analysis will help you make the right decision.

Founded in 1990, Lifting Gear Hire (LGH) is the largest single organization in the U.S. devoted exclusively to the provision of lifting and moving equipment for rent and sale. LGH provides hoisting, pulling, jacking, rigging, material handling and safety equipment available for immediate and safe use. LGH's mission is to offer expertise in the rental of the safest and most reliable hoisting and rigging equipment to build and support a better America. LGH puts safety first.

www.lgh-usa.com

Moving from paper to digital PDF turnover packages

Bluebeam Revu software has helped a contractor streamline its workflow and add value to the equipment it designs and fabricates for oil and gas companies

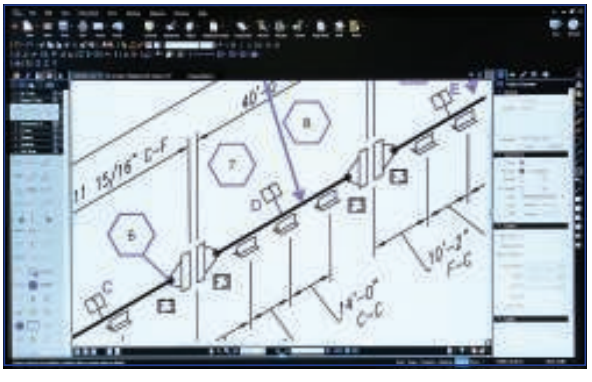
"If a picture is worth a thousand words, a marked-up PDF is worth 10,000," says Mark Henry, a Sr. Field Engineer with McCarl's Inc., an industrial contractor and fabricator serving the steel, chemical, manufacturing, and oil and gas industries. In 2013, McCarl's was awarded a contract to build a fractionation plant for a mid-stream oil and gas company. One of the customer's requirements was to provide a digital turnover package at the end of the job.

To make this possible, McCarl's began using **Bluebeam Revu**, a PDF creation, markup and collaboration solution. Having a digital copy linked to every related file in Revu meant it could be easily searched, with everything accessible in a few clicks.

Since then, the team has been using Revu throughout their latest project, a mid-stream oil and gas compressor station. Henry starts by creating isometric drawings of the piping design, then exports them to PDF so he can add comments and instructions in Revu. Next, the documents are sent to McCarl's fabrication shop, where Fabrication Draftsman Jim Cummings creates a digital dashboard in Revu with links to all of the files in the job set, making it easier for everyone to access and add their fabrication markups.

When they're ready for testing, Henry will mark up the P&IDs using Revu's Line Tool to highlight the different line pressures that need to be tested so it's clear which line gets tested and at which pressure. Once the job is completed, every piece of information collected along the way is packaged and delivered to the client as a PDF.

Although going digital was initially a requirement, the advantages were soon obvious. "Now we use it in fabrication, design, engineering, document control, estimating – everywhere," says Henry. "I would like to see all contractors in oil and gas, and construction in general, use Revu. But until they do, the fact that we use Bluebeam Revu gives us an advantage, because it makes us more efficient, faster, and more accurate."



McCarl's uses the Sequence Tool in Revu to number and track all of the welds that need to be made in the fabrication shop

www.bluebeam.com/fabricates

Entire management team API 936-certified

Diamond Refractory Services, a specialist in emergency refinery shutdowns, differentiates itself through certification, quality, and expertise

For Houston-based **Diamond Refractory Services**, one measure of the company's success is the percentage of business that engages the organization on multiple projects. For the last 16 years, Diamond has enjoyed a customer retention rate of 85%, a percentage that shows just how seriously it takes client needs and meeting or surpassing expectations.

Diamond is known for providing one of the petrochemical industry's most critical services: rapid deployment in response to emergency refinery shutdowns. Some of the biggest names in refining and processing regularly rely on Diamond to provide repair, revamp, and construction services for FCCUs, sulfur units, acids plants, furnaces, and heaters.

Within an industry that is highly competitive, Diamond has risen to the top by boasting an admirably successful safety record that includes a total recordable injury rate (TRIR) of 0.00 for three consecutive years.

Comprising refractory specialists, alloy welders, nozzlemen, safety professionals,

A Diamond Refractory worker performs a 100% demolition and refractory replacement on a waste heat cooler

skilled laborers, forklift drivers, and other dedicated employees, Diamond vaunts an entire management team that is API 936-certified. Diamond's team is well versed in rapid arc welding, a fast, reliable, and accurate method to secure refractory anchors.

Since 1989, API's Individual Certification Programs have provided the petroleum and petrochemical industries with an independent and unbiased way to evaluate the knowledge and experience of technical and inspection personnel. Earning the API 936 certification has significantly bolstered Diamond's service offering. The certification virtually guarantees that the company will provide educated, specialized management to each site, and that it has established a minimum standard of knowledge and skill for its personnel. Being certified also means Diamond provides a higher level of management control over quality inspection practices, while simultaneously maintaining a high level of safety and performance, and reducing the potential for downtime due to equipment failure.

Diamond's team of refractory specialists has completed over 100 FCCU turnarounds to date, and accumulated 1.7 million hours worked. With over 200 years of combined refractory experience, Diamond Refractory's management team is uniquely positioned to tackle the industry's most difficult refractory challenges. **diamondrefractory.com**

Add a heat transfer expert without adding head count

Eastman technical support paired with Therminol heat transfer fluids provide design and operational solutions that can lead to extended life and high performance

Heat transfer fluid systems are integral to refining and petrochemical processes. Choosing the right heat transfer fluid and supplier can help optimize performance by adding an expert to the in-house team.

From a small-scale low-temperature batch reaction to a continuous, multistep process with stringent temperature control, the Eastman technical services team understands customers' needs and can provide system design support with any of the Therminol family of coolants and heat transfer fluids. Good up-front design identifies the fluid best suited to avoiding problems with corrosion or accidental intermixing, and reduces the area required for heat exchange.

Therminol heat transfer fluids span the widest temperature range available among any organic heat transfer portfolio, from –115°C (–175°F) to 400°C (750°F).

In petrochemicals, LAB (linear alkyl benzene), phthalic anhydride (PA), terephthalic acid (PTA), olefins, alcohols, and plasticizers are among the products for which heat transfer systems form an integral part of the

Choosing the right heat transfer fluid and supplier can add an expert to the in-house team, helping to optimize performance in petrochemical processes

process. A central heating and circulating system with multiple users provides temperature control for the different stages of reaction, separation and purification.

For organic separations at temperatures above 100°C, it is especially important to avoid water leakage into the process side. Eastman's team understands how design and maintenance procedures can minimize this risk, and can recommend corrective actions based on complimentary in-service fluid testing to identify moisture ingress and fluid degradation.

The thermally stable synthetic organic chemistries of Therminol fluids ensure high reliability and on-stream time for heating fractionation unit reboilers as well as cooling overhead condensers where water must be avoided. Additionally, the many energy-intensive operations in refinery units offer opportunities for innovative energy integration opportunities.

For more than 50 years, the Therminol heat transfer fluid brand has been the choice for excellence in technical support, customer service, performance, and innovation. Eastman's TLC Total Lifecycle Care program is designed to support Therminol customers throughout the life cycles of their systems. Technical support includes assistance with system design, start-up, operational and safety training, a technical service hotline, sample analysis, and fluid flush and refill. **www.therminol.com**

Ensure process piping integrity with confidence

Quest Integrity provides industry expertise and superior inspection technology for accurate and reliable operation of inaccessible process piping systems

The loss of process piping containment in a refinery can prompt several operational setbacks, including tremendous financial cost, unplanned facility downtime, and loss of public and regulatory credence. Due to limited access and complex piping configurations, a comprehensive and low-impact inspection solution is vital to the operational life of process piping systems.

Quest Integrity's InVista intelligent pigging technology mitigates the risks associated with piping damage and loss of wall thickness, including corrosion, erosion, denting, ovality, and bulging. The intelligent pigging tool measures wall thickness and detects changes in internal and external pipe diameter caused by anomalies. Operators can thus be confident that 100% of their pipe surfaces have been inspected, both internally and externally, to identify any potential degradation before loss of containment occurs.

The InVista intelligent pigging tool can inspect both below-ground and overhead piping located in crowded pipe racks, making it an ideal way to overcome the access and negotiation restrictions associated with challenging piping configurations. The advanced intelligent pig design includes a fully self-contained, untethered unit with the ability to travel bi-directionally. This unique design enables plants to inspect both axial and circumferential piping in traditionally "unpiggable" systems.

The InVista intelligent pig can navigate and inspect even complex pipework

The InVista tool produces quantitative inspection results, allowing rapid and accurate fitness-for-service (FFS) calculations in compliance with industry standards such as API-579 / ASME FFS1. The data can be viewed in high-resolution 2D and 3D formats that encompass the full length of the piping system. Inspection results are then analyzed by Quest Integrity's skilled technical analysts to determine the severity and root cause of any anomalies detected.

The InVista technology offers unique expertise in the inspection and assessment of inaccessible process piping systems, effectively avoiding costly operational delays associated with damage to process piping.

Quest Integrity is a global leader in asset integrity and reliability management services. It provides advanced inspection and engineering assessment services and products that help organizations in the pipeline, refining, chemical, syngas and power industries improve operational planning, increase profitability, and reduce operational and safety risks. **www.questintegrity.com**

Why rent? Piping products and heat exchanger tools

Compared to buying, rental often carries lower costs and fewer risks, says USA Industries

Should I rent or buy? This is a common question asked by estimators and planners when coordinating turnarounds or maintenance projects, notes manufacturer and supplier company **USA Industries**. Keeping down the costs of performing work is of paramount importance to their departments. Every cost-cutting avenue is reviewed. One major expense is the purchase of materials and equipment needed for these projects. The option to rent them, instead of buying, can lower project costs considerably.

Is renting the answer? USA Industries, the premier company for blind and blind flange rentals, believes that renting is the way to go for refineries, power plants and chemical facilities. These customers also rent pipe testing and isolation plugs, as well as heat exchanger tools. Since 1982, USA Industries has helped its customers keep their capital and maintenance project costs down through its rental program.

What are the advantages of renting tools and tooling for your projects? When purchasing tools, project funds are tied up in part-time assets. By renting the same tools, your expense is only for the time of use.

Besides the cost of purchased tools, having unused inventory around the project site can be costly. Pipe testing equipment can be damaged or corroded if not stored properly. There are also storage costs to consider. With owned equipment, the odds of tools being misplaced, lost or stolen increases.

USA Industries carries a large inventory of tools and tooling available for rent – from one day to however long it takes to finish the project. The company ensures quality products that meet their respective code specifications. Not only is USA Industries available to take orders 24 hours a day, 7 days a week, but most orders are shipped out within 24 hours after receiving the order.

Whatever your project requirements, USA Industries can rent the tools and tooling needed to get the job done, in any quantity for any length of time. Some of USA Industries' rental inventory includes:

USA Industries' patent-pending EZ Lock Blind Rack is available for rent

- paddle blinds for isolation and hydrotesting;
- blind flanges (RF or RTJ);
- pipe plugs;
- heat exchanger tools; and
- Snap It tube plugging kit.

www.usapiping.com

Follow these steps to select the proper boiler

The correct boiler increases efficiency, reduces operating costs and ensures safety, says Cleaver-Brooks

The Cleaver-Brooks D-style boiler is ideal for industrial process and building heat applications

When a process application requires higher pressures, large quantities of steam or the possibility of additional heat through integrally mounted superheaters, an industrial watertube (IWT) boiler is the best solution, says **Cleaver-Brooks**. IWT boilers are noted for their fast steaming capability. To select the proper IWT boiler for an application, consider these basic evaluation steps.

Steam and process-load needs. Determine the total system load, measured in either BTUs or pounds of steam at a specific pressure and temperature. There are three types of loads: heating, process, and power. A heating load typically is low-pressure steam or hot water used to maintain building heat. A process load is a high-pressure steam load that mainly pertains to manufacturing operations. Many facilities have a combination of both heating and process loads. The third type of steam load is for producing power.

Footprint. Allow plenty of room to walk around the boiler as well as access to conduct boiler maintenance. Ceiling height is also important, since it needs to accommodate items such as boiler piping, valves, and possibly an economizer.

Specification considerations. There are several boiler types to choose from, including the D-type, O-type and A-type. A D-type watertube boiler is ideal for nearly any steam need and is by far the most common boiler type. An O-style boiler has a symmetrical shape with a central center of gravity, making it ideal as a portable or rental unit. An A-type watertube has two mud drums instead of one, which enables a much larger furnace for higher steam capacity, pressure and superheat.

Emissions requirements. There are a number of pollutants that must be managed when burning natural gas, particularly nitrogen oxides (NOx) and carbon monoxide (CO). If ultra-low NOx (<9 ppm) is required, consider a system that includes a low-NOx burner with flue gas recirculation. To reduce NOx emissions to the near-zero level, add selective catalytic reduction. **www.cleaverbrooks.com**

New FCC catalysts help to optimize yields and margins

BASF introduces BoroCat FCC catalyst to help refiners maximize margins and optimize production yields

BoroCat is the latest evolution of **BASF's** resid oil fluid catalytic cracking (FCC) catalysts for the refining market. BoroCat is the first FCC catalyst based on BASF's new Boron-Based Technology (BBT) platform, which is designed to optimize refiners' production yields. Successful commercial trials have verified BoroCat's ability to provide improved nickel passivation, leading to demonstrably lower coke, lower hydrogen, and improved bottoms conversion when compared to existing technologies.

"BoroCat is a best-in-class innovation developed to help refiners optimize their operations and maximize margins," said Detlef Ruff, Senior Vice President, Process Catalysts at BASF. "BoroCat yielded excellent results during its first round of ongoing commercial trials," added Jim Chirumbole, BASF's Global Business Vice President for Refining Catalysts. "It exceeds the performance that made BASF's Flex-Tec and Fortress products leaders in the resid oil market."

For more than 50 years, BASF Catalysts has been pioneering innovative catalyst technologies for the petroleum refining industry. BASF's Refining Catalysts FCC technology portfolio creates value for refiners and covers all feedstocks: vacuum gas oil, resid, tight oil, and Canadian oil sands.

BASF Catalysts offers a wide range of state-of-the-art solutions for refiners and petrochemical producers

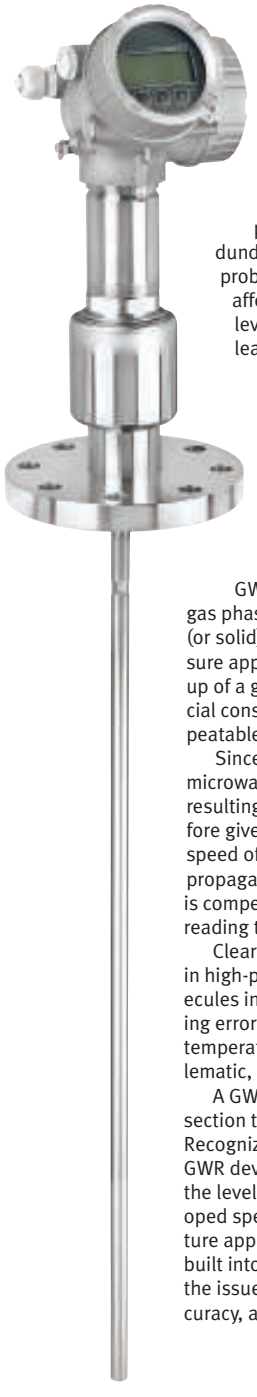
Building on the success of its Distributed Matrix Structures (DMS) technology platform, BASF continues to develop high-conversion catalysts to meet ongoing needs for gasoline. In North America, tight oil crudes require high-activity catalysts tailored for processing these highly reactive feeds. Based on their activity, DMS-based catalysts are the best option for customers working with tight oil feeds.

As heavier, sourer crudes continue to proliferate globally over the longer term, BASF continues to develop suitable catalysts through its Proximal Stable Matrix and Zeolite (Prox-SMZ) and BBT platforms. These feeds may require metals passivation to mitigate the impact of contaminants such as vanadium and nickel.

New refineries under construction in the Middle East and Asia are complex systems designed to produce petrochemical feedstocks such as propylene. BASF currently offers MPS (Maximum Propylene Solution) to address this application. BASF also remains strongly committed to supporting the demand for diesel in key markets including Western Europe and, increasingly, North America. **www.basf.com**

Measure level with higher reliability and fewer alarms

Endress+Hauser compensates for polar molecules in guided wave radar applications



Are you experiencing deviation alarms in high-pressure process vessels? In many high-pressure vessels, redundant level measurement technologies are employed to provide multiple level indications for safety, points out **Endress+Hauser**. It is common for these instruments to use different technologies, so as to provide what is referred to as "diverse redundancy". A process condition that may give problems for one technology will likely not affect the others, ensuring that a reliable level measurement is being provided by at least one technology.

Guided wave radar (GWR), also called time-domain reflectometry, is a time-of-flight level measurement technology for level measurement in high-pressure vessels. How an instrument will function in the application in which it is being applied is particularly true of GWR transmitters in high-pressure vessels. Typically, a GWR will send a pulse through the upper gas phase in the vessel to reflect off of the liquid (or solid) material being measured. In high-pressure applications where the upper phase is made up of a gas with a polar molecular structure, special consideration needs to be taken to obtain repeatable measurements.

Since polar molecules alter the speed of microwave pulses, the microwave are slowed, resulting in measurement errors. GWR will therefore give the wrong level unless the reduction in speed of the microwave pulse, which slows as it propagates through the upper polar gas phase, is compensated. The result is an indicated level reading that is less than the actual process level.

Clearly, when using a GWR for measurement in high-pressure applications with polar molecules in the gas phase, corrections to the resulting error must be made based on pressure and temperature measurements. This can be problematic, especially during process startup.

A GWR can be manufactured with a reference section that provides the required compensation. Recognizing the effects polar gas has on GWR, a GWR device was installed that compensates for the level deviation. The GWR device was developed specifically for high-pressure and temperature applications with a unique reference rod built into the top section of the unit to combat the issue of polar gas, ensure reliability and accuracy, and minimize deviation alarms.

www.us.endress.com

Understanding NFPA 654 for combustible dust

Nol-Tec Systems explains how the rules are tightening, and what to do about it

Combustible dust is a critical concern for any industry that processes or conveys dry bulk materials. Changes in regulations have brought this issue into even greater focus. **Nol-Tec Systems'** design teams are experts in developing systems for hard-to-handle materials so as to minimize the production of dust and the possibilities of combustion.

The combustible dust pentagon: removal of any one element can prevent explosions

The U.S. National Fire Protection Association (NFPA) has issued stricter standards for safety measures to prevent and mitigate explosions and fires in facilities where a combustible mix of dust and air could be present. Also, the U.S. has fully adopted the Globally Harmonized System for the Labeling and Classification of Chemicals (GHS), which has new standards for combustible dust that are incorporated into the NFPA recommendations.

These changes mean the reach of the various NFPA codes has changed substantially. Coarser particle sizes (up to 40 mesh) and more organic materials are now included. Many chemicals not previously classified as hazardous are now designated as dust explosion hazards. The K_{st} (dust deflagration index) of many powders has been updated. In fact, so many dusts are classified as combustible that the focus is now on mitigating hazards.

In late 2014, the U.S. Occupational Safety and Health Administration (OSHA) received a mandate to fully enforce the updated NFPA standards. This stricter enforcement has been, in no small part, due to several high-profile dust explosions. Informative material can be found on the website of the U.S. Chemical Safety Board (CSB), which investigates these accidents. An excellent example from a titanium plant can be found at http://www.csb.gov/al-solutions-fatal-dust-explosion/.

Hazard control has typically focused on two areas. The first is housekeeping and containment. Nol-Tec is an expert in handling difficult bulk materials – those that are fragile, friable, or abrasive – through fully enclosed dense- and dilute-phase pneumatic conveying systems. Minimizing breakage of materials means less dust.

The second area of focus has been explosion mitigation. This is generally accomplished through the use of explosion panels, venting systems, and/or explosion suppression systems. Panels and venting can help control the release of energy in case of an explosion, which can minimize damage to the plant and increase personal safety. There is, however, damage to the processing system itself, as well as loss of material. Suppression systems, on the other hand, stop the explosion but leave materials and conveyors contaminated with the chemical used to quench the explosion.

Nol-Tec has therefore partnered with Air Products and Chemicals on research for a system to prevent dust explosions through the use of inert gases for conveying. Removing oxygen means that in the vast majority of cases no explosion is possible. Nol-Tec researchers co-authored a paper in the March 2015 issue of *Chemical Engineering*. With over 30 years' experience, Nol-Tec is in an exceptional position to understand dust explosions. **www.nol-tec.com**

Plastic control valves handle corrosive chemicals

Collins 2-in. valves and actuators are specially designed to handle corrosive fluids – acids, bleaches, chlorine, pH control – and aggressive environments

Collins Instrument Company's line of economical 2-in. flanged plastic control valves handle corrosive liquids including hydrochloric acid, caustic, sulfuric acid, and many others. With bodies of either PVDF or polypropylene, these highly-responsive control valves are specifically designed for use with corrosive media and/or corrosive atmospheres.

Suitable for applications in numerous industries, including chemical, petrochemical, pulp and paper, and municipal, these valves are extremely corrosion-resistant, and feature fast-acting positioning (stroke rate approximately ½ in./s). They are available with a wide selection of trim sizes, in globe, angle, and corner configurations.

The differential-area piston eliminates the necessity for auxiliary loading regulators. All actuator parts apart from the integral positioner are molded of glass-filled, UV-inhibited polypropylene. Before shipment, the aluminum positioner and a portion of the cylinder are immersed in Dip Seal to provide atmospheric protection.

Plastic valves and actuators from Collins

The integral positioner eliminates the need for external linkages which are subject to corrosion and malfunctioning. Valves may also be furnished without a positioner for on/off applications.

Collins also offers a plastic pneumatic actuator. The combination of a plastic actuator and a plastic valve body provides an effective way to handle both corrosive materials flowing through the valve, and harsh environments that can attack the outside of the valve and actuator. Collins plastic control valve packages withstand salty marine atmospheres as well as industrial environments that are too corrosive for metal valves and actuators.

Collins actuators incorporate a unique internal locking ring to attach the cylinder to the yoke. A semicircular groove is machined inside the lower edge of the cylinder, and a matching groove cut in the yoke. When the yoke and cylinder are assembled, a flexible polypropylene rod is inserted into the groove through a slot in the side of the cylinder, securing the two sections together.

Along with its corrosion resistance the Collins control valve features a stem packing arrangement that virtually eliminates the problem of fugitive emissions, thereby protecting the environment.

Located on the Texas Gulf Coast in the town of Angleton, Collins Instrument Company has been serving the chemical and petrochemical industry for over 65 years. **www.collinsinst.com**

What you don't know can cost you

RedGuard explains some myths around blast-resistant buildings, which can be cost-effective as well as offering excellent protection to people and assets

Well-designed blast-resistant buildings are in no way inferior to traditional constructions, says RedGuard

A lot of myths still surround the use of blast-resistant buildings (BRBs) as traditional building replacements, *writes Tim Taton, North American Sales Manager with* **RedGuard**. Understanding these myths could save many thousands of dollars, not to mention lives.

Myth #1: Modular blast-resistant buildings (BRBs) are only available for lease.

When we pioneered the BRB industry, we offered only lease units, but we quickly learned that every application is different.

Fact: Our SafetySuites are permanent BRBs that can be purchased to meet specific operational needs for years to come.

Myth #2: BRBs are only for rush construction jobs.

Though SafetySuites can be erected in a fraction of the time needed for traditional buildings, they are a superior, permanent construction solution. They often cost less than traditional buildings, and do a better job of protecting personnel and resources.

Fact: BRBs are superior to traditional buildings for all construction projects.

Myth #3: BRBs lack the comforts and amenities of traditional buildings.

This myth is probably a holdover from the early days, when all of our engineering resources were devoted to creating the safest building in the world.

Fact: The inside of a SafetySuite is often indistinguishable from that of a traditional building, offering all the same amenities.

Myth #4: A blast pressure rating is the only important factor when specifying a BRB.

Blast pressure is a key part of the BRB design formula, but duration and response level ratings tell the real story of how a BRB will hold up to a blast. Some manufacturers claim a 5 or 8 psi rating, but with a high response level. This is virtually meaningless, as "high response" equates to high damage, with a high risk of casualties. Interior fittings are important, too, since a tough steel box, alone, does not make a safe BRB.

Fact: Blast pressure ratings, taken alone, can provide a misleading view of safety.

Myth #5: BRB design is still experimental.

While blast engineering is a comparatively new science, RedGuard has worked with some of the world's most respected authorities—and then performed blast testing under realistic conditions. A SafetySuite designed for a specific application will protect personnel during a blast event, at a fraction of the cost and construction time of a traditional building.

Fact: SafetySuites are built on proven engineering concepts that have been fully tested and proven safe. **www.redguard.com**

A world leader in combustion technology

Zeeco has nearly four decades of experience in designing, supplying, and servicing burners, flares, thermal oxidizers, and flare gas recovery systems

People count: Zeeco provides rapid service at crucial times

Zeeco is a world leader in the design and manufacturing of combustion and environmental technologies for the chemical, refining, petroleum, petrochemical, LNG, marine and offshore, and pharmaceutical industries. The company's reputation comes from nearly 40 years of innovative burner, flare, thermal oxidizer, and flare gas recovery system designs. Zeeco's Aftermarket: Parts, Service, and Engineered Solutions group delivers heroic turnaround times and localized project response on a worldwide level. With a dedicated Houston service center and personnel located throughout the Gulf Coast region, Zeeco is well positioned to meet today's challenges of emission regulations and efficient, reliable operation.

Tight turnarounds are no problem for Zeeco. Gulf Coast refineries and chemical plants experiencing unplanned outages count the cost per minute until the plant resumes operation, so the pressure to deliver replacement items be intense. Zeeco's Rapid Response Team is built from the ground up to meet those demands from the quote/engineering process through to shipment or installation of the new components. One recent Saturday morning, Zeeco received word that a facility in Corpus Christi, Tex., undergoing a turnaround had identified damaged gas heads, inoperable air doors, and corroded air/gas mixer bodies on non-Zeeco burners. The affected heaters needed to be back in service in three days. Zeeco reviewed the situation and offered several options including back works assembly, burner inserts/mixers, gas tips, and complete burner assemblies to directly replace another OEM's equipment. The Zeeco team worked through the night to complete the order and shipped the complete burner inserts and gas tips before noon on Sunday. The facility received the shipment on Monday morning and replaced the failed components in time to meet the deadline.

Zeeco employs industry-leading combustion experts with experience in the world's largest facilities to conduct preventative and cost-saving pre-turnaround maintenance inspections. A complete inventory analysis and component checklist is conducted to help customers prepare, including a list of the necessary parts and components needed during the next turnaround. Customers save not only on expediting fees but also by eliminating errors caused by inexperienced technicians. Zeeco has thousands of installations worldwide and a team of more than 1,000 experienced combustion experts. **www.zeeco.com**

Minimizing downtime, maximizing performance

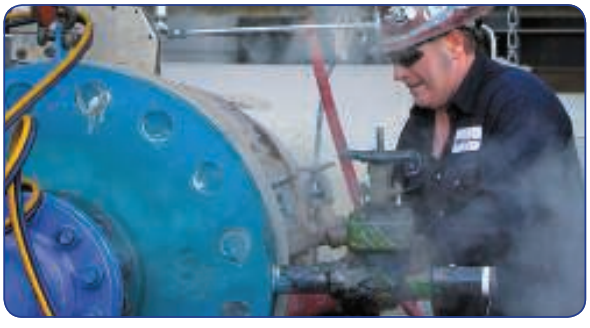
Team Industrial Services offers a wide range of specialized services that allow plant turnarounds to be conducted quickly, effectively, and above all safely

Turnarounds allow for necessary maintenance and upkeep of operating units and are needed to maintain safe and efficient operations. Founded in 1973, **Team Industrial Services** is the worldwide leader in minimizing equipment and asset downtime, providing a number of services to assist with turnarounds and outages including on-line maintenance, inspection and repair. The company provides critical services to its customers that enable them to maintain and operate their facilities and equipment in a safe and productive manner.

Team's line of specialized industrial services includes bolting/torquing, concrete repair, emissions control, exchanger services, field machining, fitness for service, heat treating, hot tap/line stop, isolation test plugs, leak repair, manufacturing/engineering, mechanical integrity, NDE/NDT inspection, project services, specialty welding, turnkey tank program, valve insertion, and valve repair.

Team employs only the best, most qualified technicians to ensure each and every job is completed to the highest standards every time. The company maintains management systems and documented work procedures designed to assure compliance with all applicable laws, regulations and internal requirements, as well as to facilitate the continuous improvement of its processes, products, and personnel. The highest priority at Team is the safety of employees, clients, and other contractors. The company is committed to safety excellence and strives daily for zero injuries and incidents.

Today, Team is rapidly growing its global footprint across a wide range of industries – with service locations in five continents. The company recognizes that its global success is ultimately measured by its customers' trust and confidence, which can only be earned through continuing outstanding service. Team's trained and certified technicians are available worldwide 24/7/365. From single part repair to turnarounds and shutdowns – planned or unplanned – Team has the training, experience, technology and know-how to deliver high-quality maintenance, inspection, and testing services anytime, anywhere. **www.TeamIndustrialServices.com**



Safe working methods are always a priority for Team personnel

Get *Chemical Engineering*'s Plant Cost Index to improve plant cost estimates…and delivered in advance of the print edition!

CHEMICAL ENGINEERING
Plant Cost Index

For more than 40 years, chemical process industries professionals- engineers, manager and technicians, have used Chemical Engineering's Plant Cost Index to adjust process plant construction costs from one period to another.

This database includes all annual archives (1947 to present) and monthly data archives (1970 to present). Instead of waiting more than two weeks for the print or online version of Chemical Engineering to arrive, subscribers can access new data as soon as it's calculated.

	Sep '06 Prelim.	Aug '06 Final	Sep '05 Final
CE Index	513.1	510.0	467.2
Equipment	606.5	602.3	541.2
Heat Exchanges and Tanks	565.1	560.9	509.2
Process Machinery	559.6	556.2	521.7
Pipe, valves and fittings	734.7	731.7	620.8
Process Instruments	441.4	437.2	379.5
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Construction Labor	314.7	312.9	309.1
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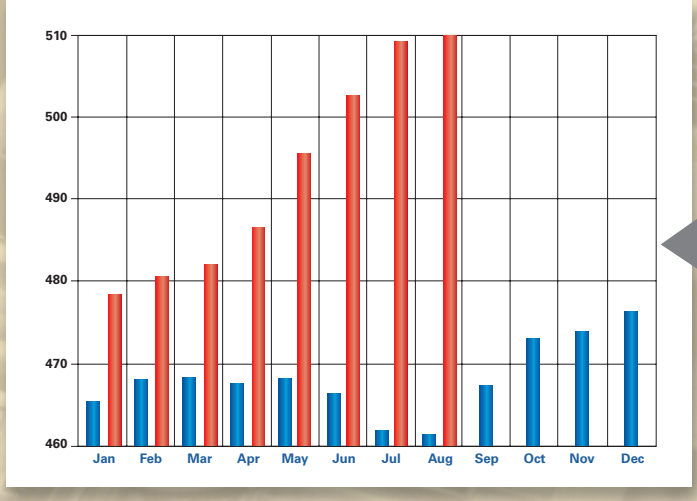

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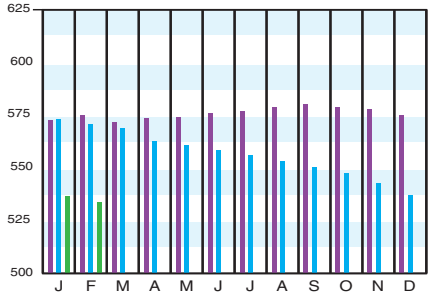
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Feb. '16 Prelim.	Jan. '16 Final	Feb. '15 Final
CE Index	533.9	536.4	570.5
Equipment	636.9	640.5	691.8
Heat exchangers & tanks	546.2	551.7	631.4
Process machinery	647.7	649.3	674.0
Pipe, valves & fittings	791.2	795.0	863.2
Process instruments	379.0	378.9	403.9
Pumps & compressors	972.2	979.1	950.9
Electrical equipment	506.7	509.0	513.8
Structural supports & misc	700.0	701.9	748.0
Construction labor	319.2	319.6	318.4
Buildings	536.8	537.7	545.3
Engineering & supervision	316.3	316.6	319.6

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

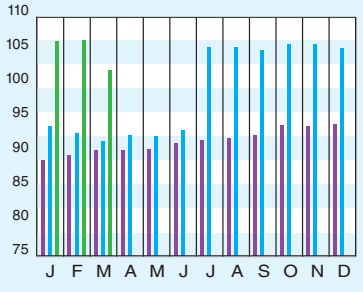
Annual Index:
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8



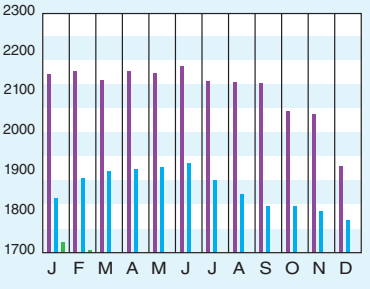
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS		YEAR AGO
CPI output index (2012 = 100)	Mar.'16 = 102.1	Feb.'16 = 102.1	Jan.'16 = 102.2	Mar.'15 = 100.9
CPI value of output, $ billions	Feb.'16 = 1,706.6	Jan.'16 = 1,713.4	Dec.'15 = 1,773.5	Feb.'15 = 1,911.4
CPI operating rate, %	Mar.'16 = 75.1	Feb.'16 = 75.1	Jan.'16 = 75.1	Mar.'15 = 74.8
Producer prices, industrial chemicals (1982 = 100)	Mar.'16 = 219.2	Feb.'16 = 221.7	Jan.'16 = 225.0	Mar.'15 = 244.7
Industrial Production in Manufacturing (2012=100)*	Mar.'16 = 103.1	Feb.'16 = 103.4	Jan.'16 = 103.5	Mar.'15 = 102.7
Hourly earnings index, chemical & allied products (1992 = 100)	Mar.'16 = 159.2	Feb.'16 = 158.7	Jan.'16 = 160.5	Mar.'15 = 157.6
Productivity index, chemicals & allied products (1992 = 100)	Mar.'16 = 102.8	Feb.'16 = 102.6	Jan.'16 = 102.6	Mar.'15 = 101.8

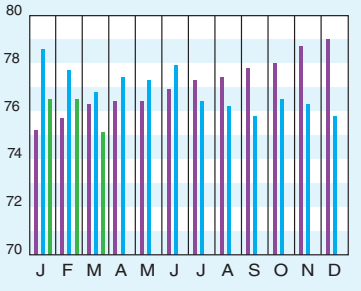
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The February 2016 preliminary value for the *CE* Plant Cost Index (CEPCI; top; the most recent available) was down from the previous month, with all subindices seeing a small decline. Within the Equipment subindex, the process instruments category was the only one experiencing an increase. The preliminary CEPCI value for February 2016 is 6.4% lower than the corresponding value from February last year. This is a smaller year-over-year difference than the previous month. Meanwhile, the latest Current Business Indicators (CBI; middle) for March 2016 showed that the values for the CPI output index and the CPI operating rate were unchanged from the previous month. CPI value of output for February was down from the previous month.

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