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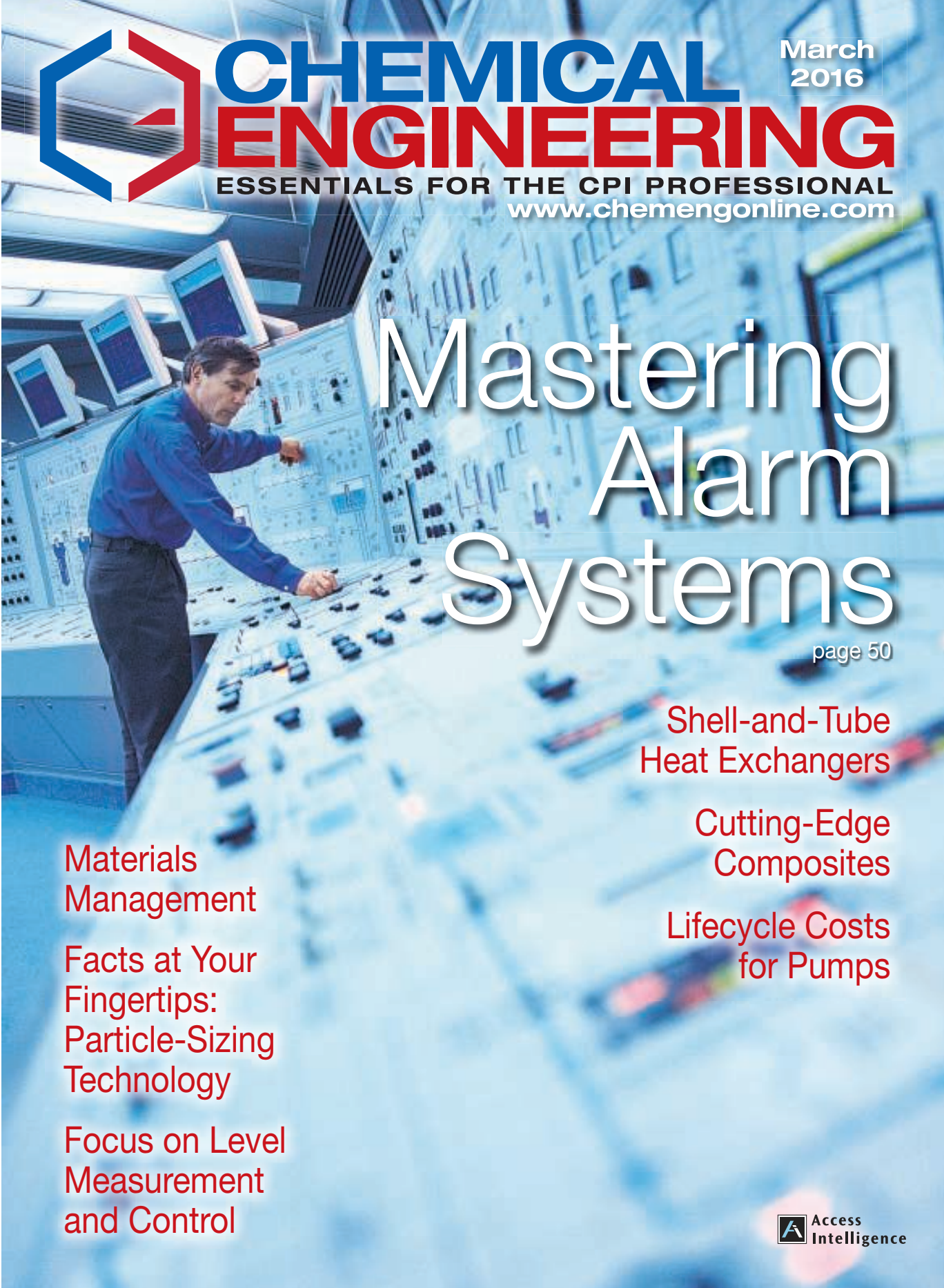

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page 50

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March 2016 Volume 123 | no. 3

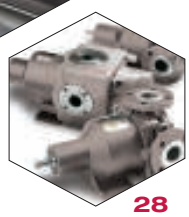
Cover Story

In the News


50


56


18


28

Technical and Practical

36

75

79

40

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BPA

Editor's Page

Advancing with automation

Many, if not most, of us have heard of the Industrial Internet of Things (IIoT). Simply stated, it refers to the manufacturing application of the Internet of Things, or the interconnectedness of "smart" machines. Similar to what we see with the rapid advances to our personal devices, such as smart phones, smart cars, smart televisions and more, smart devices in industrial settings offer the ability to move to new manufacturing strategies.

A number of the new technologies that are enabling the IIoT include mobile devices, self-learning machines, drones, 3-D visualization, cloud applications and more. At the recent ARC Industry Forum, "Industry in Transition: Navigating the New Age of Innovation" (February 8–11; Orlando, Fla.), Andy Chatha, president of ARC, suggested that more "connected" products are and will continue to be available for the production environment. Just as an automobile company can monitor cars in the field, he envisions that industrial machine manufacturers would be able to monitor their equipment (pumps, for example) over the lifetime of the asset. Chatha expects that the "cloud connected plant is at hand," with connected machines, supply chains and workers. Designing for connectivity, however, needs to be done from the start.

A significant step toward a new process-automation system

Cybersecurity and open platforms for interconnectivity are important challenges for advances in process automation. Lockheed Martin (Bethesda, Md.; www.lockheedmartin.com) was recently contracted by ExxonMobil Research and Engineering Company (EMRE) to develop a "next-generation" open automation system for process industries. According to EMRE's vice president of R&D, Vijay Swarup, "This breakthrough initiative could help transform refining and chemical manufacturing through the use of high-speed computational components, modular software, open standards and the use of autonomous tools." The intention is to design the platform with intrinsic cybersecurity protection that can be adapted to emerging threats. This development represents a new approach to process automation.

Training with new technology

One way in which technology can enhance manufacturing procedures is through training programs with advanced simulators. While there is much going on with 3-D immersive simulators for training, advanced screen simulators can address a number of the challenges facing today's plants, such as engaging new operators in a familiar "game-like" environment, providing realistic "hands-on" training and preparing operators to respond to unplanned events. Simulators can help, for example, to manage alarms (see our two-part feature on alarm management in this issue, pp. 50–60). At the ARC Forum, Ron Cisco, O&M supervisor IV with the Salt River Project – Coronado Generating Station, gave an insightful presentation on how use of a modern-day simulator resulted in an "observable increase in confidence and knowledge levels of trainees."

Keeping up-to-date with the latest technologies in process automation is increasingly important for the chemical process industries (CPI), as the advances are coming quickly and can bring significant changes to the way manufacturing plants operate. While caution in implementing new systems is warranted, the new technologies offer a wide breadth of new possibilities. ■

Dorothy Lozowski, Editor in Chief

Letters

Designing for distillation

I read your article "Flooded Condenser Controls: Principle and Troubleshooting" [*Chem. Eng.*, January 2016, pp. 37–49]. The article was very informative. Thank you for sharing your knowledge and experience.

I need your guidance related to Figure 4b. In the article you have stated: "A common design practice is to introduce the liquid from the top of the drum via a slotted or perforated pipe, . . . especially in situations with a high degree of sub cooling, such as during cold winter nights or low-rate operation."

In this article you have not given the method/design of the slotted pipe or perforated pipe for liquid inlet. Can you please share your experience and knowledge on how to size the slotted or perforated pipe so that system will operate with less trouble over the entire operating range and ambient condition?

I have faced this problem (i.e., hammering due to vapor collapsing, pressure fluctuation) while running the system at turndown condition during winter nights when ambient temperature reached to around 5°C. At that time to avoid hammering, we have operated the system above turndown condition by diverting the entire flow to one system and closing the second parallel system and the system worked fine. Thank you

Mehul Gandhi

Author's response:

Many thanks for your kind words about my article.

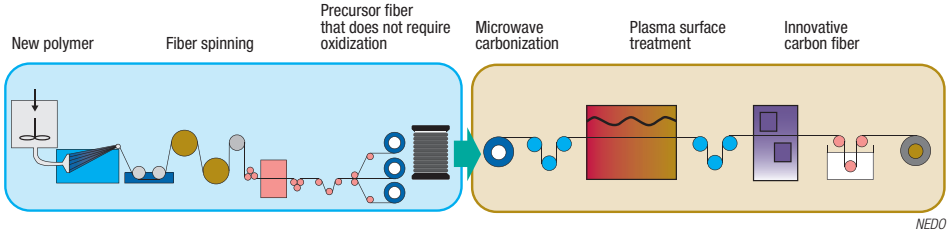
As you could have inferred from the article, the line that you quoted, "this method is better than introducing all the liquid into the vapor space, but is not as good as introducing all the liquid near the bottom of the drum" means exactly what it says. My experience is that the best method is to introduce all the liquid near the bottom of the drum, no slots. When we had to deal with an existing pipe with slots that hammers at turndown, we just blanked the slots or replaced the slotted pipe with one that has no slots. In Figure 4 we used a solid pipe that went down to about 6 in. above the drum floor, no slots. Recently we experienced two incidents of hammering similar to yours. Both had slotted pipes that were designed by others. In one, we blanked the slots — no more hammering since. In the other, we did not have a turnaround yet. Reducing the condensate subcooling (by switching off fans or cutting on cooling water) had been effective in both and other cases, but switching off fans or throttling cooling water generates its own problems. I also like your solution of increasing the loads to get the system out of turndown — neat.

Normally the pipe size is usually dictated by the maximum flowrate, typically designed for no more than 3–4 ft/s liquid velocity at maximum rate to avoid incurring excess turbulence.

Henry Kister
Fluor, Aliso Viejo, CA, 92698

Editor's note: Some excerpts were removed from the above letters to fit to page. The full letters can be found on our website at www.chemengonline.com

Making more carbon fibers for less



NEDO

An efficient, energy-saving process for making carbon fibers (diagram) is being developed by a collaboration team of the University of Tokyo, the Institute of Industrial Science and Technology (AIST), Toray Industries, Inc., Teijin Ltd., Toho Tenax Co. and Mitsubishi Rayon Co. The team expects to enhance the production capacity to nearly 20,000 ton/yr in a single production line — ten times higher than existing production lines — while lowering production costs and cutting CO_2 emissions in half. Started in 2014, the four-year project is being supported by the Japanese Ministry of Economy, Trade and Industry under a program of the New Energy and Industrial Technology Development Organization (NEDO, Kawasaki, Japan; www.nedo.go.jp), and is being coordinated by professor Kazuro Kageyama at the University of Tokyo.

The key achievements thus far are: new precursor polymers have been developed by Toray that do not require an oxidization pretreatment to impart flame-retarding properties; a direct, microwave-based carbonization technology operating at atmospheric pressure has been developed by Teijin; and a dry, very fast plasma surface-treating process that enables control of the surface properties of the carbon fibers has been developed by Teijin.

The new precursor polymers enable the production of up to 24,000 filaments to be spun per "toe" to make carbon fibers with diameters of 9–17 μm, which is two times thicker that fibers made by conventional polyacrylonitrile (PAN)-based polymers. The carbonization yield is also 1.5 times higher than PAN-based fibers, says NEDO. By the end of the project, the team plans to develop a commercial production line to make fibers with "excellent" mechanical properties (tensile elasticity in the range of 240 GPa, and a 1.5% elongation — equivalent to the existing PAN-based fibers).

Bio-based BTX test facility breaks ground in Texas

Construction has begun on a testing and development facility for a bio-based process to produce benzene, toluene and xylenes (BTX) from woody biomass. The test facility is intended to demonstrate all unit operations and prove process economics for the Bio-TCat process, a proprietary thermal catalytic biomass-conversion technology developed by Anellotech Inc. (Pearl River, N.Y.; www.anellotech.com) in partnership with IFP Energies Nouvelles (Rueill-Malmaison, France; www.ifpenergiesnouvelles), a public-sector research institute, Axens (Rueill-Malmaison, France; www.axens.net) and Johnson-Matthey Catalysts (London, U.K.; www.matthey.com).

The facility, known as TCat-8, has been pre-fabricated on skids and will be installed and operational by the end of 2016 at an existing chemical production site known as South Hampton Resources, a wholly owned subsidiary of Trecora Resources, in Silsbee, Tex., says Anellotech CEO David Sudolsky. It will process about 1,000 lb/d of biomass when commissioned.

The biomass conversion technology has been advanced and scaled up since the company was formed to commercialize catalytic fast-pyrolysis technology developed in the laboratory of George Huber at the University of Massachusetts (Amherst; www.umass.edu), but the fundamental elements of the technology remain the same (*Chem. Eng.*, August, 2009, p. 13). The process is capable of generating cost-competitive BTX using a one-reactor system directly from non-food biomass, Sudolsky says. Anellotech is working with Johnson-Matthey on a new variation of its catalyst, and with IFP on process technology for the fluid-bed reactor and the overall process development program.

Anellotech has received several significant investments in the technology in the past year, including from the beverage company Suntory, which is interested in bio-based aromatic chemicals for making renewable polyethylene terephthalate (PET) drink bottles.

Edited by:
Gerald Ondrey

BIO-BASED PET

Later this year, Suntory Holdings Ltd. (Osaka, Japan; www.suntory.com) will start up a demonstration plant in Silsbee, Tex. for the production of 100% bio-based PET bottles. The company will introduce these PET with its Suntory Beverage & Food's mineral water under the "Suntory Tennensui" brand.

Up to now, most bio-based PET bottles contain 30 wt.% bio-based mono ethylene glycol, with the remainder made up of petroleum-based terephthalic acid. In 2012, Suntory and Anellotech Inc. (Pearl River, N.Y.; www.anellotech.com) began to jointly develop bio-based aromatics, including bio-*para*-xylene, the key component needed to make bio-based PET bottles. In order to avoid competition with the food chain, two companies aim to use only non-food biomass (wood chips) to produce *p*-xylene, a precursor to terephthalic acid, which makes up 70% of PET resin.

FURFURAL FROM PULP

Next month, Oji Holdings Corp. (Oji, Tokyo; Japan; www.ojiholdings.co.jp) plans to test marketing of furfural being manufactured in its verification plant, which produces furfural as a coproduct in the production of "dissolving pulp" made from wood chips at its Oji Paper Yonago Mill, Tottori Prefecture.

In the production of dissolving pulp, furfural is continuously separated from the hemi-cellulose. Furfural is used mainly as a solvent in petroleum refining and for the production of lubricants, but has the potential to be used as a precursor for bioplastics, such as polyurethane and PET.

(Continues on p. 8)

Note: For more information, circle the 56-digit number on p. 90, or use the website designation.

Dissolving pulp is a pulp manufactured by enhancing the purity of cellulose, the main component of wood. The term generally refers to pulp with a cellulose content of 90% or greater, compared with about 85% for pulp for general paper manufacturing. Dissolving pulp is mainly used as feedstock for rayon or acetate that is used in applications such as clothing, and demand for the substance is expected to increase in the future.

BIO-GASIFICATION

Researchers at Southern Illinois University (SIU; Carbondale, Ill.; www.siu.edu) are developing microbial processes to convert coal into methane. The team has developed strains of bacteria and archaea that consume coal and excrete methane, and is looking at how to apply them to waste coal leftover from mining operations, as well as to in-situ coal, such as material left in abandoned coal mines. The researchers say the microbes and associated processes could allow the harvesting of methane from areas where the coal is "unmine-able" for various reasons, such as poor quality, small seams, or dispersed distribution of coal. More than 200 species were identified from samples taken from water surrounding coal deposits. The researchers then applied various techniques to stimulate the microbes' production of methane.

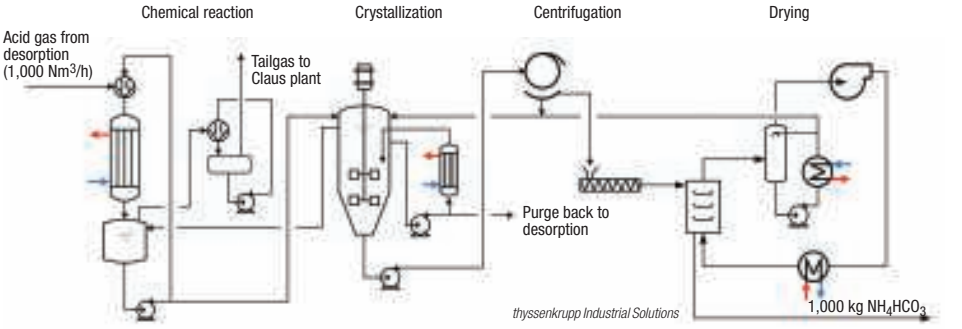
RECYCLING BRINE

Covestro AG (Leverkusen, Germany; www.covestro.com) is testing a new process for recycling saline process wastewater that is generated in the production of polycarbonate, a high-performance plastic. A pilot plant for the process, located at the Krefeld-Uerdingen site in Germany, was opened last month.

The current project at Cove-

(Continues on p. 10)

Monetizing coke-oven gas, while capturing CO_2



A process that converts process gases, generated during the production of metallurgical coke, into marketable chemicals is being developed in a pilot plant installed on the works site of thyssenKrupp Steel Europe AG (www.thyssenkrupp-steel-europe.com) in Duisburg, Germany. The process is being developed in a collaborative project by the Schwelgern coke plant (KBS), plant-engineering company thyssenKrupp Industrial Solutions AG (Essen; www.thyssenkrupp-industrial-solutions.com) and Berlin Technical University (TU Berlin; all Germany; www.tu-berlin.de).

In the conventional treatment of coke-oven gas (COG), H_2S and NH_3 are scrubbed from COG with aqueous ammonia solutions (deacidified water, stripped water) by the CyclaSulf process. The rich absorption solution (enriched water) is pumped to the regeneration, H_2S/NH_3-desorption column. The head product of the H_2S/NH_3-desorption is acid gas, which is rich with H_2O, NH_3 (20–30 vol.%), CO_2 (15–25 vol.%) and H_2S. The rate of H_2O, NH_3 and CO_2 in acid gas is nearly equimolar, which makes it possible to synthesize crystalline ammonium bicarbonate.

In the new, patented process (flowsheet), the acid gas from the CyclaSulf process is first compressed (by acid-gas-condensate jet flow) in a jet ejector, where a spontaneous condensation of H_2O and NH_3 takes place. The gas-liquid mixture flows directly from the ejector through a falling film apparatus, in which selective conditions accelerate the chemical absorption of CO_2 by NH_3. The condensate flows to a vessel, and the gas (mostly CO_2, H_2S and HCN) is directed to the Claus plant or the sulfuric-acid plant. In the collecting vessel, the absorbed CO_2 reacts further to HCO_3^-, and the NH_3 to NH_4^+. The condensate in the collecting vessel, which is produced under specific reaction conditions, is an under-saturated mother liquor of NH_4HCO_3. As the mother liquor is fed to the crystallizer, a decrease in temperature causes the NH_4HCO_3 to crystallize and precipitate from the solution. The suspension is then centrifuged and the crystalline NH_4HCO_3 dried to achieve the final product quality.

With the pilot plant, 95% of the ammonia contained in the COG can be utilized, producing 15 kg/h of solids from 15 Nm^3 of acid gas and 2 Nm^3 of CO_2. A commercial plant — for example a medium-sized coke plant with a capacity of 150,000 Nm^3/h COG and a concentration of 6 gr/Nm^3 ammonia in COG — could produce 4.2 ton/h of NH_4HCO_3, in addition to the other byproducts produced (tar, COG, sulfur and benzene, toluene and xylenes).

The end products can be put to a range of uses, such as nitrogen fertilizers, propellants and foaming agents for plastics or porous ceramics, and also in the food industry (baking soda). Although the process economics have to be evaluated individually for each coke plant, some samples of byproduct plants that have been economically analyzed have shown a return on investment after 3–5 years, say the companies.

Collaboration lowers cost for bio-based FDME process

A partnership between DuPont Industrial Biosciences (Wilmington, Del.; www.dupont.com) and Archer Daniels Midland Co. (ADM; Chicago, Ill.; www.adm.com) has developed a less costly and more efficient process for producing bio-based furan dicarboxylic methyl ester (FDME) from the six-carbon sugar fructose. Applications for the renewable material could be in packaging, textiles, high-performance plastics and others, the companies say.

FDME is a high-purity derivative of furandicarboxylic acid (FDCA), one of 12 building blocks identified by the U.S. Dept. of Energy that can be converted into a number of high-value, bio-based chemicals. Despite consid-

erable effort, an economically viable process for FDME had not been achieved previously.

"Some of the hurdles [to commercial-scale FDME] in the past have been low yields and high capital requirements, as well as the ability to provide materials with polymer-grade purity," explains Simon Herriott, global business director for biomaterials at DuPont. DuPont and ADM were able to increase the cost-effectiveness of the process by integrating process steps to reduce capital cost requirements and lower energy use while simultaneously boosting yield.

The FDME process begins with fructose from cornstarch. The fructose is dehydrated and the products from the reaction are oxidized to form FDCA. The FDCA is then reacted with methanol, resulting in FDME.

DuPont and ADM are targeting late 2016 to complete a 60 ton/yr pilot plant in Decatur, Ill. to produce bio-based FDME.

Among the first applications of the compound will be to make polytrimethylene furandicarboxylate (PTF), a polyester made from FDME and DuPont's bio-based propanediol through a condensation process. "We believe that PTF will find uses in the carbonated beverage packaging industry (and other applications) due to its superior gas-barrier properties," says Herriott.

Progress for high-efficiency ammonia-cogeneration plant

A process that produces anhydrous ammonia while also generating thermal power has reached a milestone toward commercialization. In January, Amec Foster Wheeler (AFW; London, U.K.; www.amecfw.com) was awarded a project development and design contract for the world's first plant to employ Grannus LLC's (Tucson, Ariz.; www.grannusllc.com) process, which combines ammonia production with advanced power generation. At present, AFW has completed initial front-end engineering design (FEED) work for the plant, and the project is preparing to initiate the permitting process for a site in Kern County, Calif., says Corey Smith, vice president of corporate development at Grannus. The plant, which is slated for startup in late 2017, will produce around 80,000 metric tons per year (m.t./yr) of anhydrous ammonia.

The exhaust [in the form of synthesis gas (syngas)] from a partial oxidation boiler is sent to the reaction vessel, where ammonia is produced via the Haber-Bosch process. The excess process heat from the syngas formation is used for steam co-generation, supplying electric power. According to Smith, the only raw materials required for the process are natural gas, air, electricity and limited amounts of water, making it more efficient than competing processes that employ steam-methane reformers (SMR). "The process utilizes 100% of the natural gas input as feedstock rather than utilizing a portion as fuel as in an SMR-based system," explains Smith. Although the process can be configured for world-scale plants, the company believes that transportation and financing factors provide great opportunities for regional-scale plants, as long-haul freight can be eliminated and customers are provided with an uninterrupted product supply.

stro marks the first time in Germany that saline industrial wastewater has been recycled at an industrial pilot plant. Pretreated salt water such as this is usually released into waterways, specifically the Rhine river, which runs directly along the site. Thanks to the new plant, some of this wastewater can now be used in an electrolysis process to manufacture chlorine. Chlorine itself is one of the key raw materials for producing polycarbonate and other plastics.

The new process helps save up to 30,000 metric tons per year (m.t./yr) of salt and 400,000 m.t./yr of fully desalinated water in chlor-alkali electrolysis. The process stops up to 70 m^3/h of saline wastewater from being released into the Rhine.

The total cost of investment is around €3.7 million, with €740,000 provided by the German Federal Ministry for the Environment.

Making aerogel absorbants from wastepaper

A team from the National University of Singapore (www.nus.edu.sg), led by assistant professor Duong Hai Minh from the Dept. of Mechanical Engineering, has succeeded in converting paper waste into cellulose aerogels that are nontoxic, ultralight, flexible, extremely strong, and water repellent. The team has produced a polysaccharide-based aerogel comprising a network of polysaccharide fibers with pores of a few micrometers. The large size of the pores enable the aerogel to absorb huge amounts of liquid.

Where the polysaccharide is cellulose, the aerogel has pores in the micrometer range, the diameters of the cellulose fibers are also in the micrometer range, and the lengths of the fibers are of the order of millimeters. For a nanocellulose aerogel, the pores are three orders smaller (in the nanometer range), the diameters and lengths are also three orders smaller — diameters of the order of nanometers and lengths in the order of micrometers.

The team developed a method for forming a polysaccharide-based aerogel by dissolving polysaccharide fibers from a recyclable material in a polysaccharide solvent in the presence of sound energy to form a polysaccharide dispersion, then forming the dispersion into an aerogel. Eventually the aerogel can be coated with an hydrophobic agent.

The team envisages many applications for the materials, including oil spill cleaning, heat insulation, packaging, coating for drug delivery, and as smart material for biomedical applications. When coated with trimethoxymethylsilane (MTMS), the aerogels are water repellent and are capable of absorbing oil up to 90 times their dry weight, making them up to four times more effective than commercial oil sorbents.

Duong said polypropylene-based absorbents are widely used for oil absorption, but they are non-biodegradable and their absorption capabilities are low and slow.

The team has also discovered a way of expanding the weight capacity of the aerogels, by infusing the fibers of the aerogels with a solution of metallic nanoparticles. The aerogels are then hammered flat to remove most of the air, resulting in a magnetic thin film with a weight capacity of more than 28 m.t./cm^2.

Extracting platinum metals

The traditional method for recovering platinum-group metals (Pt, Pa, Ir, Os, Rh, Ru and Au) is not economically viable in the case of low-grade deposits, but researchers from the Western Australian School of Mines, Curtin University (Perth; www.curtin.edu.au) and the Dept. of Processing Engineering, Stellenbosch University (Matieland, South Africa; www.sun.ac.za) may have found a cost-effective alternative.

One of the researchers, professor Jacques Eksteen of Curtin University, says the traditional smelting process can be replaced with low-cost leaching. He said: "We found that if we could recover economic levels of platinum metal using heap leaching, then we were able to recover it from solution."

Platinum-group metals form a complex range of 30 to 40 minerals, each with a different resistance to leaching, making it difficult to find a unique solution for all deposits, explains Eksteen. Once leached, the metals are adsorbed from solution on to activated carbon, he says. The next step is to elute (wash with solvent) metals from the carbon in a concentrated form so they can be released one by one.

The researchers investigated the feasibility of eluting platinum- and palladium-cyanide complexes from activated carbon with the well-known ARRL (Anglo American Research Laboratory) process. The AARL process consists of three steps: a hot acid wash followed by a hot caustic cyanide pre-treatment and afterwards elution with hot deionized water at high pressures (up to 300 kPa). According to the researchers, test results show that effective elution of platinum- and palladium-cyanide with the AARL method is feasible.

Graphene-based membranes

Graphene has received much attention as material for membranes due to its high surface area, high mechanical strength and chemical stability. Graphene-based membranes are also expected to exhibit much greater permeability than the current state-of-the-art membranes. However, it has been difficult to fabricate leak-free porous graphene membranes with large surface area; and besides, supported graphene is hydrophobic. Those limitations have led to the development of graphene oxide with oxygen-containing functional groups (–OH, –COOH) attached to both sides of the graphene flake.

Researchers from Ngee Ann Polytechnic (Singapore; www.np.edu.sg) and Newcastle University (Newcastle-upon-Tyne, U.K.; www.ncl.ac.uk) have reported a simple method for the fabrication of a graphene-based composite membrane for real downstream applications. To achieve this, they increased the graphene's wettability to ultra-wetting level by incorporating amine and carboxyl functionality onto it. While graphene oxide attains an increased level of hydrophilicity via –COOH and –OH functional groups, the researchers chose a combination of –COOH and $–NH_2$ functional groups instead to modify the graphene for use in water-filtration membrane applications.

(Continues on p. 13)

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(Continues from p. 11)

The novelty introduced by the researchers is that in addition to the presence of amine and acid functional groups, they covalently attached the ultra-wetting modified graphene to an anhydride polymer matrix — poly acrylonitrile-co-maleic anhydride (PANCMA) — via a simple condensation reaction to form poly(amic acid). The ultra-wetting graphene increases the water permeability of the membrane by 126% without any changes in selectivity.

The researchers believe the ultra-wetting graphene will be an ideal material for new-generation water-filtration membranes.

Novel cathode material for lithium-ion batteries

Initial validation testing has been completed on a novel cathode material that could lower the manufacturing costs and lengthen the lifetimes of lithium-ion batteries. The new cathode material represents a departure from the traditional Li-ion intercalation chemistry used in current batteries, in favor of a reduction-oxidation (redox) chemistry that offers several advantages.

"With intercalation, the lithium ions move into and out of the electrode lattice structure, and in doing so, degradation in the lattice structure over time reduces charge capacity," explains David Lee, CEO of BioSolar Inc. (Santa Clarita, Calif.; www.biosolar.com), the company that is commercializing the cathode material based on research at the University of California-Santa Barbara (www.ucsb.edu). The damage typically results in losses in energy storage capacity of 20% per 1,000 charge-discharge cycles, Lee says, adding, "Our approach was to use a redox chemistry that is fundamentally different from intercalation chemistry to avoid this type of storage capacity loss, and so extend battery life."

BioSolar's cathode uses a proprietary combination of commercially available polymers and other raw materials to make up the redox-supporting cathode structure. The polymer blend is then coated onto an aluminum substrate using a simple proprietary process. This method allows the cathode material to realize another key advantage: "It avoids the need for the relatively expensive and energy-intensive slurrying and calendaring processes required for the manufacture of current cathodes for Li-ion batteries," Lee remarks.

Lee says the new cathode material has the potential to lower the energy storage costs for Li-ion batteries to below $100/kWh — less than half of the current cost. And the material can be made using existing battery-manufacturing infrastructure, Lee stresses.

Following demonstration and validation of the new material, BioSolar is now working on optimizing the cathode, and then plans to test it inside a real Li-ion battery. Eventually, the company seeks to license the technology to battery manufacturers or start a joint venture to produce the battery, Lee says. ■

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Plant Watch

Evonik to expand capacity for special PA12 powder in Marl

February 10, 2016 — Evonik Industries AG (Essen, Germany; www.evonik.de) plans to build a new production line for special polyamide 12 powder (PA12) in Marl, Germany. The new plant, which is scheduled to become operational in late 2017, will increase Evonik's existing annual capacity for polyamide 12 powders by 50%.

LyondellBasell awards FEED contract to Fluor for Channelview PO/TBA plant

February 9, 2016 — LyondellBasell (Rotterdam, the Netherlands; www.lyondellbasell.com) has selected Fluor Corp. (Irving, Tex.; www.fluor.com) to perform front-end engineering and design (FEED) work for its proposed propylene oxide (PO) and tertiary butyl alcohol (TBA) plant in Channelview, Tex. The scope includes a PO plant with a capacity of around 450,000 metric tons per year (m.t./yr) and a TBA plant with a capacity of around 900,000 m.t./yr, as well as an ethers plant at the Bayport Choate site.

Solenis to double production capacity of polyacrylamide powders in Russia

February 8, 2016 — Solenis (Wilmington, Del.; www.solenis.com) is investing approximately $5 million at its facility in Perm, Russia to double the production capacity for polyacrylamide powders, which are used in a wide variety of water-based industries. Solenis will also create two new production lines to increase production of sizing and defoamer products.

Maire Tecnimont subsidiaries awarded EPC contract for Socar PE plant

February 5, 2016 — Maire Tecnimont S.p.A.'s (Milan, Italy; www.mairetecnimont.com) subsidiaries Tecnimont S.p.A. and KT–Kinetics Technology S.p.A. have signed an engineering, procurement and construction (EPC) contract with Socar Polymer for the realization of a polyethylene (PE) plant to be located in the Sumgayit Petrochemical Complex near Baku, Azerbaijan. The total contract value is approximately $180 million, and the plant will have a capacity of 120,000 m.t./yr of PE.

Gevo enters license agreement to build renewable isobutanol plants in Argentina

February 2, 2016 — Gevo, Inc. (Englewood, Colo.; www.gevo.com) has entered into an agreement with Porta Hnos. S.A. to construct multiple isobutanol plants in Argentina using corn as a feedstock. The first plant is to be wholly owned by Porta and is anticipated to begin producing isobutanol in 2017. The plant is expected to have a production capacity of up to five million gal/yr of isobutanol.

Chandra Asri completes major naphtha-cracker expansion project

January 25, 2016 — PT Chandra Asri Petrochemical Tbk (CAP; Jakarta, Indonesia; www.chandra-asri.com) announced the completion of a naphtha-cracker capacity-expansion project, which has been ongoing since 2013. After the expansion, the CAP's production capacity will increase by up to 43%, with ethylene capacity increased from 600,000 to 860,000 m.t./yr, propylene capacity increased from 320,000 to 470,000 m.t./yr, pyrolysis gas capacity increased from 280,000 to 400,000 m.t./yr and mixed C4 capacity increased from 220,000 to 315,000 m.t./yr.

Covestro expanding film production in Dormagen

January 25, 2016 — Covestro AG (Leverkusen, Germany; www.covestro.com) is expanding production capacity for polycarbonate films at its Dormagen site. The company is investing roughly €20 million in the construction of a new co-extrusion plant for multilayer flat films, including the associated infrastructure and logistics. The plant is scheduled to come onstream in 2017.

Ube Industries to build new cyclohexanone plant

January 21, 2016 — Ube Industries, Ltd. (Ube; Tokyo, Japan; www.ube-ind.co.jp) announced the adoption of a new manufacturing process for cyclohexanone, and will build a new facility in Ube City, Japan with a production capacity of 80,000 m.t./yr cyclohexanone. The new plant is scheduled for completion in Nov. 2017.

Wacker expands production capacity for functional silicone fluids

January 18, 2016 — The Wacker Group (Munich, Germany; www.wacker.com) has expanded its production capacity for functional silicone fluids at its Burghausen site. With an investment of around €26 million, the new expansion stage came onstream in early January. Functional silicone fluids serve as important precursors in the coatings, paper, textile, cosmetics and personal-care industries.

Mergers & Acquisitions

Rockwell Automation to acquire conveying system manufacturer

February 11, 2016 — Rockwell Automation (Milwaukee, Wis.; www.rockwellautomation.com) has agreed to purchase MagneMotion (Devens, Mass.; www.magnemotion.com), a manufacturer of intelligent conveying systems. MagneMotion will be integrated into Rockwell Automation's motion business, within its Architecture & Software segment. The acquisition is expected to close this quarter.

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Lanxess and Saudi Aramco to launch Arlanxeo JV in April

February 10, 2016 — Lanxess AG (Cologne, Germany; www.lanxess.com) and Saudi Arabian Oil Co. (Saudi Aramco; Dhahran, Saudi Arabia; www.saudiaramco.com) have announced that their new joint venture (JV) for synthetic rubber will be named Arlanxeo. All relevant antitrust authorities have cleared the transaction, and the JV will be launched on April 1, 2016.

Ametek completes acquisition of Brookfield Engineering

February 5, 2016 — Ametek, Inc. (Berwyn, Pa.; www.ametek.com) has completed the acquisition of Brookfield Engineering (Middleboro, Mass.; www.brookfieldengineering.com), a manufacturer of viscometers and rheometers. Acquired for approximately $167 million, Brookfield joins Ametek as a unit of its Instrumentation and Specialty Controls Division.

Virent and Tesoro form commercialization partnership

February 2, 2016 — Virent, Inc. (Madison, Wis.; www.virent.com) has entered into a strategic relationship with Tesoro Corp. (San Antonio, Tex.; www.tsocorp.com) to accelerate the development and commercialization of Virent's BioForming technology to produce bio-based fuels and chemicals. The agreement provides funding to Virent and allows for Tesoro to offer support during deployment.

Shell to divest majority stake in Malaysian refining company

February 1, 2016 — Royal Dutch Shell plc (The Hague, the Netherlands; www.shell.com) has reached a conditional agreement with Malaysia Hengyuan International Ltd. for the sale of Shell's 51% ownership stake in the Shell Refining Co. in Malaysia for $66.3 million.

Siemens to acquire simulation software supplier CD-adapco

January 25, 2016 — Siemens AG (Munich, Germany; www.siemens.com) and engineering simulation company CD-adapco (Melville, N.Y.; www.cd-adapco.com) have entered into an agreement for the acquisition of CD-adapco by Siemens for a purchase price of $970 million. CD-adapco's software products cover many engineering disciplines, including computational fluid dynamics, solid mechanics, rheology and heat transfer.

3M to sell Pressurized Polyurethane Foam Adhesives unit to ICP

January 21, 2016 — 3M (St. Paul, Minn.; www.3m.com) has entered into an agreement to sell its Pressurized Polyurethane Foam Adhesives business to Innovative Chemical Products Group (ICP). 3M's Pressurized Polyurethane Foam Adhesives business has annual sales of approximately $20 million.

AkzoNobel acquires full ownership of EkO Peroxide joint venture

January 19, 2016 — AkzoNobel N.V. (Amsterdam, the Netherlands; www.akzonobel.com) has acquired the outstanding shares in EkO Peroxide LLC from JV partner OCI Peroxygens LLC. Headquartered at AkzoNobel's site in Columbus, Miss., the JV owns and controls a hydrogen-peroxide manufacturing facility with a nameplate capacity of 70,000 m.t./yr. ■

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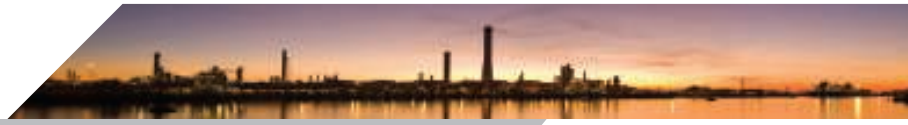

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FIGURE 1. As wind power becomes more universal, the manufacturing processes for turbine components must also grow more efficient

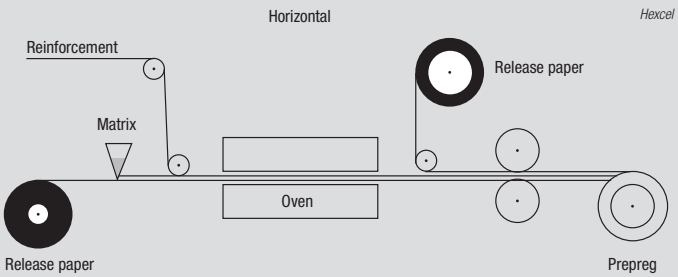
Cutting-edge Composites: Materials for a New Era

The combination of advanced materials and processing techniques results in new composites that can aid industries in achieving increased levels of efficiency

IN BRIEF

By their nature, composite materials lend themselves to a vast array of applications. A composite's constituent materials and processing methods can be tailored to yield seemingly infinite combinations of physical and chemical properties. Although composites have long been essential in countless industries, technological advances continue to expand their reach, and industries are increasingly seeking out cutting-edge materials to increase operations' sustainability. This article focuses on innovative composite materials and processing techniques designed for use in two major industries where sustainability and efficiency are key — wind power and aerospace.

HOW IS AN INDUSTRIAL COMPOSITE MADE?



Due to their considerable diversity, there are several widely used preparation methods for industrial composites. Hexcel's Wind Energy team explains one such method, wherein industrial composites are produced on horizontal (diagram) or vertical impregnation lines. A thermosetting, hot-melting epoxy resin is blended and filled into a resin bath, which is used for casting a film on silicone-coated release paper. The weight of the resin film is adjusted by the gap between the resin bath and the release paper, allowing for precise control of resin distribution and weight, and thus precise control of final composite weight. The reinforcement material (glass, carbon or aramide) is added onto the epoxy resin film, and the assembly is subsequently pulled through a heated impregnation zone, where the reinforcement material is impregnated by the resin, ensuring that no dry fiber is left. At this point, the release paper is removed, and the impregnated fabric (also called prepreg) is wound onto a core with a thermoplastic polyfilm interleaf. ❑

Elevating wind turbine efficiency

A major application area for composite materials is in wind turbines (Figure 1). With the push for more renewable sources of energy, wind-farm construction has intensified in recent years. Wind turbines must be able to withstand continued operations in extreme heat, freezing temperatures, precipitation, lightning, and of course, high winds. Composites' versatility and strength make them well suited for these environmental demands. Furthermore, the composite materials used for turbine components can actually make the overall turbine-manufacturing process more efficient.

Although many parts of a wind turbine, including the nacelle (the enclosed box that houses the various generating components) and spinner, can be constructed of composite materials, composites are mainly used for the rotor blades. "They have to be light, stiff, long-lasting and need to resist environmental influences," says Johannes Moser, R&T manager at Hexcel Corp. (Stamford, Conn.; www.hexcel.com). Hexcel's portfolio consists of epoxy-resin composites reinforced with glass or carbon fiber for high fatigue resistance. Since rotor blades can be massive structures, they must be produced in a very efficient manner, and the composite material's properties and handling requirements must withstand the rigors of the rotor-manufacturing process. "To develop an epoxy resin for wind-energy applications, the reaction enthalpy should fit the process. Furthermore, the mechanical properties of the resin have to fit with glass and carbon fiber," explains Hexcel's Wind

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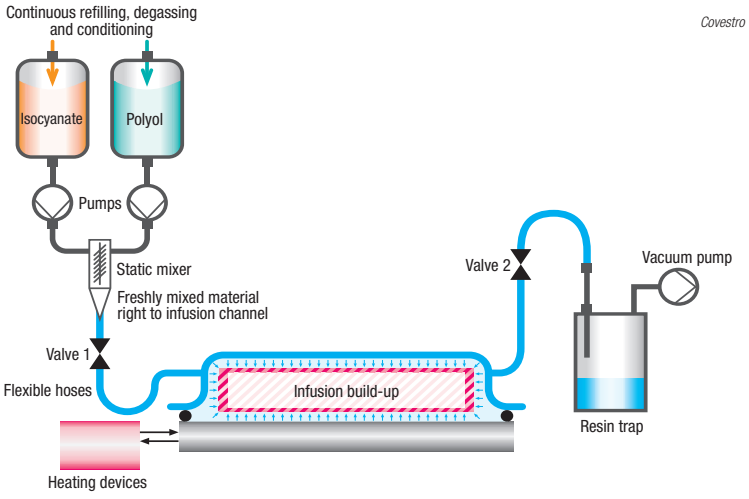

Covestro

FIGURE 2. This process infuses polyurethane resins throughout a glass-fiber matrix to form rotor-blade parts

Energy team.

One of the main considerations in making the rotor-manufacturing process more efficient is the curing temperature of the composite. The high curing temperatures (greater than 100°C in some cases) of some commercial composites are a major disadvantage, since a considerable amount of energy is released by the exothermic curing reaction, resulting in a temperature rise within the composite part. Moser emphasizes the number of issues that can arise with high curing temperatures, which include greater energy costs, and ensuring that the molds and any auxiliary materials used are stable at high temperatures. Additionally, more accurate process controls may be required to eliminate the risk of an uncontrolled exothermic reaction within the composite part. To address these concerns, Hexcel developed the new HexPly M79 material, which cures at temperatures as low as 70°C with a shorter cure time, while maintaining the same strength as conventionally cured composites. "A less exothermic reaction allows for the production of thick parts without risking superheating when curing," says Moser.

In late 2015, Covestro AG (Leverkusen, Germany; www.covestro.com) announced a milestone in the development of composite materials for wind turbines — the introduction of polyurethane, rather than epoxy, into the composite. "In the past, polyurethane has not been used for making composite parts using the vacuum infusion process," says Kim Klausen, head of Covestro's global wind projects. "Epoxy is the most widely used type of resin for this process. Today, 80% of all vacuum-infusion parts are made using epoxy." Vacuum infusion is a widely used process for constructing turbine blades, in which glass fabric is set up between two vacuum foils. At one end of the foils, a liquid resin is introduced, and a vacuum is applied at the other end. However, polyurethane resins have a much lower viscosity than epoxies, which allows for faster infusion and better wetting of fibers, explains Klausen. The polyurethane-based parts are also said to produce less heat during the curing process and experience low shrinkage, which results in accurate parts and decreased risk of fiber buckling.

Covestro

FIGURE 3. Polyurethane-based composites have been used to create large components for wind-turbine blades, including a 45-m spar cap

Covestro has collaborated with Saertex GmbH & Co. KG (Saerbeck, Germany; www.saertex.com) to determine the best type of glass to use with the resin. The non-crimp glass fabric used for the material imbues stability and strength, while helping to lower the weight of the overall blade. For the vacuum-infusion process, Covestro is employing a process from Hübers Verfahrenstechnik Maschinenbau GmbH (Bocholt, Germany; www.huebers.de) that allows for controlled mold filling through automatic adjustments to the output based on the infusion pressure. Within this cooperation, Hübers has also developed a machine that can effectively degas both components of the polyurethane resin (isocyanate and polyol), and also dry the polyol, in a continuous process. Figure 2 illustrates the process for infusing polyurethane resins.

The groups are continuing to optimize the process and material properties so that larger parts can be made. Covestro has produced parts made from the polyurethane-based composites that are as large as 25 m^2. They have also demonstrated a wide range of thicknesses; as small as a few millimeters thick with just two layers of glass all the way up to

90-mm-thick parts that contain 120 layers of glass. A recent milestone was the manufacture of a 45-m spar cap (Figure 3), which is the portion of the turbine structure that must bear the full force of the wind. "The next step is to make a full blade," says Klausen.

Protecting against the elements

Regardless of ambient conditions, wind turbines must continue to operate efficiently whenever the wind is blowing. This can require some unique design considerations. Researchers at Rice University (Houston; www.rice.edu) have developed a composite material consisting of an epoxy filled with graphene nanoribbons (GNRs) that acts as an effective de-icer for aircraft, wind turbines and other outdoor surfaces. The material can be applied as a thin surface coating or incorporated into a structure, depending on the application. The GNRs provide conductivity to the composite, so that when a small amount of voltage is applied, Joule heating occurs, melting any ice on the surface. In the case of wind turbines, a self-contained system can be configured, explains James Tour, professor of materials science and nanoengineering at Rice. A small amount of the power generated by the turbine itself can actually be directly drawn to the coating to provide the required heating when a built-in thermocouple indicates the potential formation of ice, activating the epoxy-GNR composite. Additionally, the rotating motion of the blades aids in the removal of melted ice.

Currently, the team has demonstrated the assembly of GNRs in the epoxy at laboratory scale, but the availability of raw materials makes commercial-scale production of this composite feasible. The epoxy is a standard two-part epoxy, and GNRs are commercially synthesized by Merck EMD (Darmstadt, Germany, www.emdgroup.com), according to a procedure developed at Rice University. The GNR composites are also quite versatile, explains Tour, as they can be made super-hydrophobic, transparent for use on glass surfaces, or can even provide a layer of electromagnetic shielding. The composite's versatility and stability over a wide temperature range (GNRs are stable up to 1,000°F) allow for a multitude of potential applications, including blending with ceramics.

GE Aviation

FIGURE 4. High-pressure turbine shrouds constructed of ceramic matrix composites (CMCs) are resistant to the extreme temperatures experienced in jet engines

Flying high with ceramics

In addition to the strength and stability required by composites in harsh environments, new composite combinations can also create materials that are more lightweight than traditional metals and alloys — an especially important quality for aerospace applications. This is where the integration of ceramics can become extremely beneficial. Ceramics impart strength into composites, while remaining lightweight and resistant to high temperatures. A category of composites known as ceramic-matrix composites (CMCs) is gaining ground in many sectors, due to their extremely desirable suite of properties. CMCs usually consist of a ceramic matrix reinforced with a network of ceramic fibers. GE Aviation (Evendale, Ohio; www.geaviation.com) is one of the first companies to manufacture CMCs commercially, and last October announced plans to construct two adjacent CMC production facilities in Huntsville, Ala.The two plants will work in tandem — one pro-

GE Aviation

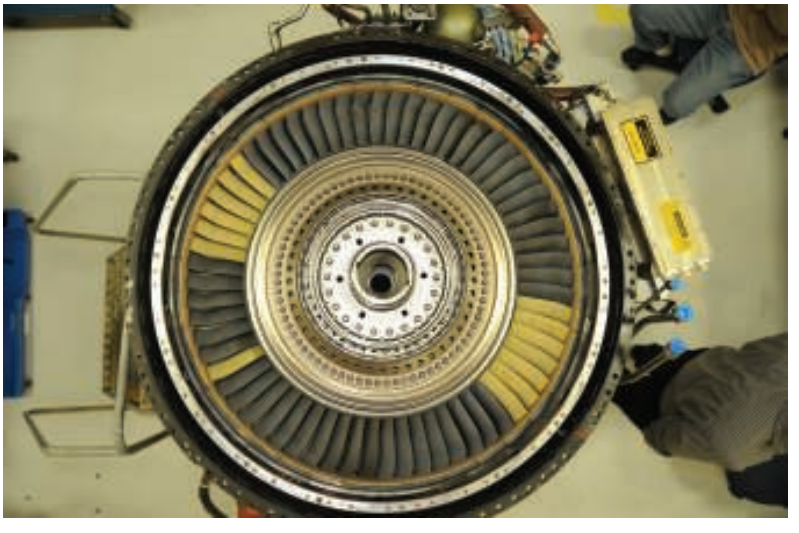

FIGURE 5. These low-pressure turbine blades are said to be the first-ever use of CMCs in rotating parts in an engine

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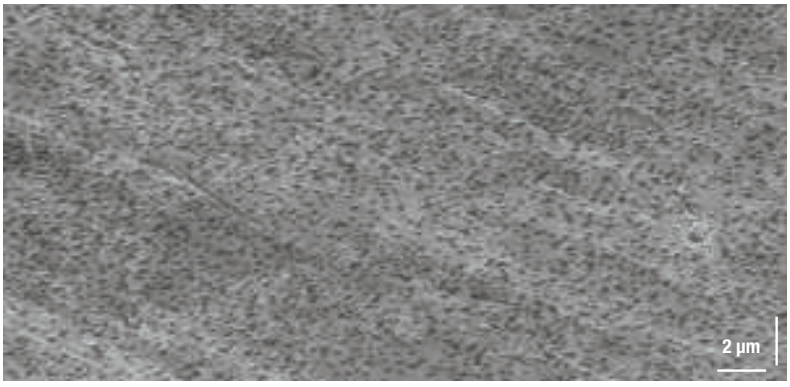

FIGURE 6. Uniform distribution of dispersed nanoparticles in a magnesium matrix gives this material unique qualities

ducing silicon carbide (SiC) ceramic fibers, and the other applying proprietary coatings to the fibers and forming them into a matrix to produce what is known as CMC tape. The CMC tape will then be sent to another GE site in Asheville, N.C., which is currently the only site in the world where CMC components are mass produced, according to GE.

Until the Huntsville plants start up in 2018, the Asheville site, which opened in late 2014, will continue to receive raw materials from NGS Advanced Fibers Co. (NGS), a company in Japan jointly owned by Nippon Carbon, Herakles Safran France and GE. According to GE, the Huntsville plants will be the first in the U.S. to mass-produce SiC fibers, and more CMC tape will be made there than anywhere else in the world. NGS is also currently constructing a new factory for SiC fibers in Japan to meet global demand, which GE projects will grow tenfold by 2020.

In the past, CMCs were difficult to produce at a large scale and were only able to be used in large structures — the ability to produce smaller, more complex components is a breakthrough. At present, the main end-use for GE's CMCs is to replace metal composites in components for the company's LEAP jet engines, specifically high-pressure turbine shrouds (Figure 4).

When compared to other materials used in jet-engine components, CMCs are more lightweight (reportedly one-third the density of metal alloys) and resist higher temperatures, leading to better fuel efficiency. The CMCs are said to operate at temperatures as high as 2,400ºF, which is 500ºF hotter than superalloys can handle. "Withstanding higher temperatures means we can push more air through the engine instead of diverting some to cool off metal parts and keep them from melting," explains a representative from GE Aviation. "CMCs are also stronger than some metal parts and will last longer, resulting in less time and money spent on maintenance, repair and overhaul." GE Aviation has also demonstrated the use of rotating CMC components in a low-pressure turbine (Figure 5), said to be an industry first. GE emphasizes that the applications for CMCs go beyond jet engines — the company's Power and Water business has tested CMCs in air-cooled gas turbines and also used prototype CMC parts to replace superalloys in large gas turbines.

Beyond CMCs, SiC is an important part of other composites. A new metal nanocomposite developed by researchers from the University of California, Los Angeles (UCLA; www.ucla.edu) has garnered a great deal of attention due to its very high strength, lightweight structure and mechanical stability at temperatures up to 400ºC. Composed of a magnesium-zinc alloy infused with SiC ceramic nanoparticles, the key to this material's unique properties is the ability to uniformly disperse the dense SiC nanoparticles throughout the magnesium (Figure 6) — a task that has not been achievable at this scale until now. The attractive forces between nanoparticles tend to form clusters within the metal matrix, but UCLA's method leverages the small van der Waals attractions between the particles and the molten metal and high thermal-motion energy to stabilize the dispersion.

The research team, led by Xiaochun Li, Raytheon Chair in Manufacturing and professor of materials science and engineering at UCLA, injected the SiC nanoparticles into a molten bath of the magnesium alloy, and incrementally concentrated the nanoparticles in the mixture by partially evaporating the molten metal in a vacuum furnace. Once solidified, the resulting composite contained 14 vol.% SiC, and after mechanical processing, it boasted a record-high yield strength of 710 MPa for magnesium alloys. "In our lab, samples of a few grams of magnesium were used. But the process is solidification-based and would be scaled up without much difficulty," says Li. Potential applications for the new metal are wide-ranging, spanning the automotive, aerospace, medical and electronics industries. In fact, according to Li, industrial in-

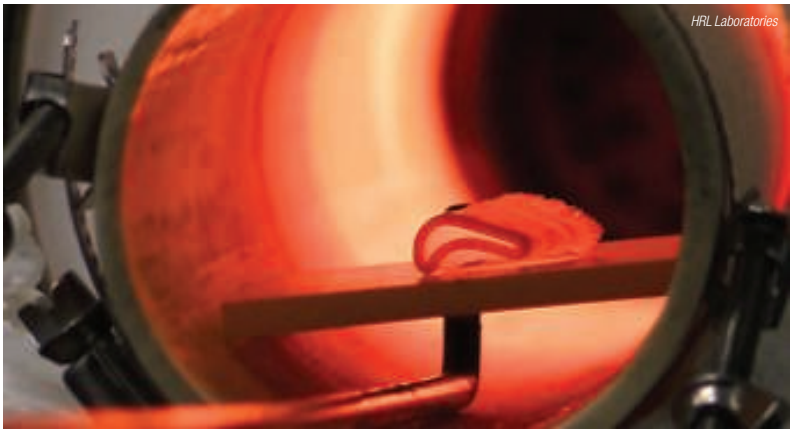
HRL Laboratories

FIGURE 7. Following 3-D printing, ceramic-composite parts are sent into a conventional firing process

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terest in the technology has been significant, with over 30 companies inquiring about commercialization for various applications. When compared to other crystallized metals, this material's high specific strength and specific modulus — said to be the highest ever reported for a polycrystalline metal — make it especially useful for energy-efficient applications, explains Li.

Going a step further, the team has also considered the recyclability of the material, citing the ease of recycling magnesium compared with other materials, such as polymers, as a key benefit. "The recycling of magnesium is very easy, since magnesium can be evaporated by a low-vacuum mechanical pump and then condensed to a cold plate. The magnesium nanocomposites can be recycled by this technique too, as evaporation can be used to recycle magnesium while the nanoparticles will be left behind for collection and cleaning," says Li.

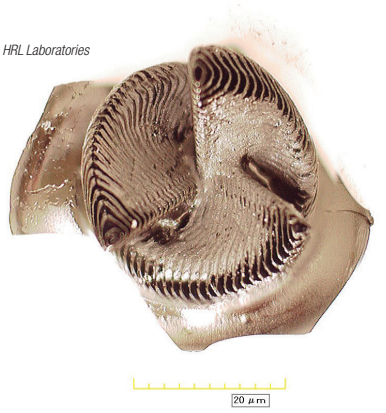

FIGURE 8. Additively manufacturing parts from ceramic-based materials has been demonstrated at bench scale

Boosting materials via 3-D printing

While ceramics boast many attractive qualities for a variety of applications, there are some limitations, due to their extremely high melting point and brittle structure. Ceramics are notoriously difficult to machine, and conventional processing techniques can inhibit the strength and versatility of end products. Researchers at HRL Laboratories, LLC (Malibu, Calif.; www.hrl.com) have overcome these restrictions by formulating a resin system based on a polymer-derived ceramic that is compatible with additive manufacturing processes, also known as three-dimensional (3-D) printing. This approach extends the potential for parts of nearly any shape or size to be constructed from ceramics. For more information on 3-D printing, please see 3-D Printing Accelerates, Creating CPI Opportunities, *Chem. Eng.*, Feb. 2015, pp. 20–23.

The silicon oxycarbide-based ceramic was attractive for 3-D printing, says Zak Eckel, HRL senior development engineer, because the polymer's silicon backbone has the ability to carry ultraviolet-active functional groups, which lends itself to the additive manufacturing process. The resin's potential was first demonstrated in a self-propagating photopolymer wave-guided process, and researchers decided to test its feasibility for additive manufacturing. A major advantage of using this resin for additive manufacturing is that traditional firing

processes can be used (Figure 7), with no additional processing steps, says Eckel. The 3-D printed part is simply pyrolized in an inert atmosphere at temperatures up to 1,000ºC, converting the resin into a fully dense, nonvolatile ceramic. The research team has manufactured several parts at benchtop scale (Figure 8), and plans to scale up production to make even larger parts of increasing complexity. A hurdle in scaleup, according to Eckel, will be to ensure that the material is adaptable and consistent with different 3-D printing equipment and techniques.

The team is also investigating other polymer backbone materials besides silicon for additional 3-D-printable ceramic resins, allowing for a wider range of final product properties. There is even potential for the resin and resulting parts to be integrated into CMCs, says Eckel. Although present research is focused on manufacturing ceramic parts for the aerospace and automotive industries, the material's versatility lends itself to numerous applications, including catalyst supports and high-temperature-resistant burners.

Oak Ridge National Laboratories (ORNL; Oak Ridge, Tenn.; www.ornl.gov), in collaboration with Cincinnati Inc. (Harrison, Ohio; www.e-ci.com), has also developed a system for integrating composites into additive manufacturing processes. The project, dubbed BAAM-CI, is said to be the first process that can deposit carbon-fiber-reinforced plastic composites into printed materials, making the resulting parts stronger and stiffer. The additive manufacturing process for these parts is also more efficient than other production methods involving composites, such as stamping and blow molding, says ORNL.

Composite maintenance

As materials become more advanced and end-product lifetimes continue to increase, composite maintenance and repair is another significant area for development. Researchers at Sandia National Laboratory (Albuquerque, N.M.; www.sandia.gov) are investigating non-destructive testing methods for composites, including techniques based on sonograms, infrared imaging, ultrasonic spectroscopy, flashed thermography and more. These methods are being evaluated for accuracy and applicability for detecting fractures and deformities in composites during various stages of processing. Nondestructive testing is particularly valuable for composites, since the outside surface may not reflect the condition inside the material. Citing the decades-long lifecycle required for many composite parts, the research team is currently writing inspection procedures based on their new testing methods.

Going forward, such inspection techniques, along with methods for composite repair and recycling, will certainly continue to be crucial to ensuring that composite parts in demanding applications like aerospace and wind power live up to their full potential. ■

Mary Page Bailey

CPI Demands Pumps with Lower Lifecycle Costs

Improved designs result in leak-free, reliable, longer-lasting pumps

IN BRIEF

- SEAL RELIABILITY
- ABILITY TO RUN DRY
- EASE OF MAINTENANCE
- WITHSTAND HARSH ENVIRONMENTS
- ACCURACY AND REPEATABILITY

FIGURE 1. The E Series, from EnviroGear Pumps, includes positive-displacement seal-less gear pumps that offer a between-the-bearing support system and a single-fluid chamber with a seal-less design to eliminate leaks

Because pumps move media through reactors, valves and piping, they serve as "the heart" of any process in which they are placed. So, whether the pump is a large sump pump, a small metering pump or anything in between, processors demand pumps that perform without stopping because when the pump goes down, it often takes the entire process and, in some cases, the whole facility, with it. For this reason, processors require pumps that not only function in the harshest of conditions, but they expect them to do so without leaking and without a lot of maintenance to keep costs at a minimum and safety and reliability at a premium.

"Chemical processors tend to be the kind of pump users for whom downtime becomes excessively expensive," says Chad Wunderlich, engineering manager with Viking Pump (Cedar Falls, Iowa; www.vikingpump.com). He says this is especially true if the pumps are involved in the front end of the process where, if that pump were to shut down, the entire process would follow. "Of course they have scheduled downtime, but if a pump should fail outside of that, it becomes a far bigger, more costly problem for them than it is in other industries due to the nature of the business and associated downtime costs. Reliability is critical for these guys."

Here, we will explore processors' major demands and how manufacturers are addressing them with innovative pump designs.

Seal reliability

One of the biggest issues regarding reliability of pumps is the seal. The seal is usually the first point of failure in a pump. In the chemical process industries (CPI), leaking pumps are not only excessively dangerous because of the nature of the media, but they are incredibly costly, as well. "When you are moving very aggressive chemicals, you can't afford to have any of the material leak or spill on the ground because it becomes a safety issue for the employees and the environment," notes Mike Solso, director of business development with PSG, a Dover Company (Oakbrook Terrace, Ill.; www.psgdover.com). "It is also an expensive issue due to the cost associated with wasted chemical dripping to the floor and the cost of cleaning up and reporting a leak, as well as the expense of using water to flush the seal and properly disposing of the flush water and chemicals."

For this reason, many processors turn to pumps that offer leak-free, seal-less designs that act to truly contain aggressive or expensive chemicals. One such example is the E Series Seal-less Internal Gear Pumps (Figure 1), from EnviroGear Pumps, part of PSG. These positive-displacement, seal-less gear pumps offer a between-the-bear-

ing support system and a single-fluid chamber with a seal-less design to eliminate leaks. The pumps are also interchangeable with mechanically sealed and packed-gear pumps. These features combine to reduce maintenance costs, increase environmental and fluid-handling safety and lower the overall cost of ownership, according to Solso.

Viking Pump's Wunderlich agrees that when leaking seals are an issue, processors will begin to seek other alternatives, including seal-less mag-drive pumps, which can reduce maintenance and environmental costs by eliminating the pump shaft seal. Viking offers the Universal Mag Drive (UMD) Series, which can save users more than 50% of the total pump, parts and downtime costs in one year, according to Wunderlich. No packing or mechanical seals means there is no seal failure or replacement, which reduces costs associated with material loss, contamination and housekeeping. This series, according to Wunderlich, is also dimensionally interchangeable with Viking's Universal Seal and Heavy-Duty bracketed pumps.

Iwaki America

FIGURE 2. The MDM chemical process pumps from Iwaki America feature a unique non-contact system design that enables them to withstand unexpected dry running

Magnetic drive and canned motor technology has also begun to find its way into liquid-ring-type vacuum pumps, which are often used in processes that use liquid to compress a gas in distillation columns, reactors, evaporators and other unit operations where vapors and gases need to be evacuated or compressed. "In these applications, some operations handle extremely toxic or explosive vapors, which generates much concern for chemical processors," notes Peter Klipfel, director of marketing with Gardner Denver Nash (Bentleyville, Pa.; www.gdnash.com). As a result, the 2BM1 line of liquid-ring vacuum

Netzsch

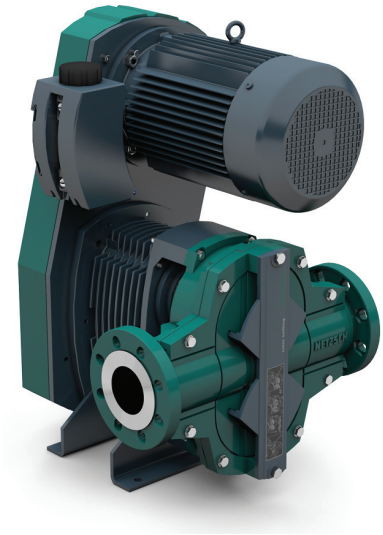

FIGURE 3. Netzsch's Tornado T2 rotary lobe pump features an elastomer housing liner and steel lobes and can be fully serviced through its front cover

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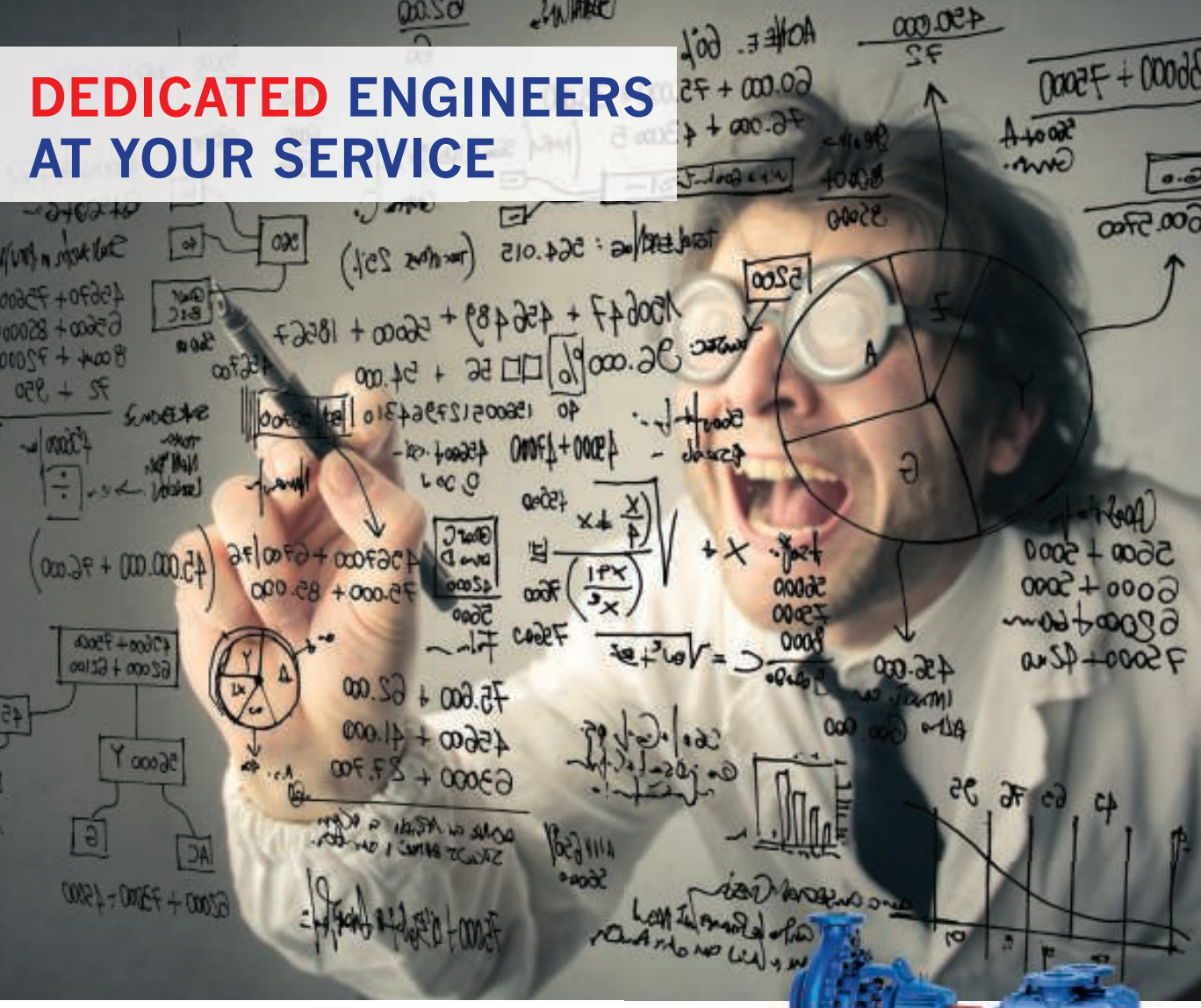

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pumps with magnetic drives, which are hermetically sealed for safety and reliability in dangerous and demanding applications, was introduced.

The pump's inner working space is hermetically sealed from atmospheric conditions, eliminating any possibility of leakage. They are sealed through the use of static seals, which are almost wear-free. The pump's operating fluid ensures optimum lubrication and cooling of the friction bearings and magnetic coupling, eliminating the need for grease lubrication.

Ability to run dry

"While mag-drive pumps tend to provide a leak-free solution, the Achilles Heel of magnetically driven pumps, historically, has always been their inability to run dry," says Tom Marcone, national sales manager with Iwaki America (Holliston, Mass.; www.iwakiamerica.com). "When a mechanically sealed pump runs dry, you may burn up the seal and it will cost a few hundred dollars to replace the seal, but when seal-less technology pumps run without fluid, you may burn up the whole pump and face costs in the tens of thousands to replace the whole unit."

For this reason, Iwaki has developed a dry-run-capable chemical pump that can run dry for up to one hour, repeatedly, without any damage to the pump. The MDM chemical process pumps (Figure 2) feature a unique non-contact system design that enables them to withstand unexpected dry running. The pumps are offered in two materials of construction and mounting configurations for use in many aggressive chemical and high-purity applications. "This is the ideal pump for processors trying to design a failsafe into their pumps so they will survive if there's an upset in the process," says Marcone.

Then, there are operations that require pumps that can run dry for an extended period. "Many facilities that use sump pumps to drain pits rely on level controls, but sometimes the level control system goes down and the pump is left in an atmosphere where there's no fluid," says Larry Lewis, president of Vanton Pumps (Hillside, N.J.; www.vanton.com). "This can be a costly problem if the pump can only run dry for a short period of time."

In an effort to provide a solution for applications that may experience extensive dry-run conditions, as well as unknown chemistries or abrasive media, Vanton developed the SGK cantilevered vertical sump. The large-diameter shaft design of the SGK pump eliminates the need

Wanner Engineering

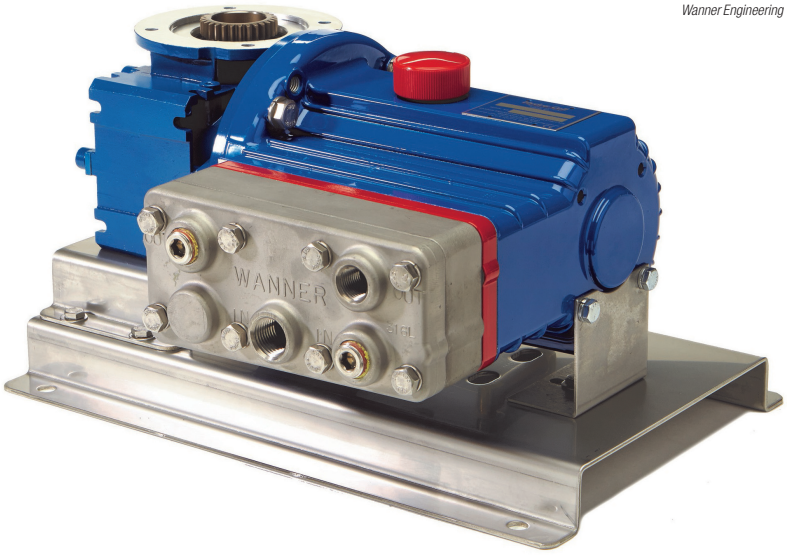

FIGURE 4. Hydra-Cell metering pumps from Wanner Engineering often find use where durability and low maintenance, as well as accuracy and repeatability, are crucial

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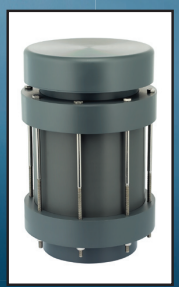

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for immersed bearings, providing indefinite dry-run capability and dependable operation. These pumps, which are available in corrosion-resistant thermoplastics, are specified for applications in which brief or long-term stoppages of fluid may occur, as well as for applications in which regulations prohibit draining tanks from the bottom.

Ease of maintenance

"Processors need to be able to keep their processes running as close to continuously as is possible, so there is a strong push in the industry for pumps with low lifetime costs, easy-to-maintain designs and extremely low downtime," says John Dean, NPA Business Field manager for Chemical, Pulp and Paper with Netzsch North America (Exton, Pa.; www.netzsch-pumps.com).

To decrease downtime and simplify maintenance, Netzsch offers Full Service-In-Place, or FSIP, versions of its rotary lobe and progressing cavity pumps. "For a long time, progressing cavity pumps had to be detached from their outlet piping to be serviced, but with the FSIP design, all parts of our NEMO progressing cavity pumps can be maintained or replaced without disturbing the piping."

Additionally, the company's Tornado T2 rotary lobe pump (Figure 3) was developed with the FSIP concept. The T2 has the same operating concept as other rotary lobe pumps, but instead of featuring elastomer lobes that wear out quickly and require time-intensive repair or replacement, the T2 features an elastomer housing liner and steel lobes. "The design change reduces maintenance frequency," says Dean. "Because the pump can be fully serviced through its front cover and features a timing belt instead of timing gears to eliminate the need for oil changes, the T2 can provide more uptime than other rotary lobe pumps."

Withstand harsh environments

"One of the biggest challenges when supplying pumps into the chemical processing industry is the ability to provide pumps and materials that will last, given the chemicals and chemical concentrations of these demanding applications," says William Parry, manager of engineering with CECO Environmental's Global Pump Solutions Group (Cincinnati, Ohio; www.cecoenvironmental.com). "Pumps need to survive in process conditions that may include high concentrations of sulfuric acids, high concentrations of basic solutions and a range of other corrosive or destructive environments."

The answer to this issue is in the use of specialty materials. "Often, non-metallic pumps are the only solution in these environments," says Parry. The company's Fybroc fiberglass-reinforced pumps are offered in multiple resins for a broad range of applications to solve corrosion problems. They feature high-quality and high-purity vinyl ester/epoxy resins to meet a range of corrosion-resistant applications. Offerings include pumps with synthetic veil for resistance to hydrofluoric acid, materials to handle moderate to heavy abrasives, special catalyst systems for handling strong bleaches, special resin systems to meet U.S. Food and Drug Admin. (FDA) specifications and second-generation epoxy resins for certain acid and solvent combinations.

High temperatures are often another consideration when selecting utility pumps for CPI applications. "Typically in chemical applications we aren't pumping water," explains Keith Grgurich, director of sales with BJM Pumps (Old Saybrook, Conn.; www.bjmpumps.com). "Rather, it's liquids that have a high volatility or they are hot or they have a very high specific gravity. Any of these conditions support using a pump end that's down in the liquid rather than on top, so we have had to perfect the use of a submersible pump for use in chemical environments, and what we've come up with is a high-endurance, high-temperature submersible pump."

BJM's Fahrenheit pumps can operate in environments where the liquid is up to 200°F, and are available in both cast iron and stainless steel. The innovation comes from the design of the motor, which is protected by double mechanical seals. The lower seal is made of silicon carbide/silicon carbide and the upper seal is made of carbon/ceramic. An ad-

ditional lip seal has been installed above the impeller to help prevent abrasives from entering the seal chamber. Winding protection and motor insulation with a thermal cut-out switch allows the stator to have a high winding temperature.

Accuracy and repeatability

In metering applications, accuracy and repeatability are crucial to providing consistent product and eliminating chemical waste, so pump manufacturers are supplying pumps designed to shine in these operations. "The use of stepper motors in diaphragm metering pumps used to feed chemicals has provided highly accurate chemical feeds," notes Harland Pond, vice president of business development for industry OEM at Grundfos (Downers Grove, Ill.; www.us.grundfos.com). "In precision chemical feed, our Smart Digital dosing pumps use stepper motors to offer 1,000-to-1 turndown with repeatable accuracy, streamlining application design and eliminating chemical waste."

Wanner Engineering (Minneapolis, Minn; www.hydra-cell.com) offers its Hydra-Cell metering pump (Figure 4) for use in place of traditional metering pumps where durability and low maintenance, as well as accuracy and repeatability, are crucial. "Years ago we found that processors were using our Hydra-Cell positive-displacement pumps, which have no mechanical seals and no packing, to meter products, so we decided to look into the metering capabilities and found that they offer the accuracy, linearity and repeatability of traditional metering pumps and that they exceeded the API standards," says Donelle Capriotti, business development director with the company.

She says the accuracy of the pump, which has a constant replenishing system in the back end, has made it very useful. "The biggest advantage is the lack of pulsation," she says. "Traditional metering pumps are usually single-diaphragm and, as a result, deliver slugs of chemicals into the system. Ours have anywhere from one to five diaphragms and the overlapping flowrates from those diaphragms deliver flow in an even stream."

Additionally, pulsating pumps require dampeners that have to be replaced and serviced. "Our pumps don't require these extra elements, which makes our pumps inexpensive to own and maintain. And, because they were originally designed to run at higher RPMs, when you slow them down for metering, they last for extremely long periods of time."

It would seem that no matter the application or pump style, manufacturers are working to address common concerns such as leaks, process compatibility, maintenance costs and accuracy and repeatability. And, by addressing these issues, they are helping chemical processors reduce the lifecycle costs of their pumps, while also increasing the uptime and safety of the process. ■

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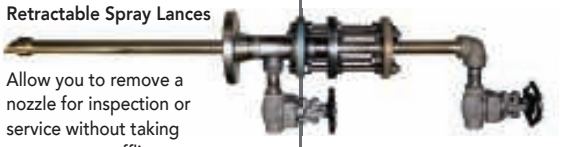

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Acoustics-based device monitors uneven topography

The BinMaster 3D Level Scanner (photo) uses non-contact, dust-penetrating technology to detect solid material surfaces. It provides early warning of surface irregularity, the development of cones, or side-wall buildup in bins and vessels, and is suitable for pellets, granular and powdered materials and other bulk solids in a wide array of chemical process industries (CPI) applications. This advanced, acoustics-based technology measures multiple points within the bin, and performs well in powders and bulk solids enclosed in tanks, silos and warehouses, as well as open bins and piles. With a measuring distance of up to 200 ft, this device uses 3-D mapping capabilities to provide a visual representation of bin contents, detecting irregular material surfaces and providing highly accurate bin-volume calculations. Communications include 4–20-mA HART, Modbus RTU, TCP/IP and RS-485. It has the following hazardous-location classifications: CFM Intrinsically Safe Class I, II, Division I, Groups, C, D, E, F and G (U.S. and Canada). It is self-cleaning, requires minimal maintenance and has a variety of extensions and configurations to allow it to meet a range of challenging applications, says the company. — *BinMaster, Lincoln, Neb.*
www.binmaster.com

Interface detector supports hydrocarbon separation

The FlexSwitch FLT93S flow-level-temperature switch (photo) is a dual-function, insertion-style instrument that can identify the interface between any type of media, including foam, emulsion layers, liquids and slurries. The FLT93S switch allows one instrument to control two different product interfaces. Two or more switches can be used to control product discharge and intake at specified points. It offers either flow/temperature sensing or level/temperature sensing in a single device. With its advanced thermal-dispersion sensing technoogy, the FLT93S switch provides precision interface detection of fluids, helping users to manage the separation of crude oil, gas and water during petroleum-recovery and refining operations using either two-phase (oil/gas and condensate) or three-phase (oil, gas and water) separation tanks. It can be used in tanks, for monitoring, controlling and alarming of flowrates or levels of critical fluid layers, such as emulsion layers, foams, liquids and slurries. Unlike density displacers, which are often used for level and interface control, the FLT93S switch relies on specific heat-transfer properties of the media to identify the interface of different products, says the company. Level/interface accuracy is ±0.25 in. and measurement repeatability is ±0.125 in., says the company. The standard unit withstands operating temperatures from -40 to 350°F, and an optional configuration is available for temperatures from –100 to 850°F. — *Fluid Components International LLC, San Marcos, Calif.*
www.fluidcomponents.com

Ultrasonic level transmitter measures liquids and slurries

The Sitrans LU150 (photo) is a non-contacting ultrasonic transmitter with a range of 16 ft. The two-wire, 4–20-mA loop-powered transmitter incorporates the sensor and the electronics in a single compact unit. It can be used for continuous level measurement of liquids, slurries and bulk materials in both open and closed vessels. It is designed primarily for use in the water, wastewater and energy-management industries. The Sitrans LU150 has a rugged, fully encapsulated polyvinylidene fluoride (PVDF) transmitter that is resistant to corrosion, chemicals and extreme shock. With only two cables to be connected, the Sitrans LU150 can be installed quickly and easily. The company's Sonic Intelligence signal-processing software deliv-

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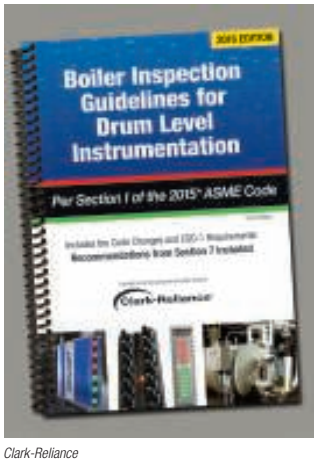

Clark-Reliance

ers reliable measurement readings by differentiating between the true material level and echoes, says the manufacturer. It has an accuracy of ±0.025%, with a measuring range of 0.25–5 m, and an operating range of –30 to 60°C. It is suitable for use in chemical storage vessels, filter beds, mud pits, liquid storage vessels and food applications. — *Siemens, Atlanta, Ga.*
www.usa.siemens.com/level

Advanced transmitters improve level measurement

The Jupiter Model JM4 magnetostrictive level transmitter (photo) is available as a direct-insertion option or an external-mount option on any Orion magnetic level indicator or modular instrumentation bundle. The JM4 provides innovative features to ensure safe, simple measurement in both total and interface level applications, says the company. The magnetostrictive transmitter features improved signal-to-noise ratio, a full graphic local user interface, HART 7.0 (Foundation Fieldbus is available), local waveform capture and an intuitive device-type manager that allows for remote configuration, trending and diagnostics. The JM4 is said to be the first magnetostrictive transmitter to offer a field-removable head, which allows for easier transmitter maintenance and troubleshooting without disrupting the process. Head rotation of 310 deg provides greater accessibility to operate the JM4's onboard graphical interface. The remote-mount option allows the transmitter head to be attached to the probe via a flexible cable (available in 3- and 12-ft lengths), allowing for easier viewing when spatial constraints exist. — *Orion Instruments, Baton Rouge, La.*
www.orioninstruments.com

This radar level-measurement device is for bypass operations

The Optiwave 1010 FMCW radar level device is a two-wire, loop-powered HART transmitter designed for continuous level measurement of liquids in bypass applications in a variety of industries, including chemical, power, water and wastewater. When combined with the company's BM 26 Advanced bypass chambers and magnetic level indicators, this device adds a 4–20-mA output to the mechanical devices. A combination can be ordered as a single package (called the BM 26 W1010), says the company. This device can also be welded onto any bypass chamber with internal diameter of 1.5–2 in. (38–56 mm). It has a measurement accuracy of ±0.2 in. (5 mm), and it offers better accuracy in bypass applications, says its maker, because while reed chain and magnetostrictive level detectors measure the float position (which depends on product density), radar measures the liquid surface directly. — *Krohne Messtechnik GmbH, Duisburg, Germany*
www.krohne.com

This submersible pressure transducer can travel

The AST4510 submersible pressure transducer (photo) measures liquid level in tanks. This instrument is designed with stainless steel and Hytrel materials, and is suitable for use in both stationary and mobile tank applications. Mobile applications may include tanks that are being transported between locations at a construction site, chemical totes that are moved during chemical process operations, well-site injection chemicals, as well as tanks located on ships and train cars. The AST4510 comes standard with a 0.5-in. NPT male conduit connection at the base of the cable connection. If the tank is likely to experience turbulent conditions due to an inlet/fill pipe or the use of an agitator, the transducer can be installed with a metal or plastic conduit over the cable, to safeguard against sensor movement within the tank, says the company. — *American Sensor, Mt. Olive, N.J.*
www.astsensors.com

Publication supports level sensor use in boiler drums

This company recently released the new 2016 edition of its guidebook, entitled "Boiler Inspection Guidelines for Drum Level Instrumentation" (photo). This informative resource for boiler drum-level instrumentation concisely presents the latest ASME Section 1 Code, says the company. It provides handy, on-the-job reference materials for boiler operators, and includes ASME Code requirements for water columns, water-gage valves,

gage glass, remote level indicators, magnetic water-level gages, and water-column-isolation shutoff valves. It incorporates the 2015 ASME Code changes and CSD-1 requirements, as well as recommendations from Section 7. The handbook also lists the most common non-compliant drum-level equipment arrangements and suggests alternative solutions, says the company. Its size, spiral binding and laminated pages make it appropriate for in-plant reference and referral. It is available free of charge to qualified recipients. — *Clark-Reliance, Strongsville, Ohio*

www.boilerinspectionguide.com

Electronic level sensor detects changes in buoyancy

The Magnetrol Digital E3 Modulevel Displacer Level Transmitter (photo) is a liquid level-measurement and control device for a variety of CPI applications. The electronic-displacer level-transmitter technology detects and converts changes in buoyancy force, caused by a change in liquid level, into a stable output signal. These forces act upon the spring-supported displacer, causing vertical motion at the core within the Macro Sensors' linear variable differential transformer, says the company. As the core position changes with liquid level, voltages are induced across the secondary windings of the sensors. These signals are processed in the electronic circuitry and used to control the current in the 4–20-mA current loop. — *Macro Sensors, Pennsauken, N.J.*

www.macrosensors.com

Open-architecture wireless system enables sensor choice

Monitoring level in tanks is a common wireless application, and when used in upstream pumping, oil-and-gas, wastewater and other industrial applications, it can help to eliminate run-outs and overflows while optimizing and ensuring the integrity of the operations. The SignalFire Remote Sensing System (photo) integrates an open architecture mesh network, which allows users to choose the preferred sensor type for an application, and to mix different sensor types in the same network. By comparison, most tank level-monitoring systems limit sensor choice, says the company. Depending on the conditions of the operating environment and tank contents, the ideal sensing technology might be a float device, pressure sensor, ultrasonic sensor, piezoresistive sensor, or one based on air-guided wave radar. The SFRSS communicates with and powers virtually any sensor with a 4–20-mA, 1.5-V, Modbus, HART, digital I/O and other analog and digital interfaces, says the company. In a typical application, the SignalFire wireless nodes interface with a standard sensor, providing power for the sensor and connectvity to a gateway located at a central location where the data are concentrated. Because the SFRSS mesh network operates at lower frequencies, it can communicate at ranges of up to 3 miles between nodes, and it is significantly less sensitive to foliage, obstructions and moisture when compared to traditional wireless sensors, according to the manufacturer. — *SignalFire, Hudson, Mass.*

www.signal-fire.com

Electronic level sensor detects changes in buoyancy

The Total Tank Level Measurement System (photo) incorporates magnetostrictive sensing technology and multivariable functionality. The system's digital Modbus output measures total level, interface level and temperature from an explosion-proof housing. The system features five temperature-sensor outputs, distributed over the active length of the system's polymer and stainless-steel probe. The rugged and flexible probe is available in lengths up to 50 ft. It is also available in a rigid Type 316 stainless steel version. The system's intrinsically safe, explosion-proof design and all-welded construction makes it suitable for use in oil-and-gas, chemical and petrochemical storage tank and inventory-control applications, says the company. It has an accuracy of 0.01% of measured span (less than 1 mm absolute), over the full measurement range. It meets FM and FMc hazardous-area approvals and requires minimal maintenance. — *Ametek Drexelbrook, Horsham, Pa.*

www.ametek.com ■

Suzanne Shelley

Macro Sensors

SignalFire

Ametek Drexelbrook

New Products

OPW Engineered Systems

Charles Ross and Son

Physik Instrumente (PI)

Ball-valve mechanisms in these couplings protect against spills

Epsilon dry-disconnect couplings (photo) are designed for use in critical in-plant and chemical-transfer applications in pharmaceutical manufacturing. Examples of volatile, hazardous or high-value pharmaceutical compounds whose transfer can benefit from the use of Epsilon disconnects include dichloromethane, toluene, ammonia and pharmaceutical slurries. Epsilon products utilize ball valves rather than poppets to facilitate the opening and closing of the coupling, which allows a convex ball to seat with a concave ball when the valve is opened, producing a straight-through flow path that creates no areas where chemicals can nest. The result is fluid transfer that experiences no reduction in flowrate while virtually eliminating the occurrence of product spills when the coupling is disconnected. A series of five independent and redundant mechanical locks also prevents the Epsilon coupling from becoming accidentally disconnected, which removes the threat of unintentional spills and releases. Epsilon couplings are constructed of 316 stainless steel or Hastelloy, and are available in sizes ranging from ¾ to 3 in. — *OPW Engineered Systems, Hamilton, Ohio*
www.opw-es.com

Clean fragile filters with these ultrasonic systems

This line of ultrasonic cleaning systems for filters range from tabletop to industrial-size floor models, each of which can provide a quick, thorough cleaning to filters. Ultrasonic filter cleaning is an economical alternative to cleaning with high-pressure water sprays or brushes, especially for metal and plastic filters that are very susceptible to damage. Cleaners are equipped with ultrasonic generators operating at frequencies that excite tank-mounted transducers to create millions of microscopic bubbles in the cleaning solution. Bubbles implode on contact with the filter to remove contaminants from any surface immersed in the ultrasonic cleaning solution. Depending on the model, the cleaning system may include timers, temperature controllers and sweep and degas options. Rinse stations and drying stations are also available. — *Tovatech, LLC, Maplewood, N.J.*
www.tovatech.com

These mixers are now available for higher capacities

This company has expanded its most advanced planetary mixer line, the PDDM (photo), to include larger working capacities up to 750 gal. The PDDM is a multi-agitator mixer featuring two planetary stirrer blades and two high-speed disperser shafts. Designed for highly viscous and highly filled applications, the hybrid system can quickly incorporate large amounts of dry ingredients into thick or sticky liquid, and apply intense shear to achieve a smooth and uniform consistency. The PDDM is rated for vacuum operation up to 29.5 in. Hg and includes a jacketed change-can vessel, sight and charge ports on the cover and an automated lift for raising or lowering the agitators. The mixer is usually supplied with a discharge system for fast and convenient transfer of the finished product. — *Charles Ross and Son Co., Hauppauge, N.Y.*
www.mixers.com

A new line of motion controllers with programmable automation

This company's line of controllers for ultrasonic direct-drive motors and positioning stages offer responsiveness for a range of user requirements, including precision positioning and handling. The small-footprint C-877.1U11 single-axis controller (photo) and low-cost two-axis controller are among the product line's offerings. Also available is the new C-867.262 multi-phase controller, which allows for extremely smooth motion with velocities below 1 µm/s, a critical feature for microscopy and surface nano-metrology. The controllers are delivered with extensive software packages, including dynamic libraries for Windows and Linux operating systems. In addition, a powerful macro programming language is available for automation tasks and standalone operation. — *Physik Instrumente (PI) LP, Auburn, Mass.*
www.pi-usa.us

These flowmeters' gas-selection feature has been expanded

Fox Thermal Instruments

The Gas-SelectX gas-selection feature of the FT1 thermal mass flowmeter (photo) has been expanded to include more pure gases. The 11 available pure gases for the device are: air, argon, butane, carbon dioxide, helium, hydrogen, methane, natural gas, nitrogen, oxygen and propane. Additionally, the Gas-SelectX feature includes a new three-gas mix option, which allows the user to choose any three pure gases (excluding natural gas) from the menu and mix them in 1% increments to total a 100% custom mixture. These features make the FT1 suitable for measuring digester gas, liquefied petroleum gas (LPG) and a variety of biogases. — *Fox Thermal Instruments, Inc., Marina, Calif.*
www.foxthermalinstruments.com

These vacuum regulators are now available in aluminum


Equilibar

This company's dome-loaded vacuum regulators are now available in an anodized aluminum version (photo). Previously, the regulators were only available in stainless steel or polyvinyl chloride. The lightweight, corrosion-resistant aluminum models are suitable for many vacuum applications, such as extrusion and forming systems, casting, molding and dehydration. The regulators provide accurate and precise control of vacuum pressure with just one moving part — a large, sensitive diaphragm that directly seals against a field of parallel orifices, acting as both the vacuum-sensing element and the valve. This design eliminates the internal friction of traditional vacuum regulators, which use a spring-loaded diaphragm to modulate a sliding valve shaft. — *Equilibar, LLC, Fletcher, N.C.*
www.equilibar.com

Feed spacers improve RO membrane performance

Introduced at the Membrane Technology Conference & Exposition (Feb. 1–5; San Antonio, Tex.), the reverse-osmosis (RO) elements from this company's Lewabrane product line now feature a novel feed spacer used in the membrane element.

Wanner Engineering

KIN-TEK Analytical

Material Transfer & Storage (MTS)

Hiden Isochema

The spacer provides for optimized flow in the RO element, resulting in lower energy consumption. Combining it with the Lewabrane RO membrane makes products suitable for numerous applications. Initially, two new products are to be introduced: Lewabrane B400 LE ASD and Lewabrane B400 FR ASD. Optimized for applications in brackish water, these elements have standard geometries (40-in. length, 8-in. dia.) and are characterized by very low energy consumption and high fouling resistance, says the company. — *Lanxess AG, Cologne, Germany*
www.lanxess.com

Higher pressure ratings for these sealless pumps

Previously rated at 1,000 psi maximum discharge pressure, Hydra-Cell D10 Series sealless pumps with metallic pump heads (photo) can now operate at pressures up to 1,500 psi. Used for a wide range of processing applications and in manufacturing plants, Hydra-Cell D10 models have a flow capacity of 4.26 gal/min with a motor speed of 790 rpm when performing at the higher pressure rating. Spring-loaded, horizontal-disk check valves and the sealless design enable model D10 pumps to handle viscous fluids and those containing abrasive particulate up to 500 µm in size. The D10 also features the patented KelCell technology so that in the event of a closed or clogged inlet condition, the D10 will run dry indefinitely without damage to the pump. — *Wanner Engineering, Inc., Minneapolis, Minn.*
www.wannereng.com

Expanded selection for these gas-sorption analyzers

The new MultiPort inlet selector (photo) is now available for this company's IGA and XEMIS series gas-sorption analyzers. MultiPort offers expansion of the number of gases that can be simultaneously connected and the level of automation available. There are connections for up to 12 gas species and control is integrated within HIsorp .NET software suite. Multiport not only allows the user to determine consecutive gravimetric-sorption isotherms with more species at one or more gas temperatures, but also offers the user full control of the inlet for advanced method development. — *Hiden Isochema, Warrington, U.K.*
www.hidenisochema.com

This gas-standard generator allows for automatic control

The 491Flex Calibration Gas Standards Generator (photo) is an update of the 491M manual system, retaining the modular construction and expandability of the previous model, but replacing the analog controls with the computer-controlled FlexStream system. Other features include capabilities for automation and expandability, as well as electronic mass-flow control and full PID temperature control. The 491Flex uses permeation (or diffusion) tubes as the component compound source for creating very low-concentration mixtures. — *KIN-TEK Analytical, La Marque, Tex.*
www.kin-tek.com

Discharge and weigh bulk bags with this heavy-duty unit

The Material Master bulk-bag discharging, weighing and feeding system (photo) features heavy-duty stainless-steel construction with an integral screw feeder and loss-in-weight load cells for material batching. The unit includes a 6-in. square structural-tube lower frame and a bulk-bag support pan for operator safety. The system's Flo-Master bulk-bag massaging system promotes material flow, while a powerful Flo-Lock slide gate halts material flow for partial bag discharge. — *Material Transfer & Storage (MTS), Allegan, Mich.*
www.materialtransfer.com

A new mid-range rackmount network security appliance

To optimize networking and virtualization performances, this company has introduced a highly integrated 14-nm system on a chip (SoC) 1U rackmount network security appliance NCA-4010 (photo, p. 43). Designed with optimization capabilities at the mid-range tier, NCA-4010 is driven by the Intel Xeon processor D-1518 (4-core) and D1548 (8-core) 14-nm CPU, codenamed Broadwell-DE to deliver high networking performance, large memory capacity, an external crypto accel-

Lanner Electronics

erator, and a scalable local-area network (LAN) configuration. The 14-nm SoC integrates a platform control hub and delivers powerful memory capacity and an error-correction control-data-integrity capability. The platform design of NCA-4010 is purposely targeted on networking and virtualization applications for enhanced performance at mid-level ownership cost. — *Lanner Electronics Inc., New Taipei City, Taiwan*
www.lannerinc.com

A new crossflow filtration system for process development

SartoFlow Smart (photo) is a new benchtop crossflow system for optimized ultra- and diafiltration applications. It can be used in many downstream processes, such as purification of vaccines, monoclonal antibodies and recombinant proteins. The system is suitable for flexible use in laboratory environments for process development and clinical trials, as well as for cGMP environments. The system is equipped with a low-shear four-piston membrane pump that enables high product yields. In addition, the pump provides a wide range of flowrates, allowing users to choose membrane surface areas ranging from 50 cm^2 to 0.14 m^2. The crossflow system is supplied with the company's DCU-4 control unit, which, when combined with the company's BioPAT SCADA, MFCS-4 software, provides data logging and export capabilities. Its touchscreen offers instant access to all critical process parameters and displays control and alarm functions. A logbook function stores alarms, setpoints and user logs. — *Sartorius Stedim Biotech, Aubagne, France*
www.sartorius.com

Sartorius Stedim Biotech

PVDF eductor nozzles for aggressive chemicals

Bete

Eductor nozzles are often used to agitate the contents of tanks to prevent separation and sedimentation. If the chemicals are aggressive or stored at higher temperatures, eductors made from brass or stainless steel are typically used. Now, this new range of polyvinylidene difluoride (PVDF) eductors (photo)

are a viable alternative to the more expensive stainless models. PVDF (Kynar) is a fluoroplastic that is extremely chemical-resistant and boasts superior heat resistance compared to many other plastics. The eductors are submerged inside the tank and the motive liquid is pumped under pressure though the discharge orifice. Depending on the model and the operating pressure, the volume of liquid discharged from the eductor will be up to four or five times greater than the volume of motive liquid being pumped. This highly efficient operation reduces energy use and therefore cuts costs, says the company. — *The Spray Nozzle People (Bete Ltd.), Lewes, U.K.*
www.bete.co.uk

Respiratory-air-line monitor for carbon monoxide

CO-Guard (photo) is a compact, user-friendly monitor for compressed-air-line carbon monoxide (CO). The instrument incorporates a rotameter for confirmation of proper airflow, a backlit digital display and a highly specific electrochemical CO sensor for trouble-free and reliable operation. With simple use and installation, CO-Guard is designed for use in a wide variety of applications, ranging from automotive paint-spray operations to wood finishing. This monitor can be used in virtually any

Enmet

commercial or industrial process that requires CO monitoring of compressed breathing air for personnel working in such operations. The device covers a detection range of 0 to 50 parts per million (ppm) CO, with three adjustable alarms (5, 10 and 20 ppm CO). — *Enmet Corp., Ann Arbor, Mich.*
www.enmet.com

This steam-trap monitor has ISA100 Wireless certification

This company's SWWRF40 wireless steam-trap monitor has successfully achieved ISA100 Wireless certification from the International Society of Automation (ISA). The device monitors gas and steam leaks, temperature, pressure and other relevant information related to valves and the steam system. The SWWRF40 wirelessly transmits temperature, pressure and ultrasound data, which is analyzed to determine the status of steam valves. It also enables fast response to undesirable events, such as steam leaks. The instrument's ISA100 Wireless compliance assures robust, secure and reliable transmission of critical asset-condition information. — *Bitherm S.L., Madrid, Spain*
www.bitherm-sistemas.com

Optimize particle-sizing systems with this light-scattering device

The Litesizer 500 is a light-scattering device for determining the size and stability of nanoparticles and submicroparticles in liquids, allowing for optimization of particle systems by revealing how they change with time, pH, temperature and concentration. The Litesizer 500 determines particle size, zeta potential and molecular mass by using light-scattering technology in combination with transmittance measurements. The instrument's software features a simple user interface where input parameters, results and analysis are all on a single page. In addition, advanced algorithms in the Litesizer's firmware technology allow users to resolve several different particle sizes in a single suspension, and a patented technology allows for very robust measurements of zeta potential. — *Anton Paar GmbH, Graz, Austria*
www.anton-paar.com ■
Mary Page Bailey and Gerald Ondrey

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Particle-sizing technology selection

Department Editor: Scott Jenkins

This column summarizes the strengths and limitations of some widely used industrial particle-analysis techniques.

TABLE 1. CHARACTERISTICS OF PARTICLE-SIZING TECHNIQUES

Technique	Size	Shape	Zeta potential	Dynamic range	Rapid	Resolution	Sampling	Wet	Dry
Laser diffraction	●			●●●●	●●●	●●	●●●	●	●
Dynamic light scattering	●			●●●	●●●	●●	●●	●	
Electrophoretic light scattering			●	●●●	●●●	●●	●●	●	
Automated imaging	●	●		●●	●●	●●●	●●	●	●
Sedimentation	●			●●	●	●●	●●	●	
Electrozone sensing	●			●	●●	●●●	●	●	
Sieving	●			●	●	●	●	●	●

Sieving

Sieving determines particle-size distributions by measuring the mass of material that passes through progressively finer meshes.The measurement range for sieving is about 100 µm to 10 mm.

Key advantages. Sieving is a well-established technology and forms the original specification for many products. Further, relative to other techniques, it is simple, inexpensive, easy to use and requires little training.

Limitations. Results are prone to operator-to-operator variability, and measurement times are relatively long (5–10 minutes). The measurement resolution can be poor, as the number of size classes are few and wide (defined by the number of sieves in the stack), leaving the technique blind to subtle differences in particles. Measurements become more problematic for finer particles because they tend to agglomerate, causing sieve-blocking and, possibly measuring agglomerates, rather than primary particle size. Rigorous sieve examination and maintenance is essential for data integrity, but is time-intensive.

Most common uses. Uses include quality assurance (QA) and quality control (QC) across the solids-handling industries, most often in sectors where profit margins are tight.

Laser diffraction

Laser diffraction generates particle-size distributions from measurements of the angular variation in intensity of light scattered by a dispersed sample when it passes through a laser beam. The measurement range for laser diffraction is about 0.01 µm to 3.5 mm.

Key advantages. Laser diffraction measurements take less than a minute. Calibration is not necessary, and with a modern system, routine maintenance requirements are minimal. Full automation reduces manual input to a minimum and at the same time, increases repeatability and reproducibility. Laser diffraction reports over 100 class sizes, providing good resolution for detection of particle-size-distribution changes. Robust process analyzers, for inline and online use, enable application of the technique from laboratory to process line, and for automated process control.

Limitations. Samples must be diluted for analysis, which may cause particle-size changes (dilution shock). The size-distribution calculation assumes the measured particles are spherical, so the results can be affected by changes in particle shape.

Most common uses. The technique is used as an alternative to traditional manual methods in industries from cement to pharmaceuticals, to accelerate R&D, enhance product quality, and to support automated process control.

Imaging

Automated imaging technology captures images of individual particles, and uses these to calculate number-based particle size and shape distributions. The measurement range is about 0.5 µm to 1 mm.

Key advantages. Automated imaging produces microscope-quality images of thousands of particles in a few minutes. The added ability to quantify shape permits the efficient and robust differentiation of particle types in a sample, (for example, agglomerates from primary particles or contaminants from product particles). Compared with microscopy, imaging is faster and less subjective.

Limitations. Automated imaging, a laboratory technique, is slower than techniques like laser diffraction, and equipment costs are relatively high.

Most common uses. Uses include product development, QC and process troubleshooting, when size data alone is insufficient, and in the development of particle-sizing methods.

Dynamic light scattering

Dynamic light scattering (DLS) determines the diffusion speed of particles moving under Brownian motion from measurements of light scattering intensity, and converts this to a particle-size distribution using the Stokes-Einstein relationship. The measurement range is about 0.3 nm to 10 µm.

Key advantages. DLS is non-invasive, allows complete sample recovery and offers fast, automated, high throughput analysis. Required sample volumes are very small (as little as 12µL) and with modern systems that incorporate backscatter technology, samples can be measured over a wide range of concentrations. New technology for online implementation is an important advance for process monitoring and automated control.

Limitations. Light scattering intensity scales with particle size to the power of six, so large particles in a sample can dominate a result. Although the accessible size range is good, the measurement resolution can be poor, especially when measuring polydisperse (wide) size distributions.

Most common uses. DLS is used in R&D, because of its ability to measure at the nanoscale using small sample volumes, but increasingly for process monitoring as particle-size specifications become finer, and for QC. Typical samples include proteins, polymers, emulsions and nanoparticles. ■

Editor's note: The material for this column was authored by John Duffy, product marketing manager, Malvern Instruments Ltd., (Malvern, U.K.; www.malvern.com).

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Aniline Production from Nitrobenzene (Liquid-Phase)

By Intratec Solutions

Aniline, also known as amino benzene or benzenamine, is an aromatic amine with the formula $C_6H_5NH_2$. It is mainly used as a raw material in the production of methylene diphenyl diisocyanate (MDI), an intermediate in polyurethane manufacture. Aniline is also used as an intermediate for dyes and pigments, explosives, agricultural chemicals and pharmaceuticals.

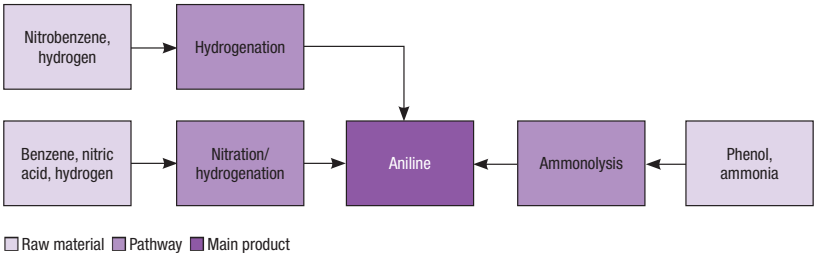

FIGURE 2. Multiple production pathways are available for aniline

The process

The following paragraphs describe aniline production from nitrobenzene via a liquid-phase hydrogenation process, similar to the one owned by DuPont (Wilmington, Del.; www.dupont.com). The process can be divided into three main parts: nitrobenzene hydrogenation, dehydration and purification. Figure 1 presents a simplified flow diagram of the process showing the main pieces of equipment.

Nitrobenzene hydrogenation. Nitrobenzene (mononitrobenzene or MNB) is fed with hydrogen into a plug-flow tubular reactor containing a noble metal catalyst supported on carbon. The hydrogenation is carried out in the liquid phase and the nitrobenzene conversion to aniline is near 100% in a single pass.

Dehydration. The reactor effluent is virtually free of nitrobenzene due to the high conversion of the reaction. The hydrogen excess is separated from the reactor effluent and the liquid product is directed to a dehydration column. In this column, the water generated is removed as the overhead product and the bottoms stream is sent to the purification area.

Purification. In the purification area, heavy impurities (tars) are separated from the crude aniline stream by the bottom of a distillation step. The final product obtained as the distillate of the column is high-quality aniline, with purity above 99.95 wt.% and containing less than 0.1 parts per million (ppm) of nitrobenzene by weight.

Aniline pathways

Aniline was first commercially produced using nitrobenzene as starting material in 1930s. This pathway remains the most common for aniline production today. Currently, almost all existing plants producing aniline from nitrobenzene are integrated with facilities to produce nitrobenzene from benzene. The other existing production pathway for aniline is based on phenol as the starting raw material. Figure 2 illustrates such aniline production pathways.

Economic performance

The total fixed capital estimated to construct a plant to produce 350,000 metric ton/yr of aniline in the first quarter of 2015 in the U.S. is about $200 million. The total fixed capital estimated includes the inside and outside battery limits (production units, storage installations, utilities facilities and auxiliary buildings).

This column is based on "Economics of Aniline Production from Nitrobenzene," a report published by Intratec. It can be found at: www.intratec.us/products/aniline-production-processes. ■

Edited by Scott Jenkins

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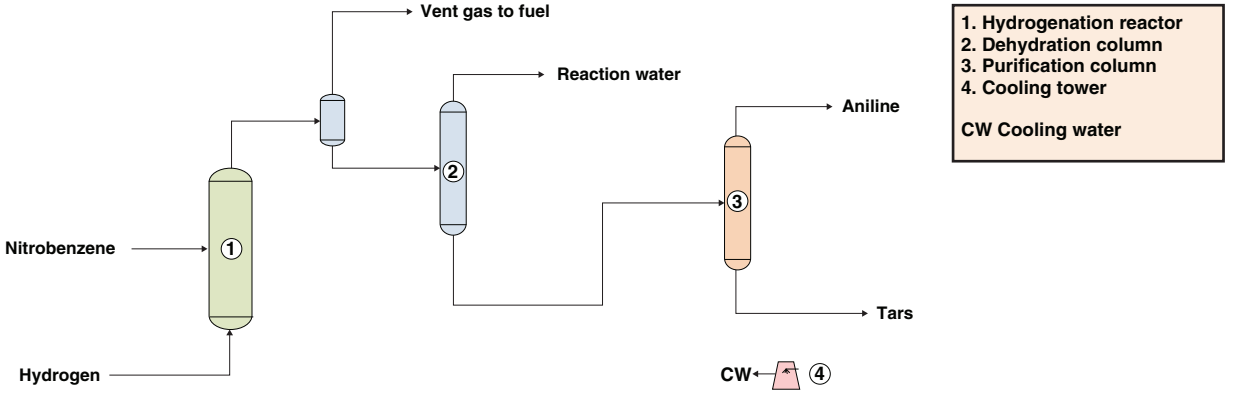
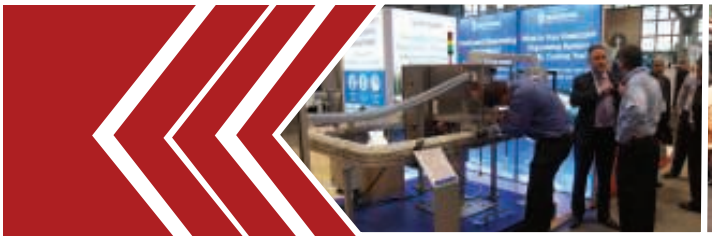


FIGURE 1. The diagram shows aniline production from nitrobenzene via a liquid-phase hydrogenation process



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Alarm Management By the Numbers

Deeper understanding of common alarm-system metrics can improve remedial actions and result in a safer plant

Kim VanCamp
Emerson Process Management

IN BRIEF

FIGURE 1. A better understanding of alarm system metrics can lead to more focused remedial actions and help to make the plant safer

Do you routinely receive "alarm management performance" reports, or are you expected to monitor a managerial dashboard equivalent? What do you look for and what does it mean? We all know that fewer alarms mean fewer operator interruptions and presumably fewer abnormal process or equipment conditions. But a deeper understanding of the more common alarm-management metrics can yield greater insight, leading to more focused remedial actions and ultimately to a safer, better performing plant (Figure 1).

This article reviews the now well established benchmark metrics associated with the alarm-management discipline. Most articles previously published on alarm managements cover alarm concepts (for example, defining a valid alarm), alarm management methods (for instance, rationalization techniques), justification (such as the benefits of investing in alarm management) and tools (including dynamic alarming enablers). This article provides a different perspective. Written for process plant operation managers or others that routinely receive alarm management performance reports, this article aims to explain the most common metrics, without requiring an understanding of the alarm-management discipline in depth.

Alarm-management KPIs

The first widely circulated benchmark metrics, or key performance indicators (KPIs), for alarm management relevant to the chemical process industries (CPI) were published in the

TABLE 1. EXAMPLE OF TYPICAL ALARM PERFORMANCE METRICS, TARGETS AND ACTION LIMITS

Metric	Target	Action limit
Average alarm rate per operator (alarms per day)	< 288	> 432
Average alarm rate per operator (alarms per hour)	< 12	> 18
Average alarm rate per operator (alarms per 10 minutes)	1 – 2	> 3
Percent of 10-minute periods containing > 10 alarms	< 1%	> 5%
Maximum number of alarms in a 10 minute period	≤10	> 10
Percent of time the system is in flood	< 1%	> 5%
Annunciated priority distribution (low priority)	~80%	< 50%
Annunciated priority distribution (medium priority)	~15%	> 25%
Annunciated priority distribution (high priority)	~5%	>15%
Percent contribution of top 10 most frequent alarms	< 1% to ~5%	> 20%
Quantity of chattering and fleeting alarms	0	> 5
Stale alarms (number of alarms active for more than >24 hours)	< 5 on any day	> 5

1999 edition of the Engineering Equipment and Materials Users Association publication EEMUA-191 Alarm Systems – A Guide to Design, Management and Procurement [*1*]. Later works from standards organizations, such as the 2009 publication International Society of Automation (ISA) 18.2 Management of Alarm Systems for the Process Industries [*2*] and the 2014 publication IEC62682 Management of alarms systems for the process industries [*3*], built upon EEMUA-191 and have furthered alarm-management thought and discipline. For example, they provide a lifecycle framework for effectively managing alarms and establish precise definitions for core concepts and terminology. Yet fifteen years later, little has changed regarding the metrics used to measure alarm-system performance. This consistency in measurement has been positive in many respects, leading to the wide availability of generally consistent commercial alarm analytic reporting products, from both control-system vendors and from companies that specialize in alarm management. Consequently, selection of an alarm-analysis product may be based on factors such as ease of use, integration and migration, reporting capabilities, price, support availability and so forth; with reasonable certainty that the KPIs derived from the chosen product can be interpreted consistently and compared across sites and across differing process control, safety and other open platform communications (OPC)-capable alarm-generating sources.

In addition to defining the KPI measurements, the EEMUA-191, ISA-18.2 and IEC62682 publications also suggest performance targets, based in large part on the practical experience of the companies participating in the committees that contributed to each publication. As an example, these publications state that an average long-term rate of new alarms occurring at a frequency of up to 12 alarms per hour is the maximum manageable for an operator. Suggested performance levels such as this can provide a reasonable starting point if you are just beginning an alarm-management program. But before deciding what constitutes a reasonable set of targets for your site, you should also consider other firsthand inputs, like surveying your operators and reviewing in-house studies of significant process disturbances and alarm floods. Note that more research into the human factors that affect operator performance is needed to validate and potentially improve on the current published performance targets. Important work in this area is ongoing at the Center for Operator Performance (Dayton, Ohio; www.operatorperformance.org).

Alarm system example metrics

A typical alarm-performance report contains a table similar to Table 1, where the metrics and targets are based upon, and in many cases, copied directly from, the EEMUA-191, ISA-18.2 and IEC62682 publications. It is also common to see locally specified action limits based on a site's alarm philosophy. When a target or action limit is exceeded, it is important to ask: what problems are likely contributing to the need for action, and what are the actions? These questions are the focus of the following discussion.

Average alarm rate

The average alarm rate is a straightforward measure of the frequency with which new alarms are presented to the operator, expressed as an average count per day, hour or per 10-minute interval. As alarm frequency increases, an operator's ability to respond

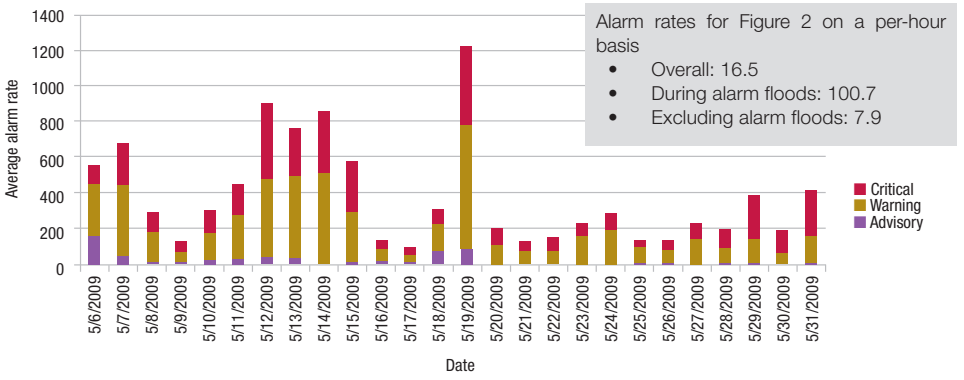

FIGURE 2. Timeline views of the data can reveal periods where alarm performance is not acceptable

correctly and in time to avoid the ultimate consequence of inaction decreases. If the rate is excessively high, it is probable that some alarms will be missed altogether or the operators will ignore them, thus eroding their overall sense of concern and urgency. So clearly it is an important metric.

Averages can be misleading, however, because they provide no sense of the peaks in the alarm rate, making it difficult to distinguish "alarm floods" from steady-state "normal" operation. Consequently, most alarm performance reports supplement this basic KPI value with a timeline view or separate calculation of alarm rates for both the times when operation is normal and for times of an alarm flood. Figure 2 presents a typical example. The average alarm rate of 16.5 alarms per hour exceeds the target KPI value of 12 from Table 1, but is slightly less than the action limit of 18 per hour, and so might not raise concern, while the timeline view shows that there are significant periods of time where the performance is unacceptable.

Common contributors to an excessively high alarm rate include the following:

- The alarm system is being used to notify the operator of events that do not constitute actual alarms, such as communicating informational "for your information" messages, prompts, reminders or alerts. According to ISA-18.2, an "alarm" is an indication to the operator that an equipment malfunction, process deviation or abnormal condition requiring a timely response is occurring
- Chattering or other frequently occurring nuisance alarms are present. These often originate from non-process alarm sources of marginal interest to the operator, such as field devices or system hardware diagnostics. Chattering alarms can also indicate an incorrect alarm limit or deadband
- Redundant alarms, where multiple alarms are presented when a single abnormal situation occurs. An example is when a pump is shut down unexpectedly, generating a pump fail alarm in addition to alarms for low outlet flow and low discharge pressure
- A problem with the metric calculation is occurring. A correct calculation only counts new alarms presented to the particular operator or operating position for which the metric is intended, taking into consideration any by-design threshold settings or other authorized filtering mechanisms that cause fewer alarms to be presented to the operator than may be recorded in system event logs

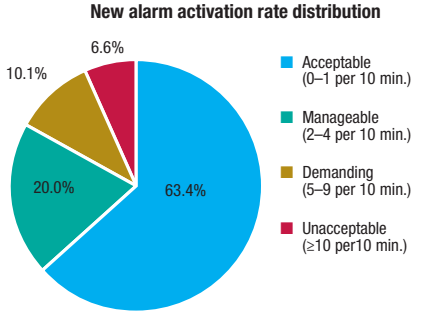

FIGURE 3. Pie charts can supplement alarm performance reports and give information on how much time is spent in the acceptable range

Peak alarm rate

The two metrics — the percentage of 10-minute periods with more than 10 alarms, and the percent of time spent in an "alarm flood" state — are calculated differently, but are highly similar in that they quantify how much of the operator's time is spent within the highly stressful circumstance of receiving more alarms than can be managed effectively.

EEMUA-191 defines the start of an alarm flood as a 10-minute period with more than 10 new alarms, continuing through subsequent 10-minute intervals until reaching a 10-minute interval with fewer than five new alarms. Equally acceptable is to define a flood simply as a 10-minute period with more than 10 new alarms. Often, an alarm-performance report will supplement these two metrics with a pie chart (Figure

3) that segments the report period into 10-minute periods that are categorized into named alarm-rate ranges, such as acceptable, manageable, demanding and unacceptable.

Another commonly included metric in the alarm-performance report, the peak number of alarms within a 10-minute period, is a straightforward measure of the degree of difficulty of the worst-case alarm flood for the operator. In poorly performing alarm systems, it is common to see peak alarm counts in a 10-minute period that exceed 250, a total that would overwhelm even the most highly skilled operator.

Common contributors to high peak-alarm-rate frequency and severity include the following items:

- ***Multiple redundant alarms for the same abnormal condition.*** The optimum situation is of course that any single abnormal event will produce just one alarm, representing the best choice in terms of operator comprehension and the quickest path to take remedial action. This requires study of alarm causes and often leads to the design of conditional, first-out or other form of advanced alarming logic
- ***Cascading alarms.*** The sudden shutdown of equipment often triggers automated actions of the control system, which in turn, triggers more alarms
- ***False indications.*** When routine transitions between process states occur, the alarm system is not usually designed to "follow the process," so it can therefore produce a multitude of false indications of an abnormal condition. Likewise, logic is typically required to detect state changes and suppress or modify alarms accordingly

Some systems provide specialized alarm views that present alarms in a graphical pattern to aid an operator's comprehension of peak alarm events and their associated causality, supplementing the classic alarm list to help provide a built-in layer of defense against the overwhelming effects of an alarm flood.

Alarm priority distribution

When faced with multiple alarms, the operator must decide which to address first. This is — or should be — the basis for assigning priority to an alarm. Most systems will employ three or four priorities: low, medium, high and very-high. There are a number of well accepted methods for assigning priority, the most common being a systematic guided (selection-based) consideration of the severity of the consequence of inaction combined with the time available for the operator to take the required action. Conventional wisdom says that the annunciated alarm-priority distribution experienced by the operator for low-, medium- and high-priority alarms should be in an approximate ratio of 80, 15 and 5%. Ultimately however, the goal should be to guide the operator's determination of the relative importance of one alarm compared to another, based on their importance to the business.

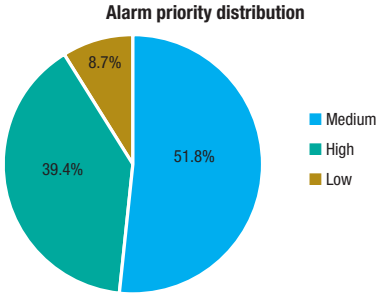

FIGURE 4. When the number of high-priority alarms exceeds that of low-priority alarms, the methodology of how alarms are assigned priority should be evaluated

Figure 4 illustrates a situation where the number of high-priority (critical) alarms being presented to the operator far exceeds the low-priority (advisory) alarms, suggesting the need to review the consistency and methodology of the priority assignment.

Common contributors to out-of-balance alarm-priority distributions include the following:

- Alarm prioritization (a step in the rationalization process) has not been performed and alarm priorities have been left at their default values
- Misuse of the priority-setting scheme to classify alarms for reasons other than providing the operator with a tie-breaker during alarm peaks. For example, using priority to classify alarms by impact categories, such as environmental, product quality, safety/health, or economic loss
- Lack of discipline in setting priority based on consideration of direct (proximate) consequences rather than ultimate (unmitigated) consequences. While it may be the case that a designed operator action could fail, followed by a protective system failure, followed by a subsequent incorrect

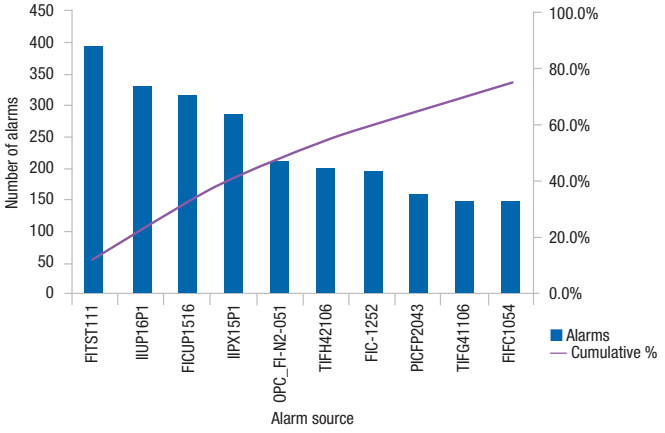

FIGURE 5. A small number of alarm sources can often account for the majority of alarms

human response, such what-if considerations are likely to lead to a vast skewing of alarm priorities toward critical

Alarm source contribution

The percent of alarms coming from the top-ten most frequent alarm sources relative to the total alarm count is a highly useful metric for quantifying, identifying and ultimately weeding out nuisance alarms and alarm-system misuse. This is especially true if the alarm performance report covers a range of time where operations were routine and without significant process upsets or equipment failures. The top-ten alarm sources often provide "low-hanging" fruit for alarm-management performance improvement. They are a handful of alarms, which if addressed, will create a noticeable positive change for the operator.

Figure 5 shows a pattern observed in many control systems, where as few as ten alarm sources (like a control module or transmitter) out of the many thousands of defined alarm sources, collectively account for about 80% of all of the alarms presented to the operator. In this example, the first alarm source (FIST111) alone was responsible for 15% of all of the alarms presented to the operator.

Another related metric is the count of chattering alarms — alarms that repeatedly transition between the alarm state and the normal state in a short period of time. The specific criteria for identifying chattering alarms vary. The most common method is to count alarms that activate three or more times within one minute.

When the top-ten alarm sources generate over 20% of all the alarms presented to the operator, it is a strong indicator that one or both of the following is the case:

- Some of those alarms are nuisance alarms — alarms that operators have come to expect, and in most cases, ignore or consider to be informational
- The alarm system is being misused to (frequently) generate operator prompts based on routine changes in process conditions or operating states that may or may not require action

Eliminating chattering alarms is generally straightforward, using signal-conditioning features found in most control systems, such as on-delay, off-delay and hysteresis (deadband).

Stale alarms

A stale alarm is one that remains annunciated for an extended period of time, most often specified as 24 hours. Stale alarms are surprisingly challenging to quantify. Metrics based on event histories require the presence of both the start and ending alarm event in order to compute an alarm's annunciated duration. There is no event representing the attainment of a certain age of an annunciated alarm. Thus, it is common to miss counting stale alarms if their activation event or all-clear event falls outside the range of dates and times covered in the event history. Consequently, there are alternate methods for quantifying stale alarms, such as periodic sampling of the active alarm lists at each operator workstation, or simply counting the number of alarms that attained an age greater than the threshold age. Given this variation in methods, it is important to exercise caution when comparing stale-alarm metrics across different sites that may be using different alarm-analytic applications.

In addition to being hard to quantify, stale alarms can also be some of the most difficult nuisance alarms to eliminate. Thus in some respects the upward or downward trend in stale alarm counts provides an informal indication of the overall ongoing health of the alarm management program.

Common contributors to stale alarm counts include the following:

- Routine transitions between process states where the alarm system is not designed to adapt and therefore provides false indications of an abnormal condition
- Alarms associated with standby or idle equipment
- Alarms configured to monitor conditions no longer relevant or available, an indicator of poor management-of-change processes
- Alarms that are essentially latched due to excessive application of hysteresis
- Alarms that persist beyond the called-for

operator action, waiting for maintenance action. This likely constitutes an incorrect use of the alarm system, using it as a recording method for outstanding maintenance actions

In conjunction with reviewing the number of stale alarms or the list of stale alarms, it is also important to review what alarms have been manually suppressed (thus removing them from the view of the operator). Suppressing the alarm will remove a stale alarm from the alarm list (effectively reducing the number of stale alarms), but will not address the underlying condition.

Closing remarks

This article touches on just some of the key alarm-system performance metrics and what the numbers represent, in terms of the issues that lay behind them and possible actions to address them. With this understanding, periodic reviews of alarm-performance reports should lead to more focused actions that can improve operator effectiveness and thereby reduce the risks for economic loss, environmental damage or unsafe situations. For further reading on these and other alarm performance metrics, including suggested methods for corrective action, one outstanding resource is Ref. 4. ■

Edited by Scott Jenkins

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Understand and Cure High Alarm Rates

Alarm rates that exceed an operator's ability to manage them are common. This article explains the causes for high alarm rates and how to address them

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IN BRIEF

FIGURE 1. Alarm rates on the order of thousands per day are not uncommon in some CPI facilities

Modern distributed control systems (DCS) and supervisory control and data acquisition (SCADA) systems are highly capable at controlling chemical processes. However, when incorrectly configured, as is often the case, they also excel at another task — generating alarms. It is common to find alarm rates that exceed thousands per day or per shift at some chemical process industries (CPI) facilities (Figure 1). This is a far greater number than any human can possibly handle successfully. This article examines the nature of the problem and its cure.

The alarm system acts as an intentional interruption to the operator. It must be reserved for items of importance and significance. An alarm should be an indication of an abnormal condition or a malfunction that requires operator action to avoid a consequence. Most alarm systems include interruptions that meet this definition, but also many miscellaneous status indications that do not.

A major reason for this situation is that control system manufacturers make it very easy to create an alarm for any imaginable condition. A simple analog sensor, such as one for temperature, will likely have a dozen alarm types available by simply clicking on check boxes in the device's configuration. Without following sound alarm-management principles, the typical results are over-alarming, nuisance alarms, high alarm rates and an alarm system that acts as a nuisance distraction to the operator rather than a useful tool.

Whenever the operators' alarm-handling capacity is exceeded, then operators are forced to ignore alarms, not because they want to do so, but because they are not able to handle the number of alarms. If this is the case, the average, mean, median, standard deviation, or other key performance indicators (KPIs; see Part 1, p. 50) for alarms do not matter, because plant managers have no assurance that operators are correctly ignoring inconsequential alarms or are paying attention to the ones that matter. This situation contributes to many major accidents.

Alarm rates

The International Society of Automation (ISA; Research Triangle Park, N.C.; www.isa.org) Standard 18.2 on alarm management identifies the nature of the problem and offers a variety of assessment measurements. An important measurement is the rate of alarms annunciated to a single operator.

Figure 2 shows an overloaded alarm system. The difference between the two lines is the effect of including or removing only 10 individual high-rate nuisance alarms. This is a common problem that is discussed later in the article.

To respond to an alarm, an operator must detect the alarm, investigate the conditions causing the alarm, decide on an action, take the action and finally, monitor the process to ensure that the action taken resolves the alarmed condition. These steps take time and some must necessarily be executed sequentially. Others can be performed in parallel as part of a response to several alarms occurring simultaneously.

Given these steps, handling one alarm in 10 minutes (that is, approximately 150 over a 24-h period) can generally be accomplished without the significant sacrifice of other operational duties, and is considered likely to be acceptable. A rate greater than 150 per day begins to become problematic. Up to two alarms per 10-minute period (~300 alarms/day) are termed the "maximum manageable." More than that may be unmanageable.

The acceptable alarm rates for small periods of time (such as 10 minutes or one hour) depend on the specific nature of the alarm, rather than the raw count. The nature of the response varies greatly in terms of the demand upon the operator's time. The duration of time required for an operator to handle an alarm depends upon the particular alarm.

As an example, consider a simple tank with three inputs and three outputs. The tank's high-level alarm occurs. Consider all of the possible factors causing the alarm and what the operator has to determine:

- Too much flow on inlet stream A, or B or C
- Too much combined flow on streams A-B, A-C, B-C or A-B-C
- Not enough flow on outlet stream D, E or F
- Not enough combined flow on streams D-E, D-F, E-F or D-E-F
- Several more additional combinations of the above inlet and outlet possibilities.

The above situation takes quite a while to diagnose, and involves observing trends of all of these flows and comparing them to the proper numbers for the current process situation. The correct action varies highly with the proper determination of the cause or causes. The diagnosis time varies based upon the operator's experience and involvement in previous similar situations.

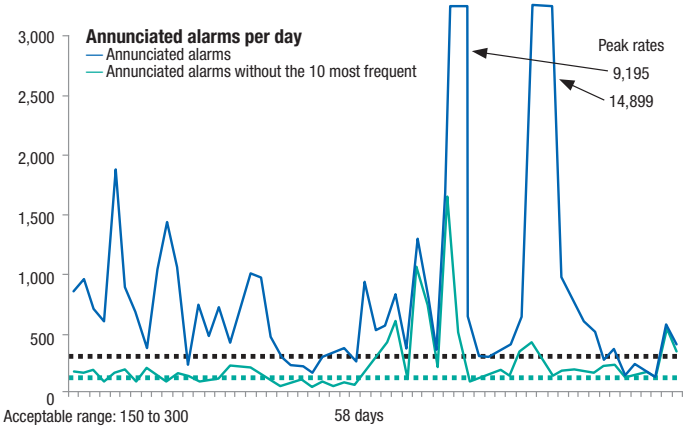

FIGURE 2. Removing a small number of high-rate alarms can have a large effect on the alarm system's overall profile

Process control graphics (human-machine interfaces; HMIs) play a major role in effective detection of abnormal situations and responses to them. Using effective HMIs, an operator can quickly and properly ascertain the cause and corrective action for an abnormal situation. However, the quality of the HMI varies widely throughout the industry. Most HMI implementations are little more than a collection of numbers sprinkled on a screen while showing a piping and instrumentation diagram (P&ID), making diagnosis much more difficult. For more discussion on this topic, search the Internet for the term "High-Performance HMI," or see the comprehensive white paper cited in Refs. 1 and 2.

As a result, the diagnosis and response to a simple high-tank-level alarm becomes quite complicated. Given the tasks involved, it might only be possible to handle a few such alarms in an hour.

Other alarms are simpler, such as, "Pump 412 should be running but has stopped." The needed action is very direct: "Restart the pump, or if it won't restart, start the spare." Operators can handle several such alarms as these in 10 minutes. It takes less time to assess and work through the situation.

Response to alarm rates of 10 alarms per 10 minutes (the threshold of a "flood") can possibly be achieved for short periods of time — but only if the alarms are simple ones. And this does not mean such a rate can be sustained for many 10-minute periods in a row. During flood periods (Figure 3), operators are likely to miss important alarms. Alarm rates per 10 minutes into the hundreds or more, lasting for hours, are common. What are the odds that the operator will detect the most important alarms in such a flood? Alarm

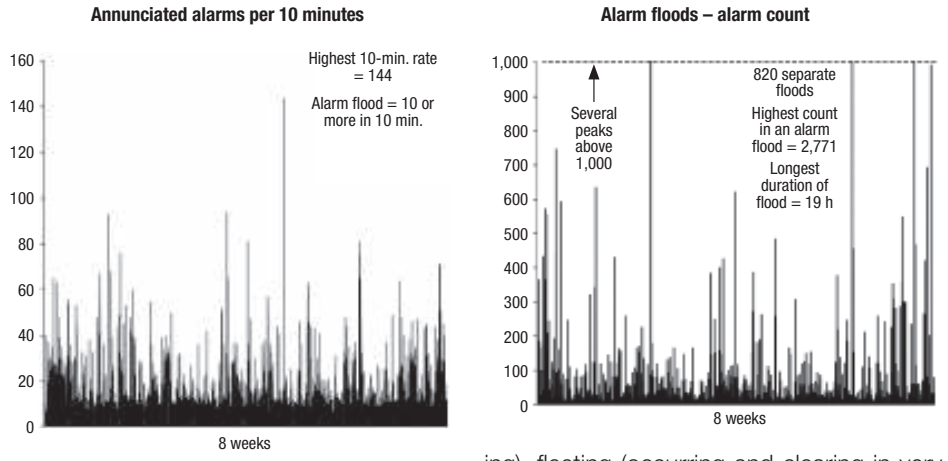

FIGURE 3. During alarm flood periods, it is very likely that operators will miss important alarms

floods can make a difficult process situation much worse, and are often the precursors to major upsets or accidents.

Averages can be misleading

Alarm performance should generally be viewed graphically rather than as a set of averages. Imagine that during one week, your alarm system averaged 138 alarms per day and an average 10-minute alarm rate of 0.96. That would seem to be well within the bounds of acceptability. But the data producing those average numbers could look like that shown in Figure 4.

The first flood lasted 40 minutes with 118 alarms. The second flood lasted 30 minutes with 134 alarms. How many of those alarms were likely to be missed? A simplistic answer (but good enough for this illustrative purpose) is to count the alarms that exceed 10 within any 10-minute period for the duration of each flood, which, for the current example, would be a total of 182. In other words, despite these seemingly great averages (many plant managers would consider these averages to be strong alarm-system performance and that they would be happy to achieve), the alarm pattern still puts the operators in the position of likely missing almost 200 alarms. Missing so many alarms can result in improper operator actions and undesirable consequences — perhaps quite significant ones.

It is easy to plot such data, as in Figure 5. During an eight-week period, almost 21,000 alarms were likely to be missed. A weekly view of such data in this way will likely gain the attention of management, whereas viewing the overall averages alone would indicate that things are satisfactory when they are not.

Bad actor alarm reduction

Many types of nuisance alarm behaviors exist, including chattering (rapidly repeating), fleeting (occurring and clearing in very short intervals), stale, duplicate and so forth. Alarms with such behaviors are called "bad actors." The most common cause of high alarm rates is the misconfiguration of specific alarms, resulting in unnecessarily high alarm occurrence rates. Commonly, 60–80% of the total alarm occurrences on a system come from only 10–30 specific alarms. Chattering alarms and fleeting alarms are both common. Simply ranking the frequency of alarms will identify the culprits. Finding and correcting these rate-related nuisance behaviors will significantly reduce alarm rates with minimal effort.

In the example data shown in Figure 6, 76% of all alarm occurrences came from only 10 individual configured alarms. In fact, the top two alarms make up 50% of the total load, with about 48,000 instances in 30 days. Alarms are never intentionally designed to annunciate so frequently, but they do. In this configuration, they would not perform a useful function; rather, they would be annoying distractions.

Many of these were chattering alarms. In summarizing 15 alarm-improvement projects at power plants, the author's employer found that 52% of all alarm occurrences were associated with chattering alarms. Proper application of alarm deadband and alarm on-delay/off-delay time settings usually corrects the chattering behavior. The calculations for determining those settings are straightforward (but beyond the scope of this article). Much more detailed information for solving all types of nuisance alarm problems can be found in Ref. 3.

Alarm rationalization

The other cause of high alarm rates requires more effort to address. Most alarm systems are initially configured without the benefit of a comprehensive "alarm philosophy" docu-

ment. This document sets out the rules for determining what kinds of situations qualify for alarm implementation. It specifies methods for consistently determining alarm priority, controlling alarm suppression, ongoing performance analysis, management of change, and dozens of other essential alarm-related topics.

Systems created without such a document are usually inconsistent collections of both "true alarms," along with many other items, such as normal status notifications that should not use the alarm system. Such non-alarms diminish the overall effectiveness of the system and diminish the operator's trust in it. They must be purged. While it may be easy to spot things that clearly have no justification for being alarms by looking at the list of most frequent alarms, a comprehensive alarm rationalization is needed to ensure the consistency of the overall alarm system.

With alarm rationalization, every existing alarm is compared to the principles in the alarm philosophy document and is either kept, modified or deleted. Setpoints or logical conditions are verified. Priority is assigned consistently. New alarms will be added, but the usual outcome of rationalization is a reduction in configured alarms by 50–75%. Since the alarm-management problem was identified in the early 1990s, thousands of alarm systems have undergone this process and achieved the desired performance.

After the bad actor reduction and the rationalization steps, alarm rates are usually within the target limits. A typical result is shown in Figure 7. Significant process upsets, particularly equipment trips, may still produce some alarm floods, which can be addressed in Step 6 listed below.

The 2009 publication of the ISA-18.2 Alarm Management Standard includes both having an alarm philosophy document and performing alarm rationalization as mandatory items. For a comprehensive white paper on understanding and applying ISA-18.2, see Ref. 4.

Alarm management work process

There is an efficient seven-step plan for improving an alarm system, proven in more than 1,000 improvement projects in plants throughout the world. Steps 1–3 are simple, and often done simultaneously as an initial improvement effort with fast, high-impact results.

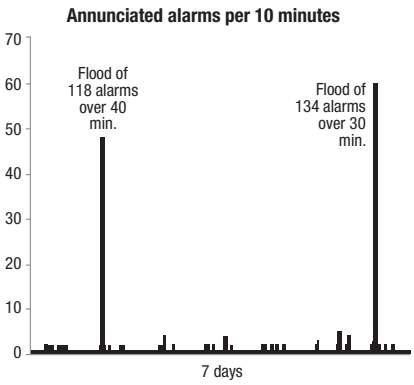

FIGURE 4. Different alarm data can generate similar average alarm rates, and the average rate may not tell the full story

Step 1: Develop, adopt and maintain an alarm philosophy. A comprehensive guideline for the development, implementation and modification of alarms, an alarm philosophy establishes basic principles for a properly functioning alarm system. It provides an optimum basis for alarm selection, priority setting, configuration, response, handling methods, system monitoring and many other topics.

Step 2: Collect data and benchmark the alarm system. Measuring the existing system against known, best-practice performance indicators identifies specific deficiencies, such as various types of nuisance alarms, uncontrolled suppression, and management-of-change issues. A baseline is established for improvements measurement.

Step 3: Perform "bad actor" alarm resolution. Addressing a few specific alarms can substantially improve an alarm system. Bad actor alarms, which can render an alarm system ineffective, are identified and corrected to be consistent with the alarm philosophy. An ongoing program to identify and resolve nuisance alarms is necessary.

Step 4: Perform alarm rationalization. Alarm rationalization is a comprehensive review of the alarm system to ensure it complies with the principles in the alarm philosophy. This team-based effort re-examines existing and potential alarms configured on a system. Alarms to be added, deleted and reconfigured are identified, prioritized and documented. The resulting alarm system has fewer configured alarms and is consistent and documented with meaningful priority and setpoint values.

Step 5: Implement alarm audit and enforcement technology. Once an

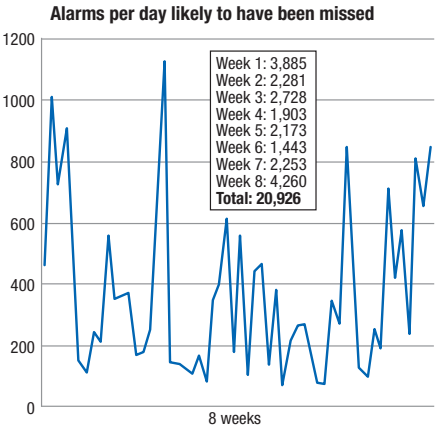

FIGURE 5. Despite sound averages for alarm rates, it can still be the case that many alarms could be missed during alarm flood periods

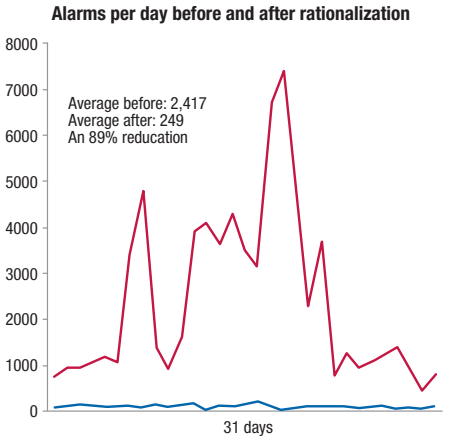

FIGURE 7. Alarm rates can usually be brought into target limits by alarm rationalization and bad-actor reduction steps

alarm system is rationalized, its configuration must not change without authorization. Because DCS systems can be easily changed by a variety of sources, they often require mechanisms that frequently audit (and enforce) the approved configuration.

Step 6: Implement advanced alarm management. Certain advanced alarm capabilities may be needed on some systems to address specific issues. For example, state-based alarming monitors the current process state, and alarm settings are dynamically altered in predetermined ways to match the alarming requirements of that process state. Alarm flood suppression temporarily eliminates the expected and distracting alarms from a unit trip, leaving the relevant alarms that assist the operator in managing that post-trip situation. Such advanced methods can ensure that the alarm system is effective even in abnormal situations.

Step 7: Control and maintain the improved system. An effective alarm system requires an ongoing and typically automated program of system analyses that may include KPI monitoring and the correction of problems as they occur.

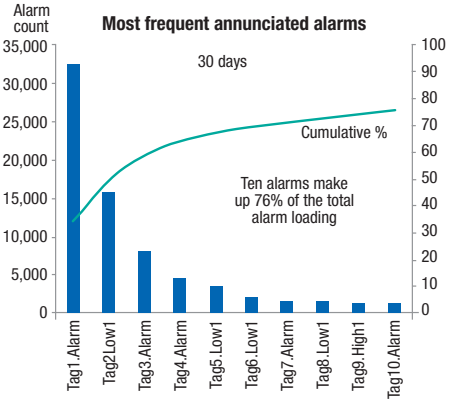

FIGURE 6. In many cases, the most frequently occurring alarms make up the bulk of the total alarm load

Concluding remarks

The various problems with alarm systems are well recognized and there are proven solutions to these problems. The principles from these solutions have been successfully applied to thousands of alarm systems worldwide. The alarm management body of knowledge is mature. Solving alarm-system problems simply requires the will and effort to do so. ■

Edited by Scott Jenkins

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Shell-and-Tube Heat Exchangers: The Design Cycle

Following this step-by-step approach will ensure that the heat exchanger will perform as required when finally fabricated

Saheli Bhattacharyya and Siddhartha Mukherjee
Air Liquide Global E&C Solutions India

IN BRIEF

Shell-and-tube heat exchangers are among the most commonly used equipment in the chemical process industries (CPI), especially in petroleum refineries and chemical manufacturing facilities. The design cycle of a heat exchanger starts with the process engineer. However, to ensure a smooth fabrication, startup and operation, the cycle further goes through a mechanical design stage followed by detailed design by the fabrication vendor. The final geometry of the heat exchanger released for fabrication should meet both the process as well as the mechanical requirements.

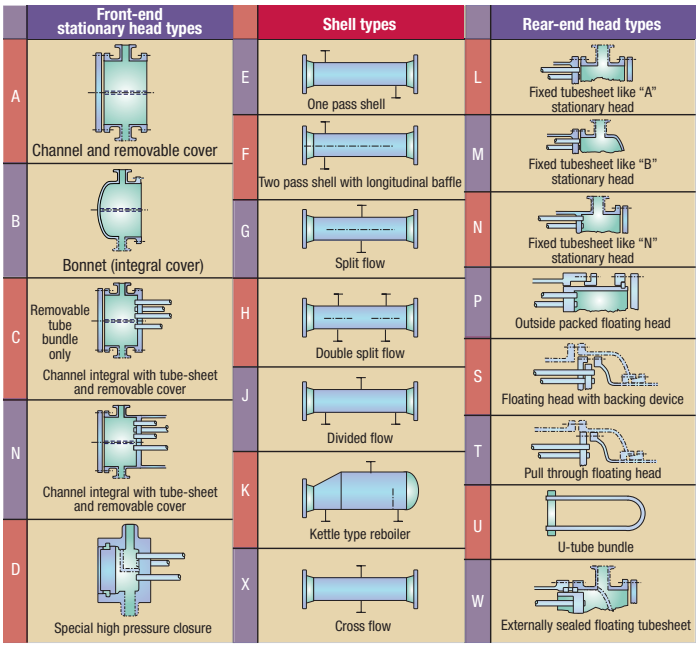


FIGURE 1. TEMA construction types for shell-and-tube heat exchangers (source: TEMA)

The design of a shell-and-tube heat exchanger involves a close interaction among three parties: the process engineer, the mechanical engineer and the fabrication vendor. The process engineer and the mechanical engineer belong to the engineering company that carries out the detailed engineering design. The third-party is the fabrication vendor. The success of the design depends on how effectively all three parties have coordinated in the course of the design cycle of this equipment.

Shell-and-tube heat exchanger types

There are three most common types of shell-and-tube heat exchangers — fixed tubesheet design, U-tube design, and the floating head type [*1*].

Fixed tubesheet. The main feature of the fixed-tubesheet heat exchanger is that it has straight tubes that are secured at both ends to tubesheets, which are welded to the shell. Figure 1 shows the different types of front heads, rear heads and shell types as specified by the Tubular Exchanger Manufacturers Assn. (TEMA; Tarrytown, N.Y.; www.tema.org).

The fixed tubesheet design is low in cost because of its simple construction. In addition, mechanical cleaning of the inside of the tubes is possible after removal of the channel cover or bonnet. However, the bundle is fixed to the shell. As a result, the bundle cannot be removed and therefore, the outside of the tubes cannot be cleaned

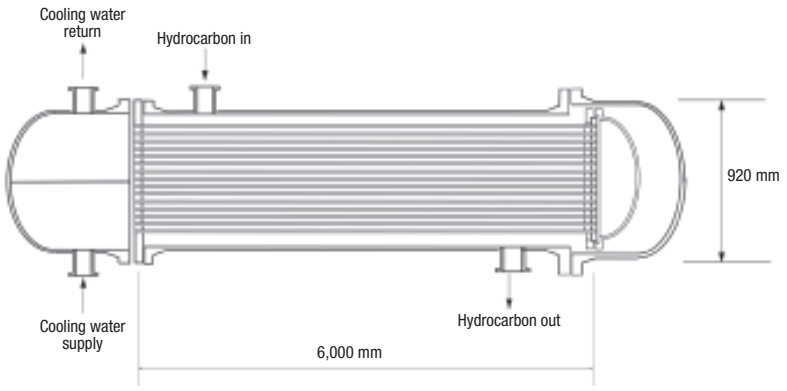
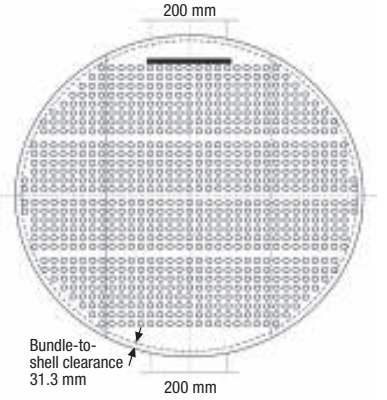


FIGURE 2. This diagram shows the setting plan drawing as per the preliminary process data sheet (PDS)



Shell insider diameter: 920 mm
Tube type: plain
Tube pitch: 25.40 mm
Tube count: 808
Outer tube limit: 888.7 mm
tube diameter: 19.05 mm
Tube layout angle: 90 deg
Baffle cut %: 27

FIGURE 3. Here is the tube layout from the preliminary PDS

mechanically. Thus, fixed-tubesheet heat exchangers are used only in applications where the shellside fluid is non-fouling, or the shellside fluid is fouling but can be removed by chemical cleaning.

In addition, in this type of construction, differential expansion of the shell and tubes due to different operating temperatures may result in thermal stresses.

U-tube. In a U-tube heat exchanger, the tubes are bent in the shape of a "U." There is only one tubesheet to which both ends of the tubes are secured. This type of exchanger is a high-cost product because of the work involved in bending the tubes inside the shell. In addition, the minimum U-bend diameter is usually three times the tube outer diameter, so the passlane width is considerably larger in a U-tube heat exchanger. Therefore, for a given number of tubes, a U-tube heat exchanger will have a larger shell diameter compared to that having straight tubes.

Unlike a fixed-tubesheet heat exchanger, the U-tube heat exchanger has one end free in order for the bundle to expand or contract depending on the process conditions. Further, the outsides of the tubes can be mechanically cleaned, as the tube bundle can be removed. The insides of the tubes in such exchangers cannot be cleaned effectively by mechanical means and must be cleaned chemically. Thus, U-tube heat exchangers are recommended for services with the dirty fluid circulating in the shellside. If there is some tube-side fouling, it should be effectively tackled by chemical cleaning.

Floating head. In this design, one tubesheet is fixed relative to the shell. At the other end, the tubes are secured to a freely moving tube sheet. A floating-head cover is bolted to the tubesheet. This arrangement allows for free expansion of the tube bundle. The feature of this construction is that the tube bundle can be removed from the shell. Thus, the floating-head heat exchanger offers the unique advantage that both the inside and outside of the tubes can be cleaned mechanically.

Shellside and tubeside fluids

The selection of fluid streams to be circulated through the shellside or tubeside is of primary importance to the designer. Theoretically speaking, the hot fluid should circulate through the tubeside. In this way, heat is effectively transferred from the tubeside fluid to the shellside fluid surrounding the tubes. Conversely, if the hot fluid flows though the shellside, a part of the heat is lost to the atmosphere since the insulation on the shell cannot be fully effective. However, there are several tradeoffs in fluid stream selection. The following parameters need to be considered while making such a decision [*1*]:

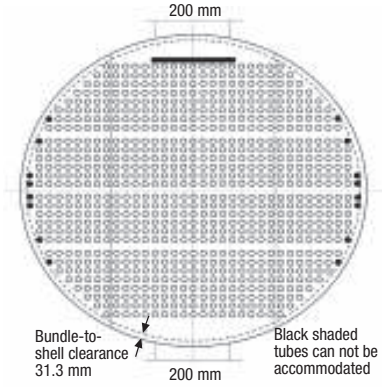
Pressure. The fluid with the higher pressure should circulate through the tubeside. Tubes, with their smaller diameter, are able to accept higher pressures. In this way, one can avoid having to design larger diameter shell components for high pressure, resulting in an expensive design. If, because of process reasons, it is required to place the fluid with the higher pressure in the shellside, then the exchanger should be designed with a smaller shell diameter and a longer shell.

Corrosiveness. If the more corrosive fluid demands superior metallurgy, then it should normally flow through the tubeside. This way, only the tubes, channel, channel cover, floating-head cover and tubeside tubesheet face need to be of superior metallurgy. This reduces the cost of the exchanger.

Conversely, if the more corrosive fluid circulates through the shellside, then the shellside components as well as the tubes would have to be of a superior metallurgy. The cost of the latter exchanger would definitely be higher.

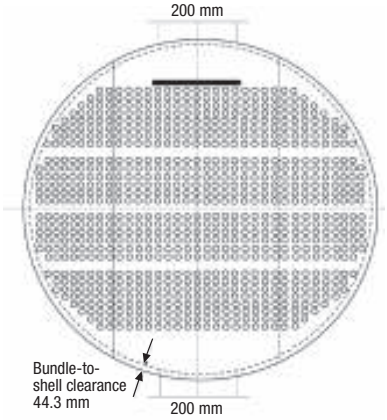
Viscosity. Viscous fluids should preferably flow through the shellside. Since the shellside is prone to higher turbulence for a given pressure drop, a higher heat-transfer coefficient is achieved on the shellside rather than on the tubeside.

Fouling tendency. The fluid that has a higher fouling tendency should preferably flow through the tubeside. This is primarily because mechanical cleaning of the inside of the tubes is much easier than cleaning the outside of the tubes. Furthermore, shellside is more susceptible to fouling because of dead spaces. In this connection, it may be noted that the dirtier fluid will be more viscous as well, and we have discussed above that the more viscous fluid should circulate through



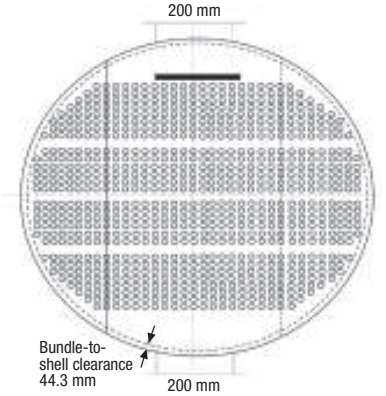
Shell insider diameter: 920 mm
Tube type: plain
Tube pitch: 25.40 mm
Tube count: 808
Outer tube limit: 888.7 mm
tube diameter: 19.05 mm
Tube layout angle: 90 deg
Baffle cut %: 27

FIGURE 4. Here is the comment on the preliminary PDS tube count, based on the mechanical design check



Shell insider diameter: 960 mm
Tube type: plain
Tube pitch: 25.4 mm
Tube count: 848
Outer tube limit: 915.73 mm
tube diameter: 19.05 mm
Tube layout angle: 90 deg
Baffle cut %: 27

FIGURE 5. Here is the tube layout as per the final PDS



Shell insider diameter: 960 mm
Tube type: plain
Tube pitch: 25.4 mm
Tube count: 848
Outer tube limit: 915.73 mm
tube diameter: 19.05 mm
Tube layout angle: 90 deg
Baffle cut %: 26

FIGURE 6. Here is the final tube layout by the vendor

the shellside. The designer's experience is useful here to arrive at the most suitable solution.

Flowrate. If the stream with lower flowrate circulates through the shellside, the heat-transfer coefficient can be increased by increasing the velocity. For a given shell diameter, this requires reducing the baffle spacing and baffle cut. Very low baffle spacing or cut, however, does not give a good flow pattern and thus is not recommended. In such cases, one can have two shells for a better heat-transfer coefficient, although it is expensive. On the other hand, if the stream with the lower flowrate circulates through the tubeside, its velocity (and hence the heat-transfer coefficient) can be increased by increasing the number of tube passes. This is, however, subject to pressure drop limitations.

Geometrical parameters

TEMA type. The TEMA type of a shell-and-tube heat exchanger includes the front-end stationary head type, shell type and the rear end head type, and are represented as AES, BEM, BKU and others. A detailed discussion of the various TEMA types is beyond the scope of this article. For additional details, readers are invited to consult TEMA [*2*].

Tube pitch and layout patterns. There are four types of tube layout patterns deployed in shell-and-tube heat exchangers: triangular (30 deg), rotated triangular (60 deg), square (90 deg) and rotated square (45 deg) [*1*].

The tube pitch is the center-to-center distance between adjoining tubes. For a triangular pattern, TEMA recommends a minimum tube pitch of 1.25 times the tube outside diameter. For square patterns, TEMA additionally recommends a minimum cleaning lane of 6.4 mm between adjacent tubes. Thus, the minimum tube pitch for square patterns is either 1.25 times the tube outside diameter or the tube outside diameter plus 6.4 mm, whichever is larger.

The selection of pitch is a compromise between a small pitch for improved shellside heat transfer and surface compactness, and a larger pitch for decreased shellside plugging and ease of shellside cleaning. A triangular or rotated triangular pattern will accommodate a larger number of tubes compared to a square or rotated square pattern. Furthermore, a triangular pattern produces higher turbulence and therefore a higher shellside heat-transfer coefficient. For identical tube pitch and cross flowrate, the tube layouts, in decreasing order of shellside heat-

TABLE 1. PRINCIPAL PROCESS PARAMETERS FOR CASE STUDY

	Parameter	Units	Shell side	Tube side
1	Fluid		Hydrocarbon	Cooling water
2	Flowrate	kg/h	112400	To be calculated
3	Mass vapor fraction in/out		0.077 / 0.016	0.0 / 0.0
4	Temperature in/out	°C	66.0 / 43.0	32.0 / 42.0
5	Heat duty	MW	2.3	
6	Inlet pressure	bar (g)	5	5.5
7	Allowable pressure drop	bar	0.3	0.7
8	Fouling resistance	m^2K/W	0.00026	0.00036
9	Material of construction		Carbon steel	Carbon steel
	Physical properties (liquid)			
10	Density in/out	kg/m^3	558.8 / 585.3	995.3 / 991.7
11	Viscosity in/out	cP	0.14 / 0.16	0.76 / 0.63
12	Heat capacity in/out	kJ/kg K	2.89 / 2.34	4.18 / 4.18
13	Conductivity in/out	W/m-K	0.11 / 0.12	0.62 / 0.63
	Physical properties (vapor)			
14	Density in/out	kg/m^3	12.1 / 8.0	-
15	Viscosity in/out	cP	0.01 / 0.01	-
16	Heat capacity in/out	kJ/kg K	2.04 / 2.05	-
17	Conductivity in/out	W/m-K	0.02 / 0.03	-

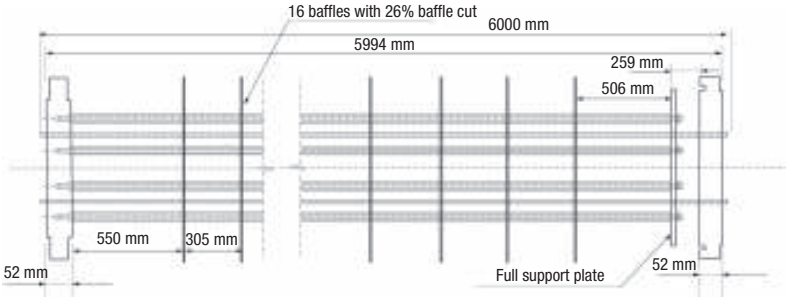


FIGURE 7. Shown here is a side view of the final tube-bundle-assembly drawing by the vendor

transfer coefficient and pressure drop are: 30 deg, 45 deg, 60 deg and 90 deg [3].

Triangular patterns with a tube pitch of 1.25 times the tube outside diameter does not allow mechanical cleaning of tubes on the shellside, since the triangular layout does not provide a free passage for mechanical cleaning. Consequently, a triangular layout is limited to clean shellside services. However, if chemical cleaning on the shellside is effective, then a triangular layout may be used for dirty shellside services since chemical cleaning does not require free passage, unlike mechanical cleaning.

In case chemical cleaning proves ineffective, then one has to resort to mechanical cleaning. In such a case, the square pattern should be selected. Fixed tubesheet design is not used because the tube bundle cannot be pulled out for mechanical cleaning. In those cases, the U-tube or floating-head exchangers are normally used.

A rotated triangular pattern seldom offers advantages, except that it is sometimes used to eliminate acoustic vibration problems.

Type of baffle. The purpose of baffles is to direct shellside fluid across the tube bundle, increase shellside velocity and heat-transfer coefficient as well as provide support to the tube bundle. With proper spacing, they can even control tube vibrations. Baffles may be single-segmented or double-segmented. For more information, see Ref. 1.

Baffle spacing. TEMA recommends a minimum baffle spacing of either one-fifth of the shell inside diameter or 50 mm, whichever is greater. The maximum baffle spacing is normally the shell inside diameter. Small baffle spacing causes poor crossflow through the bundle because of higher resistance and increases the flow of leakage streams. In addition, it causes difficulties in shellside mechanical cleaning. On the other hand, large baffle spacing allows more longitudinal flow which is less effective than crossflow and also increases the unsupported tube span.

Baffle cut. Baffle cut is expressed as percentage of the shell inside diameter. Generally baffle cut varies from 15 to 45% of the shell inside diameter. Baffle cut and spacing should be in proportion to have a ratio of window flow to crossflow velocity close to one. This will give a uniform flow pattern within the shell.

Steps in the design cycle

First, the process engineer carries out the thermal calculations of the heat exchanger in order to meet the process requirements coming out of the process simulation. The prime objective here is to arrive at an optimized exchanger geometry using the process data and available pressure drops, while avoiding any unnecessary overdesign. Detailed mechanical calculations and fabrication issues are not considered at this stage.

After completion of the thermal calculations, the process information and preliminary geometry are reproduced in the form of a preliminary process data sheet (PDS), which also includes a preliminary tube layout drawing and a setting plan drawing of the heat exchanger.

In the next step, the preliminary PDS is issued for mechanical design check. A mechanical design check is carried out wherein the design

TABLE 2. HEAT EXCHANGER GEOMETRY AS PER PRELIMINARY PDS

1	Type of heat exchanger	Units	AES	
2	Shell inside diameter	mm	920	
3	Surface area	m^2	282	
4	Overdesign	%	6.4	
			Shellside	**Tubeside**
5	Design conditions			
	Temperature	°C	90	70
	Pressure	bar (g)	8	8
6	Corrossion allowance	mm	3	3
7	Allowable pressure drop	bar	0.3	0.7
8	Calculated pressure drop	bar	0.28	0.68
9	Nozzle size inlet/outlet	mm	200 / 200	200 / 200
10	**Tube Details**			
	Tube outside diameter	mm	19.05	
	Tube wall thickness	mm	2.11	
	Tube length	m	6	
	Layout angle	deg	90	
	Tube pitch	mm	25.4	
	Tube count		808	
	Tube passes		4	
11	**Baffle Information**			
	Type		Single segmental	
	Orientation		Parallel	
	Number		16	
	Central spacing	mm	319.2	
	Inlet spacing	mm	457.7	
	Outlet spacing	mm	584.7	
	Baffle cut	%	27	

TABLE 3. HEAT EXCHANGER GEOMETRY AS PER FINAL PDS				
1	Type of heat exchanger	Units	AES	
2	Shell inside diameter	mm	960	
3	Surface area	m^2	294	
4	Overdesign	%	7.8	
			Shellside	**Tubeside**
5	Design conditions			
	Temperature	°C	90	70
	Pressure	bar (g)	8	8
6	Allowable pressure drop	bar	0.3	0.7
7	Calculated pressure drop	bar	0.26	0.64
8	Corrosion allowance	mm	3	3
9	Nozzle size inlet/outlet	mm	200 / 200	200 / 200
10	**Tube Details**			
	Tube outside diameter	mm	19.05	
	Tube wall thickness	mm	2.11	
	Tube length	m	6	
	Layout angle	deg	90	
	Tube pitch	mm	25.4	
	Tube count		848	
	Tube Passes		4	
11	**Baffle Information**			
	Type		Single segmented	
	Orientation		Parallel	
	Number		16	
	Central spacing	mm	316.4	
	Inlet spacing	mm	461.0	
	Outlet spacing	mm	588.0	
	Baffle cut	%	27	

conditions and the exchanger geometry specified in the preliminary PDS are used to estimate mechanical details, such as the thicknesses of the shell, the head, the tubesheet and so on. In addition, the mechanical design check may also lead to minor changes in the number of tubes, tube layout and so on. This is then referred back to the process engineer, who might tune the thermal design to suit the requirements of the mechanical design. The final PDS is then issued.

Based on the final PDS, the mechanical design output is reproduced in the form of a mechanical data sheet (MDS). This MDS is then sent to the fabrication vendor for detailed mechanical design and fabrication. The MDS specifies certain minimum thicknesses and other guidelines for the vendor to follow. The vendor carries out the detailed mechanical calculations based on the guidelines specified in the MDS. In this step, all the fabrication-related issues are taken care of, and some of the details, such as tube layout, inlet and outlet baffle spacing and so on, may be adjusted by the vendor.

The design output of the vendor consists of detailed vendor drawings. The mechanical engineer must now check the vendor drawings from the mechanical engineering point of view. In addition, the process engineer also checks the vendor documents from the process angle. Process information and specification with regard to geometry (for example, TEMA type, type of baffle, baffle orientation and so on) in vendor documents should not be deviated from. The vendor might have made slight adjustments in the baffle spacing (central, inlet and outlet) and the baffle cut to suit fabrication requirements. These are verified by the process engineer for acceptance. Normally, if there has been good coordination among the three parties, this stage of vendor drawing review does not generate any "hiccups." If there are no further comments, then the exchanger is cleared for fabrication.

Case study

The problem. Let us consider a hydrocarbon cooler in a pertoleum-refinery complex. A hydrocarbon vapor-liquid mixture, at a pressure of 5.0 barg and a temperature of 66.0°C, enters a heat exchanger at 112,400 kg/h and is to be partially condensed using cooling water. The mass vapor fraction of the hydrocarbon mixture is 0.077. Condensation takes place in the exchanger. The hydrocarbon outlet from the exchanger should have a mass vapor fraction of 0.016 and a temperature of 43.0°C. A pressure drop of 0.3 bar on the hydrocarbon side is permissible for this service. For the cooling medium, cooling water at 32.0°C and 5.5 barg pressure is available. The return temperature of the cooling water is specified at 42.0°C. An allowable pressure drop of 0.7 bar is specified for the cooling water side.

Table 1 describes the principal process parameters for this case study.

Design step 1 (preliminary PDS). TEMA type "AES" was used for this heat exchanger. Cooling water was chosen as the cooling medium and was allocated to the tubeside. The condensing hydrocarbon was allocated to the shellside equipped with a parallel single-segmented baffle to avoid undesired exchanger flooding. This arrangement, with horizontal shellside condensation and cooling water flowing through the tubeside is the most common configuration used in CPI. Floating head was selected for ease of both shellside and tubeside cleaning. In addition, a 90-deg tube layout pattern was considered, since it provides a free passage for shellside cleaning.

Thermal calculations for this heat exchanger were carried out, and the preliminary PDS was prepared. The geometric details and the tube layout resulting from thermal calculations were also included. Table 2 illustrates the heat exchanger geometry as per the preliminary PDS. The results of the thermal design are further illustrated in Figures 2 and 3.

Design step 2 (mechanical design check). Based on the preliminary PDS, along with the preliminary tube-layout drawing generated during the thermal design, the mechanical engineer carried out a design check. His findings were as follows:

TABLE 4. HEAT EXCHANGER GEOMETRY AS PER MDS AND VENDOR DRAWINGS						
	As per MDS			As per vendor drawing		
1	TEMA type	Units	AES	TEMA type	Units	AES
2	Shell inside diameter	mm	960	Shell inside diameter	mm	960
3	Overdesign	%	7.8	Overdesign	%	5.9
4	Allowable pessure drop (shellside / tubeside)	bar	0.3 / 0.7	Allowable pressure drop (shellside / tubeside)	bar	0.3 / 0.7
5	Calculated pressure drop (shellside / tubeside)	bar	0.26 / 0.64	Calculated pressure drop (shellside / tube-side)	bar	0.28 / 0.65
6	Tube information:			Tube information:		
	Tube outside diameter	mm	19.05	Tube outside diameter	mm	19.05
	Tube wall thickness	mm	2.11	Tube wall thickness	mm	2.11
	Tube length	m	6	Tube length	m	6
	Layout angle	deg	90	Layout angle	deg	90
	Tube pitch	mm	25.4	Tube pitch	mm	25.4
	Tube count		848	Tube count		848
	Tube passes		4	Tube passes		4
7	Baffle information			Baffle information		
	Type		Single segmental	Type		Single segmental
	Orientation		Parallel	Orientation		Parallel
	Number		16	Number		16
	Central spacing	mm	316	Central spacing	mm	305
	Inlet spacing	mm	461	Inlet spacing	mm	550
	Outlet spacing	mm	588	Outlet spacing	mm	506
	Baffle cut	%	27	Baffle cut	%	26
8	Total tube sheet thickness	mm	104	Total tube sheet thickness	mm	104
9	Full support plate at floating head		Provided	Full support plate at floating head		Provided
10	Support plate to head distance	mm	107	Support plate to head distance	mm	259

- From a fabrication point of view, it was not possible to accommodate 808 tubes (the number of tubes proposed in the preliminary PDS) with the given tube layout and within a shell of diameter 920 mm. Only 792 tubes were possible. Figure 4 illustrates the sixteen tubes (black shaded) that could not be accommodated from the mechanical design point of view.
- In the preliminary PDS, the tube bundle-to-shell clearance was specified as 31.3 mm. The mechanical engineer recommended a figure of 44.0 mm or higher.
- The total tubesheet thickness in the preliminary PDS was 68.0 mm based on a preliminary assumption. The mechanical engineer calculated it as 104.0 mm. Tubesheet thickness affects the effective tube length. Hence the tubesheet thickness recommended by the mechanical engineer needs to be considered for thermal performance check.

Design step 3 (final PDS). Based on the feedback from the mechanical design check, the tube count was reduced to 792. In addition, the bundle-to-shell clearance was increased from 31.3 mm to 44.3 mm. The tubesheet thickness was also increased to 104.0 mm.

A thermal calculation was carried out with the above changes. This resulted in a heat-exchanger surface area of 275 m^2 and an overdesign (based on surface area) of 2.8%. This overdesign of 2.8% is rather low.

In order to arrive at a reasonable overdesign, the option was to increase the shell diameter, keeping the tube length unchanged. The shell diameter was therefore increased from 920 mm to 960 mm, while keeping the tubes 6 m in length (a tube length of 6 m is a standard length and is also the preferred tube length by most users). The number of tubes was now 848. After incorporating the above mentioned changes, we arrived at an overdesign of 7.8%.

Table 3 illustrates the revised heat exchanger geometry based on the final PDS. Figure 5 illustrates the revised tube layout.

The final PDS, after incorporation of the above numbers, was then released for mechanical design.

Design step 4 (final mechanical design and MDS). Based on the final PDS along with the corresponding tube layout drawing (Figure 5), the mechanical engineer carried out the final mechanical design. The results of this mechanical design were reproduced in the form of an MDS. Most of the revised parameters in the final PDS were incorporated in the MDS. The baffle spacings were, however, slightly adjusted. The MDS typically consists of the following information:

- Elevation drawing
- Tube layout drawing
- Tubesheet thickness, girth flange thickness, thickness of shell and bonnet
- Key plan
- Design data
- Nozzle data
- Material of construction

The MDS was then submitted to the vendor for generating the vendor drawings.

Design step 5 (vendor drawings). The vendor provided a number of drawings of the heat exchanger. Certain parameters have an impact on the thermal performance of the heat exchanger, hence the relevant

drawings of the vendor need to be checked. The tube-layout drawing and the tube-bundle-assembly drawing received from the vendor for this particular case study were two such drawings, and are illustrated in Figures 6 and 7.

The vendor considered the baffle type and orientation as mentioned in the MDS. However, the inlet, outlet and central baffle spacings calculated by the vendor were slightly different from those mentioned in the MDS. Table 4 illustrates the comparison between the heat exchanger geometry at the MDS stage and the design provided by the vendor.

The baffle cut mentioned in the MDS was 27%. The vendor had considered a baffle cut of 26%. A closer look at the vendor's drawing revealed that the baffle edge passes along the tube center line. From the fabrication point of view, the baffle edge should pass through the central line of tubes and not through the gaps between the tubes.

This was a type "AES" heat exchanger. During the thermal calculations, a full support plate at floating head was provided. The distance between the full support plate and the floating head was assumed by the calculation tool with a default value of 101 mm. The vendor performed the detailed mechanical calculations, which resulted in a distance between the full support plate and the floating head of 259 mm (see Figure 7). This means that the dead zone between the floating head and the support plate has increased, resulting in reduced effective area for heat transfer. ***Design step 6 (final process crosscheck).*** A final process check of the thermal performance was carried out, keeping in mind that the vendor had provided different numbers for the baffle cut, the baffle spacings, and the distance between the full support plate and the floating head. As the baffle arrangement affects the shellside flow pattern and hence the shellside heat transfer coefficient, the actual baffle arrangement provided by the vendor needed to be checked with respect to thermal performance.

A revised thermal check was carried out and it was confirmed that the changes in process performance were not significant. If Steps 1–5 are systematically carried out, this sixth step is usually a formality.

Final remarks

A solid understanding of the heat exchanger fundamentals and the process requirements are essential for an effective heat exchanger selection and its thermal design. In addition, a close coordination among the process engineer, the mechanical engineer and the vendor is important to achieve a smooth design cycle and avoid unnecessary last minute changes, which ultimately lead to delays in delivery and overall project execution. ■

Edited by Gerald Ondrey

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Materials Management — Evolving the Process for an Evolving Marketplace

The case examples presented here show that proper planning, communication and execution of tasks can add value and reduce unintended negative consequences for many capital-intensive projects

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Materials management means something different to different groups of people. For the engineering and construction (E&C) industry, the Construction Industry Institute (CII; Austin, Tex.; www.construction-institute.org) [*1*] defines materials management as "a complex and comprehensive process involving people, organizations, technologies, and processes that manage the definition, source planning, quantification, supplier qualification, purchasing, supplier quality assurance and quality control (QA/QC), expediting, transportation, logistics and control of materials and associated information across the life cycle of a capital project" (Ref. 1, p. v).

In the 30 years since the E&C industry first began focusing on materials management as a concept, the practice has evolved and continues to evolve. As E&C contractors face challenges to remain competitive in a dynamic marketplace, a lightly structured materials-management organization that functions as a coordinating resource provides a vehicle to facilitate the delivery of lowest possible total-installed-cost (TIC) facilities. And — if thoughtfully structured within the overall E&C organization — a thoughtful materials-management framework can be the most effective tool that the E&C project management has to support all business objectives.

Discussed below is one example of how a materials-management organization should be structured to optimize materials-related work processes in an evolving environment. The discussion shows how proper materials-management effort can help an organization to add value and defray unintended negative consequences (Figures 1 and 2).

FIGURE 1. By establishing a well-developed materials-management organization to coordinate the management of resources involved in capital-intensive engineering projects, chemical process industries (CPI) facilities can both reduce the facility's total installed cost and support all business objectives

Key activities

In Ref. 1, p. 17, CII articulates the key materials-management activities as the following:

- Materials-related requirements planning
- Project-acquisition strategies
- Purchasing and subcontracting activities
- Expediting activities
- Supplier-quality management
- Transportation and logistics actvities
- Site-materials management
- Planning for operations and maintenance turnover

Further details can be found in in additional CII publications [*1–5*].

Scope and breadth

To facilitate the lowest TIC, materials-management planning and activities need to be "cradle-to-grave," "cross-functional" and assertively proactive. In terms of cradle-to-grave, this means the materials-management team engages at the earliest phases of project planning, and continues, actively engaged, until all materials-related issues on a project have been addressed, resolved and dispositioned.

In this context, cross-functional means that the materials-management team addresses every function within project execution that involves project materials, specifically the following:

- *All engineering disciplines* — This includes activities related to civil, structural and mechanical engineering, piping, electrical, instruments and architectural

considerations

- *Procurement activities (as organized by the E&C company)* — This involves purchasing, expediting, ensuring supplier quality, and managing traffic and logistics
- *Construction activities* — This involves field engineering, receiving, warehousing and withdrawal
- *Startup and turnover* — This includes the materials that are "permanent plant" (meaning they will become part of the physical plant); those that are temporary (those that are used and scrapped during construction); and spares that are used in installing, commissioning or operating the facility

Most important is the need for the materials-management organization to be assertively proactive — not just proactive, but assertively so; this is discussed in detail below.

Organization and reporting

Within the E&C industry, some organizations have chosen to simply re-describe or re-characterize their procurement organization as materials management. But historically, materials-requirements planning and project-acquisition strategies typically involve a substantial amount of engineering. Site-materials management and planning for operations and maintenance turnover typically involve the construction, startup and turnover organizations. The act of simply re-describing the "procurement function" as "materials management" subverts this broad process and underestimates the contributions that both the engineering and construction infrastructure have to offer. Accordingly, the most effective materials-management organizations are operated independently of the engineering, procurement, or construction organizations, and operate as a non-transactional organizing resource, reporting directly to project management.

Similarly, we need to emphasize the need for the materials-management organization to be non-transactional and silo-free. The engineering, procurement and construction organizations are often described as silos, as are many of the individual disciplines or sub-functions. These silos are typically individual cost centers within the E&C organization and execute transactions. For instance, engineering disciplines produce drawings and data sheets; the purchasing group produces purchase orders (POs); the traffic and logistics organizations execute orders for transportation.

FIGURE 2. To be most effective, the materials-management framework should strive to break down silos and function independently of the procurement department, to ensure that the efforts remain focused on the overall objectives and not simply focused on material transactions

These cost centers are driven by project management to optimize individual work processes. However, while each needs to be as efficient as possible, they often optimize their processes to the detriment of inter-related disciplines or functions. This negative activity often leads to the formation of silos that isolate individual groups or functions. As discussed below, materials-management organizations that take on transactions or constitute a silo are at risk of becoming part of the problem instead of part of the solution; specifically, if the materials-management organization starts to do work (such as carrying out transactions) that should be done by an engineering or procurement discipline, they tend to become an entity unto themselves — instead of simply coordinating the effort and seeing that the responsible disciplines execute their duties.

Automation: An optimizing tool

The CII definition of materials management [*1*] incorporates concepts such as "technologies…processes… and control of… information." Today, the same evolving automation landscape that is transforming how E&C contractors design and construct CPI facilities has the potential to play a pivotal role in how materials are managed. Materials-management staff must not only be conversant with specific materials-related processes across the engineering, procurement and construction functions, but also conversant in automation-related tools and technologies. This knowledge must not be limited to automation-related tools and technologies that are utilized specifically within the particular E&C enterprise — whether internally developed or commercially purchased. Ideally, this should also extend to a working knowledge of automation tools used by partners, suppliers and clients, as well as trends and emerging automation-related technology developments. Such broad-based knowledge allows the materials-management organization to identify nascent opportunities for optimization, and to coordinate project-specific work process improvements early in project execution — while the potential to capture the benefits still exists.

Project landscape

So why is all of this important? Despite the best efforts of all E&C contractors, clients and manufacturers to standardize facilities, work processes and products, the project landscape is constantly evolving. Underlying facility processes evolve or incorporate new technology; manufacturers improve and change products; project sites differ; logistical challenges vary site by site, depending on available

FIGURE 3. Capital-intensive CPI projects typically involve a mix of off-the-shelf and customized equipment components and systems, which adds complexity to the overall materials-management process

infrastructure; brownfield projects differ from greenfield projects; new suppliers appear from emerging-economy countries; and many minor parameters change from project to project.

While E&C contractors strive to maximize the use of standardized off-the-shelf materials, the nature of most facilities requires an extensive amount of customized equipment and materials (Figure 3). As such, the design process is often described as a series of successive approximations, changing as the engineering disciplines and suppliers interact and react to finalize design. So every individual project presents new and varying challenges, each of which, if addressed in a timely manner, offers opportunities to lower TIC, or conversely, can negatively impact TIC if not properly managed.

Materials-management skillset

The scope and scale of major projects these days require E&C contractor organizations to be highly specialized. Design engineers often struggle to comprehend how many of the facilities on the project they design will be erected. Construction engineers and superintendents often lack knowledge of many design parameters that impact and complicate the design. Purchasing and expediting staff often lack the ability to fully visualize or comprehend the complexity of the materials they order and expedite. And automation support staff often understand data flows among interacting automation tools, but do not fully understand the underlying work processes.

The best materials-management organizations employ personnel who have a range or general knowledge of all processes and automation tools but are not specialists in any, except by chance. Staffing levels needs to be consistent with the ability to identify opportunities for materials-related, work-process enhancement, in order to coordinate work-process modifications where justified, to monitor work-process execution, and to identify negative trends. Personnel can be drawn from all disciplines — including engineering personnel, such as design engineers; procurement experts (such as buyers, expeditors and inspectors), construction (staff such as field engineers), warehouse staff, and more. But most important is that the materials-management organization is managed by a materials manager who is conversant in all processes, including the design office, construction site and supplier processes.

The benefits of being proactive

Individual disciplines or functions (silos) will, by nature, work to optimize their individual processes, often unaware that internal process modifications related to materials work may negatively impact other disciplines or functions. Also, opportunities may exist within an individual discipline or function that offer noteworthy savings in other disciplines or functions, and the owning discipline may not be aware.

A knowledgeable, involved materials-management organization that is proactively monitoring project development will recognize, capture and implement materials-related process enhancements. Conversely, it will also work to deflect and defray downstream costs in cases where an upstream discipline or function is about to modify an internal process that is unaware of downstream materials impact and costs. And since most work-process modifications tend to be in some way related to automation, this emphasizes the need for the materials-management organization to be knowledgeable of discipline/function functionality (in terms of what activity a set of software executes) within the E&C, as well as supplier functionality, and evolving automation trends. Often an upstream discipline or function will possess information within an automation tool or system, or have the ability to enhance upstream information at relatively minor impact; if passed to downstream disciplines or functions, such advances often provide opportunities for significant downstream cost savings.

Gap removal versus gap filling

In an evolving environment, materials-management work processes evolve and gaps develop. An assertive, proactive materials-management organization will work to close or eliminate those gaps within existing disciplines or functions, as far upstream as possible. Those disciplines and functions will, by nature, tend to resist adding additional duties and transactions, particularly when project management refuses to provide the additional resources needed to do so.

Reactive and passive materials-management organizations tend to close those gaps by "filling" the gap — that is, by taking on the additional transactions themselves. While there may be limited cases that justify this, they need to be exceptions, and not be undertaken in a way that creates an independent structure or silo within the E&C organization. A gap

that is filled as opposed to closed organizationally tends to add overhead and unnecessary cost, particularly, in cases where an upstream work-process modification may offer an opportunity to close the gap altogether.

Consider some specific examples. We'll take a look at three different situations, each exhibiting a different class of materials-related issue that can develop on a project where less-than-optimal materials management was executed. Then we'll look at how an assertive, proactive materials-management team could have added value.

Example 1. Minor protocol variations delay construction. For many process plants, piping systems constitute a major portion of the plant, and the piping design, supply, fabricate and erect process is not only almost always on the critical path, but constitutes one of the most complex work processes the E&C contractor faces (Figure 4). Unique pipe, fitting, and valve combinations (in terms of type, metallurgy, pressure rating and size combinations, or individual products) can involve quantities in the thousands, with the actual item count in the hundreds of thousands, spread over tens of thousands of construction drawings. Fortunately, experienced E&C contractors have developed sophisticated protocols and procedures to address this complex process. Even minor deviations can have a serious impact on construction.

On a recent gas-plant project, the engineering team encountered some piping in a size range that was larger than normal. The team chose to modify the normal requisitioning protocol, using the mechanical team to requisition some piping components (a function that the piping team normally completed). In doing so, the mechanical team failed to follow the consistent component identification (ID) protocol used by the piping team — unaware that downstream protocols relied on upstream consistency. The components were purchased and shipped to the pipespool fabricator, but figuratively speaking, they were lost in the thousands of details that the materials-management system must track because they possessed a different component ID than the construction drawings.

FIGURE 4. Piping design, supply, fabricate and erect process constitutes one of the most complex work processes the E&C contractor faces. The use of a consistent, sophisticated management protocol is essential for success

This large-diameter piping required careful construction planning, utilizing limited cranage resources at the site. When the construction team began detailed planning two months ahead of erection, it came to light that several critical pipespools had not been fabricated, as the materials-management systems had been assigning a status of "short of materials" due to the inconsistency in component ID assignment. Upon closer examination, the misidentified items were physically located at the fabricator, and the pipespools released into fabrication. Unfortunately, these pipespools had a ten-week fabrication cycle and, due to challenges in the logistics at the site, an additional ten-week shipping cycle. The pipespools finally arrived, 12 weeks late, and the construction team was forced to reschedule significant erection work to accommodate modified crane usage.

Example 2. Major mechanical POs are poorly managed by procurement. At many facilities, the E&C contractors deliver major sub-processes where the suppliers are employed to deliver not just equipment, but also to design and guarantee many subsystems. Examples include bulk-materials-handling facilities in smelters, conveyor systems on concentrators, and onsite manufacturing facilities, such as casthouses and anode rodding shops. These complex POs can entail tens of thousands of individual components and associated delivery lines or data records in the materials-management system — typically ranging into tens or even hundreds of millions of dollars. For such POs, procurement organizations tend to be the weak link. While design engineers and construction staff may be technically versed on the specific components of the PO, often the expediting staff is overwhelmed and fails to manage delivery information in the materials-management system to provide useful planning information. In the worst cases, shipment information is so poorly coordinated that site warehouse staff is unable to associate the physical shipment with the data in the materials-management system, and delays in the receiving process create delays for installation.

Example 3. Structural steel fabrication sub-processes are not timely managed. Almost all CPI facilities involve structural steel (SS). The process to design, supply, fabricate and erect SS is another complex materials-management undertaking, but not nearly as complicated as that required for piping. The process for steel is generally organized so that the fabricator handles most of the supply process, and often executes detailing. Project scope can range from 5,000 to 50,000 tons or more.

On a project involving a PO with a scope of 10,000 tons of SS, the E&C

engineering organization designed the structure using 3-D modeling software and delivered that model to an SS fabricator for detailing and delivery. Detailing entailed approximately 50,000 individual piecemarks (individual pieces of fabricated steel).

The structure was broken into about 50 sub-structures, or areas, within the model. For each area, the E&C engineering organization transmitted individual area models. Execution involved fabricator-detailed design and submittal to the E&C engineering organization, review and approval by the E&C engineering organization, release into fabrication by the fabricator, and subsequent delivery of the individual piecemarks to the jobsite. Each of these 50 area scopes involved approximately 1,000 piecemarks, and within the process was a data-delivery sub-process integrated into the materials-management system.

This data-delivery process captured 25 or more individual piecemark attributes (including component ID, description, weight, length, cost code and more) that the E&C contractor used to validate design, manage the steel, pay the fabricator, manage erection of the steel and so on. All POs involve some degree of supplier submittals, depending on the subject matter. SS-fabrication POs with detailing typically involve an extensive submittal process, with each piecemark drawing requiring review. E&C contractors typically use a review process that allows some fabrication to proceed, subject to conditions, with one common mode being released subject to incorporation of minor comments.

Meanwhile, the area data-delivery process required a submittal unto itself, with the E&C engineering organization feeding the materials-management system with these data. Both the E&C engineering organization and the fabricator were slow to finalize these area data submittals — so slow, in fact, that steel was being fabricated and shipped to the jobsite before the data were fed into the materials-management system. The net result was that many shipments of steel could not be "received" in the material-management system upon arrival at site, and this significantly impacted both warehouse operations and construction operations. The situation reached a level where an SS installation contractor filed a claim for delay, while tons of steel needed for erection sat in the laydown area, with the E&C contractor unable to "issue" the steel to the contractor, due to data-related issues.

Opportunities for improvement

Now let's review each of these three specific opportunities to see a proactive materials-management organization can add value.

Opportunity 1. Material-management review of POs, material requisitions (MRs), and extra-charge approval requests (ECARS). In the example noted above, project management failed to comprehend the value that a cross-functional materials-management team could offer, and did not fully support the

materials-management team — often siding with an engineering organization that portrayed the materials-management team as making recommendations that offered little apparent value. For the piping process, issues arise almost daily that can lead to a serious unintended consequence, such as the delays described in this example. A competent materials-management team —one that has the attributes described above, the support of project management, and the work process knowledge and vision to see downstream issues — can help to avoid many of these problems. One way to integrate this knowledge is to require the materials manager to review and sign off an all MRs, POs, or ECARs. Adding such a requirement can help to reduce many of the issues mentioned above.

Opportunity 2. Provide materials-management assistance to the procurement organization. As noted in this example, procurement — generally the expediting organization — is the weak link in the chain for these complex POs. Expeditors do not generally possess the technical knowledge needed to understand how many of the components of these large POs will ship, or the significance of separate shipments of individual components. Also, expeditors are generally unaware of how the jobsite intends to manage materials — for instance, will each shipment be direct-issued to construction on receipt, will all items be received into the materials-management system and stored and issued to the construction department as needed and requested by the construction department and so on. Many E&C contractors fail to recognize the inefficiencies in their construction and warehouse operations. Such inefficiencies result from poor delivery information (incurring unnecessary costs in additional jobsite warehouse operations), and poor use of construction craft (due to less-than-optimal planning).

This represents a major opportunity for a knowledgeable materials-management team to work with the expediting team, coordinate with the jobsite, organize the shipments, and manage data in the materials-management system, to leverage information that will both facilitate construction planning and optimize warehouse operations.

This represents a major opportunity for the materials-management team to bridge the gap. With some technical knowledge of the subject matter, interaction with both engineering and construction personnel, and close contact with the warehouse operations, a materials-management team can and should involve itself early with the expediting effort to facilitate planning of shipments and development of data in the materials-management system. This will support overall improvements in construction planning and optimization of warehouse operations.

Opportunity 3. Minor intervention in the SS process. In this example, the submittal process, which fed the materials-management system and was pivotal to efficient jobsite operations, took a back seat to shipment from the fabricator. Here, the procurement organization was optimizing the important milestone of shipping the steel from the fabricator, but failed to comprehend the impact of missing data in the materials-management system — to the extent that it significantly and detrimentally impacted jobsite operations. The materials-management team recommended a simple solution — the release of steel from the fabricator for shipment should require verification by the E&C supplier quality team at the fabricator, and that all steel data related to a given shipment be captured in the materials-management system. Failure to do so caused trucks to back up at the fabricator's facility, underscoring the importance of timely execution of the submittal process, which the fabricator corrected almost overnight. The net result of making this procedural change was that subsequent steel deliveries were all entered into the materials-management system at the jobsite at the time of delivery, making the steel issuable to the installation contractor almost upon receipt.

Closing thoughts

Each of the three examples discussed here represents different types of materials-related issues that can occur on a project. In Example 1, we saw the impact of a minor protocol variation that resulted in

significant disruption to construction planning, emphasizing the need for both vigilant materials-management review of all process modifications, and the need for the materials-management team to be integrated into the review and approval processes to facilitate identification of detrimental variations that can easily slip under the radar.

Example 2 underscores the value that a knowledgeable, cross-functional materials-management team can offer to individual transactional disciplines, especially when it comes to working with upstream disciplines to streamline and optimize downstream work process such as warehouse and construction planning.

Example 3 emphasizes the need for the materials-management team to actively monitor execution of all materials-related processes, because over the lengthy course of any capital-intensive project, even a well-coordinated process will likely deviate at some point. Active monitoring by the materials-management team will help to identify these deviations early, and mitigate negative downstream impact.

Addressing work-process evolution, E&C contractors that structure their materials-management organizations according to the following objectives will be able to meet evolving market conditions:

- Maintain cradle-to-grave oversight throughout project duration
- Develop skillsets that are knowledgeable in all enterprise and supplier materials-related work processes
- Address all materials-related work processes cross-functionally
- Remain knowledgeable in enterprise, partner and supplier automation tools
- Be assertively proactive and non-transactional in execution
- Maintain close alliance with, and support by, project management ■

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Show Preview

Taking place April 26–28 at the Jacob Javits Convention Center in New York City, Interphex 2016 (www.interphex.com) will bring together professionals from the pharmaceutical, biotechnology and medical-device industries for a technical conference and exhibition. This show preview highlights some of the products that will be on display at the Interphex 2016 exhibit hall.

A new type of hydroformed valve body for hygienic applications

This company has debuted a new body type for diaphragm valves, dubbed the tube valve body (photo). Particularly suited for hygienic applications, the tube valve body is manufactured via a hydroforming technology from high-quality stainless-steel tubing, enabling hygienic tube-to-tube welding of virtually identical materials. When compared with cast bodies, cavities and other defects are much less likely to occur in the manufacturing process, which means the risk of contamination is significantly decreased. The housings enable improved temperature control, easier process validation, shorter response times and reduced installation costs. The valve bodies satisfy the current requirements and regulations of many sectors, including pharmaceuticals, bio-pharmaceuticals, cosmetics and food. Booth 3553 — *Bürkert Fluid Control Systems, Ingelfingen, Germany*
www.burkert.com

Handle the challenges of microsphere processing

The MicroSphere Refiner (photo) has been developed for microsphere formulation from small-scale processes up to full commercial production. Microspheres are small spherical particles that have a required size range (typically 5 to 250 µm). Suspended microspheres obtained from various microencapsulation processes require unique handling techniques that differ from a typical filtration and drying operation. Microspheres are random in size and must be filtered and classified into the desired size before drying. Designed to address the challenges faced by drug manufacturers, such as mesh blocking, lengthy drying and steam-in-place (SIP) difficulties, the MicroSphere Refiner has been designed to meet the criteria for the formulation step of this advanced manufacturing process. Booth 2232 — *Powder Systems Ltd. (PSL), Liverpool, U.K.*
www.powdersystems.com

This filling and closing machine has retrofit flexibility

The H4 filling and closing machine (photo) processes nested vials, syringes and cartridges. It can accommodate filling systems based on rotary dosing pumps, peristaltic filling and time-pressure filling. Many new functions have been integrated into the modular unit to further enhance the underlying flexibility of the machine. H4 achieves a standard output of up to 24,000 objects per hour, but can be retrofitted for capacities as high as 36,000 objects per hour. The machine can also be upgraded with IPC (in-process control) and vacuum filling or stopper insertion without any alterations to the machine base. Booth 3103 — *Optima Pharma GmbH, Schwäbisch Hall, Germany*
www.optima-packaging-group.de

Discharge containment drums via gravity or conveying

This company's containment drum discharging station features a glovebox and integrated lifting device. Depending on process requirements, the transport to the next process step is possible by gravity (multi-floor productions) or pneumatic conveying. Depending on the product, it is possible to connect a suction shoe for the conveying system or, optionally, a stirring device. The integrated front glass allows for observation of the conveying process. The gloves support easy product-handling. Booth 3063 — *Hecht Technologie GmbH, Pfaffenhofen, Germany*
www.hecht.eu

These cleanroom doors provide high resistance to acids and bases

FasTrax cleanroom doors (photo, p. 76) feature a one-piece radial header, which is machined from a solid block of ultra-high-molecular-weight (UMHW) plastic. With a quick-operating rollup design, the door's fabric consists of

INTERPHEX

Bürkert Fluid Control Systems

PSL

Optima Pharma

Rite-Hite

smooth polypropylene, which provides higher resistance to acids and bases and a lower water-absorption rate than vinyls and urethanes. This fabric makes FasTrax cleanroom doors highly resistant to mold and provides high-performance washdown qualities, even with harsh cleaning chemicals. The doors' design also uses non-corrosive, lightweight and easily removable side frames that meet government guidelines for washdown and bacteria control. Side frames stand off from the wall to minimize surface-to-surface contact, reducing pockets where bacteria can grow. Additionally, the door has washdown-rated drive system and controls, which are completely sealed and protected. Booth 1857 — *Rite-Hite Corp., Milwaukee, Wis.*
www.ritehite.com

Nordson Medical

Easily attach sanitary fittings with these clamps

This company's line of PharmaLok clamps (photo) simplify assembly processes by reducing the effort involved with securely attaching sanitary fittings to bag ports and filters. All PharmaLok clamps operate at a maximum pressure of 80 psi. Single-use and easy-open clamp sizes include 0.5 to 0.75 in. and 1 to 1.5-in., and the tube clamp supports tubing sizes from 0.5 to 1.25 in. The tube clamp is also designed for use with silicone and thermoplastic elastomer tubing. Booth 2854 — *Nordson Medical, Fort Collins, Colo.*
www.nordsonmedical.com

Marchesini Group

A compact filling and stoppering solution for lyophilized products

The Dara SX-300-Lyo aseptic filling and stoppering machine for lyophilized products in vials features fully servo-driven automation and a compact footprint, while offering accurate filling and precise stoppering, as well as low-maintenance, simple changeovers and a straightforward setup for adding new vial sizes. Suitable for use with suspensions, vaccines and cellular tissue, the Dara SX-300-Lyo fills glass or plastic vials with volumes from 1 to 100 mL. It inserts rubber stoppers halfway into the vials for lyophilization. The system can be configured with one to eight filling heads, one or two stoppering stations and up to four rotary piston pumps or up to six peristaltic pumps to achieve throughputs as high as 7,200 vials per hour. For sterile or cleanroom applications, the Dara SX-300-Lyo can be equipped with a laminar airflow, isolation barrier or restricted access barrier. Other options include a clean-in-place (CIP) system, a sterilize-in-place (SIP) system and gas flushing. Booth 2353 — *NJM Packaging, Lebanon, N.H.*
www.njmpackaging.com

This integrated blister line has been expanded and updated

Integra 520V (photo) is a new robotic integrated blister line capable of packaging 520 blisters and 500 cartons per minute. Integra 520V is a larger and enhanced version of this company's Integra 320, featuring new pushers and a drum-type carton opener to handle high speeds. Since the feeding area is separate from the electrical and mechanical areas, the system is easy to clean, and size changeovers are simplified. The mechanical parts are in an oil bath so they are more resistant to wear and tear. The machine is designed to handle all types of carton closures, including tuck-in, alternated, flap and so on. Booth 3125 — *Marchesini Group S.p.A., Pianoro, Italy*
www.marchesini.com

Specialized polymer materials for antimicrobial flooring

This company's Flowfresh range of cementious urethanes can incorporate natural antimicrobial compounds for additional layers of protection against microbial degradation. Polymer floorings based on Flowfresh materials provide a seamless finish, and patching mortars can be used to slope floors to prevent the pooling of stagnant water. Flowfresh systems are certified as safe for use in both wet and dry processing environments by the Hazard Analysis and Critical Control Point (HACCP), a methodology that is increasingly applied in the pharmaceutical industry as a framework to mitigate risk. Booth 1126 — *Flowcrete Americas, Spring, Tex.*
www.flowcreteamericas.com

Numerous compression fittings are added to this product range

This company has added over 90 new compression fittings to its prod-

uct offerings. Individually packaged in a cleanroom, they are available in a variety of materials for tubing outer-diameter connections in the following sizes: 1/8, 1/4, 3/8, 1/2, 3/4 and 1 in. Available accessories include ferrules, nuts and plugs. These compression fittings are suitable for gas, pneumatic and fluid connections in applications that require an alternative to a barb or bond connection. Once tubing has been cut to the desired length, the simple design allows for ease of installation and requires no tools. The fittings can withstand temperatures up to 212°F. Booth 3634 — *Qosina, Ronkonkoma, N.Y.*
www.qosina.com

This hose has been redesigned for enhanced kink resistance

Bioflex Ultra (photo) is a flexible polytetrafluoroethylene (PTFE) hose for use in the pharmaceutical and biotechnology industries. The hose's patented PTFE liner design provides a smooth bore for clean, non-turbulent flow, and a convoluted outer structure provides flexibility and kink resistance. The redesigned convolution profile of the Bioflex Ultra's liner tube introduces a high-tensile, stainless-steel wire that is helically wound into the root of the convolutions. This wire provides greatly increased kink resistance by providing radial reinforcement to the tube, and axial reinforcement to the web section, preventing web-section collapse when the tube is heavily flexed. Booth 1432 — *Aflex Hose Ltd., West Yorkshire, U.K.*
www.aflex-hose.com

Various configuration options for this filling and stoppering system

The Xtrema filling and stoppering machine (photo) can process vial sizes from 2 to 500 mL, at up to 400 vials per minute. The possibility to have different machine configurations on the same machine frame (right-to-left or left-to-right execution) allows Xtrema to be easily installed in any line layout, and also when space may be a constraint. The modular nature of the system provides ver-

Aflex Hose

IMA Life North America

Mar Cor Purification

satility — equipment modules can be added and integrated when users are developing new production concepts. Xtrema's vial systems are designed to continuously transfer vials from the liquid filling equipment to the freeze dryer, as well as offer complete lines back from the vial washer, up to and including the freeze dryers. Booth 2545 — *IMA Life North America Inc., Tonawanda, N.Y.*
www.ima-pharma.com

These disinfectant cleaners require no PPE during use

PreEmpt is a new line of disinfectant cleaner for critical areas in cleanrooms and laboratories, including workstations, fume hoods, equipment and other non-porous surfaces. PreEmpt products utilize AHP, a patented blend of commonly used ingredients combined with low levels of hydrogen peroxide. The products have a Category IV toxicity rating, meaning they are non-irritating to eyes and skin, and no personal protective equipment (PPE) is required during their use. PreEmpt disinfectants are available in a ready-to-use solution and as pre-saturated wipes, as well as a concentrated solution. Booth 1133 — *Contec Inc., Spartanburg, S.C.*
www.contecinc.com

Effectively disperse vapors into cleanrooms and critical areas

The Minncare Dry Fog 2 system (photo) provides an easy-to-use solution for cleanroom and critical area fogging. Vapors can be delivered with effective dispersion in all areas of a room, including room areas up to 1,000 m^3 using a single unit. Penetration is ensured, even into inaccessible areas. The system features eight different spray-nozzle positions, and spray diffusion can be horizontal or vertical. Droplet size is controlled and consistent (the average droplet diameter is 7.5 µm), and the risk of condensation is minimized. The portable Dry Fog 2 system requires no electrical connection, and is designed to be autoclavable. Booth 3163 — *Mar Cor Purification, Plymouth, Minn.*
www.mcpur.com

Mary Page Bailey

Show Preview

The American Filtration and Separations (AFS) Society (Nashville, Tenn.; www.afssociety.org) will be holding the Oil, Gas and Chemicals Filtration & Separations Conference and Expo (www.spring.afssociety.org) in Houston on May 9–11, 2016. Focusing on both mechanical and chemical means to promote process separations, the conference will gather presentations on a variety of separation methods used in the oil-and-gas and petrochemicals sectors, such as filters, coalescers, membranes, cyclones and many more. Additionally, key subject areas will be given special focus, including produced-water treatment, industrial air purification and natural-gas processing. During the course of the conference, three plenary lectures will be offered, as well as short courses and specialized training sessions. In addition to the technical conference, the event will also feature an expo pavilion giving exhibitors an opportunity to showcase their products and services. The following is a selection of these exhibitors' offerings.

Use these polypropylene tubes for filter supports or cages

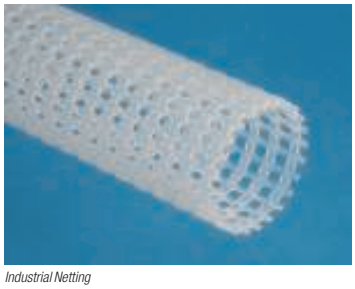
This company's range of extruded polypropylene tubes (photo) are available in nearly 100 configurations of diameter, wall thickness and open area, and are intended for use as center core supports or outer cages for cartridge filters. Several tubing options are greater than 0.2 in. thick for use in high-pressure environments. In addition to being resistant to chemicals and corrosion, some polypropylene tube models are also compliant with FDA regulations for food contact. Well-suited for air, liquid or gas separation, the tubes' versatility and modularity for filter configurations can eliminate traditional assembly steps like screw fastening or welding. When compared with metal, the plastic has a lower density and a lighter weight, while still maintaining strength qualities. Furthermore, polypropylene is readily recyclable, which is another advantage for users. — *Industrial Netting, Minneapolis, Minn.*
www.industrialnetting.com

This filter reduces waste and makes cake-washing easy

The Fundabac filter operates automatically and is totally enclosed from the environment, preventing exposure to toxic or hazardous substances, such as mercury or hydrogen sulfide. The filters can accommodate varying solids loads and can remove particulate matter smaller than 1.0 µm. The self-cleaning, modular Fundabac system features an enclosed nitrogen-purged collection bin for cake disposal, and the cake can also be washed and dried in-situ. Waste is reduced, since the dry cake can be discharged in liquid-cleanup systems with relatively high or fluctuating impurity levels. Typical applications for the Fundabac filter include the following: amine filtration in acid-gas removal plants; mercury removal from crude oil; catalyst fine filtration in flue-gas processes; produced-water filtration; and removal of divalent salts in monoethylene glycol (MEG) regeneration processes. — *DrM, Dr. Mueller AG, Maennedorf, Switzerland*
www.drm.ch

This helical-coil process is effective at purifying natural gas

The KLS helical-coil natural-gas separation technology (photo) utilizes impingement, coalescence and inertia to remove 99.9% of solids and 99.5% of liquids (0.3 µm and larger) without the maintenance and expense of replaceable filter systems. KLS is typically employed to remove black powder, iron sulfides and oxides, lube oil, glycol, salts and condensates from natural-gas streams. The patented helical coil of the process forces contaminants to impinge on the housing wall, creating a film that falls downward into a contaminant sump. The clean-gas outlet-tube's position directs the flow inward toward the center axis, and away from contaminants, preventing re-entrainment. Unlike cyclonic processes, the KLS process is not velocity-dependent, so turndown is not a concern. — *Mueller Environmental Designs, Inc., Brookshire, Tex.*
www.muellerenvironmental.com



Industrial Netting

Mueller Environmental Designs

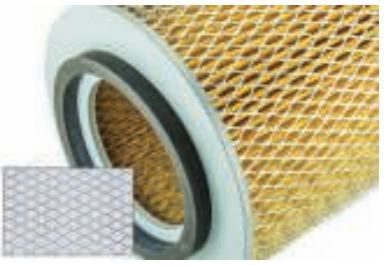
GKD-USA

Pore geometry optimizes these filter meshes' flow capacity

This company's Optimized Dutch Weave (ODW) line of filter meshes (photo) has recently been updated to enhance flow capacity. The flow-optimized ODW meshes boast a specific mesh construction that allows for a pressure–loss coefficient that is reportedly 8.5 times lower than competitive products in the market. A special weave creates a slot-shaped pore geometry on the mesh surface, where the openings are smaller than the pores inside the mesh. ODW meshes are used where precise filtration rates are required that involve high flowrates and dirt-holding capacities, and are especially suitable for use in filter cartridges and filter discs for high-viscosity media, such as oils and polymers. ODW meshes also have a very low tendency to clog and a long service life, according to the manufacturer. Optimized cleaning properties make the meshes appropriate for backflushable filters and rotating-disc filters for solid-liquid filtration. — *GKD-USA, Inc., Cambridge, Md.*

www.gkdusa.com

Wallner Expac



Use this expanded metal pattern as structural support

This company's 0.8-in. expanded metal pattern (photo) is typically used in industrial cartridge filters for gas turbines, environmental dust collection and in other commercial applications, including those in the construction industry. The pattern's high strength-to-weight ratio makes it suitable for use as structural support, and also as a replacement for metal lath. The larger 0.8-in. opening in the pattern provides versatility for a variety of filtration applications. The company's full line of metal patterns ranges from micro-mesh up to larger open-area patterns, and customized patterns are available for specific applications. — *Wallner Expac, Inc., Rancho Cucamonga, Calif.*

www.expac.com

Mary Page Bailey

Instrumentation and Control

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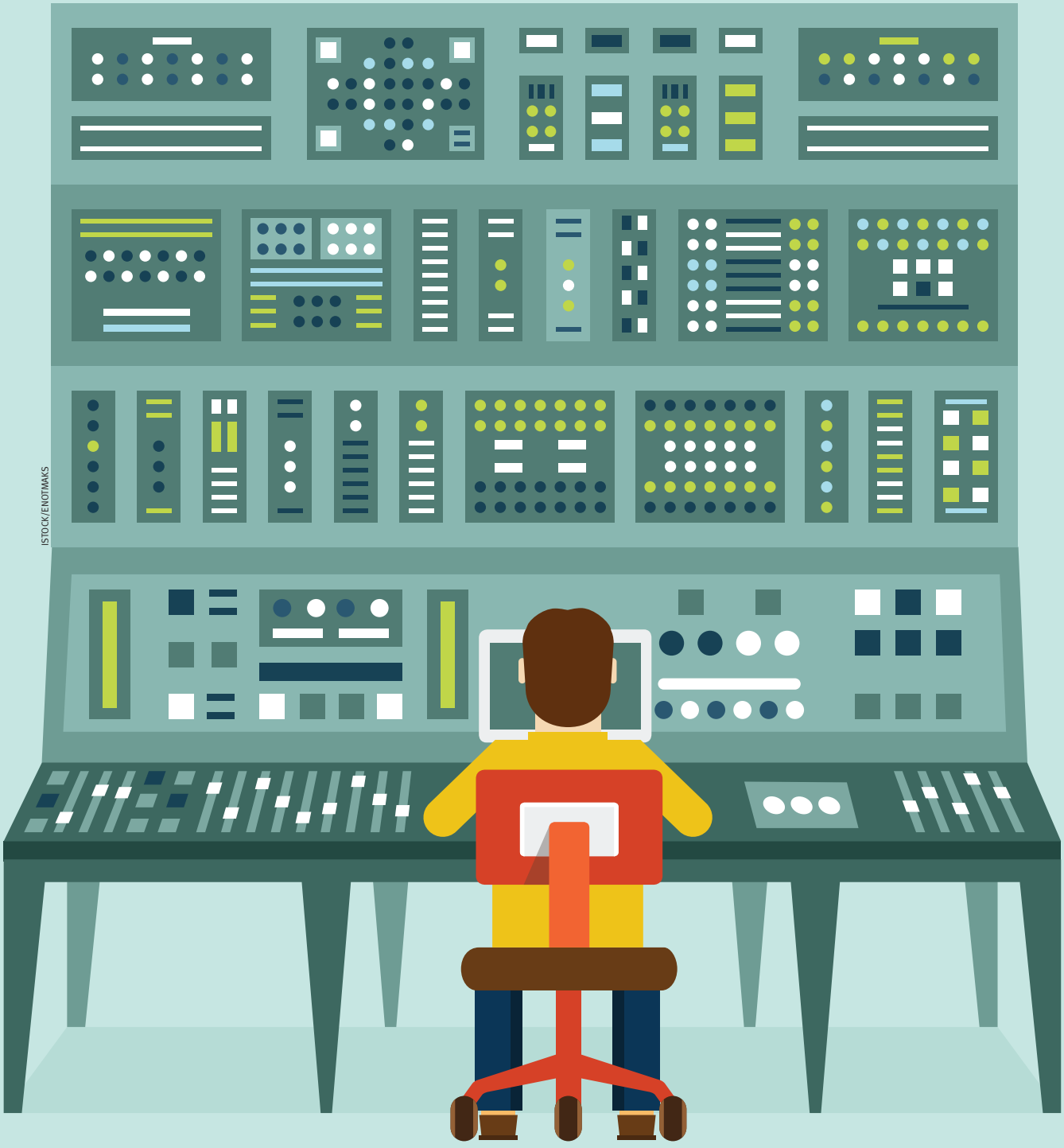
special advertising section



ISTOCK/ENOTMAKS

Monitor and control your plant

Our special section on instrumentation and control presents a range of technologies with wide applications

FLICKR/MARK MORGAN

Simple gauges and sight glasses still have a part to play alongside the most powerful networked control systems

From humble pressure and level gauges to the most sophisticated distributed control systems (DCSs), instrumentation and control are essential to the safety and smooth running of any process plant.

On the following pages of this special advertising section you will find electric actuators for reliable operation of valves; miniature pumps for accurate dispensing in OEM applications; a rugged new ultrasonic flowmeter; and a level transmitter based on the magnetostrictive principle that offers several advantages over other level measurement technologies. There are a novel environmental monitor for control cabinets, an innovative small turbopump for high-vacuum applications, a comprehensive test system for steam traps, gas pressure regulators, and an all-electronic differential pressure measurement system. Viscosity measurement both in the lab and online, furnace temperature measurement, hazardous-area isolation and alarm management complete our roundup. ■

Inside:

OEM dispensers and pumps

Fluid Metering has many years' experience in ultra-precise fluid control for applications such as medical devices

Fluid Metering, Inc. (FMI) is a major manufacturer of OEM fluid control solutions specifically designed for the medical product market.

A new catalog describes how the company meets the demanding needs of the medical, analytical, process and industrial markets for ultra-precise fluid control from microliters to liters.

Fluid Metering is certified to ISO 9001 and has proven performance, with over 55 years of experience and more than 250,000 OEM pumps in service. Its engineering team works with customers to provide dispensers and pumps to meet their specific application requirements.

The Fluid Metering catalog details operating principles, pump capacities, motor characteristics, materials of construction, typical applications and ordering information.

Precise control from Fluid Metering

Fluid Metering will be exhibiting at INTERPHEX in Booth #1468.

www.fmipump.com

Electric actuators handle tough jobs

AUMA extends its portfolio for process applications

AUMA offers a comprehensive portfolio of compact electric actuators to control and automate valves with nominal diameters from DN 15 up to approximately DN 400 in a broad variety of process applications.

AUMA's extended portfolio of compact actuators comprises (l–r) the established SGC/SVC series as well as the new EQ and SD series

AUMA's established SVC globe valve and SGC part-turn actuator series have recently been complemented by the new EQ part-turn actuators and the new SD actuator series comprising multi-turn, part-turn and linear actuators. Designed for harsh industrial environments, they all feature high-protection enclosures, wide operating temperature ranges and robust corrosion protection. Options include positioner, Modbus RTU, and Profibus DP interfaces.

High positioning accuracy makes both the SVC/SGC and SD actuator ranges suitable for demanding control tasks. They achieve their outstanding performance through variable-speed motors, hard-wearing gears, and integral microprocessor-based controls that combine flexible configuration with powerful diagnostics. The SD series is suitable for continuous modulating duty (class D). ATEX-certified versions for use in potentially hazardous areas are also available.

The extended portfolio underpins AUMA's commitment to innovative actuation solutions for the process industries. By concentrating all its activities related to the industrial sector into a new division, AUMA Industry + Marine, AUMA has created a sound basis to more effectively meet these customers' specific requirements.

www.auma.com

Keep a close eye on your cabinets

Turck's new monitor checks temperature and humidity

At the Hannover Messe in April, **Turck** will be showing an entirely new device class: the IMX12-CCM (Cabinet Condition Monitoring) cabinet guard. The new device appeared in prototype form at Achema last year, and will be available ex stock from the beginning of the Hannover Messe.

Turck's new IMX12-CCM cabinet guard detects creeping changes in the physical environment of the control cabinet

Installed in a control cabinet or protective housing, the CCM continuously monitors the actual degree of protection provided by the enclosure. Whenever the temperature and interior humidity fall outside preset limits, or the cabinet doors are not properly closed, the device alerts the control system via a simple switch signal.

The rail-mounted 12-mm wide IMX12-CCM comes with an intrinsically safe 2-wire isolating transducer interface, thus enabling it to be used in hazardous areas. The simple teach-in process can be carried out directly on the device without the need for a computer or any additional tools. A standard HART interface provides additional diagnostic options such as reading out the absolute measured values.

Turck's control cabinet guard monitors the environment via three sensors: a temperature sensor, an absolute humidity sensor, and a triangulation sensor. This last sensor measures the distance to the enclosure cover or cabinet door, and thus monitors correct closing. To detect humidity problems, the IMX12-CCM monitors long-term trends and compares them with the safe condition it has been taught.

www.turck.com/ccm

Tiny turbopump is a big performer

The HiPace 30 is the smallest high-performance turbopump on the market, says Pfeiffer Vacuum

Pfeiffer Vacuum has introduced the new and powerful HiPace 30, the only turbopump on the market in its size class offering pumping speeds of 32 l/s. Its small installation footprint and low level of vibration make this pump particularly suitable for integration into compact analytical systems such as benchtop mass spectrometers, small electron microscopes and leak detectors. Weighing as little as 2 kg overall, the HiPace 30 is also ideal for mobile applications.

The sophisticated rotor design of the HiPace 30 achieves high gas throughputs and very good compression of light gases. This ensures the low residual gas background that is desirable for mass spectrometry applications, Pfeiffer Vacuum says.

The HiPace 30 is designed with a so-called hybrid bearing. This combination of ceramic ball bearings on the backing vacuum side and permanent-magnet radial bearings on the high-vacuum side makes for a particularly sturdy bearing design. The pumps therefore have a long life, with a maintenance interval of around four years.

Founded in 1890, Pfeiffer Vacuum invented the turbopump and today employs around 2,250 people. The company offers a full range of hybrid and magnetically levitated turbopumps, backing pumps, leak detectors, measurement and analysis devices, vacuum chambers and systems.

www.pfeiffer-vacuum.com

The HiPace 30 by Pfeiffer Vacuum

Ultrasonic flowmeter sets standards

FLEXIM presents a new generation of clamp-on ultrasonic flowmeters: the FLUXUS F/G 721

With its new hardware design and improved, powerful digital signal, the FLUXUS F/G721 sets standards in accuracy, reliability and versatility, says **FLEXIM**.

It offers non-intrusive flow measurement of virtually any kind of liquid or gas, from the smallest tubing to the largest penstock, independent of pressure and over a very large temperature range.

Setting standards: the FLUXUS F/G 721

Sophisticated signal filters and substantially improved measurement algorithms, together with the proven transducer technology and sturdy mountings, make the FLUXUS F/G721 a state-of-the-art measuring solution even for the most challenging applications, such as liquids with entrained gas or solids, or wet gas. The meter adapts itself automatically to the measurement conditions and compensates for perturbations. Extremely fast measurement cycles allow for precise real-time monitoring of dynamic processes. Independent calibration of transmitters and transducers aids accuracy under real plant conditions.

The FLUXUS F/G721 comes with all common digital communication protocols, including Ethernet, for bidirectional field communication, parameterization and online diagnostics. It can also be parameterized via USB. Explosion-proof versions for hazardous areas are available.

www.flexim.com

Alleviate headaches caused by faulty steam traps

The TrapMan system from TLV uses a combination of ultrasonic and temperature measurement, backed up by a powerful database, to diagnose steam trap condition

One faulty steam trap loses an average of 11 lb/h (5 kg/h) of steam, notes steam specialist **TLV**. Faulty steam traps can cause a number of headaches for plant managers. There is the increased cost of maintenance, loss of plant efficiency, lowered manufacturing quality, and a greater safety concern for workers. TLV's TrapMan alleviates these pains by being the first diagnostic instrument to test a steam trap and make an automatic judgment of its operating condition.

TrapMan records both temperature and ultrasonic levels to identify dangerous blocked steam traps, or quantify steam loss. This combination improves site safety, reduces cost, and efficiently allocates maintenance expense.

The operator needs only to hold the probe tip on the trap for 15 seconds – then TrapMan collects and measures the trap's condition automatically. It compares the measurements against empirical test data of over 4,000 trap selections, and can store 1,600 individual tests.

Data is then uploaded to TrapManager database software for detailed analysis and reporting. The software can be configured to a user's needs, help predetermine inspection routes, and track and plan preventative maintenance. TrapManager is compatible with Windows XP/Vista/7.

The TrapMan is easy to train on, weighs only 2 lb and is intrinsically safe. The device eliminates variations in testing caused by human error, with its accuracy validated by Lloyd's Register.

www.tlv.com

Properly-working steam traps save time and money, and increase safety

Electronic dP extends distillation plant availability

Electronic differential pressure measurement can eliminate problems associated with traditional systems, says Endress + Hauser

A plant in the U.S. suffered problems with traditional capillaries used to measure dP

A chemical company in the U.S. specializing in customized batch processes used traditional differential pressure (dP) systems to measure continuous level in distillation columns. However, changing ambient temperatures compromised the reliability of the measurements. The oil filling in the capillaries of the dP system would expand and contract with changing temperatures, creating an increase or decrease in the output signal that was independent of any level change in the distillation column. Additionally, the thermal and mechanical impact of the temperature changes destroyed the capillaries every 4–6 months. This meant a shutdown of the entire process, with at least one day of production lost on each occasion.

To solve these issues, the company installed an electronic dP system from **Endress + Hauser**. The job took just 10 minutes, and the benefits of the new system were seen immediately. The modular electronic components that replaced the capillary system are unaffected by ambient temperature changes, and maintenance needs were significantly reduced. The plant gained three days of production a year, and saved several thousand dollars in annual maintenance costs.

Electronic dP systems (above) resist changing ambient temperatures

Electronic dP sensors can also be used to measure level, pressure, volume and mass of liquids in pressurized tanks. They can accommodate a variety of process connections including threads, flanges and hygienic clamps, and handle process temperatures typically from –40 to +257°F (–40 to 135°C). Special configurations can even withstand temperatures up to 500°F (260°C).

In the right applications, the robust versatility of an electronic dP system can provide distinct advantages over traditional systems. **www.us.endress.com**

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

A choice of solutions for pressure regulation

Cashco has launched three new devices for the control of gas pressure

The new ULR-1 ("Un-Loading Regulator") valve from **Cashco** is more than an enhanced product. It also brings clarification and new information, says Clint Rogers, General Manager of Cashco's Valve Division.

The ULR-1 was originally marketed as the U1 by Kaye MacDonald, which Cashco bought in 1999. Unfortunately, the only documentation for the U1 and similar products was the original schematics, which showed how the tubing and fittings were to be installed, Rogers says.

"Previously, a customer would have had to locate the technical bulletin, work their way through its product coder and then a separate product coder for the correct bill of materials for the hookup," Rogers explains. "Not any more. With these new products, all of the information is in the technical bulletin and the operating manual."

As Rogers explains, the ULR-1 is a DA4 regulator with a Cashco CA1 back-pressure valve mounted onto it. Using the inlet pressure from the valve, the CA1 is set to control the outlet pressure of the main valve. Because the outlet of the CA1 constantly exhausts into the atmosphere, the media through the valve must be environmentally safe gas such as oxygen or nitrogen.

For even more choice in pressure regulation, Cashco has also introduced the SLR-1 and SLR-2 Self-Loading Regulators. The SLR-1 is a high-performance, pressure-loaded, pressure-reducing regulator with a self-contained regulator mounted onto it. Inlet pressure from the main valve is diverted to the pilot, which, in turn, reduces the loading pressure to the cover dome in order to maintain the set point of the main valve. The pressure inside the dome is static, so gas is only released to atmosphere when the outlet pressure setting is reduced or the system is shut down.

Cashco SLR-1 (left) and SLR-2 (right)

The new SLR-2 self-loading regulator is similar to the SLR-1, but its loading valve is not self-relieving. Instead, the cover dome bleeds through a filter and check valve back into the outlet of the main valve. This feature allows the SLR-2 to be marketed for hydrogen gas, natural gas and sour gas (NACE) applications.

www.cashco.com

In-process viscosity measurement and control

Affordable costs and increased reliability makes online viscosity measurement a good option for many routine quality control tasks, says Brookfield AMETEK

Laboratory viscometers like this Brookfield DV3T are the usual solution

Quality control (QC) labs generally run single-point viscosity measurements for simple pass/fail tests on fluids and soft solids, notes **Brookfield AMETEK**. The rotational viscometer is the instrument of choice for quick and efficient measurements. Today's instruments offer automated testing and data transmission to a PC or central database. Purchase price is usually under $5,000. Grab samples of the product are taken from the production floor and brought to the QC lab for evaluation. Turnaround time can range from minutes to hours, depending on the backlog in the lab. Samples that fail established control limits for acceptable viscosity are cause for concern and require immediate attention. Possible actions include re-testing the same sample, grabbing a new sample and repeating the test, or in the worst case stopping production until the problem is rectified.

Online viscosity measurement is an alternative approach that has been available for many years, but not widely practiced by manufacturers. Concerns range from the initial expense of purchasing and installing the instrument to ongoing maintenance requirements. Improvements in instrument design, however, have yielded process viscometers with no moving parts, thereby eliminating one major concern. Purchase prices below $5,000 for a sensor and controller mark another breakthrough that gives manufacturers reason to revisit this choice. The reliable performance offered by the new generation of process viscosity sensors is giving manufacturers confidence in this approach.

Corporate justification for a process viscometer depends on evaluating the inefficiencies related to the sampling practice currently in use. If lost material and production-down-time could be improved by measuring viscosity online, then the process viscometer is worth considering. If process adjustments can be made automatically by linking a controller to the process viscometer, then there is no question that the investment will pay back within the first year of operation, often within a few months.

Online viscometers like this Brookfield AST-100 can quickly pay for themselves

www.brookfieldengineering.com

Measuring and imaging reformer tube temperatures

The latest thermal imager from AMETEK Land is designed for continuous skin temperature measurement of reformer and ethylene cracker tubes, and furnace optimization

AMETEK Land has launched the Near Infrared Borescope (NIR-b) 3XR for reformer and ethylene cracker tube continuous temperature measurement and furnace optimization and monitoring. ATEX and IECEX approved to Ex nA IIC T4 Gc for use in Zone 2 hazardous atmospheres, the NIR-b 3XR provides a high-resolution thermal image with real-time high-accuracy temperature measurements of both the tube skin and the refractory surface.

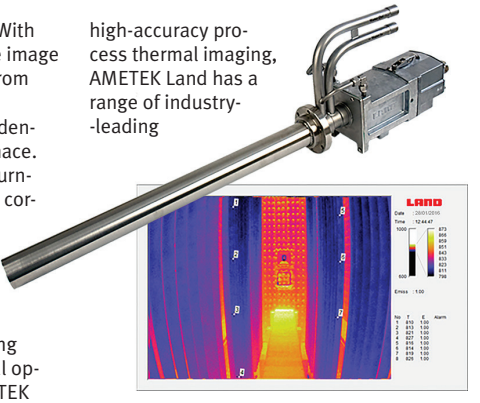
Building on AMETEK Land's long history with the Cyclops portable pyrometer in the syngas industry, the NIR-b 3XR thermal imager has been designed to improve accuracy through automation and reduce personnel risk at the same time. It uses the shortest wavelength possible to minimize errors associated with varying emissivity, allowing highly accurate temperature point data to be measured, stored and trended over the lifetime of the furnace.

The high-resolution image combined with the wide-angle field of view (90°) allows multiple tubes in the lane to be imaged and measured simultaneously. With advanced digital communications the image and data can be viewed in real time from the safety of the control room.

The image allows users to easily identify hot and cold areas within the furnace. Uneven heating due to unbalanced burners or gas mix can be visualized, with corrections viewed in real time. During start-up, any burners that are not operating correctly can be clearly identified and the effect of any impinging flames can be seen.

Working in partnership with leading syngas catalyst manufacturers, global operators and reformer designers, AMETEK Land has developed the NIR-b 3XR as a tool to prolong reformer tube life, optimize production throughput and reduce energy consumption. An additional benefit of fixed thermal imaging is the opportunity to improve plant safety by removing the need for an operator or technician to be in the hazardous area on a regular basis.

Based on over 20 years' experience in high-accuracy process thermal imaging, AMETEK Land has a range of industry-leading features in its image and data processing software platform that support long-term data trending, aiding process optimization while potentially avoiding catastrophic tube failure.



A wide viewing angle allows the NIR-b 3XR to monitor several reformer or cracker tubes simultaneously with high accuracy

www.landinst.com

A flexible, cost-effective solution for Ex i isolation

Signal conditioners from the Phoenix Contact MACX Analog Ex range handle multiple Ex zones and material groups, and are quick to install

Ex i isolators are deployed in hazardous areas to ensure electrical safety. Devices from the MACX Analog Ex product line are slim, well-designed, and certified for use in multiple zones, says **Phoenix Contact**.

These Ex i isolators are ATEX-certified to Ex il(1)G [Ex ia Ga]IIC and Ex il(1)D [Ex ia Da] IIIC for Ex i circuits up to Zone 0 (gas) and Zone 20 (dust). This means maximum flexibility for users since the devices are suitable for all Ex zones and material groups. The MACX isolators can also be installed in Ex zone 2 with protection class Ex n, making them easy to use in distributed automation systems. Certification to other international standards (IECEx, EAC, UL) allows use in global applications.

If a measurement and control signal within the Ex plant structure is a component of the protective layer, the plant operator is required to qualify the availability and quality of the signal transmission in addition to the proof of intrinsic safety. The MACX Analog Ex interfaces are thus designed for use in safety-related circuits in accordance with EN 61508 and certified by independent testing bodies for applications up to SIL 2, and up to SIL 3 with certain devices. Type tests by an independent laboratory to Namur specification NE 95 confirm that the single-channel and dual-channel isolators meet the high standards required by the chemical industry.

Almost as important as their electrical characteristics is the ease with which isolators in the MACX family can be installed and connected. Measuring just 12.5 mm wide, they feature corrosion- and vibration-resistant terminals and test sockets located accessibly on the top of the housing. Optional push-in connections allow tool-free wiring. In addition, slots for two cables per termination point make it easier to perform migrations or modifications on live devices.

The amount of time required to connect to the isolator's power supply is reduced thanks to modular T-connectors with protected contacts that can be placed into standard DIN rails. This allows the use of redundant power supplies for added reliability. In system applications, patented terminal carriers and pre-assembled system cables allow quick and correct connection of MACX Analog signal conditioners to the I/O cards (photo, below).

www.phoenixcontact.com/us

MACX Analog Ex i isolators from Phoenix Contact

Manage alarms to boost safety and reduce shutdowns

The PAS Alarm Management solution improves operator situation awareness using a 7-step methodology

Poorly performing alarm systems – plagued by alarm floods, inaccurate alarms, and disabled alarms – diminish situation awareness, which negatively impacts plant production and safety.

An effective alarm system optimization strategy, one that leverages a proven methodology enabled by software automation, addresses these challenges making operators more effective during abnormal situations.

PlantState Suite (PSS) provides actionable information for plant personnel while reducing alarms to ISA-recommended levels, improving efficiency of alarm detection and response, lowering operator fatigue and training requirements, and improving overall productivity and safety.

PSS modules include Alarm & Event Analysis, Documentation & Rationalization, Audit & Enforce, Dynamic Alarming, Boundary Management, and Control Loop Performance. Companies can utilize one or many of these modules to achieve their alarm management goals.

PAS benchmarks the performance of the alarm system against industry best practices and provides a baseline for measuring gains.

For more than 20 years, PAS has helped processing and power plants around the world optimize their alarm systems using a proven, comprehensive 7-step methodology comprising these steps:

1. Alarm philosophy development
2. Data collection and benchmarking
3. "Bad actor" alarm resolution
4. Alarm documentation and rationalization
5. Alarm audit and enforcement
6. Real-time alarm management
7. Alarm system control and maintenance.

The Alarm Management Handbook, now available in its second edition, provides detail on this methodology as well as best practices accumulated during hundreds of alarm management optimization projects.

The PAS alarm management solution combines industry expertise and proven software technology to optimize alarms, address compliance and standards requirements, and improve operator situation awareness. **www.pas.com**

PlantState Suite software from PAS

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(please answer all the questions)

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06 Soaps & Detergents
07 Paints & Allied Products
08 Organic Chemicals
09 Agricultural Chemicals
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11 Rubber & Misc. Plastics
12 Stone, Clay, Glass, Ceramics
13 Metallurgical & Metal Products
14 Engineering, Design & Construction Firms
15 Engineering/Environmental Services
16 Equipment Manufacturer
17 Energy incl. Co-generation
18 Other______

JOB FUNCTION

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

EMPLOYEE SIZE

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

YOU RECOMMEND, SPECIFY, PURCHASE

(please circle all that apply)

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

1	16	31	46	61	76	91	106	121	136	151	166	181	196	211	226	241	256	271	286	301	316	331	346	361	376	391	406	421	436	451	466	481	496	511	526	541	556	571	586
2	17	32	47	62	77	92	107	122	137	152	167	182	197	212	227	242	257	272	287	302	317	332	347	362	377	392	407	422	437	452	467	482	497	512	527	542	557	572	587
3	18	33	48	63	78	93	108	123	138	153	168	183	198	213	228	243	258	273	288	303	318	333	348	363	378	393	408	423	438	453	468	483	498	513	528	543	558	573	588
4	19	34	49	64	79	94	109	124	139	154	169	184	199	214	229	244	259	274	289	304	319	334	349	364	379	394	409	424	439	454	469	484	499	514	529	544	559	574	589
5	20	35	50	65	80	95	110	125	140	155	170	185	200	215	230	245	260	275	290	305	320	335	350	365	380	395	410	425	440	455	470	485	500	515	530	545	560	575	590
6	21	36	51	66	81	96	111	126	141	156	171	186	201	216	231	246	261	276	291	306	321	336	351	366	381	396	411	426	441	456	471	486	501	516	531	546	561	576	591
7	22	37	52	67	82	97	112	127	142	157	172	187	202	217	232	247	262	277	292	307	322	337	352	367	382	397	412	427	442	457	472	487	502	517	532	547	562	577	592
8	23	38	53	68	83	98	113	128	143	158	173	188	203	218	233	248	263	278	293	308	323	338	353	368	383	398	413	428	443	458	473	488	503	518	533	548	563	578	593
9	24	39	54	69	84	99	114	129	144	159	174	189	204	219	234	249	264	279	294	309	324	339	354	369	384	399	414	429	444	459	474	489	504	519	534	549	564	579	594
10	25	40	55	70	85	100	115	130	145	160	175	190	205	220	235	250	265	280	295	310	325	340	355	370	385	400	415	430	445	460	475	490	505	520	535	550	565	580	595
11	26	41	56	71	86	101	116	131	146	161	176	191	206	221	236	251	266	281	296	311	326	341	356	371	386	401	416	431	446	461	476	491	506	521	536	551	566	581	596
12	27	42	57	72	87	102	117	132	147	162	177	192	207	222	237	252	267	282	297	312	327	342	357	372	387	402	417	432	447	462	477	492	507	522	537	552	567	582	597
13	28	43	58	73	88	103	118	133	148	163	178	193	208	223	238	253	268	283	298	313	328	343	358	373	388	403	418	433	448	463	478	493	508	523	538	553	568	583	598
14	29	44	59	74	89	104	119	134	149	164	179	194	209	224	239	254	269	284	299	314	329	344	359	374	389	404	419	434	449	464	479	494	509	524	539	554	569	584	599
15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390	405	420	435	450	465	480	495	510	525	540	555	570	585	600

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Economic Indicators

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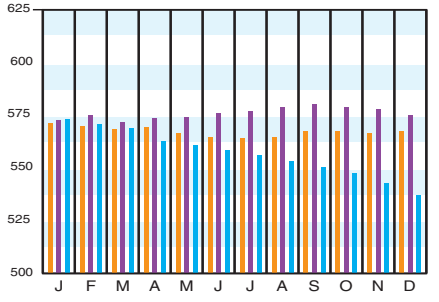
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Dec. '15 Prelim.	Nov. '15 Final	Dec. '14 Final
CE Index	537.1	542.8	575.7
Equipment	641.0	648.9	698.8
Heat exchangers & tanks	556.0	566.5	642.5
Process machinery	648.5	653.0	662.8
Pipe, valves & fittings	791.3	803.4	872.2
Process instruments	381.4	386.4	410.7
Pumps & compressors	965.0	956.5	943.4
Electrical equipment	507.7	508.4	515.2
Structural supports & misc	703.0	713.4	765.8
Construction labor	322.0	323.7	322.1
Buildings	536.7	538.9	546.4
Engineering & supervision	317.3	317.1	319.1

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

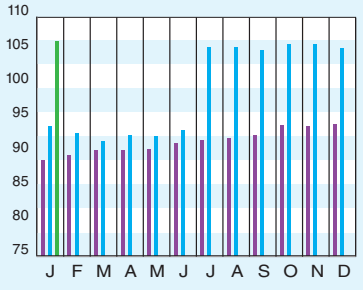
Annual Index:
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1



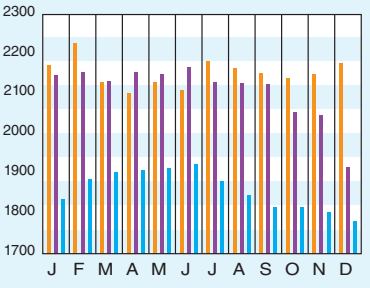
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS		YEAR AGO
CPI output index (2012 = 100)	Jan.'16 = 106.4	Dec.'15 = 105.9	Nov.'15 = 106.1	Jan.'15 = 105.0
CPI value of output, $ billions	Dec.'15 = 1,782.1	Nov.'15 = 1,796.2	Oct.'15 = 1,813.3	Dec.'14 = 1,961.8
CPI operating rate, %	Jan.'16 = 76.5	Dec.'15 = 76.1	Nov.'15 = 76.3	Jan.'15 = 76.2
Producer prices, industrial chemicals (1982 = 100)	Jan.'16 = 225.0	Dec.'15 = 233.4	Nov.'15 = 234.6	Jan.'15 = 242.0
Industrial Production in Manufacturing (2012=100)*	Jan.'16 = 106.2	Dec.'15 = 105.7	Nov.'15 = 105.9	Jan.'15 = 104.9
Hourly earnings index, chemical & allied products (1992 = 100)	Jan.'16 = 159.0	Dec.'15 = 159.5	Nov.'15 = 160.7	Jan.'15 = 157.6
Productivity index, chemicals & allied products (1992 = 100)	Jan.'16 = 108.4	Dec.'15 = 108.6	Nov.'15 = 107.7	Jan.'15 = 107.7

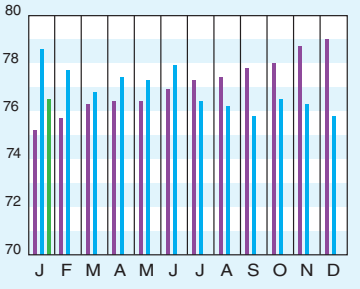
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†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 preliminary value for the December 2015 *CE* Plant Cost Index (CEPCI; top; the most recent available) was down compared to the previous month's data, continuing a string of declines in recent months. All subindices saw declines in December, except Engineering & Supervision, which rose slightly. The preliminary CEPCI value for December 2015 is 6.6% lower than the corresponding value from a year ago at the same time. Meanwhile, the latest Current Business Indicators (CBI; middle) for January 2016 showed an increase in the CPI output index, reversing the previous month's decline, as well as a decrease in producer prices. The CPI value of output for December of last year was down from the previous month.

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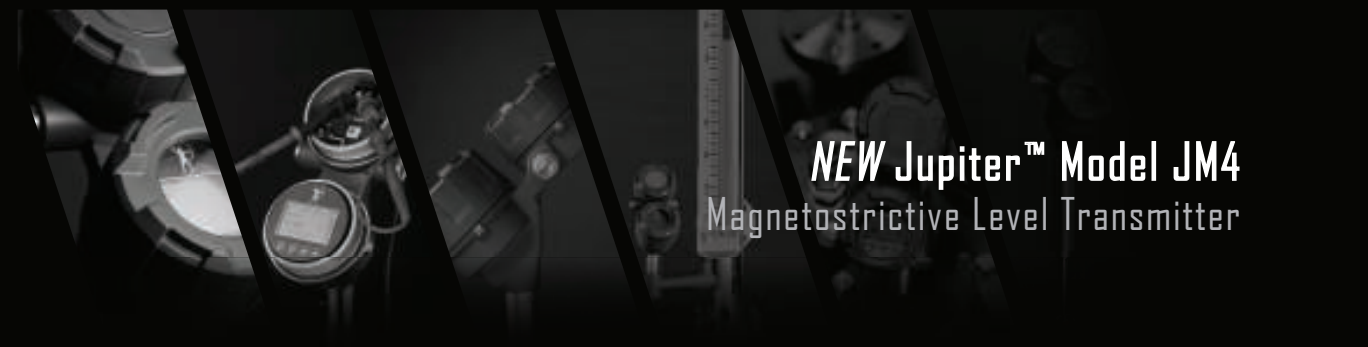

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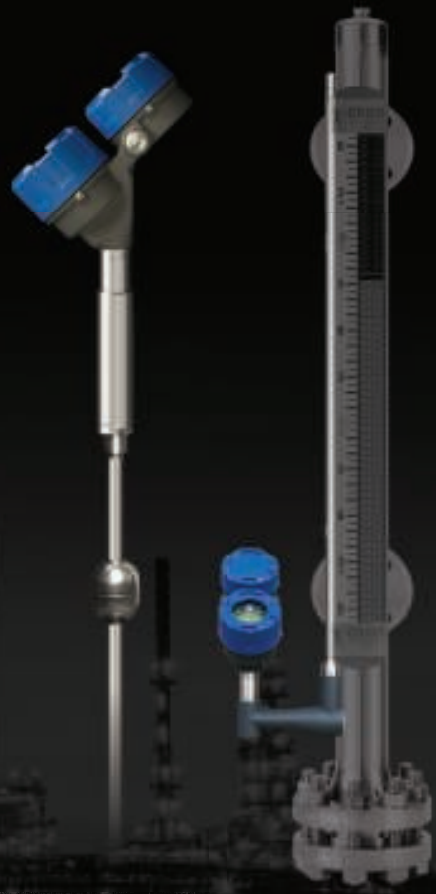

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