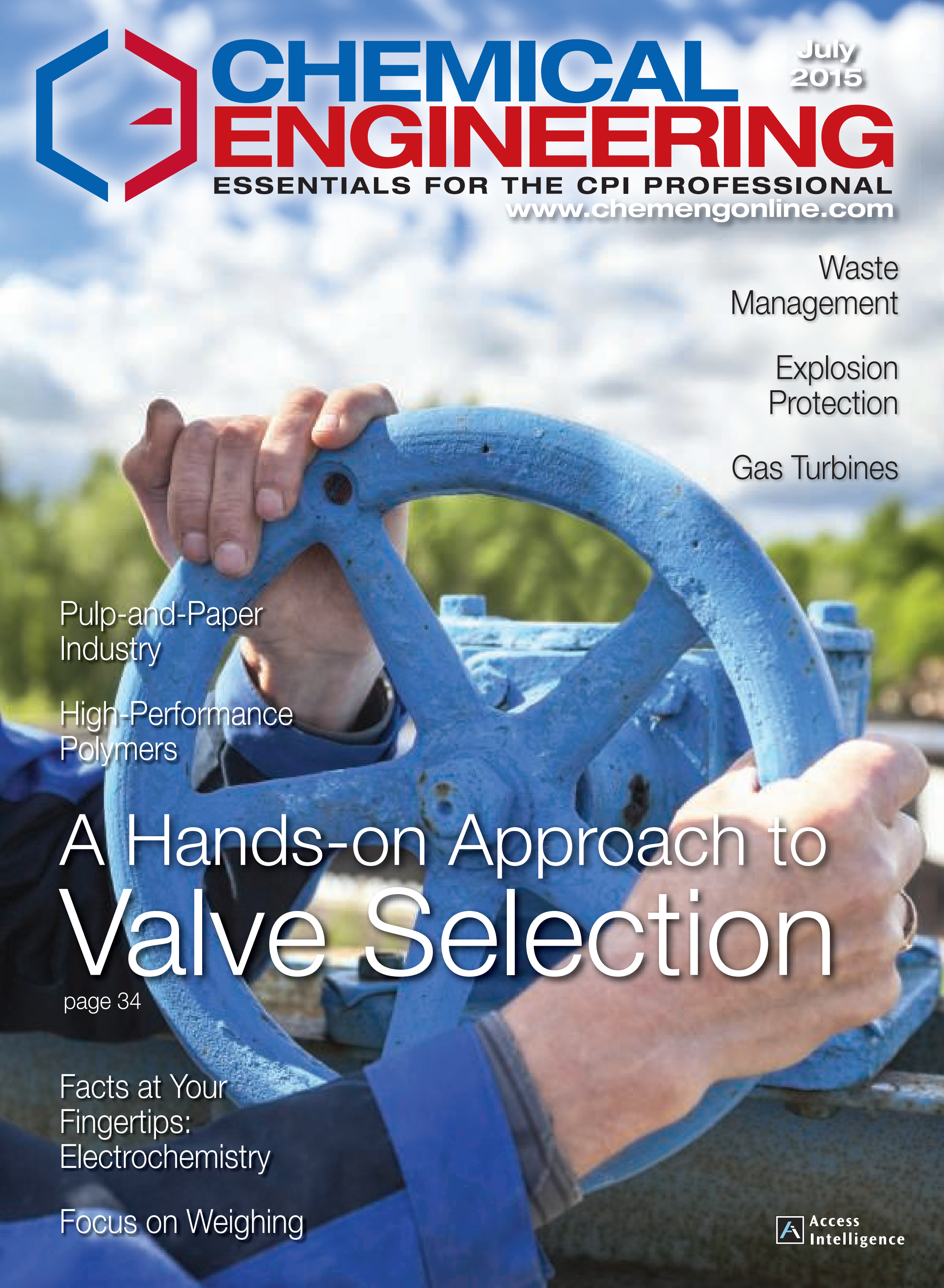

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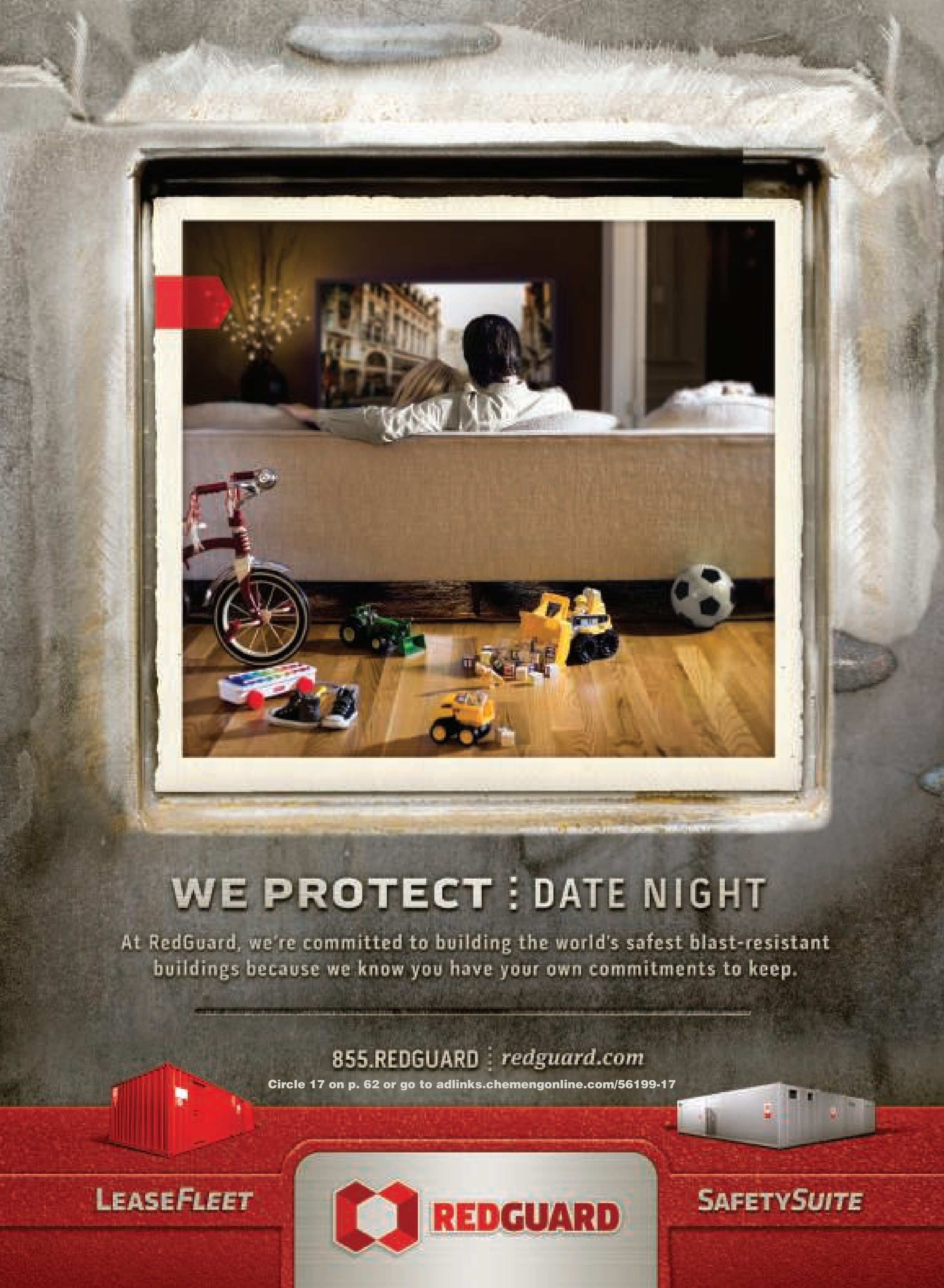
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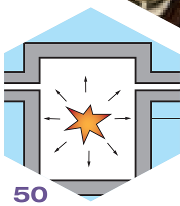
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Cover: Rob Hudgins

Editor's Page

Incorporating social media at work

The explosion of electronic devices that surround us greatly influences the way we function, particularly in the area of communication — how we find entertainment, get information and make connections with others. Video screens seem to be everywhere: at work, at home, in the gym, in our cars, at the supermarket, on-the-go with mobile devices, and now even on our bodies with wearable devices. In addition to emails and texting, one of the most popular means of communication enabled by advances in electronics is via social media.

Are you linked in?

While the use of social media for personal interactions abounds and has significantly changed our lexicon ("liking" isn't what it used to be), the extent of the use of social media for business-to-business purposes has been somewhat less obvious. In a survey of our own readers taken last year, about a third of respondents said they found social media useful to very useful for staying informed about the chemical process industries (CPI). And, the most popular network amongst the well-known platforms was said to be LinkedIn.

A recent survey done by IHS (www.ihs.com) titled "2015 Social Media Use In The Industrial Sector" delves into some detail on the topic. The survey of over 1,300 engineers and technical professionals shows that when it comes to work-related use, 61% of respondents spend only one hour or less per week on social media and 24% spend one to two hours per week. The most popular social media platform was found to be LinkedIn, with 66% of respondents maintaining an account there. LinkedIn was also the most popular choice among the well-known platforms for reading content or product/industry news, following companies or groups, participating in discussions, recommending products and searching for contacts. For posting or sharing images, videos or articles, Facebook took the edge.

The two most popular uses of social media were said to be finding product reviews and keeping on top of latest company news and technologies. When asked about the challenges in using social media, however, 67% of respondents said that methods other than social media were more efficient for work-related purposes and 53% agreed that there was "too much noise and not enough substance" in social media.

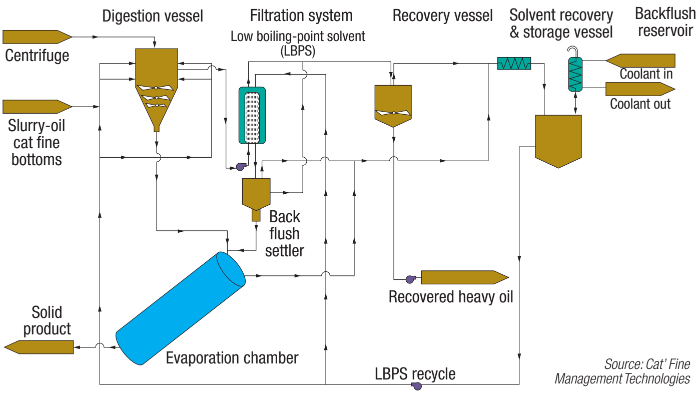
Social media has found a prominent place in the industrial sector, as evidenced by our own LinkedIn group that is over 47,000 members strong and our Twitter presence that counts more than 10,000 followers. And while its use is significant, as one of the conclusions in the IHS report states, for engineers, it is not "the go-to digital resource for work."

In this issue

Valve selection in our Cover Story (pp. 34–42) and planning for waste management in capital projects in our Feature Report (pp. 43–49) are just two of the many topics covered in this issue. You will also find news stories on the pulp-and-paper industry (pp. 16–19) and on high-performance polymers (pp. 20–23), as well as technology news briefs in our Chementator section (pp. 7–13), an article on explosion-protection techniques (pp. 50–54) and much more. We hope you enjoy reading, and find it informative. ■

Dorothy Lozowski, Editor in Chief

This solvent extraction process can monetize tough refinery sludges



Source: Cat' Fine Management Technologies

Construction has begun on a commercial prototype of a low-boiling-point solvent-extraction process for recovering used catalyst powder and slurry oil from a recalcitrant sludge produced in the fluid catalytic cracking units (FCCUs) of petroleum refineries.

The process allows refiners to isolate two valuable materials — powdered catalyst material that can be used as an equilibrium catalyst in FCCUs, as well as slurry oil that can be used as premium-grade feedstock for the manufacture of carbon black and needle coke — that would otherwise be wasted, according to developer Cat' Fine Management Technologies LLC (CFMT; Liberty, Tex.; www.cfmtllc.com).

When catalyst powder (fines) escapes through the FCCU cyclones and accumulates in the slurry oil stream, a sludge forms that CFMT CEO Larry Weber likens to "talcum powder in molasses." The sludge is classified as an Environmental Protection Agency (EPA) Resource Recovery and Conservation Act (RCRA)-listed K-170 hazardous waste, and makes for the "toughest tank-cleaning job in the business," he says.

The current treatment approach for this sludge material involves diluting the slurry-oil storage-tank bottom sludge with light-cycle oil (LCO) and then centrifuging the mixture, explains Weber. This approach has drawbacks, because the recovered oil is high in solid contaminants, and because current methods "still generate K-170 waste, in the form of backwashed catalyst fines, that must be disposed by costly methods, including incineration, landfilling and in cement kilns," he says.

CFMT has developed a processing method, designed for integration into slurry-oil filtration systems, that processes the backwash into recyclable equilibrium catalyst (in the form of a dry powder), and recovers 100% of the slurry oil that was tied up with the fines, Weber says. The four-part modular process begins with a digester tank, where a solvent blend is mixed with the sludge material and agitated. The dissolved slurry oil is then decanted and the remainder filtered to separate solid catalyst particles. The solvent-wet catalyst is dried and the solvent is evaporated from the oil. Both are recovered. The solvent renders the material filterable without having to raise the temperature, says Weber, which saves energy

Construction has begun on a 5-ton/d prototype demonstration unit, to be installed in San Leon, Tex. at a site presently permitted to process K-170 wastes. Startup is expected in July 2015, Weber says.

Upgrading extra-heavy crude oil using supercritical water

Earlier this year, JGC Corp. (JGC; Yokohama, Japan; www.jgc.com), in partnership with Japan Oil, Gas and Minerals National Corp., commenced pilot-scale testing of their Supercritical Water Cracking (SCWC) process. The pilot has a capacity of 5 barrels (bbl) per day (800 L/d) and is located at a government research facility in Alberta, Canada. The pilot plant is part of a joint-research program aimed at upgrading extra-heavy crude oil into more easily transported synthetic crude oil (SCO).

At present, in order to transport the extra-heavy crude oil by pipeline, it must be diluted with condensates, naphtha or other lighter oils (the Dilbit process), or through a hydrocracking or delayed coking process (a thermal cracking of residual oil into lighter fractions), a technology known as a Full Upgrader. The Dilbit process requires diluents

Edited by:
Gerald Ondrey

CONCRETE ADMIXTURE

Advanced concrete mixes often demonstrate a higher viscosity due to their low water contents. Although having a high level of workability, the concrete often appears harsh, sticky and therefore difficult to pump and process. To overcome these challenges BASF SE's (Ludwigshafen, Germany; www.basf.com) Construction Chemicals div. has developed MasterEase, a new admixture range developed for low-viscosity concrete. With the new technology, plastic viscosity can be reduced by up to 30%, which results in a substantial reduction of pumping pressure required to pump the concrete on the construction site. Placing and finishing of the concrete is much easier, faster and hence more economical than using standard concrete, says BASF.

SOUND MILK SKIMMING

Australian scientists have produced, for the first time, skimmed milk at liter-scale using ultrasonic standing waves – a technique typically used only on a small-scale. The scientists, from Swinburne University of Technology (Melbourne; www.swinburne.edu.au) and CSIRO's Food Processing Center (Melbourne; www.csiro.au), outlined their work at the 169th meeting of the Acoustical Society of America last May in Pittsburgh.

The scientists used two fully submersible plate transducers placed on either end of a length-tunable, rectangular reaction vessel that can hold up to 2 L of milk. Either one plate produces 1-MHz or 2-MHz waves while the other plate acts as a reflector, or both plates are switched on simultaneously, providing greater power and increas-

(Continues on p. 8)

Note: For more information, circle the 56-digit number on p. 62, or use the website designation.

ing the acoustic radiation forces. The acoustic standing waves create forces that act on the particles, causing them to move toward either the node or antinode of the standing waves, depending on their density.

The ultrasound separates milk into a top stream containing a greater concentration of larger fat globules (cream), and a bottom stream with smaller fat globules (skimmed milk). One of the scientists, Thomas Leong, of Swinburne, says tuning system parameters allows selecting milk fat globules of different sizes in the collected fractions to produce a particular dairy product. He says cheeses made from milk with a higher portion of small fat globules tend to have superior taste and texture, while milk or cream with larger fat globules can lead to tastier butter.

The ultrasonic separation process takes only about 10–20 min, much faster than traditional methods of natural fat sedimentation and buoyancy processing, used today to make Parmesan cheeses, which can take more than 6 h. The scientists' next step will be to work with small cheese makers to demonstrate the efficacy of their technique in cheese production.

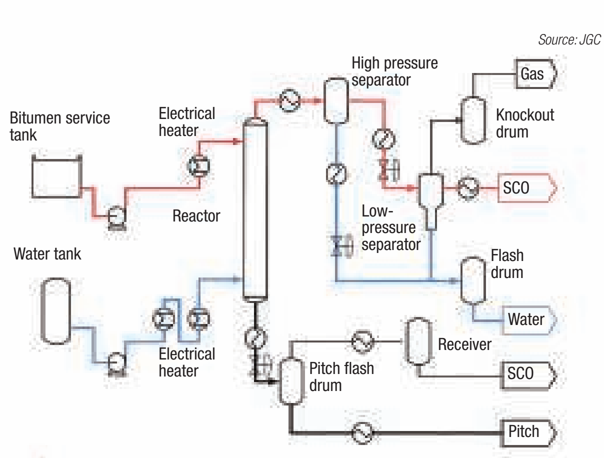
Na-ION BATTERY

The world's first sodium-ion powered vehicle, an e-bike, has been successfully demonstrated by Faradion Ltd. (London, U.K.; www.faridion.co.uk), in collaboration with Williams Advanced Engineering (Grove, Oxfordshire, U.K.; www.williamsf1.com) and Oxford University (www.oxford.ac.uk). The e-bike is a proof-of-concept and shows the capabilities of this new type of battery technology.

Faradion's sodium-ion technology is based on cathode material manufactured by Haldor Topsøe A/S (Topsoe; Lyngby, Denmark; www.topsoe.com). Topsoe has scaled up Faradion's propri-

(Continues on p. 10)

and a larger-capacity pipeline to transport the product, while the Full Upgrader method requires the use of catalysts and hydrogen, causing possible environmental problems involving the disposal of low-value solid byproducts, such as coke and sulfur, and also requires higher investment costs as well as complex plant operations.



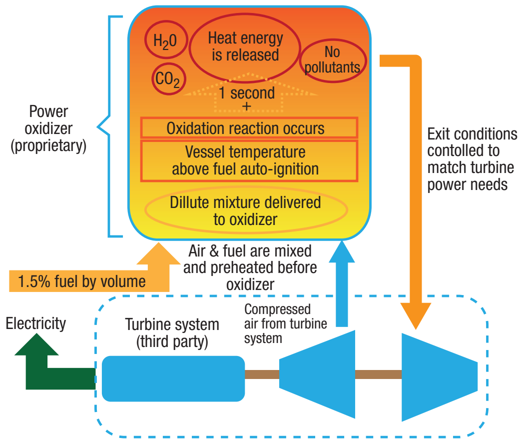
On the other hand, SCWC technology (flowsheet), which uses SCW as the thermal cracking media, requires neither diluents nor catalysts and hydrogen. Highly lipophilic, SCW also helps with the extraction and recovery of lighter portions of the cracked oil, says JGC. The pitch, produced as a byproduct of SCWC, can be used as blending stock for road asphalt.

The pilot plant has already achieved performance targets, in terms of desired viscosity and specific gravity, says JGC. Long-term demonstration of operation is planned during this year, and data will be gathered to optimize operating conditions for the design of commercial plants. The next phase will be a demonstration plant with a capacity of 500–2,000 bbl/d, leading to commercial-scale plants, with capacities of up to 30,000 bbl/d. JGC envisions integrating SCWC with steam assisted gravity drainage (SAGD).

A system to extract energy from waste gases

Many chemical process industries (CPI) operations generate gaseous byproducts that are impure and have low energy densities. Ener-Core Power Inc. (Irvine, Calif.; www.ener-core.com) has introduced a technology to extract valuable energy and heat from gases that would otherwise be wasted by flaring or venting.

"Annually, there are about 65,000 MW of 'free-energy' available in the U.S. alone, in the form of low-quality methane from landfills, oil-and-gas operations, ethanol plants, chemical production facilities, coal mines and others," explains John Millard, Ener-Core's director for Europe and the Middle East. "Ener-Core's technology allows companies to capture the energy and reduce pollutants," he says.



The technology depends on carefully controlling a thermal oxidation reaction such that the reaction remains stable, even with diluted and impure gases. The chemical chain reaction that is characteristic of combustion cannot ordinarily be maintained with such low-quality gases, Millard says. By slowing the reaction and lowering its temperature, the Ener-Core system can quickly oxidize methane without producing pollutants, such as CO, NOx and particulate matter.

In the Ener-Core system (diagram), the raw waste gas is first diluted with air and compressed to 6–7 bars. Then, the compressed gas is fed into a packed-bed reactor at temperatures of 900–1,000°C. All species, including volatile organic compounds (VOCs), are oxidized in the reactor and the heat generated by the reaction is used to power a turbine that can generate electric power.

The company has set up its first 250-kW power station at a landfill in the Netherlands and has pending agreements to install several more systems in the near future, including a larger 2×1.75-MW system at an ethanol-production facility in California.

etary cathode material formulation and has supported the demonstration program by delivering the cathode material used in Faradion's Na-ion cells.

Although lithium-ion batteries are currently the predominant battery technology in electric and hybrid vehicles, as well as other energy storage applications, Na-ion offers significant advantages: The base materials required for Na-ion batteries are more easily sourced than those needed for Li-ion batteries; Na-ion batteries cost around 30% less per kWh than Li-ion counterparts; and Na-ion batteries are said to have improved thermal stability and transport safety.

Faradion and Topsoe are currently developing low-cost Na-ion technology with one focus area being energy storage. Last year, Topsoe acquired 18% of the shares in Faradion. As part of the investment, Topsoe will collaborate with Faradion to further co-develop and scale up key parts of the company's Na-ion technology.

NEW GAS TURBINE

In late May, GE (Fairfield, Conn.; www.ge.com) announced the manufacture of its first 9HA Gas Turbine at the company's Belfort Gas Turbine Center of Excellence in France. Said to be the world's largest and most efficient gas-turbine technology, this 9HA unit will be shipped to Bouchain, France, where Électricité de France (EDF) and GE are developing one of the world's most flexible and efficient gas-fired power plants.

The project in Bouchain will be the first gas-fired power generation combined-cycle plant equipped with GE's 9HA gas turbine technology. It is scheduled to enter commercial service in mid- to late-2016 in the Nord Pas-de-Calais region. With a capacity of 575 MW, it will generate power that is equivalent to the power needs of 600,000 homes and it will do so in less than 30 min at greater than 61%

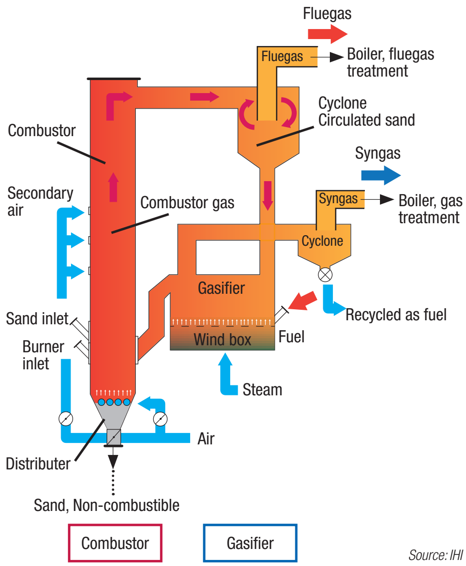
(Continues on p. 13)

Startup for a new gasification process

IHI Corp. (IHI; Tokyo, www.ihi.co.jp) has commissioned its first prototype Twin IHI Gasifier (TIGAR) plant, which IHI designed and built at the Kujang Factory of PT Pupuk Indonesia Holding Co., Indonesia's largest state-owned fertilizer company, 75 km southeast of Jakarta. The plant processes 50 ton/d of low-rank coal into 1,800 Nm^3/h of synthesis gas (syngas), which can be used for making hydrogen, ammonia and other chemicals. The prototype plant will be operated for two years to demonstrate the TIGAR process as an economical and environmentally sound method to utilize lignite for making syngas. Within 2015, IHI will start marketing the technology for a commercial plant, which will be capable of processing 500–1,000 ton/d of lignite.

In IHI's TIGAR process (flowsheet), lignite (coarse and dry) is pyrolyzed and gasified in a bubbling fluidized-bed reactor using sand (for heat transfer) and steam (as an oxygen source) at 800–900°C. Syngas emerging from the top is separated from solids by a cyclone, and the elutriated particles are returned to the reactor. Tars, unreacted char and cooled sand from the top of the bed are transported into an air-blown, pneumatic-riser furnace, where tars and char are completely burned into CO_2, and the sand is reheated by the heat of combustion.

IHI's technology has the advantage of operating at relatively low temperatures (compared to 1,400–1,500°C used by entrained gasifiers), and the use of steam instead of oxygen is said to increase the H_2 content of



Source: IHI

the syngas. The process also requires less feed preparation, using coarse coal particles instead of slurries or pulverized coal that is needed by other gasifiers.

IHI says there are ample supplies of lignite at moderate price, but its high moisture content makes it difficult to process by alternative gasifiers. The company is accelerating its efforts to utilize lignite efficiently with the development of TIGAR, along with the development of a coal pre-drying system and the lignite-fired boiler expertise of Steinmüller Engineering GmbH (Gummersbach, Germany), which IHI acquired from Siemens in 2014.

Two new product families offer help for biofuel producers

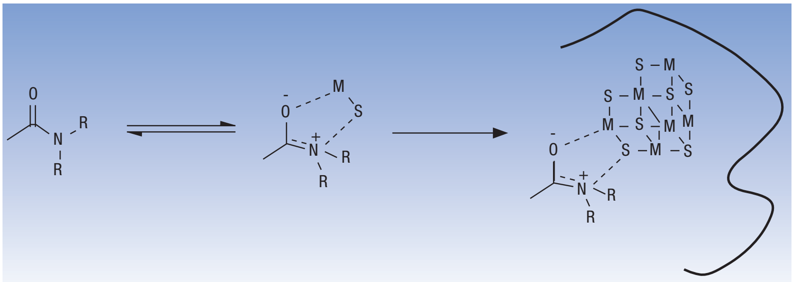
Two families of newly developed products from specialty chemical maker Solenis (Wilmington, Del.; www.solenis.com) — a portfolio of fermentation aids and scale inhibitors — have the potential to improve the production of bioethanol and related fermentation processes.

Solenis fermentation aids are additives designed to control undesirable microorganisms in fermentation processes without the use of antibiotics. The fermentation aids work by promoting yeast's metabolic pathways, enhancing the ability of yeast to compete with bacteria in the propagation and fermentation phases of the process, explains Allen Ziegler, the global biorefining marketing director at Solenis. Simultaneously, the fermentation aids — proprietary combinations of organic acids, peptides, iso-alpha acids and chlorine dioxide — inhibit the growth of gram-positive bacteria, Ziegler adds.

The products allow biofuels producers to avoid antibiotics in the control of microbes, which can have favorable regulatory implications for the Food and Drug Admin. (FDA).

Solenis also recently launched a portfolio of chemical blends for controlling the formation of inorganic scales, such as calcium carbonate, calcium sulfate, barium sulfate and others. The products, which are marketed as Polystabil scale inhibitors, consist of unique combinations of compounds that employ different mechanisms to combat scale formation in the evaporators, tanks, heat exchangers and piping of fuel ethanol plants. The advantage of the products is that they can work at lower dosages than traditional polyacrylate-based treatments, says Ziegler. Also, they can be applied at higher doses when needed, but still maintain the FDA GRAS (generally recognized as safe) designation.

This scale inhibitor uses steric dispersion principles



Source: Clariant

With the commercial release of a new scale inhibitor — called ScaleTreat FeS 13805 — researchers at Clariant Oil Services (Houston; www.clariant.com/oilinnovation), in collaboration with academia, have improved upon existing scale-treatment chemistries, adding a newly patented copolymer to the industry. This new chemistry, according to the company, allows ScaleTreat FeS to specifically inhibit the formation of iron sulfide (FeS) scale at threshold (low and non-stoichiometric) concentrations. Other inhibitor methods (such as organic acids, chelating agents and acrolein) must be dosed at stoichiometric (molar) concentrations and, therefore, at a much higher concentration, which is relatively inefficient and may introduce health and safety risks.

"The suggested reaction mechanism for ScaleTreat FeS (diagram) involves the amide bonds in the copolymer seeding into the metal sulfide crystals via electrostatic interaction," explains research scientist Jonathan Wylde. "As the metal (M) sulfide (S) crystals grow within the confines of the three-dimensional polymer shape, they experience steric resistance, limiting their size and changing their morphology."

The copolymer's architecture is key to this inhibition technique. Unlike typical sulfide scale-control methods, which are based on chelation, this mechanism is an action of steric dispersion. As seen in the reaction mechanism, many molecules that make up the metal sulfide crystal are hindered by the copolymer's structure. This leads to an action of dispersion and inhibition, rather than chelation, increasing the overall effectiveness of the scale treatment.

While primarily focused on FeS inhibition, ScaleTreat has been shown to be effective in treating other types of sulfide scales in laboratory tests. Clariant is also continuing to develop future generations of this product to further enhance the effectiveness and extend application areas.

'Nanoboxes' promise to boost energy capacity of lithium-ion batteries

Researchers from Singapore's Institute of Bioengineering and Nanotechnology (IBN; www.ibn.a-star.edu.sg) and Hydro-Quebec's Research Institute (Montreal, Canada; www.hydro.qc.ca) have synthetized silicate-based "nanoboxes" that could greatly increase the energy capacity of lithium-ion batteries as compared to that of conventional phosphate-based cathodes. IBN's executive director, professor Jackie Y Ying says IBN researchers have achieved simultaneous control of the phase purity and nanostructure of Li_2MnSiO_4 for the first time. "This will allow us to move closer to attaining the high theoretical capacity of silicate-based cathodes for battery applications," she says.

The Li_2MnSiO_4@C porous nanoboxes* have been synthesized via a wet-chemistry associated solid-state reaction method. The uniqueness of this material is the hollow nanostructure with a well-crystalline porous shell composed of phase-pure Li_2MnSiO_4 nanocrystals. The researchers' approach combines the advantages of wet-chemistry reaction methods and solid-state approaches, while avoiding their disadvantages. According to the researchers, this has not been reported previously.

Powder x-ray diffraction and transmission electron microscopy images have shown that the high phase purity and porous nanobox architectures were achieved via monodispersed $MnCO_3$@SiO_2 core-shell nanocubes with controlled shell thickness. Combined with reduced graphene oxide nanosheets, the nanocomposite performed as a promising high-capacity cathode candidate for Li-ion batteries, say the researchers.

A high initial charging capacity of 335 mAh/g was achieved with this nanomaterial. The novel strategy developed by the researchers could be useful for preparing other inorganic hollow nanostructured electrode materials with complex composition and enhanced electrochemical properties. ■

*Note: The notation A@C denotes an atom or molecule "A" inside a nanocube made of carbon, "C".

efficiency. GE's technology can help save 6.4 million Nm^3/yr of natural gas compared to using F-class technology. Fuel costs can be reduced by €1.8 million/yr, at a natural gas price of €7 per GJ, says GE.

ALL-BIO PET BOTTLES

Last month, Virent (Madison, Wisconsin; www.virent.com) announced that its BioFormPX *p*-xylene was used in the world's first demonstration-scale production of a PET plastic bottle made entirely from plant-based materials. The PET bottles use BioFormPX produced at Virent's Madison, Wisc. demonstration plant.

Virent and The Coca-Cola Co. have been working together since 2011. In 2014, Coca-Cola made an additional investment to support an expansion of Virent's demonstration plant (For details on Virent's technology see *Chem. Eng.*, May 2010, p. 11).

LINEUP

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ASHLAND
AVEVA
BASF
CHEVRON
DSM
EVONIK
GRACE
INNOSPEC
JOHNSON MATTHEY
KBR
KEMIRA
MESSER
MEXICHEM
NESTE
RAYONIER
SASOL
SUMITOMO
TOTAL FLUIDES
WACKER
WESTLAKE

Plant Watch

Sumitomo announces battery-separator capacity expansion, new plant in Korea

June 10, 2015 — Sumitomo Chemical Co. (Tokyo; www.sumitomo-chem.co.jp) plans to more than double its production capacity for lithium-ion secondary battery separators at a site in Japan. In addition, a new production plant for lithium-ion secondary battery separators will be built in South Korea, and is scheduled to start commercial-scale production in 2017.

Wacker starts up new production plant for specialty monomers at Burghausen

June 9, 2015 — Wacker Chemie AG (Munich, Germany; www.wacker.com) started up a new plant with a capacity of 3,800 metric tons per year (m.t./yr) of the specialty monomers vinyl neodecanoate and vinyl laurate at its Burghausen site in Germany. Wacker invested €8 million in the new facility.

Messer commissions production facility for krypton and xenon in China

June 9, 2015 — Messer Group GmbH (Bad Soden, Germany; www.messergroup.com) has commissioned a new production facility for the noble gases krypton and xenon, located in Panzhihua, Sichuan, China. The new facility has production capabilities for 5,000 m^3/yr of krypton and 450 m^3/yr of xenon.

Kemira opens manufacturing plant for water-treatment chemicals in Spain

June 3, 2015 — Kemira Oyj (Helsinki; www.kemira.com) opened a new production plant for the manufacture of water-treatment chemicals. The plant, located in La Canonja, Spain, produces aluminum- and iron-based coagulants, including polyaluminum chloride, aluminum sulfate and ferric chloride.

Sasol commissions first phase of wax expansion project

June 2, 2015 — Sasol Ltd. (Johannesburg, South Africa; www.sasol.co.za) announced that phase one of its Fischer-Tropsch Wax Expansion Project (FTWEP) has been successfully commissioned at its Sasolburg site in South Africa. Major construction activity is already underway for FTWEP's phase two, which is expected to be commissioned in the first half of 2017.

Mexichem subsidiary to expand specialty PVC capacity in Germany

May 29, 2015 — Vestolit, a subsidiary of Mexichem S.A.B. de C.V. (Tlalnepantla, Mexico; www.mexichem.com) is expanding its production of specialty-paste polyvinyl chloride (PVC) in Marl, Germany. Vestolit will build a new production line with a capacity of 40,000 m.t./yr of paste PVC.

AkzoNobel to build coatings-manufacturing plant in Thailand

May 27, 2015 — AkzoNobel (Amsterdam, the Netherlands; www.akzonobel.com) has announced plans to invest more than €30 million in a new manufacturing facility in Thailand to support its Performance Coatings business. Earmarked for an initial production capacity of 45,000 m.t./yr, production is due to start in the third quarter of 2016.

KBR awarded contract for revamp of seven ammonia plants in Russia

May 27, 2015 — KBR, Inc. (Houston; www.kbr.com) has been awarded a contract by OJSC Togliattiazot (ToAZ) to provide licensing, basic engineering design, front-end engineering and design services to revamp ToAZ's existing seven ammonia plants in Togliatti, Russia. With this contract, KBR will supply ToAZ with proprietary technology to significantly increase overall ammonia production capacity.

Grace-Chevron JV to build catalyst plant in Lake Charles

May 20, 2015 — W.R. Grace & Co. (Columbia, Md.; www.grace.com) announced that Advanced Refining Technologies, the company's joint venture (JV) with Chevron Products Co., will invest approximately $135 million to build a residue hydroprocessing -catalyst plant and add additional alumina production capacity at the existing Grace manufacturing site in Lake Charles, La. Construction is expected to begin in late 2015, with completion anticipated in 2018.

Evonik doubles methacrylic anhydride capacity in Germany

May 19, 2015 — Evonik Industries AG (Essen, Germany; www.evonik.com) has doubled production capacity for methacrylic anhydride (MAAH) at its site in Worms, Germany. MAAH is an important building block in the production of specialty methacrylates, which are used in concrete additives, paints, electronics applications and plastics.

Mergers & Acquisitions

BASF to sell its global paper hydrous kaolin business to Imerys

June 9, 2015 — BASF SE (Ludwigshafen, Germany; www.basf.com) has signed a contract to sell its global paper hydrous kaolin business to Imerys S.A. (Paris, France; www.imerys.com). Closing of the transaction is expected to take place during the third quarter of 2015.

Total and Neste collaborate on bio-based isoalkane products

Total Fluides (Paris; www.totalspecialfluids.com) and Neste Oil Oyj (Espoo, Finland;

www.nesteoil.com) have signed a collaborative agreement for the supply of Neste's proprietary renewable isoalkane to be used by Total Fluides as feedstock to produce bio-based fluids, including paints, coatings, drilling fluids, solvents for polymerization, printing-ink fluids, emollients and more.

Innospec to divest its aroma chemicals business

June 8, 2015 — Innospec Inc. (Littleton, Colo.; www.innospecinc.com) agreed to divest its aroma chemicals business unit (Innospec Widnes Ltd.) to Emerald Kalama Chemical, a business group of Emerald Performance Materials LLC. Terms of the transaction were not disclosed.

Rayonier and Borregaard form JV for lignin products

June 2, 2015 — Rayonier Advanced Materials (RYAM; Jacksonville, Fla.; www.rayonieram.com) and Borregaard ASA (Sarpsborg, Norway ; www.borregaard.com) intend to form a JV at RYAM's site in Fernandina Beach, Fla. for the manufacturing, marketing and sale of natural lignin-based products. The new company will be owned 45% by RYAM and 55% by Borregaard.

Aveva acquires fabrication software provider FabTrol

June 2, 2015 — Aveva (Cambridge, U.K.; www.aveva.com) has agreed to acquire FabTrol Systems, Inc. (Eugene, Ore.) from the Dowco Group. FabTrol provides fabrication-management software to the steel-fabrication industry.

Westlake acquires Ineos stake in China-based PVC resin JV

June 2, 2015 — Westlake Chemical Corp. (Houston; www.westlake.com) has acquired Ineos ChlorVinyls Holdings B.V.'s 35.7% interest in Suzhou Huasu Plastics Co. (SHPC), a JV company focused on PVC resin and downstream fabrication based near Shanghai. Westlake now owns a 95% interest in SHPC.

Ashland to divest industrial biocides assets to Troy

May 29, 2015 — Ashland Inc. (Covington, Ky.; www.ashland.com) has signed a definitive agreement to sell the industrial biocides assets within Ashland Specialty Ingredients to Troy Corp., a specialist in microbial control products.

Johnson Matthey acquires packaging business StePac

May 27, 2015 — Johnson Matthey (London; www.matthey.com) has acquired the StePac Modified Atmosphere Packaging (MAP) business from DS Smith for £18.0 million. With this transaction, all assets of StePac will join Johnson Matthey's Atmosphere Control Technologies business, within the company's New Businesses division.

DSM forms polyphenylene sulfide JV in China

May 22, 2015 — Royal DSM (Heerlen, the Netherlands; www.dsm.com) and Zhejiang NHU Co. formed a new JV for the market development and manufacture of high-performance plastics compounds based on polyphenylene sulfide (PPS). DSM will hold a 60% share in the JV, with Zhejiang NHU owning a 40% stake. ■

Mary Page Bailey

Renewed Optimism in the Pulp-and-Paper Industry

Innovations and the utilization of byproducts are helping this sector to thrive in difficult times

AkzoNobel

FIGURE 1. The Jupia paper mill in southern Brazil is one of the largest in the world

The pulp-and-paper industry has gone through difficult times. The rise of electronic media, competition from substitute materials and environmental concerns have caused thousands of mill closures and huge numbers of job losses. However, the industry is looking up again with renewed optimism (Table 1). The expanding middle classes in China, India and Brazil are creating new business opportunities, and an increasing realization of the attributes of wood is persuading governments and businesses to invest in R&D for new materials and products derived from wood.

The need to innovate

Innovation — the development of new products and processes — is crucial for the industry's future. However, according to some people in the trade, pulp-and-paper companies have not embraced innovation very well. Professor Gil Garnier, of the Dept. of Chemical Engineering at Monash University (Melbourne, Australia; www.monash.edu), and director of the Australian Pulp and Paper Institute, (now known as BioPRIA, www.biopria.com.au), says the industry, in general, has failed to adapt to a changing market. He believes the industry has been too conservative. He says there is a need to innovate in order to lower costs, and to use less fiber, less energy and less water. It is absolutely essential for the industry to develop new, high-value products, he says.

Much of the innovation within the industry has been in biofuels and nanocellulose. However, Garnier says, biofuels are still too costly to make, and nanocellulose presents two problems: there is as yet not a good market for it, and the cost of processing it is too high.

A principal of Pöyry Management Consulting Oyj (Vantaa, Finland; www.pöyry.com), Petri Vasara, agrees in part. He says that mainly small companies and U.S. companies in general have been quite conservative, while larger European companies and Brazilian companies have been going ahead on many fronts (Figure 1). He also says the problems faced by the industry tend to be very dependent on the region where they operate. In Europe and the U.S., there has been an overcapacity in certain printing paper grades. In China, there has also been an overcapacity in certain grades. One of the main problems in China has been a lack of particular raw materials. Vasara says the problems of energy usage and water consumption are common to many industries, not only the pulp-and-paper industry.

Jessica McFaul, communications director and press secretary for the American Forest & Paper Assn. (Washington, D.C.; www.afandpa.org) disagrees with the assessments of Garnier and Vasara on innovation in the U.S. pulp-and-paper industry. "There are many innovations in paper, packaging and wood products in the U.S. Paper-based packaging companies have developed innovative solutions to specific customer needs, made process innovations to improve their sustainability, and diversified into numerous niche products," she says. "Examples

IN BRIEF

THE NEED TO INNOVATE

LIGNIN

NANOCELLULOSE

REDUCING CO_2 EMISSIONS

OTHER DEVELOPMENTS

FPInnovations

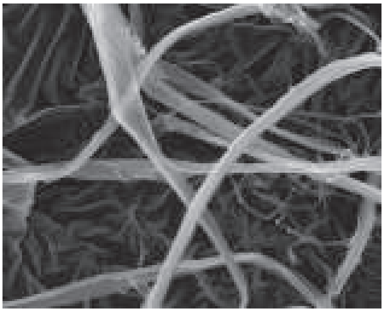


FIGURE 2. Cellulose filaments produced at the Trois Rivières pulp-and-paper mill in Quebec, Canada

include specialty printing products and innovations such as embedded electronic components combining print and digital for a richer customer experience," she says.

The industry also has a robust technology map, continues McFaul, and is working with universities and government agencies on advanced manufacturing. The U.S. industry has adapted quite well to changes in consumer demand, as evidenced by packaging, tissue and pulp sector growth, says McFaul.

Lignin

Despite the somewhat contradictory views of people in the trade, there has been a large number of innovations and technological advances in the pulp-and-paper industry around the world, especially during the last two decades.

A hot item now-a-days is lignin, an organic polymer that binds the cellulose fibers and cells of wood. It is an integral part of the cell walls of plants. It is the second most abundant natural polymer, after cellulose. Wood contains three main components: cellulose fibers, desired for paper making; lignin; and hemicellulose (shorter branched carbohydrate polymers). The aim of pulping is to break down the wood or other fiber source into its constituent fibers.

The lignin and hemicellulose that are dissolved in the pulping stage make up what is known as "black liquor." This black liquor is usually sent to a recovery system where it is burned. The recovery stage supplies much of the energy required to operate the pulp mill and regenerates the inorganic pulping chemicals.

People in the pulp-and-paper industry believe lignin may become one of the most valuable renewable materials. It is a biofuel with high heat value and it could be used as fuel in boilers and lime kilns with huge potential savings in fuel oil. Other anticipated markets for lignin include the construction and automotive industries, where lignin offers a sustainable alternative to the phenols used in plywood and wood-paneling glues and the polyols used in foams. Lignin could also be used to make carbon fibers.

A technology called Lignoboost, an add-on to the kraft pulping process to extract lignin from black liquor, has been developed in collaboration with many partners by Innventia AB (Stockholm, Sweden; www.innventia.com) — a research institute that works with innovations based on forest raw materials. Lignoboost originated from research led by professor Hans Theliander at Chalmers University of Technology (Gothenburg, Sweden; www.chalmers.se). It is now marketed by Valmet AB (Gothenburg, Sweden; www.valmet.com).

The technology uses a standalone plant, installed in parallel to the evaporation line. A portion of the mill's black liquor is redirected to the Lignoboost process, where CO_2 is added to precipitate the lignin. The lignin-lean black liquor returns to the mill process stream, while the lignin is pressed and treated with sulfuric acid. It is then washed and pressed again. The director of Lignoboost and biomaterials at Valmet, Anders Larsson, says two vertical pressure filters are the heart of the Lignoboost plant. A typical installation would have two or three vertical-plate pressure filters, he says.

The first full-scale Lignoboost plant was started up in 2013 at a mill owned by Domtar Corp. (Montreal, Canada; www.domtar.com) in Plymouth, North Carolina. The plant has an annual capacity of 466,000 metric tons (m.t.) of pulp. It is also producing lignin with the tradename BioChoice.

Another Lignoboost plant was installed in January 2015 at the Sunila Mill, in Finland. The mill has a capacity of 370,000 m.t./yr of softwood pulp. It is owned by Stora Enso Oyj (Helsinki, Finland; www.storaenso.com), a manufacturer of fine paper, packaging board, and wood products.

Nanocellulose

Innventia and partners are also developing nanocellulose products. Nanocellulose is produced by delaminating cellulosic fibers in high-pressure homogenizers. Fully delaminated nanocellulose consists of microfibrils that are 1–2-µm long and 5–20-µm dia. Nanocellulose has exceptional strength, on a par with Kevlar, but in contrast to Kevlar, it is completely renewable. Nanocellulose had not been commercialized earlier because its production process was too energy-intensive. However, Innventia claims it has developed a process that has achieved a 98% reduction in energy consumption, representing a savings of 29,000 kWh/m.t. (from a previously required 30,000 kWh/m.t. to just 1,00 kWh/m.t.).

Potential applications for nanocellulose include the manufacture of paper and board, and surface sizing and coating as a barrier against oxygen, water vapor and grease in food packaging. There are other potential applications in nanocomposites, non-caloric food thickeners, emulsions and dispersions, oil recovery, cosmetics and electronics.

"It is absolutely essential for the industry to develop new, high-value products."

Professor Gil Garnier, Montash University

A type of nanocellulose material — cellulose filaments derived from wood fiber (Figure 2)— has been produced during the past few months in a demonstration plant built at the pulp-and-paper mill in Trois-Rivières, Quebec, Canada (Figure 3).

Cellulose filaments are long, thin, ribbon-like structures found in the cell walls of trees and other plants. Due to their large surface area and high length-to-width ratio, cellulose filaments can be used as a reinforcing agent in various pulp-and-paper products and composite products.

The Trois-Rivières plant produces 5 m.t./d of cellulose filament, enough to permit commercialization and application development. The plant's process isolates cellulose filaments mechanically from pulp without the use of chemicals or enzymes and without producing any effluent.

The plant resulted from a strategic alliance between FPInnovations (Pointe-Claire, Quebec; www.fpinnovations.ca), a Canadian non-profit organization which undertakes research and technology transfer for the Canadian forest industry, and Kruger Biomaterials Inc. (Montreal, Canada; www.kruger.com), producer of publication papers, tissue, lumber and other wood products.

Reducing CO_2 emissions

Several breakthrough technologies, which will enable a competitive future in Europe, have been identified by the Confederation of European Paper Industries (CEPI, Brussels, Belgium; www.cepi.org). CEPI's innovation and bioeconomy director, Bernard de Galembert, says those innovations also aim to deliver lower carbon emissions in the pulp-and-paper industry, according to CEPI's 2050 roadmap to a low-carbon bioeconomy. The roadmap envisions an industry-wide reduction of CO_2 by 80% by 2050.

Those technologies include the use of deep eutectic solvent, the use of steam for paper making, and the use of supercritical CO_2 for paper drying.

Kruger Biomaterials

FIGURE 3. Shown here is the pulp-and-paper mill in Trois Rivières, Quebec. A demonstration plant for producing a type of nanocellulose material was recently built at the mill

According to CEPI, deep eutectic solvents (DES), naturally made by plants, allow producing pulp at low temperatures and at atmospheric pressure. Using DES, any type of biomass could be dissolved into lignin, cellulose and hemicellulose with minimal energy, emissions and residues. A eutectic system is a homogeneous solid mix forming a super lattice with a unique atomic percentage ratio between the components. It is only with this ratio that the system melts as a whole at a specific temperature. The eutectic temperature is the lowest possible melting temperature over all of the mixing ratios for the individual component.

Glucose-based natural DES can dissolve wood and selectively extract lignin and hemicellulose. It may also be able to extract cellulose. CEPI says that is what makes them predestined to replace traditional pulping techniques. DES pulping yields pure cellulose, lignin and hemicellulose at low cost, as has already been demonstrated with wood and straw.

Using steam for superheated steam-drying would save energy as most heat could be recovered and recycled. Steam can then be used as a fiber carrier for making and forming paper. Today, heated cylinders deliver the energy required to evaporate water from paper, and air is used to remove the water vapor. Steam would progressively replace air and eventually also water in the papermaking process. Three steps can be anticipated: superheated steam-drying with the total recovery of thermal energy in an air-free drying section, steam-boosted paper making within an air-free paper machine, and steam-based paper making based on completely new and more efficient forming technology.

On the other hand, supercritical CO_2 could be used to dry paper without the need for heat and steam. CO_2 in the critical state assumes many of the properties of both gas and liquid. Small changes in temperature and pressure can lead to large variations in solvent properties.

Other developments

CEPI's Galembert says next to the breakthrough technologies, the pulp-and-paper industry in Europe is following various innovation tracks, such as the functionalization of paper and smart packaging, and the development of new lignocellulosic products including biocompos-

TABLE 1. SOME OF THE LARGEST PULP-AND-PAPER COMPANIES

Company	Headquarters	Number of employees	Sales* (billion $)
International Paper Co.	Memphis, Tenn.	65,000	29.080
Stora Enso Oyj	Helsinki, Finland	28,000	14.000
Svenska Cellulosa AB	Stockholm, Sweden	44,000	13.700
UPM-Kymmene Oyj	Helsinki, Finland	21,000	13.350
Oji Paper Co.	Tokyo, Japan	27,400	12.700
Smurfit Kappa Group	Dublin, Ireland	41,000	10.600
Nippon Paper Industries	Tokyo, Japan	13,000	10.500
RockTenn	Norcross, Ga.	26,000	9.500
Mondi plc	Johannesburg, South Africa	26,000	8.600
Metsä Group	Helsinki, Finland	11,500	6.500
Sappi Ltd.	Johannesburg, South Africa	12,800	6.000
DS Smith plc	London, U.K.	21,500	5.700
Dompar Corp.	Montreal, Canada	10,000	5.400

* 2013

Source: Pricewaterhouse, Pulp & Paper International and other industry sources

Wacker Chemie

FIGURE 4. The rate at which pulp slurry is dewatered can be measured in drainage tests

ites and bio-based chemicals that could provide alternatives to existing fossil-based products. Some of the new pathways the industry is exploring are: new ways to produce textile fiber without the pulp-dissolving step; innovative lignocellulosic liquid fuels for transport; and pulp-based mouldable materials.

Individual companies often develop new technologies, independently of organizations such as CEPI or Innventia. Wacker Chemie AG (Munich, Germany; www.wacker.com), for example, recently announced its development of a silicone surfactant tradenamed PulpSill 968S, which accelerates pulp dewatering (Figure 4). PulpSil 968S is a surfactant fluid based on a polyether-modified silicone. Its molecular structure has been optimized to make it less hydrophilic without compromising its hydrophobic properties. The resultant gain in water repellency makes it an efficient dewatering agent.

Despite the innovations and R&D efforts by the pulp-and-paper industry worldwide, a global paper market study by Pöyry titled "World paper markets up to 2030," forecasts a strong need for structural changes in the paper industry. "Especially in Western Europe we find an urgent need for further capacity reductions. After the markets in the emerging Asian regions have become more mature, the industry needs to take a more disciplined approach as to capacity expansions. Industry consolidation, acquisitions, mergers and alliances start making more sense there, too," the report says. ■

Paul Grad

High-performance polymers in the spotlight

Improvements in existing materials and the development of new ones are helping to meet the demands of challenging applications

Victrex

FIGURE 1. Victrex PEEK 90GL-30BLK EU was introduced to meet the current requirements of both U.S. and European regulatory authorities for direct-food-contact applications, while providing temperature performance and chemical and steam resistance, as well as wear resistance without lubrication

IN BRIEF

DEVELOPMENT CHALLENGES

INDUSTRIAL APPLICATIONS

PIPING APPLICATIONS

NEW FRONTIERS

As the need for stronger, more durable and lighter-weight materials increases, the demand for high-performance plastics and polymers continues to grow. Although most of the materials in this category have been in use for a while, there is always room for improvement and new applications continually surface. For this reason, high-performance-plastics producers are exploring the use of additives and new processing techniques to provide even more advanced materials. Although the development process can be challenging, some interesting materials for existing and new applications are becoming available.

Development challenges

"Even though the mechanical performance of high-performance plastics and polymers is very good and we are finding ways to make them more appropriate for use in higher temperatures, it is often tricky to find the proper balance of properties for a given application," explains Ryan Dirkx, vice president of R&D for Arkema Inc. (King of Prussia, Pa.; www.arkemainc.com). "The real issue, when developing a new or improved material, is that when you enhance one property, you may compromise another."

For example, he says, when you increase the temperature resistance of a polymer, it may affect the elastic modulus, which may not be acceptable in certain applications. In addition to finding the proper balance of characteristics, producers of high-performance plastics must also consider the cost performance when creating new materials. "We have to remember that our customers aren't willing to obtain the performance they need at any cost, so the economics of our solutions have to be in line with the customer's application," continues Dirkx.

"And finally, it is important not only that a material provides the appropriate performance properties, but also that it can be processed. This means our customers have to be able to take our polymer and form or shape it into a component in a cost-effective manner," Dirkx explains. "This could be extruding a film or multi-layer tubing, injection molding a taillight or 3D-printing aerospace ducting. In any case, the material has to be capable of being processed in some way."

For this reason, he says, producers often work closely with customers during development so that they understand what balance of properties is needed for a specific component or application and, therefore, what compromises can be made while allowing the material to be affordable, easily processed and perform properly in the application. "This is one of the reasons why having fully integrated R&D capabilities is important," says Dirkx. "We need to work with our polymers in the same way our customers do."

Indeed, many materials producers have been working hard on their R&D to create high-performance plastics and polymers that better serve today's users. Here's a brief look at what has recently been launched.

Industrial applications

"In industry there is always a need for increased reliability and uptime, which means there is a growing need for better performing plastics and polymers," says Steve Dougherty, strategic marketing director with Victrex (Conshohocken, Pa.; www.victrex.com). Many industrial applications now require equipment components that behave like metal, regarding stiffness and strength, but provide resistance to aggressive chemicals, Lehvoss

FIGURE 2: The Luvocom 8000 product line combines thermoplastics such as PEEK, PPS or PA with special nano-additives to produce tribologically modified materials with higher wear resistance, while maintaining a low coefficient of friction

steam and high temperatures.

According to Dougherty, the solution for many industrial applications can be found in new grades and formulations of polyether ether ketone (PEEK) polymer, which was already well known as a high-temperature polymer with great mechanical properties and processability.

New formulations of Victrex's PEEK polymer are currently being employed in the food processing industry. In these applications, the reformulated Victrex PEEK 90GL30BLK EU (Figure 1) was introduced to meet the current requirements of both American and European regulatory authorities for direct-food-contact applications, while providing the temperature performance and chemical and steam resistance that PEEK is known for, as well as wear resistance without lubrication. Typical applications for the reformulated food-friendly polymer include machinery cleaning equipment, conveyor belt chains, espresso machines, manufacturing equipment bushings and components for aseptic processing and packaging equipment.

And, in general industrial applications that require even greater service life, lower component weight and lower costs, Dougherty says his company now provides Victrex WG Polymers. This recently developed material offers excellent wear rates, as well as reduced and very stable coefficient of friction to meet requirements for wear in applications with higher speeds and loads. The polymer can be processed into components such as bushings, thrust washers, bearing cages, seals and gaskets, bearing retainers, seal rings and gears.

Lehvoss North America, LLC (Pawcatuck, Conn.; www.lehvossllc.com) recently introduced a new generation of polytetrafluoroethylene- (PTFE) modified compounds, called Luvocom XTF, in an effort to provide a material that will reduce wear, yet still be easy to process. "Adding PTFE to PEEK is not a new development, but previously the problem with doing this was that the material was not always easy to process because PEEK processes at a very high temperature, which in turn, causes PTFE to agglomerate and disperse, eventually leading to a certain amount of wear for the finished part as the dispersion causes the PTFE to break down over time," explains Bob Healy, sales and business development manager, with Lehvoss. However, Lehvoss has developed a new technology that has solved the dispersion and agglomeration issues. "By optimizing the processing technology and using innovative raw materials, it is now possible to achieve a reduction in wear under high loads."

Because of the chemical resistance to hydrocarbons, this new generation of polymer is finding use in the oil-and-gas industry where it provides better mating, sealing surface and wear resistance than previous options.

Another way Lehvoss provides high wear resistance and low coefficient of friction is through the use of nanoscale additives. Its Luvocom 8000 product line combines thermoplastics such as PEEK, polyphenylene sulfide (PPS) or polyamide (PA) with special nano-additives to produce tribologically modified materials with higher wear resistance,

while maintaining a low coefficient of friction (Figure 2). Traditional solid lubricants, such as PTFE, are avoided in this process. The advantage to using nanoscale additives is that the materials can be better processed and the finished product exhibits enhanced mechanical-strength values.

Also employing the use of additives, as well as processing technology, RTP (Winona, Minn.; rtpcompany.com) has recently taken some of the highest performing polymers, such as PEEK, PPS, polyethylenimine (PEI) and polyphthalamide (PPA), and reinforced them with long-fiber materials to provide added strength so that they have load bearing capabilities similar to metal. "While polymers are very corrosion resistant to chemicals, the big challenge in many applications is that they lack the mechanical performance of metal, so reinforcements are typically required," explains Steve Maki, vice president of technology with RTP.

RTP's Ultra Performance Structural Compounds employ short carbon fiber, short glass fiber or very long glass fiber at loadings from 20 to 50%, allowing performance to be tailored to individual application requirements, and making these products competitive alternatives to aluminum, zinc and magnesium metals. "Across-the-board performance improvements in strength and stiffness provide added confidence and a higher design safety factor when replacing other materials," says Maki. "Additionally, lower densities make them a suitable choice for weight-critical applications." The materials also provide the design freedom and production advantages of an injection-moldable material, which allows design optimization, part consolidation and one-step production of net shapes.

Piping applications

In some cases, new materials are being developed to improve existing applications. For instance, The Dow Chemical Company (Midland, Mich.; www.dow.com) recently launched Hypertherm 2399 resin for domestic and commercial hot-and-cold water plumbing (Figure 3). The new resin enhances the

Dow

FIGURE 3. Hypertherm 2399 resin for domestic and commercial hot-and-cold water plumbing enhances the flexibility of plastic pipe so installers can bend water lines at turning joints, allowing for ease of installation.

flexibility of plastic pipe so installers can bend water lines at turning joints, allowing for ease of installation.

"Most residential plumbing is copper or rigid plastic piping, which requires the use of turning joints and elbows. These turning joints are usually the first points of failure," explains Dave Parrillo, R&D director of the Packaging & Specialty Plastics division of Dow. "But, thanks to this fusible high-performance material, the need for breaks at joints has been eliminated and the resulting leak-resistant product is actually stronger at the fused section."

Hypertherm 2399 resin has been accepted by three major U.S. building codes for plumbing and brings the highest level of chlorine certification (Level 5), while meeting the highest hydrostatic requirements for polyethylene pipe. "This is a significant advancement, as pipe products manufactured with Hypertherm 2399 will last two times longer than products with Level 3 chlorine-resistant certification," Parillo continues. The material provides the flexibility to install systems designed to optimize energy consumption for hot water use, such as continuous loop, on-demand re-circulation and traditional plumbing systems.

The patented technology of Hypertherm 2399 NT resin offers the benefits of traditional PE-RT (polyethylene of raised temperature resistance) products. This resin is very clean, providing pristine taste and color, is resistant to corrosion and there is no need to purge the lines upon installation of finished pipe, notes Parrillo. Lightweight and spool-able, the resin is a drop-in replacement for PEX B and C, enabling pipe manufacturers to run product faster on extrusion lines. Additionally, monolithic pipe formed with Hypertherm 2399 NT resin is sustainable due to its thermoplastic nature. Contrary to thermosets, a thermoplastic can be reintroduced into the manufacturing stream or recycled at the end of its lifetime. The finished pipe is ready for packaging directly off the line, eliminating time and energy used in post-extrusion curing, lengthy quality-control measures and off-line packaging.

New frontiers

And then there are tweaks to existing high-performance materials, which allow them to be used in entirely new applications, such as membrane technologies. Water filtration is a new area for high-performance plastics and polymers, according to Dave Seiler, global advisor for fluoropolymers with Arkema Inc. "The world economy is giving clean water to people who have previously not had access," he explains. "There are now personal water units and technologies that allow us to turn sea water or undrinkable water into drinking water, but it requires the use of biocides and other chemistries. And it is the use of the chemicals that purify the water that is, in turn, necessitating the use of high-performance materials in the filtration media because they are able to resist the chemistry and provide durability in these applications."

For this reason, Arkema is developing new products to meet the needs of the filtration industry. "They needed a polymer that was lightweight and could be made into a fiber without becoming brittle," says Seiler. The same characteristics — chemical resistance, mechanical toughness and long-term durability — that made the company's Kynar PVDF (polyvinylidene fluoride) resin suitable for use in the process industries is also making them a choice material for microfiltration and ultrafiltration membranes, according to Seiler.

A range of Kynar PVDF resins is now available for use in membranes. Kynar 700 series is made in a range of viscosities, permitting customers to select the appropriate product for their membrane process. Kynar MG 15 is a new grade designed specifically for hollow fiber spinning. Kynar HSV 900 is a very high viscosity grade, especially suitable for hollow fiber casting and other applications requiring high gel strength. Also available are Kynar Flex co-polymer grades with even higher pH chemical resistance and greater flexibility. Kynar membranes are stable in applications over a pH range from 1.0 to 13, and are often used in exposure to citric acid, sulfuric acid, hydrogen peroxide, sodium hypochlorite, sodium hydroxide, ozone and high levels of free chlorine.

Finally, bio-sourced high-performance materials are becoming more attractive in a variety of industries. "Arkema's Specialty Polyamides group has also expanded into bio-sourced high-performance materials with the Rilsan Clear Rnew transparent polyamide range, making Arkema the only supplier of bio-sourced transparent polyamides," says Ryan Zakszeski, technical marketing specialist with the Specialty Polyamides division of Arkema Inc.

Rilsan Clear G850 Rnew and Rilsan Clear G120 Rnew are partially bio-based materials with excellent chemical and fatigue resistance, which will provide advantages in the optics, medical and consumer electronics markets. The company has also added polyamides 10.10, 10.12 and 6.10 to its portfolio. These resins offer optimized properties between that of short- and long-chain polyamides with the added benefit of having significant bio-sourced content, providing solutions for automotive, monofilament and industrial applications. Pebax thermoplastic elastomers (TPEs), which have been well known in the sports and medical industries for years, are now breaking ground in breathable, monolithic applications. New grades of Pebax TPEs show promise in the house wrap and breathable textile applications by producing tough and tear-resistant, waterproof barriers while remaining breathable, plasticizer-free and monolithic (non-porous), says Zakszeski. ■

Joy LePree

Weighing

Cardinal

Flexicon

Indicator connects with up to 14 analog weight sensors

The ZM305 is a multi-function weight indicator that is available in two versions. The ZM305 Standard weight indicator is designed for floor scales, batch vessels and in-motion conveyors. The ZM305 GTN Inbound-Outbound model is designed for use with truck scales and weighbridges. It gives users the ability to store gross, tare and net weights against up to 1,000 container or vehicle identifications, providing inbound and outbound weighing, according to the company. It includes a harmonizer filtering system, which corrects for environmental noise and vibration that commonly occur in the target applications. The ZM305 indicator is very quick, sampling 80 times per second, which is essential for accuracy when weighing in motion, says the company. — *Avery Weigh-Tronix LLC, Fairmont, Minn.*
www.averyweigh-tronix.com

Small-footprint lab scales provide precision weighing

This company's compact Nimbus precision and analytical balances are designed for laboratory use. The internal mechanism is fabricated using hardened materials, helping it to withstand rigorous laboratory use. The aluminum base withstands exposure to potentially corrosive chemicals. The balances have precision readabilities from ±0.1 mg to 0.1 g, and data can be output via USB or RS-232 connections. Other features include backlit LCD display, color-coded keys, level indicator with adjustable leveling feet, sealed keypad, external calibration and a pan lifter to easily remove samples. Many sizes and capacities are available. — *Adam Equipment, Danbury, Conn.*
www.adamequipment.com

This DIN rail weight transmitter has PLC connectivity

The Model 201 weight transmitter (photo) is a fast, accurate instrument for process control-based static and dynamic weighing applications. The 201 is capable of powering up to eight 350-Ohm load cells, and comes with a 35-mm DIN rail-mounting bracket. The transmitter features a 0.5-in.-high, six-digit, transreflective LCD display with up to seven different colors and is viewable in all lighting levels from direct light to total darkness. The Model 201 weight indicator handles up to 200 samples per second and standard communication protocols, including serial interface RS232/RS485, mini USB-B, analog (0–10 V, or 4–20 mA), Ethernet TCP/IP, EIP and Modbus TCP, make it easier to connect to a PC, PLC and other smart devices. — *Cardinal Scale Manufacturing Co., Webb City, Mo.*
www.cardinalscale.com

Move virtually any bulk material throughout the process plant

This company offers a variety of multi-component systems (photo) to move materials from process equipment, bulk bags, silos or manual dumping stations, allowing users to weigh-batch a single ingredient or up to 50, while blending for a recipe, filling containingers and delivering materials to process vessels, packaging lines or other destinations. The engineered solution may involve individual loss-in-weight, bulk-bag weigh-batch dischargers, or automated, gain-in-weight batching and blending systems, integrated into upstream and downstream equipment. — *Flexicon Corp., Bethlehem, Pa.*
www.flexicon.com

Systems maximize packaging rates with repeatable results

These bagging and checkweigh scale conveyors are designed for applications that package hard-to-handle materials or products. The PLC retains numerous settings to accommodate multiple product recipes. The electronic load-cell weighing system allows operators to fill bags and then verify the weight, adjusting the contents as needed. The company's many system of-

Note: For more information, circle the 3-digit number on p. 62, or use the website designation.

ferings include FIBC filling systems, valve bags, open-mouth bag fillers (for bags, boxes or drums), and gravity, pneumatic, auger, impeller and vibratory models are available to meet site-specific needs and constraints. — *Chantland MHS, Humboldt, Iowa.*
www.chantland.com

This scale is designed for use in hazardous environments

The QuickSilver IS (intrinsically safe) is a bench scale that is designed for general weighing, checkweighing, filling, manual batching and grading applications that must operate in hazardous environments, where low energy usage is required during normal operation. It is approved for all hazardous area groups, classes and divisions when used with its rechargeable battery. The removeable, rechargeable battery pack provides up to 65 h of continuous operation, and 250 h when the sleep mode function is used. When used with a direct power supply, the QuickSilver IS is not approved for Groups A and B, notes the company. — *Fairbanks Scales, Kansas City, Mo.*
www.fairbanks.com

This device's status monitoring reduces downtime

The IND570 industrial terminal (photo) is constructed and approved for harsh industrial environments and offers flexible control options for simple to complex weighing applications. In manually controlled weighing applications, the high-visibility graphic display shows realtime weighing status and can be programmed with language routines to "walk" users through the operations to improve efficiency and avoid errors. For automated systems, the IND570 can function as a standalone process controller. Its digital I/O options and easily programmable software provide accurate, repeatable results, says the company. It offers selectable interfaces and programs that allow users to customize features to match application requirements. Realtime communications are provided via serial, Ethernet and PLC interfaces, which can be tailored for the application. An added feature of the IND570 is that it provides performance monitoring to ensure that the weighing system is running properly. It also provides proactive alerting to help reduce downtime. — *Mettler Toledo, Columbus, Ohio*
www.mt.com

Scale provides high-precision dosing of small batches

The 100 Series Weigh Scale Blender (photo) is designed for plastics-industry applications, such as molding and extruding, that require the blending of small amounts of color or other additives with extremely high precision. Said to be one of the smallest machines of its type, the unit weighs and blends up to four components at rates of up to 450 lb/h This blender features a Micro-Pulse metering device, which has a slide-gate apparatus attached to a pneumatic cylinder with a very short (0.125-in.) stroke. The cylinder is rapidly and sequentially pulsed up to 20 times per second during dispensing, permitting very precise dose control, says the company. The machine is also self-calibrating, and achieves an overall precision of 0.1% of specified blend. — *Maguire Products, Aston, Pa.*
www.maguire.com

This weigher is suitable for potentially explosive areas

The automatic checkweigher HC-Ex is suitable for use in potentially explosive Zone 1 and Zone 2 atmospheres. The weigher combines an anti-static transport system, an intelligent electrodynamic weigh cell, and a control unit that executes in the ignition-protection mode of "pressurized apparatus." The menu-guided touchscreen simplifies operation. — *OCS Checkweighers GmbH,Schwäbisch Hall, Germany.*
www.ocs-cw.com

Lever scales designed for tanks or hoppers

Pipe-lever scales are an economical choice for many tank or hopper applications. They provide reliable electromechanical operation that has very low maintenance requirements, says the company. These scales are made from mild steel, are available for a capacity range of 5,000 to 50,000 lb. They can be customized to meet the site-specific weighing needs. RL20000 alloy-steel


Maguire

Mettler Toledo

load cells are standard, but stainless steel, hermetically sealed load cells are always available. Customization is available.— *Rice Lake Weighing Systems, Rice Lake, Wisc.*
www.ricelake.com

Modular designs supports customization for bag-filling

The Spirofil bulk-bag weigh fillers providing high-accuracy gain-in-weight filling for low- to medium-volume applications. The system has a filling nozzle, and bags are suspended within the frame using quick-releasable latchable hooks or tubular bars. Optional vibration is available to de-aerate and stabilize the filled bags. Other options include an inflatable neck seal, a slide-gate-fill control valve, automatic height adjustment for varying bag sizes, sampling ports, a controller to manage control and data, and more. The company's Spirofil weigh-and-fill, bulk bag-filling equipment can handle bag capacities up to 4,400 lb, with a range of basic models and custom solutions. These machines are modular in construction, allowing users to specify a number of options as their needs change. Forklift bag removal, pallet truck bag removal and conveyor bag removal are available. — *Spiroflow Systems, Monroe, N.C.*
www.spiroflowsystems.com

Weight belt feeder designed for rugged materials

This company offers a large variety of weigh-belt feeders for both heavy-industry and light-industry applications. The Model MH high-capacity weigh-belt feeder, which was first desgned for steel-mill service to feed flux materials (such as limestone, dolomite, iron-ore pellets, fluorospar and coke). This heavy-duty model can handle a feed rate of 400–3,000 ton/h and particle sizes from fines to 6-in.-dia., and densities of 40–200 lb/ft^3. It is designed to withstand extreme conditions, such as abrasive dusts, corrosive fumes, wide temperature fluctuations and vibration, without any detrimental effects on performance or accuracy, says the company. The MH belt is driven from the head pulley located at the outlet of the feeder, rather than the tail pulley at the end inlet. This is said to allow for lower belt tension during operation, which provides better sensitivity and greater accuracy. — *Thayer Scale, Pembroke, Ma.*
www.thayerscale.com

Transmitter junction box allows for remote scale monitoring

The Transcell LCT-2 digital weight transmitter allows users to monitor up to four individual load cells and transmit filtered weight data to a PLC or other compatible device, via EtherNet/IP or Modbus protocol. The ability to monitor four load cells using a single transmitter helps to save money (compared to the use of individual, dedicated transmitters). The sampling rate is adjustable from 4.7 Hz, with a 24-bit resolution. This transmitter is designed for in-plant use, such as realtime scale-system diagnostics. The LCT-2 can be used in virtually any plant environment, and is well-suited to powder and

bulk-solids applications. It supports up to 20 industrial network protocols — *Transcell Technology, Buffalo Grove, Ill.*
www.transcell.com

Precision weigh cells for any size application

The EC-FS weigh cells provide ultra-fast, high-precision weighing. Using electromagnetic force restoration (EMFR), the weigh cells provide fast sampling (every 1 ms), covering a weight range up to 15,000 g with a resolution of up to ±0.01g. The company offers a large family of weigh cells to accommodate a variety of measuring ranges. — *Wipotec North America, Roswell, Ga.*
www.wipotec.com

Portable bulk-bag discarge unit discharges dust-free


Material Transfer

The customized Flo-Master portable bulk-bag discharge sysem (photo) includes a loss-in-weight scale system and a digital weigh indicator with a bulk-bag conditioning system, to promote material flow. The company's Flow-Lock gate halts material flow as needed for partial bag discharge. The company's Seal-Master bag spout access chamber with "gull wing" doors and a discharge spout-sealing system that ensures dust-tight material discharge. Discharge is managed using a vacuum takeoff adaptor with air-actuated ball valve and inlet air filter. This design allows for eay connection to a pneumatic conveying system. — *Material Transfer, Allegan, Mich.*
www.materialtransfer.com

Rugged belt scale accommodates uneven loading

The Milltronics MSI is a heavy-duty, high-accuracy, full-frame belt scale that provides continuous in-line weighing on a variety of products and industry sectors, including mining, power generation, iron-and-steel production, food processing and chemicals. The MSI's patened use of parallelogram-style load cells results in fast reaction to vertical forces, ensuring instant response to product loading. This ensures high accuracy and repeatability, even with uneven loading and fast belt speeds, says the company. It has a maximum capacity of 12,000 ton/h at maximum belt speed, a maximum belt speed of 5 m/s (1,000 ft/min) and an accuracy of ±0.5% or better. — *Siemens AG, Munich, Germany*
www.siemens.com ■

Suzanne Shelley

New model for this series of gas compression packages

This company has introduced the latest addition to its C-Series offering of configurable compression packages: the C-Series 7044 Compression Package. This model features GE's 1,680 h.p. Waukesha L7044GSI rich-burn engine, paired with an Ariel JGK4 compressor. GE's Waukesha gas engines are widely regarded for fuel flexibility on a wide gas range up to 2,300 Btu, as well as full-power capabilities without derate at altitudes up to 8,000 ft. The C-Series 7044 can be configured with more than 60 options, including advanced emissions-control systems to meet most government compliance requirements. Packages are built on heavy-duty, steel skids suitable for mounting on a compacted gravel pad, piles or an engineered concrete foundation. The C-Series is available in 13 base models in one-, two- and three-stage configurations. — *Exterran Holdings, Inc., Houston*
www.exterran.com

AURA Controls

New high-purity gas switchover system for critical applications

The EXD Series automatic differential-pressure switchover (photo) is a highly accurate, reliable gas-distribution system that automatically switches between two high-pressure gas sources to enable uninterrupted supply. The EXD system is designed to provide a continuous supply of high-purity gas in critical applications and demanding process environments. The system is suitable for carrier- and calibration-gas delivery applications used in chromatography processes, sampling systems and laboratory instrumentation. The proven switching technology provides failsafe operation utilizing a priority valve assembly, allowing the user to replace depleted gas containers without system interruption and increasing the amount of time between change-outs. — *AURA Controls, Virginia Beach, Va.*
www.auracontrols.com

Atlas Copco

Four new models of containerized power generators

The QEC 1250 containerized generator has now been joined by four new models: QEC 800, QEC 950, QEC 1000 (photo) and QEC 1200. The expanded QEC range, including two dedicated models for the U.S. and Canada, has been designed for multi-drop, prime power and critical standby applications for the rental, mining and oil-and-gas industries. The QEC 800, QEC 1000 and QEC 1250 are available for the global market (50/60 Hz switchable), and the QEC 950 and QEC 1200 are dedicated 60Hz, EPA Tier 2 certified for the U.S. and Canada. Users can tailor their QEC to individual key requirements, such as power output (up to 1 MW) and noise suppression. A host of factory-mounted and retrofit options allow this customized configuration. These include digital AVR, a coolant heater, an air shutdown valve and customized colors. — *Atlas Copco, Zaragoza, Spain*
www.atlascopco.com

Clark Solutions

High-pressure rotary gear pumps feature no-gasket design

The 700 Series Rotary Gear Pumps (photo) are designed to provide quiet and efficient service at pressures up to 2,000 psi and flowrates up to 5.0 gal/min. Featuring a gasket-free design, these pumps transfer media at temperatures up to 250°F and, with optional modifications, to 500°F. Available in cast and ductile iron, all 700 Series models can be ordered with foot or flange mounting. The gears, shafts, and housing faces are machined to extremely tight tolerances, allowing them to provide better lift, reduced slippage and longer service life. Replaceable anti-friction needle-roller bearings minimize friction and provide higher load ratings for medium- to high-pressure service. An innovative lip seal provides an ample safeguard against liquid leakage and the entrance of air. — *Clark Solutions, Hudson, Mass.*
www.clarksol.com

Lee Products

A chemically inert stepper pump dispenses tiny volumes

This miniature, chemically inert stepper dispenser pump (photo) is designed to deliver variable micro-liter volumes (50–250 µL) with a consistent performance. The LPD Series pump has

been developed to offer greater design flexibility and significant cost savings to the medical and scientific industries as a result of its maintenance-free design. It can be located wherever fluidic requirements dictate, regardless of maintenance accessibility. The pump is offered in both standard and high-performance models, with the latter incorporating a home sensor, encoder and backlash compensation for more demanding applications, and provides a C_V of ≤0.01% at total volume. The standard performance model is available with a home sensor for most other applications. Maximum discharge pressures are 60 psi. — *Lee Products Ltd, Gerrards Cross, U.K.*
www.leeproducts.co.uk

New heat exchanger technology for air-cooled LNG facilities

Together with Wieland Thermal Solutions and Technip, this company has developed a new technology to boost efficiency for air-cooled liquefied natural gas (LNG) facilities, known as Diesta (short for dual internally and externally structured tube for air-coolers). Diesta (photo) is a combination of two established technologies for the outside and inside of a tube, the key component of an air-cooler. Diesta technology typically allows increase in LNG production by 2 to 3%, while taking advantage of compression power savings. Moreover, the equipment footprint can be reduced by up to 20% due to a more compact design. Finally, the reduction in specific fuel-gas consumption lowers CO_2 emissions, says the company. — *GEA Batignolles Technologies Thermiques SAS, Nantes, France*
www.gea.com

Continuously supply hot water, on demand, with this system

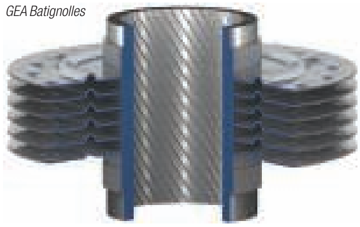
The EasiHeat DHW is a new heat exchanger that incorporates SIMS (Spirax Intelligent Monitoring System) to deliver a constant supply of hot water at a stable temperature on demand — even with sudden, wide load changes. The unit can handle process hot-water applications of up to 4 million Btu. EasiHeat DHW comes with a new control system that enables monitoring, diagnostics and status communications. A 7-in. touchscreen provides visual access to data, detailing how and where energy is consumed, leading to more informed energy-management decisions and increased efficiency, says the company. With SIMS technology, systems are compatible for connection to existing proprietary networks and can interact with Ethernet and Modbus systems, as well as Profibus, CANopen, EtherCAT, DeviceNet and more. — *Spirax Sarco, Inc., Blythewood, S.C.*
www.spiraxsarco.com

This tube connection speeds assembly of systems

Designed for working pressures as high as 22,500 psi (1,550 bars), the new "flared-cone" technology advances the performance of compression-style tube connections. It provides users with a simple and reliable means of speeding the assembly of instrument tubing systems for use in higher-pressure applications in the oil-and-gas industries. The new flared-cone connection (FCC) technology (photo) is said to be a significant advance on the type of "cone and thread" tube connections pioneered by the company. The new FCCs are much simpler to make up. Installers can typically complete the task in less than 4 min, after only minimal training. This time-saving can result in significant cost reductions on installations with a large number of tube connections. Flared-cone connections are also especially cost-effective in applications where leaks caused by vibration are an issue. — *Parker Hannifin Corp., Cleveland, Ohio*
www.parker.com

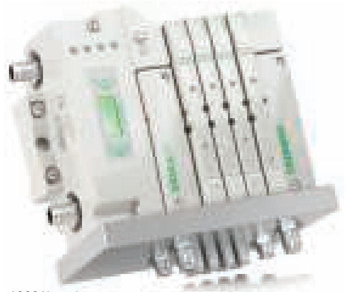
Low-pulsation piston pumps for laboratory use

The LS Class of single-headed, positive-displacement piston pumps (photo) feature very low pulsation and high accuracy, along with micro-stepping motor technology and a proven single-piston pump mechanism. Standard fluid-path materials are stainless steel and polyetheretherketone (PEEK), with optional titanium components available. Also available are jacketed heads for temperature-controlled processes. Three versions are available, capable of handling 5, 10 and 40 mL/min, respectively. With pressure capability up to

GEA Batignolles


Parker Hannifin


Scientific Systems



ASCO Numatics

ABB

Honeywell Process Solutions

Stedman Machine

OPW Engineered Systems

6,000 psi, these pumps are suitable for a wide variety of uses, including biocompatible separations, semi-prep liquid chromatography, metering, dispensing and general laboratory use. — *Scientific Systems, Inc., State College, Pa.*
www.ssihplc.com

Connect valve manifolds to panels inside cabinets

The 501 Series panel-mount adapter plate (photo) allows users to directly connect compatible valve manifolds to a panel in the wall or floor of a cabinet. This eliminates the need for complex routing of tubing and bulkhead fittings, reduces custom machining and drilling and simplifies overall panel layout. The panel-mount adapter plate is ideal for applications in the process industries where directional control valves are installed in a cabinet due to environmental or packaging constraints. — *ASCO Numatics, Lucé, France*
www.asconumatics.eu

New swirl and vortex flowmeters with quick reaction time

A new range of vortex and swirl flowmeters (photo) includes the SwirlMaster and VortexMaster product lines. The new SwirlMaster features a unique swirl technology that enables very short upstream and downstream piping requirements, which saves installation costs and enables high-accuracy flow measurement in tight spaces. The VortexMaster follows the same philosophy with a lower-cost entry-level version (FSV430) for simple applications. Both versions are available in a remote design with a cable length of up to 30 m. With the new devices, the reaction time for a change in flowrate is reduced from about 3–6 s (with previous models) to only about 1 s. — *ABB, Zurich, Switzerland*
www.abb.com

A digital platform dedicated to managing cybersecurity

This company's Industrial Cyber Security Risk Manager (photo) is a digital dashboard designed to proactively monitor, measure and manage cybersecurity risk for control systems in petroleum refineries, power plants and other automated production sites. The platform simplifies the task of identifying areas of cybersecurity risk and provides real-time visibility and decision support in multi-vendor industrial environments. Risk Manager translates complex cybersecurity indicators into clear measurements and key performance indicators (KPI). Users can create customized risk-notification alerts and perform detailed threat and vulnerability analysis. — *Honeywell Process Solutions, Houston*
www.honeywellprocess.com

Fast-impact fractures lead to uniform particle size

This company's line of horizontal shaft impactor (HSI) crushers (photo) can achieve reduction ratios of up to 30 to 1 in a single stage. Product size is varied by changing rotor speed and clearances. The size reduction takes place along short fracture lines, producing a more cubical product to meet aggregate specifications. This fast-impact fracture is different from the slow-compression breaking in cone or jaw crushers, says the company. Unlike hammer mills, there are no screens or grates holding material inside the crusher, so material is efficiently processed at high rates. HSI crushers are capable of size reduction in all material sizes and hardnesses with minimal maintenance. — *Stedman Machine Co., Aurora, Ind.*
www.stedman-machine.com

Couplings for extreme-temperature fluid transfer

The 3TL Series of all-purpose, high-performance quick couplings (photo) is designed with metal-to-metal wedge-seal technology provides leak-free and hammer-free unions for transferring fluids under extreme temperatures and pressures. The metal-to-metal wedge functionality removes the need for a hammer union, which reduces operator strain. The coupling's small profile allows it to fit in areas of limited space. The 3TL is suitable for the transfer of cryogenics, steam, oil, acids, paints, ammonia and more. — *OPW Engineered Systems, Lebanon, Ohio*
www.opw-es.com

A lightweight dust monitor with robust data logging

The Kanomax dust monitor (photo) provides highly accurate dust measurements via an intuitive interface. The device can detect particle sizes from 0.1 to 10 µm, with a measuring range of 0.001 to 10 mg/m^3. The unit can log up to 100,000 measurements, and features a USB interface for data transfer. Weighing just 2.9 lb, the Kanomax dust monitor has a run time of more than 24 h, and is capable of analog and digital output. A tripod mount for stationery locations, or a rubber protector and shoulder strap for portable use, are included. — *New Star Environmental, Roswell, Ga.*

www.newstarenvironmental.com

A new gate valve features a patented perimeter seat

The new KGC-BD Bi-Directional Resilient Seated Knife Gate Valve (photo) features a patented perimeter-seat design that provides bubble-tight shutoff in either direction, even on dead-end service. This gate valve combines a one-piece rubber molded seat with an insert, a spline and a puck that work together to lock the seat securely into the valve body. This unique seat design prevents buckling or dislodging that can occur with other perimeter seat designs, says the manufacturer. In addition, the KGC-BD features the exclusive premium packing system that includes high-performance-packing material options and anti-extrusion segments. Available in sizes from 2–36 in. (50–900 mm), and in a variety to materials, the KGC Bi-Directional valve provides improved sealing, extended packing life and reduced maintenance, says the company. The valve is designed for isolation and on/off applications, and handles clean, dirty, viscous and corrosive liquids, sludge, fibrous slurries, clean and corrosive gases. — *DeZurik, Inc., Sartell, Minn.*

www.dezurik.com

Higher data capacity with this wireless bridge

This company has released a new point-to-point high-speed wireless bridge. The carrier-class wireless-networking bridge provides more than 1 GB of data transmission. The system operates in the 5 GHz band, and is effective for up to 10 miles of line-of-sight distance. The new product provides a valuable alternative for backhaul or connecting buildings at unprecedented speeds. The product family now has twice as many channels, resulting in twice the amount of data capacity. This is important when scaling larger deployments and allows smaller sites to minimize interference with more channels to select between. — *AvaLAN Wireless Systems, Inc., Madison, Ala.*

www.avalanwireless.com

Use this software to verify process-logic code

PLC Checker software can be used to automate process-logic code review and demonstrate programming and coding rules to third parties. By ensuring that logic programs are consistent, commissioning and maintenance costs are reduced. Analyses are launched from developers' workstations and metrics and findings are shared on servers. PLC Checker also comes with over 40 pre-defined rules that can be easily customized according to user requirements. — *Itris Automation, Grenoble, France*

www.itris-automation.com

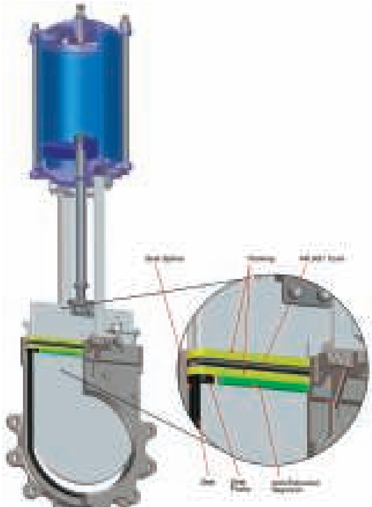
A corrosion transmitter for widely separated monitoring points

The Model 4020LT-A two-wire transmitter (photo) provides enhanced resolution measurements of metal loss due to corrosion inside pipelines. The new transmitter is designed for operation in plant locations with widely separated monitoring points and a preexisting distributed control system (DCS). According to the company, similar products only have resolutions of 0.4%, while the Model 4020LT-A features measurement resolution of ±0.1%. A switchable probe-type selector allows users to easily adjust between different electrical resistance probe types. The unit provides isolation between the probe and the 4–20-mA circuits required to power the loop, making it intrinsically safe. — *Rohrback Cosasco Systems, Inc., Sante Fe Springs, Calif.*

www.cosasco.com ■

Gerald Ondrey and Mary Page Bailey

New Star Environmental



DeZurik

AvaLAN Wireless

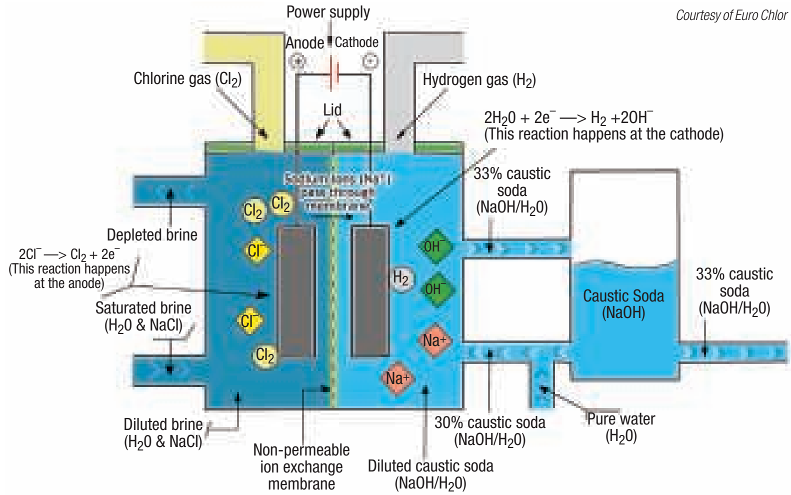
Rohrback Cosasco Systems

Facts At Your Fingertips

Key Commercial Electrochemical Processes

Department Editor: Scott Jenkins

Industrial electrochemical processes are critical to a host of chemical products across many industry sectors. Modern products of electrochemical processes include chlorine gas, sodium hydroxide, sodium chlorate, hydrogen, oxygen, aluminum, copper, magnesium, zinc, adiponitrile and others. This one-page reference provides information about four key electrochemical processes.



Chlor-alkali

The chlor-alkali process involves applying a direct electric current to a brine solution to produce Cl_2 gas, NaOH solution and hydrogen gas (see figure).

Saturated brine solution is introduced into an electrochemical cell, where chloride ions react at the anode to form Cl_2. Sodium ions pass through an ion-exchange membrane to the other side of the cell, which contains dilute NaOH. At the cathode, water is electrolyzed to produce H_2 and hydroxide ions. A more concentrated NaOH solution is removed as product. The separator membrane allows for higher-purity products and lower energy consumption than chlor-alkali technologies, such as the diaphragm cell and mercury cell, which is being phased out.

Chlor-alkali is among the most important chemical processes worldwide, because Cl_2 and NaOH are indispensable commodities for a wide range of applications. One of the two is used as a precursor in almost 55% of all specialty chemical products [*1*], including: adhesives, plastics, pesticides, paints, disinfectants, water additives, rubbers, cosmetics, detergents, lubricants, vinyl and polyvinyl chloride (PVC), soap, glass, cement, medical dressing, textiles, books, greases and fuel additives.

Aluminum

Primary aluminum comes from the mineral bauxite, which is mined and ground to separate raw alumina (Al_2O_3). The raw alumina is refined using caustic soda and lime to generate pure alumina. A solution of alumina powder is electrolyzed in molten cryolite (Na_3AlF_6), where the aluminum is reduced to produce pure Al metal. The bottom of the reduction cell usually serves as the cathode, and carbon bars serve as anodes.

Electrowinning

Electrowinning (EW) is the main method used in the mining industry to recover pure metal products (Cu, Zn and others) after the metals have been extracted from ores. Depending on the metal, the product is plated onto the cathode of an electrochemical cell, and either oxygen (sulfate-based Cu, EW, for example) or chlorine (chloride-based Cu EW) is produced at the anode.

For example, copper electrorefining is carried out by placing impure copper sheets in a cell, dissolving them by electrolysis in a bath of sulfuric acid, and electroplating pure copper at the other electrode. By judicious control of cell conditions, impurities are left behind, either as undissolved solids or as dissolved species that do not plate out.

Synthesis of adiponitrile

An important example of a commercial electrochemical process involving organic chemicals is the hydrogenative dimerization of acrylonitrile to adiponitrile. Adiponitrile is a key intermediate for the production of nylon 6, 6 polymers. It is used for the synthesis of hexamethylenediamine, which is a raw material for the production of nylon 6,6 fibers and resins.

The process involves rapidly pumping a finely divided, two-phase emulsion through a cathode-anode system. The aqueous phase contains a conducting salt — a tetra-alkylammonium salt — and a small amount of acrylonitrile (determined by its solubility), while the organic phase consists of acrylonitrile and adiponitrile. As acrylonitrile in the aqueous phase is consumed by the reaction, acrylonitrile is transferred from the emulsified organic phase.

The hydrophobic alkyl groups of the tetra-alkylammonium salt screen the cathode so that no water electrolysis can occur. Thus the hydrogenation of acrylonitrile's C=C double bond is suppressed, and only the organophilic acrylonitrile can be dimerized at the cathode. Unreacted acrylonitrile and adiponitrile product are separated and distilled. The selectivity to adiponitrile is about 90%, with byproducts propionitrile and biscyanoethyl ether. ■

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Technology Profile

Green FDCA Production

By Intratec Solutions

Concerns over limited supplies of petroleum-based feedstocks, coupled with the global issue of climate change, have increased demand from consumers and companies for more sustainable products. In this economic environment, chemical and polymer production from renewable resources is increasingly viewed as an attractive area for investment.

Following this global trend, research on the production of 2,5-furandicarboxylic acid (FDCA) has intensified over the last few years. FDCA has the potential to replace fossil-based purified terephthalic acid (PTA) in the production of polyesters and other polymers containing an aromatic ring. The most promising application segment for FDCA is for the production of polyethylene furanoate (PEF). This polymer exhibits physical properties and applications similar to polyethylene terephthalate (PET), and is produced by the use of FDCA, instead of PTA, in the PET-production process.

Production process

Figure 1 depicts an FDCA production process from a glucose solution via the furan pathway in a process similar to that developed by Avantium Technologies B.V. (Amsterdam, the Netherlands; www.avantium.com). This process can be divided into three main areas: furans production, methoxymethylfuran (MMF) purification, and FDCA production.

Furans production. The glucose content of the feed is first enzymatically isomerized to fructose, and the effluent is passed through ion-exchange resins to separate unreacted glucose from the fructose. The former is recycled to the isomerization reactor and the latter is sent to the furans conversion reactor. In the furans conversion reactor, crystallized fructose is solubilized with a 95 wt.% methanol aqueous solution and sulfuric acid. The reaction is conducted at 50 bars and 200°C. Fructose is dehydrated to hydroxyl methyl furan (HMF) and, due to the excess of methanol, most HMF is converted to MMF, which is more stable than HMF.

MMF purification. The reactor effluent is then sent to a distillation system to recover the solvent and separate the MMF from other impurities. Methanol and water are recovered and returned to the furans conversion area, while methyl levulinate is recovered as a byproduct. Also, a heavies stream is recovered to be used as boiler fuel, and finally, purified MMF is recovered and directed to the FDCA production area.

FDCA production. Purified MMF is mixed with acetic acid solvent and a catalyst in the oxidation reactor to be converted to FDCA. This stream is filtered to recover crude FDCA. The acetic-acid-rich liquid is purified using two distillation columns. Catalyst is also recovered, but it must be reactivated before being recycled to the process. Crude FDCA is mixed with water and hydrogen in a hydrogenation reactor, where impurities are removed. The effluent from the reactor is crystallized, and purified FDCA is recovered from the solid materials. The liquid effluent is a waste stream.

Economic performance

An economic evaluation of an FDCA plant was conducted, assuming a facility with a nominal capacity of 300,000 ton/yr of purified FDCA constructed on the U.S. Gulf Coast. Included was a storage capacity equal to 20 days of operation for feedstocks and products.

Estimated capital expenses (total fixed investment, working capital and initial expenses) to construct the plant are about $600 million, while the operating expenses are estimated at about $1,550/ton of purified FDCA.

Global perspective

The main production cost, as in many commodities-production processes, is the purchase of raw materials. Not only is glucose syrup an expensive source of glucose for this process, but also the conversion of fructose to MMF is relatively low, increasing the raw-material consumption. It would be beneficial for the profitability of the process to integrate it with biomass treatment, in order to obtain raw materials at lower costs. This process could easily integrate with a biorefinery, where it is possible to achieve a more efficient valorization of the biomass used as feedstock. ■

Edited by Scott Jenkins

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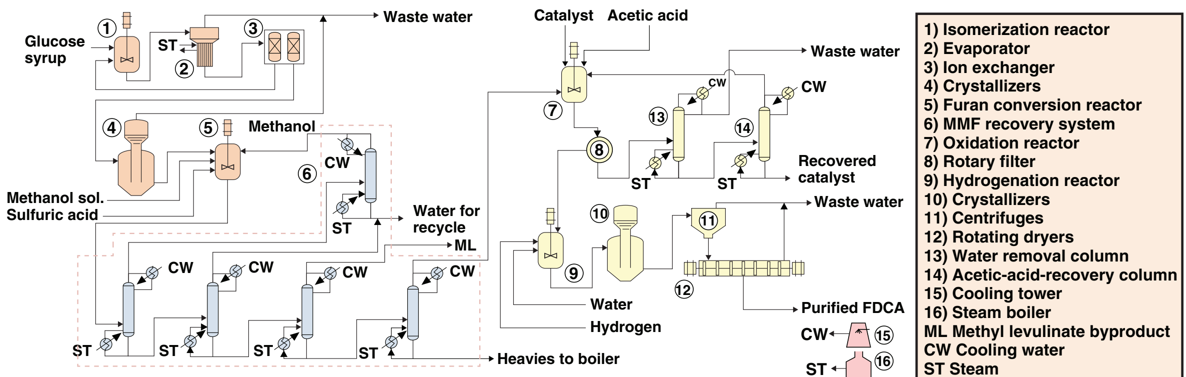

FIGURE 1. FDCA production process via furans pathway similar to Avantium YXY process

Valve-Selection Best Practices

Precise combinations of valves and other equipment lead to process success. A biopolymer fermentation process provides an example of proper valve selection

Ray Herrera
Valin Corp.

IN BRIEF

VALVE SELECTION PROCESS

TEMPERATURE AND PRESSURE

MATERIALS OF CONSTRUCTION

OPERATING MODE

VALVE ACCESSORIES

EXAMPLE BIOPOLYMER PROCESS

ADDITIONAL UTILITIES

FIGURE 1. Properly selected valves enhance the safety, efficiency and reliability of a chemical processing application. Correctly selected valves reduce maintenance and promote optimal system function

In chemical processes requiring automated control, a properly selected valve can make the difference between a mediocre outcome and a top-quality product. Mistakes are often made when selecting the proper equipment for each job function. The decision process of selecting these components requires extensive knowledge and expertise. There are many factors to consider when engineering an automated chemical process, including motion requirements, cost effectiveness and chemical compatibility. In most cases, a precise combination of valves, sensors and other equipment is required to ensure an efficient and successful operation.

Using a biopolymer fermentation process as an illustrative example, this article discusses how specific pairings between valves and surrounding equipment, such as sensors, can increase safety and product quality. Each individual step in the process of fermenting the liquid to create this biopolymer requires a different valve/sensor pairing to ensure the success of the overall process. The article analyzes the process from beginning to end and explains how and why the decisions were made for selecting each individual valve involved.

The benefits of selecting the correct components for a chemical processing application are numerous. The most obvious is the overall quality of the operation. Another important benefit of proper valve selection is the prevention of system damage and process malfunctions. When a valve is required to fulfill an essential process function, but is not properly designed to do so, the results can be catastrophic to the individual valve, as well as the overall process. Finally, correctly selected valves will enhance the safety, efficiency and reliability of a chemical processing application. Choosing the correct valve will result in the system performing at the peak of its ability for the longest period of time and with the least maintenance requirements (Figure 1). An example process is used to illustrate valve-selection considerations.

VALVE-SELECTION PROCESS

Before turning to the details of the fermentation process, it is useful to review the general steps to take when selecting a valve for a chemical processing application.

The first step in every situation is to consider the type of application for which the valve will be used and select the most cost-effective option that fulfills the requirements of that particular application. Common application types for chemical-processing valves include the following: frequent versus infrequent operation, process versus drain, fire-safe, normally open (N/O), normally closed (N/C), critical service, safety and environment. All other valve selection decisions will be based on the category and specific requirements of the application.

Once the application data are gathered, engineers can move on to examine the details of the application and determine which valve will work best for the particular requirements at the lowest price.

The most common types of valves used in chemical processing operations include the following: ball, butterfly, check, control, diaphragm, float, gate, globe, needle, plug, relief, solenoid, segmented or V-port, Y-pattern and three-way. Each of these valve types has unique characteristics that make it more suitable for some applications than for others. The details of all the valves will be discussed in further depth when we look at their involvement in the fermentation operation.

The valve-selection process involves a series of questions designed to systematically narrow down the possible valve solutions until one particular valve stands out as the ideal choice. First, consider the size required by the application. Ask the following questions:

- What is the pipe size at the inlet and outlet of the valve?
- What is the flow capacity (C_v)?

The answers to these questions will immediately limit the options of valves depending on the sizes available from the manufacturer.

Temperature and pressure

Moving forward with the process, critical consideration are the temperates and pressures to which the valve will be exposed. A few important questions to ask at this point include the following:

- What is the maximum pressure of the process?
- Where does the fluid go between the source and the valve (upstream)?
- Where does the process media go after it leaves the valve (downstream)?
- What is the maximum fluid temperature?

The process fluid's combined pressure and temperature must be within the manufacturer's published rating for a given valve. The rating will be unique to a given body shell, valve body and trim-material combination, as well as seal material and end connections. Select a rating that ensures these combinations are sufficient to handle the maximum possible process conditions for temperature and pressure.

Materials of construction

After evaluating the temperature and pressure, narrow down the valve selection based on the materials involved in the process. First, consider the media being processed and ask the following questions:

- What fluid is going through the valve?
- What is the source of the fluid?
- What is the fluid temperature?
- Is the fluid clean? Is the fluid being treated before it reaches the valve?

The answers to these questions will help determine the body materials required for the valve. Select the body and trim materials based on their strength (pressure/temperature rating), the internal/external environment, chemical compatibility and resistance to corrosion and erosion for a given process fluid. Plastic can be used for very low-pressure systems where corrosion is of primary concern. Brass and bronze are very economical choices for valve material and are fairly corrosion-resistant. Iron is a very cost-effective material and can be economically coated or lined for compatibility with corrosive fluids. Select carbon steel for the valve material where strength is needed. Stainless steel has very good strength as well as corrosion resistance.

Seals and ends

The material that the valve seals are composed of is equally important in the decision process. Select elastomeric and plastic seals, liners and diaphragms based on their chemical compatibility to the process fluid. Elastomeric elements (natural and synthetic rubbers) have better sealing characteristics, but plastics [for example polytetrafluoroethylene (PTFE), perfluoroalkoxy (PFA) and so on], are typically chosen for better resistance to harsh chemicals. Chemical-resistance guides, which are offered by most manufacturers, can be a good resource for proper selection of seal materials.

Additionally, take the end-connections on each side of the valve into consideration. The following questions are useful in making a decision:

- What is the pressure/temperature rating?
- What is the installation/maintenance cost?
- What industry and plant standards need to be met?
- What type of seal welding will be used?

Valve-body end connections are typically chosen based on initial cost, plant standard, and maintenance preference.

FIGURE 2. Selecting a valve type, like this diaphragm valve, requires whether it will be automated versus manual and other considerations

Maintenance consideration is the preferred method of selection. Threaded ends (either NPT or screwed) have a low initial cost, but are subject to leak paths and stripping. Use threaded ends where maintenance is not a concern. Welded ends provide for rigid, leak-tight connections. They have a low initial hardware cost, but a high maintenance cost, should they need to be cut out of the line for repair or replacement. Flanged ends have the highest initial cost, but are preferred from an installation and removal standpoint. Wafer bodies give the benefits of a flanged installation with very low initial cost. Use wafer bodies only where the pipe is rigid or fully supported. Three-piece ball valve designs give the benefit of threaded or welded joints with integrally flanged wafer bodies.

Operating mode

After evaluating the materials and connections, the operation and actuation method of the valve should be taken into account (Figure 2). The following are the major considerations that can influence the valve type:

- Does the valve need to be manual or automated?
- Will the valve operator be lockout type, oval or deadman?
- Will the actuator be pneumatic, electric or hydraulic?

For automated valves using pneumatic, electric or hydraulic actuators, the force output of the actuator must be sufficient to overcome valve static friction and dynamic torque. Static friction is developed in the metal-to-metal surfaces, seats and seals. Dynamic torque is that unbalanced force of the process acting on the plug, disc or ball. Valve torque requirements are supplied by the manufacturer and are based on the pressure drop across the valve. A minimum of 10–20% safety factor should be added to ensure reliable operation. An on/off actuator positions the valve in the open or closed position. Modulating actuators use controllers and positioners to maintain a valve position based on an input signal.

Valve accessories

The final consideration in the valve-selection process is choosing the accessories required to complete the process. Accessories are components within a valve-automation system that are required to operate, override and support the actuation assembly. Select accessories based on the valve, actuator and control-system requirements. These requirements can include: solenoids; switches; Indicators; overrides; positioners; and gages.

Of these options, the most common considered are the solenoid valve, the limit switch for on-off valves and the positioner for modulating valves.

Solenoid valves — simple electronic devices ideal for fluid shutoff and switching in general-service applications — are connected to the actuator either directly or remotely, so compact size and reliability are of concern. Solenoid valves are used on every pneumatically actuated valve and are also used as automated valves for small lines between 1/4 and 2 in. The difference between a solenoid valve and an automated valve is that solenoid valves do not support accessories. Where an automated control valve would be used in a process-control application due to its ability to use an accessory switch to confirm its operation, solenoid valves would fail due to their lack of that additional functionality.

Limit switches (valve position indicators) are connected directly to the actuator and must be compact, due to size constraints. The must also be highly visible and have the ability to provide reliable feedback to the control system. An unreliable switch will upset continuous process control and adversely affect quality and safety.

Positioners are devices used to position a modulating valve based on a control signal and are also attached to the actuator. Newer digital (smart) positioners are advantageous because they are more reliable and have more installation options than analog positioners. They are microprocessor-based and can also provide valuable fieldbus communications and diagnostic information.

BIOPOLYMER PROCESS

The example process described here is a fermentation process within a biopolymer-processing facility from raw-material injection to extraction of fermented product. Each fermentation tank has a capacity of 50,000 gal and converts glucose syrup into a fermented liquid broth that is eventually dried and milled into a powdered biopolymer product. This biopolymer powder is used in foods, industrial lubricants and pharmaceuticals, among other applications, for its ability to allow oil and water to mix and become bound together. One area where this biopolymer finds use is in the lubrication on the head of an oil drill, which is often washed off by water in the ground. The biopolymer prevents the water in the ground from washing the lubricant off of the drill head and results in a smoother, more efficient drilling operation. Another example is in consumer pharmaceuticals and food products. The biopolymer is used to bind the contents of pill capsules together or to keep the oil and other ingredients in salad dressing from separating from one another.

The chemical plant that produces the biopolymer product contains a total of 18 fermentation tanks that feed the fermented product into secondary systems once the process is complete. This article focuses primarily on the operations taking place during the fermentation of the raw material.

There are eight main components of the fermentation process (Figure 3) and they occur in roughly the following order. Some processes, such as temperature and pH-level regulation, can occur at the same time:

1. Heated product fills the fermenter
2. Oxygen is added to feed the fermentation process
3. Carbon dioxide is removed to reduce tank pressure and promote growth
4. Fluid pH level is regulated by injecting acidic or caustic solutions
5. Fluid temperature is maintained by a jacket surrounding the tank that is filled with cold water
6. Fermented product is treated to inhibit bacterial growth
7. The resulting fermented liquid is fed into a distribution system and sent on to be precipitated, dried and milled into final powdered product
8. The tank is drained and steam-sterilized to prevent any cross-batch contamination

Each of these steps will now be explained in chronological order, including the details of each type of valve and sensor involved in the system. There will also be an overview of the several auxiliary systems running alongside the fermentation tank to provide the fluids and gases needed for the process.

1. Filling the fermentation tank. The tank is filled with a heated glucose syrup solution using a diaphragm valve, which opens to allow the product to enter the tank. The valve is operated remotely using an actuator triggered by a computer in the plant control room.

Diaphragm valves are by far the simplest valves. A resilient diaphragm provides tight shutoff and isolates the body from its operator. The operator consists of a plunger and handwheel assembly. Diaphragm valves are ideal for corrosive, slurry and sanitary services. They are easily and inexpensively actuated with pneumatic and electric actuators.

A primary benefit of diaphragm valves, especially in this application, is their inherently hygienic qualities. It is very important to avoid contamination during the beginning of the fermentation process so that no complications arise later.

To determine the amount of liquid that needs to enter the tank, the diaphragm valve works in conjunction with a pressure sensor at the bottom of the tank that acts as a level sensor, basing its measurement on the weight of the liquid.

After the liquid is added to the tank, it is inoculated with enzymes to result in the desired level of fermentation. An internal agitator with a propeller-type device continually mixes the contents over the course of the entire process.

2. Adding oxygen to the tank. At this point in the process, oxygen must be added to promote growth of the bacterial fermentation agent. This is done using a high-performance butterfly valve connected to a "spray ball" injector inside the tank (a ball-shaped device with holes for air to escape into the tank). A differential-pressure flowmeter is used to gauge the amount of air entering or

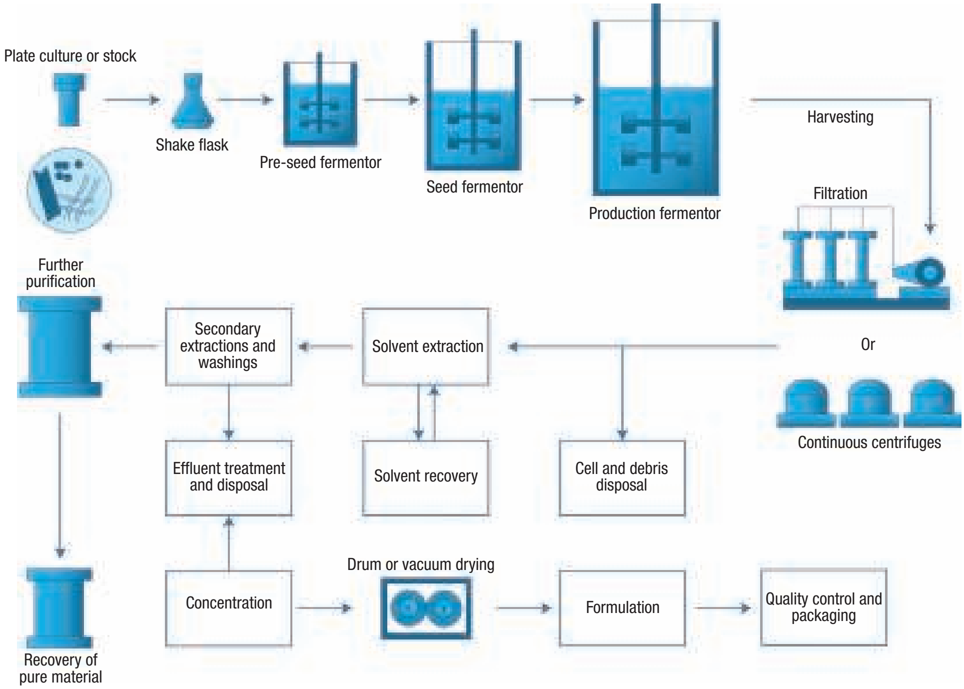

FIGURE 3. The fermentation-based process used to illustrate the valve selection process is depicted here

leaving the tank. The air must also be pressurized beforehand so that the difference in pressure causes the air to flow into the tank and not vice versa.

Outside of the tank, an air compressor runs the oxygen through a filter using a rotary globe valve, specifically a segmented V-port design. In this example, the V-port design offers a better, more precise flow characteristic that can be used for proportional control, as opposed to on/off operation.

Rotary globe valves are of either cammed-plug or segmented V-port ball design. They have similar control characteristics to reciprocating globe valves, with the benefit of low friction from rotary motion. Rotary valves inherently have significantly more capacity and turndown (that is, rangeability) than reciprocating globe valves. Their low cost and comparable installed accuracy make rotary globes valves the preferred type in general-service applications.

After the air is compressed and filtered, a butterfly valve is used to feed the air into the tank. A check valve is installed in conjunction with the butterfly valve to prevent backflow of the liquid in case of a process upset with the air supply.

Butterfly valves are designed for general-, as well as severe-service, applications. Their resilient liners provide tight shutoff in general service applications. Triple-offset, metal-seated butterfly valves are designed for severe-service applications. Butterfly valves are the most economical valves per comparable capacity, and are easily automated with pneumatic and electric actuators.

Check valves are uni-directional flow control devices used to prevent potential damage and contamination caused by backflow. Check valves use a disc, ball or plates that open when forward-flow starts in the pipeline. When pressure drops, either gravity or backpressure forces the disc back against its seat to prevent reversal of flow (backflow). A mechanical spring can be used to assist closure of the disc in applications with low pressure and flow. However, closure of the disc is dependent on actual backpressure.

The butterfly valves used in this particular application are high-performance in two unique ways. First, the valves are double-offset, meaning that the disc pulls out and away from the seat to give the valve better control characteristics. Also, the valve has a dynamic seat, which allows it to seal better over time due to a lack of friction while throttling.

A rotary actuator is used to control the butterfly valve, benefitting the process due to its smaller size, lower cost and added customization options. There is a general lack of space in chemical plants, so every step that can be taken to make the equipment more compact can result in a more efficient operation.

The sensor used to detect the airflow, as mentioned above, is a differential-pressure flowmeter that senses the pressure of the flow across the device and calculates the volumetric flow based on the difference of pressure to known area. Working in conjunction with the butterfly valve and the check valve, this sensor helps ensure proper airflow into the tank at all times.

3. Removing carbon dioxide. Removing carbon dioxide is a necessary step to relieve the pressure created by adding oxygen into the tank. To accomplish this, another high-performance butterfly valve is paired with a pressure sensor located in the air space at the top of the tank to determine when and how much gas needs to be removed to maintain a favorable pressure. This high-performance butterfly valve is used as a backpressure control valve to protect the tank and piping system from overpressure and allows oxygen to continuously feed the fermentation process.

A safety-relief valve is also installed to prevent an overpressure condition should there be a process-equipment failure. Relief valves generally begin to open as the pressure increases past the set amount, but they require about 10% overpressure to completely open. As the pressure drops, the valves begin to close, shutting fully after dropping sufficiently below the set pressure. Special care was taken in selecting a relief valve that would pass enough flow to relieve the system from overpressure.

4. Regulating the pH level. The pH level must also be regulated to create the correct chemical reaction in the fermentation process. This is achieved by injecting either a caustic or acidic solution, depending on the pH level at the time. The chemical makeups of the caustic and acidic solutions necessitate different injection methods, due to material compatibility issues.

A pH sensor is used to determine the state of the fluid before any caustic or acidic solutions are injected into the tank.

The caustic solution, potassium hydroxide, is injected into the tank through a Y-pattern valve, specifically an angle-body piston valve capable of rapidly injecting very small doses of the chemical at a time. This is necessary because too much of the chemical will denature the enzymes needed for the process. The valve must also be made of stainless steel in order to resist the harmful corrosion that potassium hydroxide would cause to other materials. Angle-body piston valves are designed with an integral pneumatic spring-return actuator, making them very compact and an excellent alternative to automated ball valves, especially in high-cycle applications.

The acidic solution, hydrochloric acid, is not compatible with stainless steel and requires a special alloy (Hastelloy C) that can withstand the acidity of the liquid. This material is not available in a piston valve, so the next best option for the engineers was a high-cycle ball valve. These valves provide tight shutoff and high capacity with just a quarter-turn to operate. Ball valves also offer the advantage of being easily actuated with pneumatic and electric actuators.

5. Regulating temperature. Regulating the temperate is a critical part of the process because fermentation will only take place within a certain temperature range. To maintain the desired temperature inside the tank, a jacket, attached to the exterior of the tank, is filled with water to cool down the contents. The jacket is not needed to heat the tank because the fermentation process produces heat on its own.

To monitor the temperature of the tank's contents, there are several thermowells on the exterior of the tank, each containing a resistance temperature detector (RTD) paired with a transmitter that sends the temperature information back to the control system. The sensors must be located in a thermowell to avoid contamination via direct exposure to the media. These RTDs are all used in combination to determine the media's average temperature based on the input from each individual sensor. This information is then used to make the decision on the amount of water injected into the tank jacket.

The valves used to fill the jacket with water are globe valves. Globe valves have a conical plug which reciprocates into and out of the valve port, making them ideal for shutoff, as well as throttling service in high-pressure-drop and high-temperature applications. Multi-turn electric actuators are typically required to automate globe valves; however linear-stroke pneumatic and electrohydraulic actuators are also available. These valves were chosen for this application due to their inherent precision of control, which is considerably higher than other types of valves. This precision is achieved through the design of the valve, which tightly regulates the fluid traveling through the valve using the controlled movement of the conical valve plug to modulate the flowrate very precisely.

A magnetic flowmeter on the pipe leading into the jacket is used to measure the flowrate of the water into the jacket. The primary objective of this application is to control the temperature of the material within the tank, and the flow measurement is only used to monitor the usage of water. The magnetic flowmeter has the benefit of a plastic liner that resists corrosion from constant exposure to water.

6. Removing the fermented product from the tank. When the fermentation process is complete, the resulting liquid is removed from the tank and mixed with isopropyl alcohol to precipitate the product for further processing.

Outside of the fermenter is an elaborate manifold system of valves and sensors used to introduce or remove various materials to or from the tank. The same diaphragm valve used to inject the fluid is used to remove the product from the tank. A Coriolis flowmeter is used to measure the density and mass of the product to ensure the correct consistency. This flowmeter works in conjunction with the pressure sensor at the bottom of the tank (which measures the level and volume of the product) to determine the actual flow and density of the final product.

After the product is removed, the tank is flushed with reverse osmosis (RO) water that is directed through the manifold and measured using a magnetic flowmeter. The differential-pressure meter at the bottom of the tank is then used to ensure that no residual fluids remain. The tank is then sterilized with steam from the boiler that is injected through the same manifold and measured with a differential pressure flow transmitter with a self-averaging pitot tube to calculate the flowrate. The steam is pumped into the tank until it reaches a certain temperature, as measured by the RTDs on the exterior of the tank. This process flushes any residual fluids out and kills any remaining bacteria before the next batch of fluid is introduced. This helps prevent any contamination between batches.

7. Routing the product to the distribution system. The fluid is then routed through the exterior manifold into a header distribution system, which also utilizes diaphragm valves that are either manual or automated depending on their location and accessibility. The manual valves are primarily bypass valves used to drain the system in case of an overflow or malfunction. Coriolis flowmeters are used to measure the flowrate of the product throughout the rest of the distribution system.

When the fermented product, which at this point is referred to as a "broth," arrives at its desired location, it is converted to a solid substance that resembles a cake or a baked good. It is then dried to remove moisture, ground and then milled into a powder as the final product.

Additional utilities

A few utilities outside of the fermenter are required to complete the temperature regulation part of the process. First, natural gas used to generate the steam that sterilizes the tank is sent through small pipes operated by fire-safe ball valves. These valves will close in case of a fire or gas leak. If the valve material burns, there is a secondary metal backup that will prevent gas from escaping and further fueling the fire. The gas is also fed through larger pipes (more than 4-in. diameter) using fire-safe butterfly valves actuated by rotary actuators.

Steam. As noted above, natural gas is used to fuel a boiler to heat the water into steam. To feed water into the boiler, a globe-style control valve is used specifically to negate flashing or cavitation that often occurs when dealing with heated water. Globe-style control valves are available with an anti-cavitation trim that consists of staged holes that prevent the fluid from flashing or cavitating. This trim is not exclusively available in globe-style valves, but these valves offer the most robust design for severe-service applications.

As steam comes out of the boiler, a steam-isolation valve is used to shut down the system. The purpose of this valve is to shut off the steam when the boiler is not in use. This does not occur on a regular basis, so a gate valve is used, due to its durable metal-seated design and full flow path, which does not reduce the pressure or create differential pressure that affects the quality of the steam. Gate valves have a sliding disc (gate) that reciprocates into and out of the valve port. This makes them an ideal isolation valve for high-pressure-drop and high-temperature applications where operation is infrequent. Multi-turn electric actuators are typically required to automate gate valves; however long-stroke pneumatic and electro-hydraulic actuators are also available. In this case, the valve is actuated by a multi-turn actuator, which is not easy to automate or control but is still advantageous in this case because of the valve properties.

Downstream from the boiler, the steam branches off to different locations at junctions, or steam headers, each of which uses an isolation valve and a control valve. The isolation valve is used to turn the steam on or off to a particular location, while the control valve is used to modulate the flow and amount of steam needed for the particular location. Both the isolation and control valve are triple-offset butterfly valves. The reason the engineers chose the triple-offset valves for this application is the ease of automating these valves, as compared to gate valves. The triple-offset design makes this valve an excellent throttling valve in severe-service applications. Triple-offset butterfly valves are torque-seated, which tightens the valve seal proportionately as more pressure is put on the disc closing. This is a very rugged valve that can control large amounts of steam flow and effectively prevent leakage.

Water. In addition to heating the steam, the system uses several sources for its water, including city water, RO-filtered water and de-ionized (DI) water. The more impurities that are removed from a water source, the more chemically aggressive the water will become, so different equipment must be used for different sources of water.

For DI water, which is more aggressive than RO water, large pipes with diaphragm valves are used. The diaphragm valves have metal bodies lined with plastic, which prevents the DI water from damaging the metal. For the RO water, which is considerably less aggressive, small pipes with plastic ball valves are used.

Each type of water used in the process has a different purpose. The city water is used to fill the jacket surrounding the tank to reduce the temperature of the contents. It is then fed through a cooling tower and back into a reservoir to be used again when needed. The DI water, being the most pure, is used to feed the boiler and produce the steam used to sterilize the tank. A vortex flowmeter is used to measure the flowrate of this water into the boiler. The RO water is used to flush the tank after fermentation to wash away any impurities that remain. The flowrate of the RO water is measured using a magnetic flowmeter, similar to the city water used to fill the tank jacket. A magnetic flowmeter, which relies on an electric current to measure the rate of flow, could not be used with the DI water due to its lack of conductivity. ■

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The Integral Role of Waste Management in Capital Projects

To avoid unnecessary efforts and mitigate risks, all phases throughout the design and implementation of large capital projects should incorporate comprehensive planning for waste management

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Proper waste-management planning and execution during all phases of a large capital project in the chemical process industries (CPI) can contribute greatly to a project's success. How well waste management is integrated into a project is often an indicator of the project's overall risk management.

This article provides guidance on how to integrate waste-management planning and execution into the entire lifecycle of capital projects to reduce risk, manage costs and maintain schedules. This lifecycle approach takes the process from project scoping and early design through startup, operations and decommissioning. The article also identifies specific approaches and mechanisms that can be integrated into a company's existing project-development and execution tools, and provides approaches to move waste-management programs forward within and between all stages of a capital project.

FIGURE 1. Scrap metal, along with scrap wood, spent solvents, used filters and used oils are among the high-volume waste streams that must be handled during the construction phase of a capital project

An area of waste-management planning found most frequently to be challenging is integrating and managing the ever-expanding contractor activities into the operator's waste-management strategy and philosophy. Contractor-management approaches, such as auditing programs and third-party contract requirements, are often not addressed until the project is well into design and construction, resulting in confusion, delays, higher costs and increased liability for the project owner. Construction wastes are usually high-volume streams, such as used oils, used filters, used tires, solvents, scrap metal and wood, waste cement and so on (Figure 1). Although many of these waste streams are not hazardous, the high volume can be a problem for disposal, especially if local handling capacities are exceeded. Particularly in greenfield areas outside the U.S., implementing proper waste-handling proce-

TABLE 1. EARLY-PHASE CONSIDERATIONS FOR WASTE MANAGEMENT IN CAPITAL PROJECTS	
Waste-management objectives, philosophy and strategy	Determine the most important objectives and strategies for project waste management, addressing priorities and considering tradeoffs. There is no one right way to manage wastes; a specific vision that team members can plan for will ensure consistency across project phases and disciplines.
Permit acquisition and execution plan	The plan should include anticipated permit requirements, required data, reports, timing, fees, reporting and training.
Waste inventory	Identify anticipated waste for all project phases (early works, construction and operation) and activities (camp, infrastructure construction and facility construction). The inventory will be a living document and will be expanded in its level of detail as the project progresses.
Waste-management infrastructure review	Identify and evaluate local and regional waste-management facilities for all anticipated waste streams and management methods. Consider all possibilities at a high level.
Transportation infrastructure review	Identify and evaluate local and regional transportation options for all anticipated waste streams and management methods. Consider all possibilities at a high level.
Requirements inventory	Develop an inventory and comparison between regulatory, company and lender project requirements. Ensure all possible requirements are inventoried and considered with a high level of rigor. Any possibly applicable requirement should be included, with the understanding that if it is later determined to not be applicable, it can be removed. See below for additional notes.
Risk analysis	Identify and determine the magnitude of waste-management risks, and develop options for resolving major risks. How can past risk-review findings be utilized and expanded to this phase? Are resolutions of risk still applicable?
Preliminary waste-management plan (P-WMP)	Integrate all of the above information. The P-WMP provides a guiding document for all subsequent project activities. More detailed activity and phase-specific waste-management plans will be developed based on the project P-WMP.
Bridging document	Define design-basis contract requirements for early works to support the front-end engineering design (FEED) contractor designs for waste facilities when appropriate.

Additional notes on the requirements inventory: Any possibly applicable requirement should be included, with the understanding that if it is later determined to not be applicable it can be removed. This is key, as it is not uncommon for a regulation or lender requirement originally thought to not be applicable to later be found to be applicable. For example, the domino effect of more stringent discharge requirements than originally thought can have a tremendous impact on project design once the design has been initiated — and may result in project delays. The resulting facility may end up being suboptimal, as a facility design that mitigates late new information will often differ from a facility design whose basis originally included the applicable limits. Have a third party review the inventory and confirm that all possible requirements are considered.

dures is critical, because low waste-handling capacity, poor, potentially high-risk transportation routes and local regulations can often prove to be problematic.

Company philosophy

Most companies have developed a basic waste-management philosophy and strategy based on good practices and home-country standards and regulations, as well as internal operating and management systems. References 1–7 give more details on specific waste-management standards and regulations.

Based on the company's international presence, these internal guidelines are often the first stage and foundation of a capital-project waste-management program. For companies that are expanding into international areas for the first time, the first step to a sound waste-management approach is often to review these corporate guidelines and expand them if necessary to include issues that will impact a capital-project program. Some issues of concern may include the following:

- Expanded and more restrictive country regulations (for example, those related to wastewater-discharge standards, hazardous-waste definitions and final handling, treatment and disposal requirements)
- Local-country third-party contractor requirements related to waste management
- Infrastructure limitations
- Engineering, procurement and construction (EPC) contractor programs

Another important aspect of a company's program during international expansion is to ensure that its overall operational excellence/operational integrity management (OE/OIM) system is robust enough to handle international considerations and capital projects. Waste is only one aspect of this overall OE/OIM system, but if the OE/OIM system is not structured well, then all of the management programs will be hampered, including waste management. Once these foundational issues have been addressed, the focus can be shifted to the specific capital project in question.

Capital project structure

Successfully planning for and integrating waste management into a capital project requires both planned and free-flowing communication between project sub-teams that are simultaneously executing different project work scopes. As with all aspects of a project, the extent to which sub-teams are "siloed" increases the risk that waste-management planning will be inadequately integrated into project development. Specific approaches that can encourage more disciplined integration earlier in the project-development process are detailed in the sections below.

Establish a collaborative project culture. Companies have come to recognize the importance of fully integrating personnel from all project scopes, including facilities development, design and construction, as well as auxiliary operations, such as housing, wastewater-treatment, solid-waste management, spill response, pipeline operations and so on. Personnel involved with all project phases (including personnel from operations) should also be integrated into project development and execution. However, environmental planning functions are often not integrated into project planning.

Environmental, social and health-impact assessment (ESHIA) preparation is typically conducted by an environmental team (in many instances, a third-party contractor). At this point, the core environmental team is in a non-collaborative role, such as gathering information from other team members instead of having an active role in the planning and execution of the project. If ESHIA preparation is a company's sole mechanism for waste-management planning during the early project phases, and if the personnel preparing the ESHIA are not fully integrated into the project, the common outcome is that waste-management planning will be inadequate and untimely.

Include waste management in the project development, design and execution. All project planning evolves from the initial project's philosophy, objectives, plans and basis of design (BOD). Ensuring waste management is included in the original project philosophy and BOD will help to ensure its timely consideration in the subsequent plans for environmental management, contractor management, construction management and other programs that follow.

Consider waste management as necessary infrastructure. Civil engineers were the original waste-management engineers. Over the last 30 years, waste management has shifted to being an environmental discipline, and is no longer specifically covered by a core engineering discipline during project development. As a result, planning for waste-management infrastructure is often conducted separately from other infrastructure planning — and often lags behind other infrastructure planning. Ensuring that the waste-management infrastructure scope is covered by the project's overall infrastructure development will ensure waste-management planning is in step with the overall project development. Waste-management planning should take place in parallel with plans for power distribution, roads and water-supply infrastructure.

TABLE 2. FEED-PHASE CONSIDERATIONS FOR WASTE MANAGEMENT IN CAPITAL PROJECTS

Expand strategy and objectives	Expand the strategy to include lifecycle waste generation.
Waste inventory development	Develop a more detailed waste-generation inventory and an analysis of waste streams for all phases (early works, construction, operations and closure). Evaluate what risks are related to the volume and types of wastes generated.
Waste-management infrastructure expansions	Identify optimal waste-management infrastructure installation timing and scaling. With increased personnel comes an increased demand for camp facilities, resulting in more domestic and industrial waste streams. Volumes are initially low. However, if not managed correctly and accounted for in the initial camp construction, they can cause problems. Sewage overflows and solid-waste disposal problems are typical examples.
Risk analysis	Conduct a more detailed risk analysis that covers all aspects of construction and operation. Hazard identification (HAZID) analyses are the industry standard; however, environmental considerations are sometimes limited in these HAZID analyses. Make sure waste-management is included. Additional considerations regarding risk analysis are addressed below.
Waste-management facility and transportation audits	Conduct a more detailed audit of candidate waste-management facilities and transportation options to determine the viability, capacity and compliance status of each option. The initial baseline review and preliminary audit should be conducted during the early new-venture operations so that operations personnel have a basis for waste disposal. The scope is expanded to include infrastructure and construction waste streams during this audit.
Baseline studies	Conduct detailed studies to provide data relevant to FEED design and to ESHIA development, including waste-management facility design.
Baseline and other site activity wastes	The baseline studies themselves will generate wastes that must be handled as part of the project. These wastes need to be planned for as part of, or separate from, early works.
Integrated waste-management plan (I-WMP)	Update each of the waste documents discussed above with more specific information from FEED contractors, personnel involved in government engagement and other sources. The resulting I-WMP will be used for the updated and final capital project basis of design (BOD). The I-WMP must also address how to tie multiple contractor waste streams into an overall project waste program. While addressed to some extent during the FEED phase, this will become a major issue during initial construction activities within the construction phase.
Additional notes regarding risk analysis: The risk analysis should consider changes made to initial design, construction and execution concepts as the BOD is finalized. The expanded risk analysis should include scenarios for the lifecycle of the project. Representatives from the FEED and construction contractors, as well as baseline and ESHIA contractors should be involved. Regulatory compliance must also be considered as part of the risk analysis.	

Project infrastructure planning

Large capital projects in remote locations or countries with poor infrastructure typically require an infrastructure to be established in order to support the project. The infrastructure is usually established in phases, with multiple and sequential developmental projects required to establish basic infrastructure before full construction of the capital project itself can be initiated. Waste-management planning in such situations is quite challenging, as the infrastructure projects, in many instances, have to be advanced faster than the capital project itself.

It must be understood that waste-management methods will change as infrastructure develops. Waste-management methods likely need to be unique for different project phases — and a specific waste stream may have more than one solution at different points in time. As a result, blanket management requirements (for instance, the refusal to ship waste out of a region because it is cost prohibitive, or that waste cannot be sent to a certain facility because the facility's throughput will not be adequate) can be detrimental to project development and execution. Instead, a company may recognize that a solution or combination of solutions may be costly but necessary in the short term. In the meantime, it can develop more economical, localized facilities to support later project phases. Writing off a legally and logistically viable management method in the short term often results in stockpiled wastes. These stockpiled wastes will frequently require continued investment to maintain stability while a permanent solution is developed or awaits government approval. Often, the stabilization method increases the waste volume, and the low-cost solution that was originally envisioned ends up not being viable.

Also crucial to develop is a philosophy that dictates waste-management infrastructure development be nested

TABLE 3. CONSTRUCTION-PHASE CONSIDERATIONS FOR WASTE MANAGEMENT IN CAPITAL PROJECTS	
Contract development	Ensure early alignment among personnel who are developing contract packages, to ensure that the contracts clearly communicate waste-management roles and expectations. If one contractor is expected to manage wastes for other contractors, this needs to be clearly communicated.
Consolidated waste-management plan	Develop a consolidated waste-management plan shortly after the EPC contract award. All contractors and company or operator personnel should be involved in the plan's preparation. The plan must address waste streams that will change custody, how custody exchanges will be managed, specifications the waste streams must meet in order for another contractor to take custody of the waste streams, timing and frequency available for custody transfer and how the receiving party will manage the waste thereafter.
Waste-management market-development plan	Develop a plan to clarify how involved the EPC contractor will be in developing waste-management and recycling markets. The operator will need to engage with the EPC contractor to ensure that the EPC contractor meets company expectations, and understands the operator's long- and short-term market-development plan.
Contractor waste-management plans	Include requirements for all contractors to prepare their own waste-management program for their activities, which shall be aligned with the operator's consolidated waste-management plan (discussed above).
Waste-management facility consolidation	If the project is in a remote area with little or no waste-management infrastructure, the EPC contractor typically constructs project waste-management facilities shortly after mobilizing. It is at this time that waste management becomes more consolidated. Typically, incinerators used for early works are taken out of service or combined with the EPC waste facility. Waste is often redirected to a central project facility. Sewage is also typically redirected from the previously established camps and is taken to the construction or permanent wastewater-treatment plant. The point at which these waste streams are consolidated requires engineering and logistics planning.

within and integral to the overall capital project. The greatest challenge with waste-management infrastructure planning is the "chicken-and-egg" scenario — finalizing the waste-management infrastructure BOD, when the capital project facility BOD scope and front-end engineering design (FEED) are not yet finalized. Ensuring that the waste-management infrastructure work is fully integrated within the capital-project design will provide the foundation for the waste-management infrastructure and ensure that the projects advance on time and within the capital project budgets.

The company must also work with and demonstrate great competence to stakeholders at planning and executing the early project phases, in order to ensure that the project stays on schedule, and that stakeholders continue to be aligned with the project. Planning project development phases requires project team integration for all functions as detailed below.

Early works and camp. The early-works scope consists of the infrastructure required to enable the capital-project construction contractor to mobilize and establish a construction camp at the site. An early camp will often be required, along with associated waste and wastewater-treatment facilities. The early-works contractor should consider building out from earlier camps, depending on conditions and location. The waste-management infrastructure requirements may then be a simple expansion of these camp structures. Alternatively, a new camp may be required. From a waste-management perspective, this would typically still include a package wastewater-treatment plant, one or more incinerators and perhaps other solid-waste-management facilities, such as storage facilities, initial treatment facilities and possibly the beginning of a limited landfill. Waste recycling opportunities should be considered for certain waste streams, such as scrap wood, scrap metal and used oil.

Full construction camp and activities. The construction contractor will construct and initiate the use of some permanent waste-management facilities, such as a landfill and a waste-storage and transfer station. Other waste-management facilities will be part of the permanent-camp project and will not be used until the operations personnel arrive onsite. Depending on the size and complexity of the project, multiple sites may be developed, each with varying levels of waste-management facilities. Construction may also continue well after operations startup, resulting in overlapping needs and requirements that will need to be considered in the design, as well as the management of facilities.

Operations camp. While a project landfill may have been in operation during early project construction, new permanent waste-management facilities will often need to be brought online roughly when the capital-project facility starts up. Typically, dedicated waste equipment, such as incinerators and domestic waste-treatment facilities, are brought online with operational startup. However, construction facilities may be kept on location for future expansion work, resulting in multiple waste facilities. Remote camps may also be constructed away from the primary facility, such as those associated with pipeline booster stations and coastal loading and offloading facilities. These camps may or may not have separate waste facilities, but will surely have waste generation that will have to be managed.

Integrated waste-management planning that considers each of the above phases as possibilities will be required, in order to ensure that the waste-management infrastructure is sized appropriately and brought online at the right time. The following planning items require consideration:

1. It is imperative that all aspects of wastes from the construction and operations phase be considered when sizing waste-management facilities. If not integrated into the permanent camp, early-works camps may need to be demolished or abandoned. The construction and demolition (C&D) waste from these camps' removal will need to be captured by the construction or permanent-camp waste-management planning, or handled by a third-party contractor separately from operations. These

TABLE 4. OPERATIONS-PHASE CONSIDERATIONS FOR WASTE MANAGEMENT IN CAPITAL PROJECTS

Contractor-demobilization planning	Plan for a large influx of waste from the construction camps' demobilization. These wastes can overwhelm the operator's facilities if this occurrence is not planned for. For demobilization waste streams, timing, volume, type and treatment must be considered with careful attention.
Industrial wastewater considerations	Ensure measures, such as injection wells or bio-treatment, are considered early on during design and risk assessment. The increased levels of low-volume, high-toxicity industrial wastewater streams that are difficult to handle and treat may cause regulatory problems.
Operations waste-management during startup	If applicable, ensure that maintenance and routine waste streams are managed properly at remote locations. This is particularly the case for wastes that will be generated only during startup. Equipment often comes with lubricating oil or other materials designed specifically to maintain equipment integrity during shipping, and these typically must be drained, removed and replaced with a different material for operations.
Recycling market stability	Onsite and offsite recycling programs can be expanded in many cases now that routine volumes are generated. Recyclable material can be utilized onsite more efficiently during future construction projects, and offsite recyclers can count on a steady input stream.

added waste streams need to be incorporated into the design of the waste facilities (in particular the landfill). Figure 2 shows an example of a master-planned landfill that can incorporate industrial waste streams. Another item to consider is whether any of the early-works waste-management facilities will be or should be used by the construction contractor

2. All project-development camps (all camps except for the facility operating camp) will need to be decommissioned and abandoned at some point in time. A camp closure plan is required for each camp to establish the expected camp end-of-service timing and closure vision. Plans for these wastes and facilities must be accounted for
3. In general, the construction contractor will be advised to arrange for suppliers to remove any unused materials, shipping containers and packaging. Deviations from this expectation need to be understood and planned for
4. In some cases, unused construction materials, shipping containers and packaging, and other items may be used for community engagement and improvement. Advance planning with legal, candidate contractors, and stakeholder-engagement personnel is required in order to plan appropriately for these wastes
5. Once operations start up, will the operator manage residual and future construction project wastes or will the contractor be required to take care of its own wastes based on company restrictions? Determine how this will be managed
6. Domestic wastewater-treatment-plant discharges for the construction and operations camps need to be modeled in conjunction with industrial discharges. In many cases, the initial ESHIA covers only the first few project phases. Longer-term modeling and planning for varying discharge scenarios is required in order to understand and mitigate for this scenario, even if the ESHIA does not yet consider the intermediate and final build-out plans. Careful consideration of how discharge locations may shift as the project develops is required for this modeling

Managing phase transitions

Transitioning between the early-works, full-construction and operation phases is typically a time of overlapping contracts, with many contractors concurrently onsite. The overlap, particularly in the case of full construction and operation, may take place over several years. Minimizing project disruption and properly preparing contractors ultimately results in lower project costs, as clear expectations reduce execution risk. Some considerations to help reduce cost and risk are as follows:

1. Contractors coming onsite must have reviewed and incorporated the company's waste philosophy and BOD with regard to waste into their scope of work and work expectations. Thus, the company must include such requirements into the invitation to tender (ITT) package for each contractor, with clear understandings of how waste will be managed onsite and by whom. Before final pricing of any phase, the contractors whose onsite presence will overlap should have an opportunity to develop a coordinated transition plan that will address all areas of transition — including waste management. The plan development must also include waste generators that are not specifically involved in the transition, so that all parties understand their roles, expectations and impacts
2. What are the interdependencies between the extent to which the onsite contractor completes its scope and the ability of the next contractor to mobilize onsite? Careful consideration of the onsite contractor's schedule will show the point at which construction is sufficiently complete for the next contractor to mobilize — and take over waste-management tasks. This vision of how these will likely look needs to be clearly outlined and "frozen" for bidding. Also important to include is a transition risk review of waste management to make sure everyone is aware and knows what to do

Some of the activity-specific "nuts and bolts" to consider for each phase of a capital project are detailed in the following sections.

Early phase

During new venture reviews, several key activities, along with planning, need to be conducted prior to beginning field operations. These include understanding both the regulatory and social conditions for the

Adroscoggin Valley Regional Refuse Disposal District

FIGURE 2. A master-planned landfill is extremely helpful in aiding waste-management efforts, and landfill facility design should take into account waste streams from all project phases

TABLE 5. DECOMMISSIONING-PHASE CONSIDERATIONS FOR WASTE MANAGEMENT IN CAPITAL PROJECTS	
Facility optimization philosophy	A philosophy that abandonment is part of the facility optimization and operation needs to be followed, and the operating organization should be framed with this in mind.
Camp decommissioning and abandonment	All project-development camps (all camps except for the facility's final operating camp) will need to be decommissioned and abandoned, as discussed earlier. The decommissioning costs are typically borne by the contractor that developed the camp if they still occupy it, or the operator, if the operator is occupying the camp.
Facility rationalization and partial abandonment	A facility rationalization plan is required to provide guidance in optimizing facilities as production starts to decline.
Strategic abandonment planning	Financially, asset abandonment has been found to be best done in tandem with operations. Production sharing contracts, partnership contracts, tax incentives and financial reporting typically incentivize a company to abandon as they go, instead of abandoning at the end of an asset's life.
Asset-retirement waste-management plan	An asset-retirement plan that includes waste-management planning is required, based on the facilities rationalization and optimization plan. What scrap yards, and other facilities are required, where, when and with what throughput or capacity? How can infrastructure "log jams" be minimized by optimizing the distribution of facilities to be retired, and aligning plans with other capital projects?

environment and infrastructure of the area. How difficult will it be to obtain permission to operate? What will be the cost in time and equipment to support project activities? These are key questions that need to be answered in the initial evaluation of a new venture. Can these risks be reduced to manageable levels or will the costs be too high?

In some cases, a local office in the country will be arranged for workers to start the process of introduction of the company to the local government and get a realtime understanding of the issues that can arise. Although often of limited size and scope, this office complex will typically be the first activity the company will have related to waste management within the country of operation, and can provide insight into future problems. From a waste perspective, Table 1 describes some of the actions that should be taken.

FEED-level activities

FEED activities relate to the BOD and the beginning engineering of the project facilities and pipelines, as well as baseline studies as needed, and a full-project ESHIA program if required. Accordingly, the project often has an increased demand for rooms and lodging, increased travel in and out of the country and various contractors arriving for both short and long assignments to collect information and conduct research. Typically, the FEED contractor will manage a large part of the baseline work from an engineering standpoint, including evaluating soil types, water levels, weather and land data and so on. The company will manage other studies, such as the full-project ESHIA work and increased regulatory and social efforts, to make sure the project moves forward. Table 2 provides some considerations for FEED-level waste management.

The initial activity involves developing an ITT package for contractor bids for pre-FEED and FEED items and for the development of a BOD document. Environmental considerations, including waste management, need to be included in the development of these bid packages and BOD documents.

Construction phase

During the construction phase, the largest expansion of personnel usually occurs, and the volume of waste generated is often at its maximum. The types of waste that must be handled will expand to include remaining waste streams from the completion of work on early-phase infrastructures, and now full-blown construction waste streams, as well as domestic waste streams. Large volumes of used oils, lubricants, waste filters and used tires, as well as scrap wood, plastic and concrete are generated. Although the volume of hazardous waste increases, the main types of waste streams are still common ones (for instance, used oils). The principal waste problem now becomes one of logistics, movement and handling. Table 3 addresses some items that must be accounted for during the construction phase.

Operations phase

Operation of the facility usually results in demobilizing the construction facilities and consolidating residual waste streams into the permanent waste facility during closeout. Some residual construction may continue with a reduced construction camp. The camp and associated equipment may remain onsite with the anticipation of expansion needs or may be removed completely, depending on operator strategy. The volume of waste will be reduced considerably; however, with the startup of operations, other waste streams will come online that may be more hazardous (process wastewater streams, solvents, tank bottoms and so on) that may require additional third-party contractors and possibly expanded recycling and or treatment facilities. Table 4 explains of the waste-management concerns that arise once the capital project becomes operational.

Decommissioning

Planning for capital-project decommissioning (including asset retirement) has historically been done to meet facility operating requirements, often in response to a sudden need for the facility to ratchet down its operating parameters to accommodate production decreases. The industry has recently begun to initiate asset retirement in a more planned and proactive fashion. As a result, wastes related to decommissioning and asset retirement require more advanced planning and earlier management, while the waste-generation rate peaks at a lower rate. Table 5 lists some considerations related to decommissioning.

Closing thoughts

Waste management is generally not viewed as a "make or break" item for capital projects. However, if not managed correctly, it can be a major frustration and distraction to the team leads, resulting in lost time and efforts to correct problems that arise. Waste management can also create a loss in value to the project, and in many instances can be a very costly liability, if not managed correctly. Risk assessment, and transitioning lessons learned from one phase to another can reduce this liability. A well-structured and communicated waste-management philosophy can go a long way toward reducing risk and costs.

Understanding local laws and requirements, and coordinating contractors through detailed BOD and ITT packages can also be a risk reducer. Understanding the local area infrastructure abilities and planning well in advance for treatment and disposal options can, in the long run, save time and expenses when dealing with waste generation.

Finally, demobilization is a key factor in a project's overall waste strategy. A large volume of waste, with large volumes of hazardous waste, can result from demobilization of facilities once construction is finished. Making sure these waste streams are accounted for in the design of the waste program can reduce liability and overall risk once the project is completed. ■

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Things You Need to Know Before Using an Explosion-Protection Technique

Understanding the different classification methods is necessary to better select the explosion-protection techniques that will be used

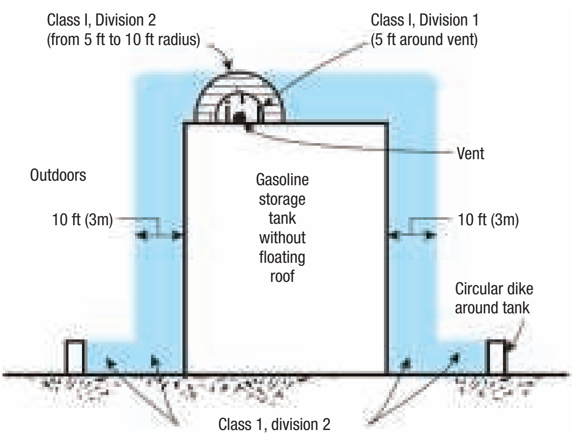

FIGURE 1. Shown here is a typical example of a Class I hazardous area utilizing division methods of area classification

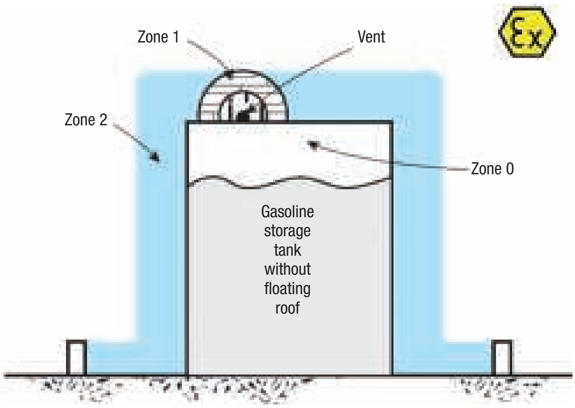

FIGURE 2. The example hazardous area shown in Figure 1 is here classified according to the zones

Robert Schosker
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Explosion protection is essential for many companies, and those companies have decision makers. But before any decisions can be made, there are some important factors one must consider. These factors include what is most efficient and economical, as well as knowing the basics of explosion protection; so the decision makers are headed in the right direction. We will highlight many of the different "things to know," but first, let's step back in time and take a look at the background of explosion protection.

Backdrop

After World War II, the increased use of petroleum and its derivatives brought the construction of a great number of plants for extraction, refining and transformation of the chemical substances needed for technological and industrial development.

The treatment of dangerous substances, where there exists the risk of explosion or fire that can be caused by an electrical spark or hot surface, requires specifically defined instrumentation located in a hazardous location. It also requires that the interfacing signals coming from a hazardous location are unable to create the necessary conditions to ignite and propagate an explosion.

This risk of explosion or fire has been the limiting factor when using electrical instrumentation because energy levels were such that the energy limitation to the hazardous location was difficult, if not impossible, to obtain. For this reason, those parts of the process that were considered risky were controlled with pneumatic instrumentation.

Moving forward

Now let's move forward 70 years, where almost everything you can think of can be found at the touch of a finger. From pneumatics to quad core processors, information gathering has definitely changed, but the same principles for working or gathering information out of a hazardous area remain the same. It's just that today we have multiple options. In order to exercise those options, we must first determine if the danger of an explosion exists and how severe it may be.

What is a hazardous area?

Hazardous areas are most frequently found in places where there is a possibility of an emission of flammable gas or dust. A hazardous area can occur in normal operation, in the event of a fault, or due to wear and tear of seals or other components.

Now the risk of an ignition of an air/gas mixture in this hazardous area depends on the probability of the simultaneous presence of the following two conditions:

- Formation of flammable or explosive vapors, liquids or gases, or combustible dusts or fibers with atmosphere or accumulation of explosive or flammable material
- Presence of an energy source (electrical spark, arc or surface temper-

TABLE 1. DEFINING AREAS FOR DIVISIONS	
Class	**Type of Material**
Class I	Locations containing flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors
Class II	Locations containing combustible dusts
Class III	Locations containing fibers and flyings

TABLE 2. THE BREAKDOWN OF CLASSES INTO SUBGROUPS		
Class	**Subgroup**	**Atmospheres**
Class I	Group A	Atmospheres containing acetylene
	Group B	Atmospheres containing hydrogen and flammable process gases with more than 30 vol.% H_2, or gases or vapors posing a similar risk level, such as butadiene and ethylene oxide
	Group C	Atmospheres such as ether, ethylene or gases or vapors posing a similar risk
	Group D	Atmospheres such as acetone, ammonia, benzene, butane, cyclopropane, ethanol, gasoline, hexane, methanol, methane, natural gas, naphtha, propane or gases or vapors posing a similar threat
Class II	Group E	Atmospheres containing combustible metal dusts, including aluminum, magnesium, and their commercial alloys, or other combustible dusts whose particle size, abrasiveness and conductivity present similar hazards in the use of electronic equipment
	Group F	Atmospheres containing combustible carbonaceous dusts, including carbon black, charcoal, coal or coke dusts that have more than 8% total entrapped volatiles, or dusts that have been sensitized by other materials so that they present an explosion hazard
	Group G	Atmospheres containing combustible dusts not included in Group E or Group F, including flour, grain, wood, plastic and chemicals

TABLE 3. THE DIVISION METHOD			
Division	**Class I**	**Class II**	**Class III**
	(gases and vapors) In accordance with NEC 500.5 and CEC J18-004	(flammable dust or powder) In accordance with NEC 500.6 and CEC 18-008	(flammable fibers or suspended particles) In accordance with NEC 500.5 and CEC 18-010
Division 1	Areas containing dangerous concentrations of flammable gases, vapors or mist continuously or occasionally under normal operating conditions	Areas containing dangerous concentrations of flammable dusts continuously or occasionally under normal operating conditions	Areas containing dangerous concentrations of flammable fibers or suspended particles continuously or occasionally under normal operating conditions
Division 2	Areas probably not containing dangerous concentrations of flammable gases, vapors or mist under normal operating conditions	Areas probably not containing dangerous concentrations of flammable dusts under normal operating conditions	Areas probably not containing dangerous concentrations of flammable fibers or suspended particles under normal operating conditions

ature) that is capable of igniting the explosive atmosphere present

Determining hazardous areas in a plant is normally performed by experts from various disciplines. It may be necessary for chemists, process technologists, and mechanical engineers to cooperate with an explosion-protection expert in order to evaluate all hazards. The possible presence of a potentially explosive atmosphere as well as its properties and the duration of its occurrence must be established.

Also understanding terms such as minimum ignition energy (MIE), upper and lower explosive limit (UEL/LEL), flash point, and ignition temperature in the evaluation of your hazardous area will also provide a clearer direction on how severe a hazardous area might be.

In any situation involving an explosive material, the risk of ignition must be taken into account. In addition to the nominal rating of materials under consideration, parameters related to the process involved are especially important in the evaluation. For example, the risk of explosion may be caused by the evaporation of a liquid or by the presence of liquid sprayed under high pressure. It is also important to know which atmospheric conditions are present normally and abnormally. The range of concentration between the explosion limits generally increases as the pressure and temperature of the mixture increases.

Divisions and zones

Once it has been determined that a hazardous area exists, it now needs to be classified. While the physical principles of explosion protection are the same worldwide and are not differentiated, there are two different and distinct models to define your hazardous area — divisions and zones — both of which are accepted and utilized worldwide.

In rather simple terms, we can differentiate between the International Electrotechnical Commission (IEC; Geneva, Switzerland) (zones) and the North American (division) procedures. The differences lie in the categorization of hazardous areas, the design of apparatus, and the installation technology of electrical systems. The categorization of these areas is carried out in North America in accordance with the National Electrical Code (NEC) NFPA 70, article 500. The European Zone practice is described in IEC/EN 60079-10.

So how does each work? First let's start at the basics, and then we'll cover each individually.

Defining the area

Hazardous location or area classification methods specify the danger of fire or explosion hazards that may exist due to flammable gases, vapors, or liquids within a plant or working environment. These are explained by defining the type of hazardous material present, severity of the hazard, and probability of the hazard. It may also depend on the likelihood of the hazard, risk of an explosion, and the boundaries of the hazardous location.

This is usually determined by a HAZOP (hazard and operability) study and documented on a set of electrical plot plans on record in every plant.

For divisions, the type of material is given by a class designation, as shown in Table 1. These can be broken down further into sub-groups, as shown in Table 2.

Once we have determined the hazardous material we are working with, the probability of an explosion and boundaries must also be taken in to

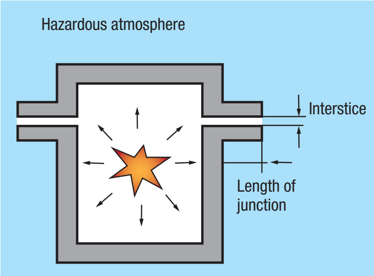

FIGURE 3. Explosion-proof protection is based on the explosion-containment concept, whereby the enclosure is built to resist the excess pressure created by an internal explosion

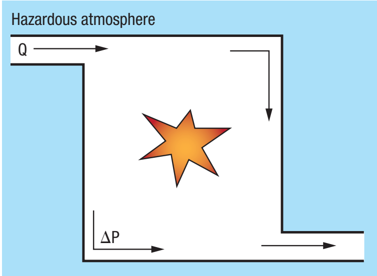

FIGURE 4. In purging or pressurization protection, a dangerous air/gas mixtures is not allowd to penetrate the enclosure containing the electrical parts that can generate sparks or dangerous temperatures

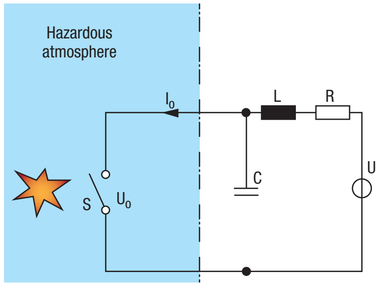

FIGURE 5. Intrinsic safety is based on the principle of preventing an effective source of ignition

consideration. The division method is divided into two areas: Division 1 and Division 2 (Table 3). These were created in 1947 when the NEC first recognized that different levels of risk exist in hazardous locations. Figure 1 shows a typical example of a Class I hazardous area utilizing Division methods of area classification.

In comparison to the division-based area classification, which is prevalent throughout North America, the zone-based architecture prevails in the rest of the world.

Zones are similar in nature to divisions where type of hazardous material present, severity of the hazard, and probability of the hazard and boundaries must be determined. Zones are in accordance with IEC/EN 60079-10, which states that any area in which there is a probability of a flammable gas or dispersed dust must be classified into one of the areas shown in Table 4.

Similar to the division method of area classification, zones can be better rationalized by looking at the example shown in Figure 2.

TABLE 4. DEFINING AREAS BY ZONES	
Zone	**Type of material**
Zone 0	An area in which an explosive air/gas mixture is continuously present or present for long periods of time
Zone 1	An area in which an explosive air/gas mixture is likely to occur in normal operation
Zone 2	An area in which an explosive air/gas mixture is unlikely to occur; but if it does, only for short periods of time
Zone 20	An area in which a combustible dust cloud is part of the air permanently, over long periods of time or frequently
Zone 21	An area in which a combustible dust cloud in air is likely to occur in normal operation
Zone 22	An area in which a combustible dust cloud in air may occur briefly or during abnormal operation

With a slightly different approach, IEC 600079-0 requires apparatus to be subdivided into two groups, as shown in Table 5.

The groups indicate the types of danger for which the apparatus has been designed. Group I is intended for mines. Group II concerns above-ground industries (electrical apparatus for hazardous areas with potentially explosive gas (dust) atmosphere except firedamp hazardous mining areas) and is subdivided into II G (gases) and II D (dusts).

Similar to divisions, the zones offer a sub material classification as well. Table 6 shows how this approach compares to the North American equivalent.

Finally, when classifying your hazardous area, whether it be division or zones, you must also classify the maximum surface temperature that can go in to the hazardous area. The maximum surface temperature must be below the minimum ignition temperature of the gas/dust present.

In North America as in Europe, six temperature classes are differentiated, T1 to T6. The classes T2, T3 and T4 are divided into further subclasses, as indicated in Table 7.

TABLE 5. APPARATUS GROUPS PER IEC 600079-0	
Group	**Apparatus**
Group I	Apparatus to be used in mines where the danger is represented by methane gas and coal dust
Group II	Apparatus to be used in surface industries where the danger is represented by gas and vapor that has been subdivided into three groups: A, B and C. These subdivisions are based on the maximum experimental safe gap (MESG) for an explosion-proof enclosure or the minimum ignition current (MIC) for intrinsically safe electrical apparatus

In Europe, the apparatus are certified on the basis of design and construction characteristics. From a practical point of view, the two systems are equivalent, even if there are minor differences, but before you run out and choose the most convenient method for you, it is important that you consult your local authority having jurisdiction to learn what method is allowed or, in fact, preferred.

The initial steps to determine whether a hazardous area exists and classify that area may seem rudimentary to some, but they are important as they now open up the multiple methods of protection, which may or may not be allowed, depending on whether you classified your area by divisions or zones.

Protection methods

There are three basic methods of protection — explosion containment, segregation and prevention.

Explosion containment. This is the only method that allows the explosion to occur, but confines it to a well-defined area, thus avoiding the propagation to the surrounding atmosphere. Flameproof and explosion-proof enclosures are based on this method.

Segregation. This method attempts to physically separate or isolate the electrical parts or hot surfaces from the explosive mixture. This method includes various techniques, such as pressurization, encapsulation, and so on.

Prevention. Prevention limits the energy, both electrical and thermal, to safe levels under both normal operation and fault conditions. Intrinsic safety is the most representative technique of this method.

TABLE 6. SUB MATERIAL CLASSIFICATION FOR ZONES			
Material	**Apparatus clasification** Europe (*IEC)	**Apparatus classification** North America	**Ignition energy**
Methane	Group I (mining)	Class I, Group D	
Acetylene	Group IIC	Class I, Group A	> 20 μJ
Hydrogen	Group IIC	Class I, Group B	> 20 μJ
Ethylene	Group IIB	Class I, Group C	> 60 μJ
Propane	Group IIA	Class I, Group D	> 180 μJ
Conductive dust (metal)	Group IIIC*	Class II, Group E	
Non-conductive dust (carbon)	Group IIIB*	Class II, Group F	
Cereal/flour	Group IIIB*	Class II, Group G	
Fibers/suspended particles	Group IIIA*	Class III	

TABLE 7. TEMPERATURE CLASSES		
T_{max}, °C	T_{max}, °F	T Class in N.A.*
450	842	T1
300	572	T2
280	536	T2A
260	500	T2B
230	446	T2C
215	419	T2D
200	392	T3
180	356	T3A
165	329	T3B
160	320	T3C
135	275	T4
120	248	T4A
100	212	T5
85	185	T6

*N.A. = North America

My application requirements

Now the questions really start racing in: Which should I use? Which one offers the best protection? What if all of my equipment is not low powered? My plant is already using a technique; can I use another protection method? Can they co-exist? Who makes that decision? Why should I use one method over the other? Can I use two methods at the same time? So many questions, all of which are very important, and with a little understanding of your process, they will guide you to best method(s) to use.

Hazardous-area protection method selection depends on three important factors: (1) area classification, (2) the application and (3) the cost of the protection method solution.

Area. Area classification depends on the type of hazardous substances used, operating temperature, and explosion risk due to how often the dangerous substance is present in the atmosphere and the boundary of the substance from various parts of the process. Area classification is determined by either the division method or zone method.

Application. Application characteristics also affect which protection method is used. For example, some methods are more appropriate for large equipment protection, while others are more appropriate for high-power applications.

Cost. Cost is also an important factor for many engineers. For example, if their application requires Division 2 protection, they may not want to purchase more expensive equipment rated for Division 1. For that reason, it is important to understand the interplay of all three factors — classification, application, and cost — in helping users find the ideal solution to match their needs.

In addition to considering the normal functioning of the apparatus, eventual malfunctioning of the apparatus due to faulty components must be a consideration. And finally, all those conditions that can accidentally occur, such as a short circuit, open circuit, grounding and erroneous wiring of the connecting cables, must be evaluated. The choice of a specific protection method depends on the degree of safety needed for the type of hazardous location considered in such a way as to have the lowest probable degree of an eventual simultaneous presence of an adequate energy source and a dangerous concentration level of an air/gas mixture.

None of the protection methods can provide absolute certainty of preventing an explosion. Statistically, the probabilities are so low that not even one incident of an explosion has been verified when a standardized protection method has been properly installed and maintained.

The first precaution is to avoid placing electrical apparatus in hazardous locations. When designing a plant or factory, this factor needs to be considered. Only when there is no alternative should this application be allowed.

Choosing the best method

After carefully considering the above, we can look at three more popular methods of protection, XP (explosion proof/flameproof), purging and pressurization, and intrinsic safety. Although these are the most commonly used methods in the division area classification, there are many other options when an area is classified using zones, but for now we will concentrate on the above as they are most commonly used.

XP. The explosion-proof protection method is the only one based on the explosion-containment concept. In this case, the energy source is permitted to come in contact with the dangerous air/gas mixture. Consequently, the explosion is allowed to take place, but it must remain confined in an enclosure built to resist the excess pressure created by an internal explosion, thus impeding the propagation to the surrounding atmosphere.

The theory supporting this method is that the resultant gas jet coming from the enclosure is cooled rapidly through the enclosure's heat conduction and the expansion and dilution of the hot gas in the colder external atmosphere. This is only possible if the enclosure openings or interstices have sufficiently small dimensions (Figure 3).

In North America, a flameproof enclosure (in accordance with IEC) is, as a rule, equated with the "flameproof" designation. In both considerations, the housing must be designed for a x1.5 explosion overpressure. The North American version "Explosion proof" (XP) must withstand a maximum explosion overpressure of x4.

Furthermore, in North America, the installation regulations (NEC 500) specify the use of metal conduit for the field wiring installation. It is also assumed here that the air-gas mixture can also be present within the conduit system. Therefore, the resulting explosion pressures must be taken into consideration. The conduit connections must be constructed according to specification and sealed (that is, lead seals) with appropriate casting compound. The housing is not constructed gas-tight. Of course, large openings are not permitted on the enclosure, but small ones are inevitable at any junction point. Some of these gaps may serve as pressure relief points. Escaping hot gases are cooled to the extent that they cannot ignite the potentially explosive atmosphere outside the housing. Ignition is prevented if the minimum temperature and minimum ignition energy of the surrounding potentially explosive atmosphere is not reached. For this reason, the maximum opening allowed for a particular type of joint depends on the nature of the explosive mixture and width of the adjoining surfaces (joint length).

The classification of a flameproof enclosure is based on the gas group and the maximum surface temperature which must be lower than the ignition temperature of the gas present.

Purging or pressurization. Purging or pressurization is a protection method based on the segregation concept. This method does not allow the dangerous air/gas mixture to penetrate the enclosure containing electrical parts that can generate sparks or dangerous temperatures. A protective gas — air or inert gas — is contained inside the enclosure with a pressure slightly greater than the one of the external atmosphere (Figure 4).

The internal overpressure remains constant with or without a continuous flow of the protective gas. The enclosure must have a certain degree of tightness; however, there are no particular mechanical requirements because the pressure supported is not very high.

To avoid pressure loss, the protective gas supply must be able to compensate during operation for enclosure leakage and access by personnel where allowed (the use of two interlocked doors is the classical solution). Because it is possible for the explosive atmosphere to remain inside the enclosure after the pressurization system has been turned off, it is necessary to expel the remaining gas by circulating a certain quantity of protective gas before restarting the electrical equipment.

The classification of the electrical apparatus must be based on the maximum external surface temperature of the enclosure, or the maximum surface temperature of the internal circuits that are protected with another protection method and that remain powered even when the protective gas supply is interrupted.

The purging or pressurization technique is not dependent upon the classification of the gas. Rather, the enclosure is maintained at a pressure higher than the dangerous external atmosphere, preventing the flammable mixture from coming in contact with the electrical components and hot surfaces inside.

In the U.S., the term "pressurization" is limited to Class II applications. This is the technique of supplying an enclosure with clean air or an inert gas, with or without continuous flow, at sufficient pressure to prevent the entrance of combustible dusts. Internationally, the term "pressurization" refers to a purging technique for Zones 1 and 2.

The divisional model of the purging protection method is based on the reduction of the classification inside the enclosure to a lower level. The following three types of protection (X, Y, and Z) are identified in relation to the hazardous-location classification and the nature of the apparatus.

- *Type X:* reduces the inside of the enclosure from Division 1 to a nonhazardous state that requires an automatic shutdown of the system in case of pressure loss
- *Type Y:* reduces the inside of the enclosure from Division 1 to Division 2
- *Type Z:* reduces the inside of the enclosure from Division 1 to a nonhazardous state, requiring alarm signals only

Intrinsic safety. Finally, intrinsic safety is based on the principle of preventing an effective source of ignition. The electrical energy is kept below the minimum ignition energy required for each hazardous area (Figure 5).

The intrinsic safety level of an electrical circuit is achieved by limiting current, voltage, power and temperature; therefore, intrinsic safety is limited to circuits that have relatively low levels of power. Of critical importance are the stored amounts of energy in circuits in the form of capacitance and inductance. These energy storage elements must be limited based on the voltage and current levels present in a particular circuit or make-break component.

In normal operation and in the event of a fault, no sparks or thermal effects may occur that could lead to the ignition of a potentially explosive atmosphere. Intrinsically safe circuits may therefore be connected and disconnected by experts during operation (even when live), as they are guaranteed to be safe in the event of a short circuit or disconnection.

Intrinsic safety is the only ignition-protection class that allows connectors to be opened and intrinsically safe apparatus to be removed and replaced by an equivalent device in a hazardous area. Because of the level of freedom this brings, intrinsic safety has become one of the most important methods of protection in the industrial automation industry.

Final remarks

Each method offers its own advantages and disadvantages, and in most cases no one method will be or can be the only method used in a process plant. Generally, this mixed system does not present installation difficulty if each of the protection methods is appropriately used and is in compliance with the respective standards.

No matter how you classify your plant or which method of protection you chose, it is always important to remember that the method you choose today may not necessarily be the appropriate choice tomorrow. Evaluate, choose and protect not only to keep your plant safe, but to keep your personnel safer. ■

Edited by Gerald Ondrey

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Gas Turbines:
Design and Operating Considerations

Follow these engineering recommendations to improve gas turbine operation and performance while reducing operating costs

Amin Almasi
Rotating Machinery Consultant

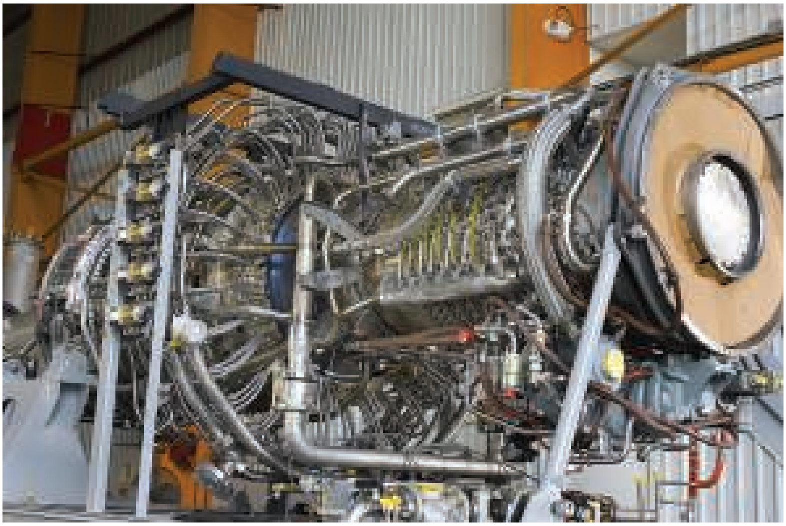

FIGURE 1. Shown here is an example of a modern, aero-derivative gas turbine for a CPI facility. This 35–MW gas turbine is used for mechanical drive applications and power generation. The 90-kg/s hot gas exhaust has a temperature of roughly 550°C, which offers a lot of opportunity for heat recovery and proper heat integration with the facility. Its modular design, coupled with its split compressor casing, in-place blade and vane replacement, in-place hot-section maintenance access, and external fuel nozzles, allow for easy and timely repair and refurbishment

Gas turbines are widely used throughout the chemical process industries (CPI) because they allow for high power output and high overall efficiency at relatively reasonable costs. In recent years, a variety of factors and ongoing technology advances have contributed to the continuing evolution of the gas turbine systems. These include the following:

- Overall efficiency and performance improvements
- Capacity and power density increases
- The introduction of various new technologies
- Tighter environmental, health and safety (EHS) standards, expectations and regulations
- Higher reliability and availability
- More compact package design
- Greater expectation of easy access, and ease of operation and maintenance

The gas turbine business is a dynamic market with new designs introduced during each decade. As a result, over the past 40 years, the turbine temperature capability has advanced by approximately 10°C per year, corresponding to a roughly 1.5–2% increase in the power output (for the same gas turbine size), along with a roughly 0.4–0.6% improvement in the simple-cycle efficiency every year (on average).

The packaging of a gas turbine is the practice of combining and integrating machineries and components for specific application and plant settings. Packaging a gas turbine typically involves customization of the design to create the most appropriate site-specific solution. Packaging decisions typically revolve around the compressor trains, large pumps, special electrical power-generator and other units for CPI plants..

Currently, the aero-derivative gas turbine is preferred for CPI applications over other types of gas turbines (such as heavy-duty frame gas turbines), because it provides superior performance in terms of operational flexibility, efficiency, compact sizes, light weight and advanced packaging concepts. An aero-derivative gas turbine consists of two parts — an aircraft-derivative gas generator section, and a free-power turbine section. The gas generator is derived from an aircraft engine that has been modified to burn fuels that are typically available in CPI units (such as natural gas).

Valued traits of the aero-derivative gas turbine include its ability to be started up and shut down quickly, its ability to properly cope with load changes, and its high efficiency and variable-speed capability. All of these attributes make these designs superior options compared to traditional industrial, heavy-frame gas turbines.

High efficiency is one of the important issues that encourages the use of aero-derivative gas turbines. As a very rough indication, the efficiency of aero-derivative gas turbines is around 9–15% greater than the efficiency of comparably sized, heavy-frame gas turbines.

Over the lifetime of most gas turbines, the initial cost accounts for about 10% of the total lifecycle cost. The operating and maintenance costs account for roughly 18% of the total lifecycle cost. Fuel is typically the biggest cost factor — accounting for about 72% of the total

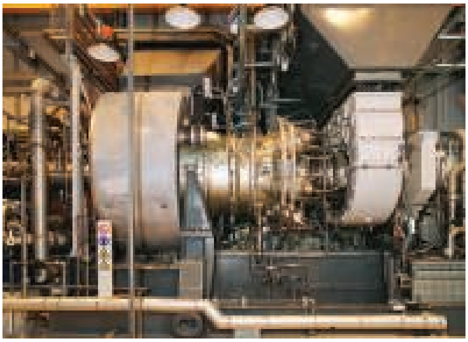

FIGURE 2. In an example of a modern gas turbine with good aerodynamics and advanced combustion technologies, this twin-shaft gas turbine achieves a useful power output of around 13–14 MW. Thus, this gas turbine model has been used for both power generation and mechanical drive. This is an example of a modern twin-shaft gas turbine that combines aero-derivative and heavy-duty technologies in one advanced gas turbine. The turbine permits an efficiency of about 35–36% for operation in a simple cycle. Adding a heat-recovery system will the improve overall efficiency. This machine has an excellent power-to-weight ratio in its application range. (Photo used with permission from Siemens)

lifecycle cost— and this underscores the critical role of turbine efficiency.

While significant strides have been made in the energy efficiency of gas turbines over the past 30 years, these improvements can mainly be attributed to better integration of the gas turbine within a modern CPI plant (particularly the heat recovery). Integration is the key for gas-turbine packaging. In simple terms, integration refers to the engineering practices and procedures for matching a gas turbine in the plant, particularly with surrounding and related facilities, for better overall combined operation.

Thanks to today's modern designs, optimal power and heat integration account for the majority (roughly 68%) of the overall efficiency improvements of the gas turbine packages that have been realized over the past three decades. Improvements in the equipment (such as better lubrication systems) and the machinery designs (such as the use of better axial compressors or turbines), and improvements in related processes (for instance, combustion processes) are responsible for around 18% and 14%, respectively, of the overall efficiency improvement.

These aspects underscore the importance of proper power-and-heat integration in modern CPI plants. Integration must be taken into account during the design of the gas turbine packaging. For instance, a good packaging concept can facilitate maximum heat recovery from the exhaust gas of turbine section, which can significantly affect the heat integration and overall efficiency. Figures 1 and Figure 2 show examples of modern turbines used in CPI plants.

Industrial turbine options

Industrial gas turbines range from microturbines to much larger designs. Often, microturbines are rated below 40 kW, and have an installed cost of nearly $1,000/kW and provide an efficiency around 15–20%. By comparison, large gas turbines (rated above 25 MW) typically cost around $300–400/kW and have an efficiency above 35%.

There are different turbine designs, including single-shaft designs (air compressor and power turbine on the same shaft), twin-shaft designs (for instance, air compressor and its turbine on one shaft and power turbine on another shaft) and multi-shaft designs. Theoretically, each shaft can have either two or three bearings. Some single-shaft designs have long shafts, and these may be better supported by three bearings.

In general, the two-bearing design is preferred in single-shaft gas turbines. Three-bearing solutions can cause some problems (such as alignment issues developed by the center bearing at the hot zone). They are the only available options for very large, single-shaft machines However, in CPI applications, these designs tend to be more rarely used (reserved for very specialized situations).

Generally speaking, the preferred gas-turbine casing is a horizontally split design that allows for easy access. Vertically split casings are used in high-pressure machinery designs; they usually offer some difficulties in access and maintenance. Figure 3 shows an example of a modern, large gas turbine with a horizontally split casing.

The internal design of each gas turbine model can affect the packaging designs, and vice versa. Some problems arise when there is a major change in the number of blades between stages. Some specifications allow for a slight rubbing of rotating blades or labyrinths in shrouded rotating blades. However, this is not a popular option for CPI operators, where excessive rubbing is always considered to be unacceptable.

There is a general tendency in many gas-turbine applications for CPI units to increase the part-load operation capabilities (a wider partial-load range that has performance and operation quality that is comparable to the full-load service). For a gas turbine that is used in an integrated arrangement in a CPI plant (that is, one that uses any form of the heat recovery), there is a preference to keep more or less the same firing temperature over the entire partial-load operating range. The airflow and hot gas flow could be variable, but all of these parameters should be carefully evaluated, and proper limits should be set. Modern gas turbines are very sensitive to the backpressure (from the hot exhaust-gas ducts, the heat-recovery unit, the stack and others).

Gas turbine packaging

Very large modern CPI plants and newer generations of small-scale CPI units both present unique challenges when it comes to the gas turbine packaging. In recent years, there has been a renewed interest in small-scale CPI plants in different parts of the world, particularly in some developing countries. The packaging of a gas turbine for such smaller-scale CPI facilities must be done in such a way as to minimize the total equipment item count (and process steps) and optimize the capital costs and footprint, while at the same time obtaining the highest possible efficiency and reliability.

On the other hand, some new, very large CPI plants offer other types of challenges. Over the past 40 years, in some CPI sectors, the throughput per production train has multiplied by a factor of about 5 to 10, while the overall efficiency of the gas turbine packages (used in those production trains) has nearly doubled. At the same time, the duration for construction and commissioning is reduced, thanks to improvements in modular works and prefabrication for very large and complex gas turbine packages. All these factors present some challenges for modern gas turbines.

Deep integration is a new term used for modern gas turbines in advanced plants; it means integration and matching a gas turbine in the plant (surrounding and related facilities) in a much better way compared to older designs. For instance, such integration involves much better use of heat recovered from the gas turbine exhaust. The deep integration of power, heat and other operational aspects, coupled with the use of modular design concepts, have been the keys for success in modern gas turbine packaging. Figure 4 shows an example of a very large gas turbine installation. The air-inlet filter and the exhaust-gas stack are also shown.

Gas-turbine fuel system

If it is available in a CPI plant, natural gas is the best fuel option for most gas turbines. The use of natural gas can reduce maintenance costs, reliability issues and emissions compared to liquid fuels.

However, despite the advantage of natural gas, about 30–40% of all gas turbines operate on liquid fuels, which can vary from light liquid fuels (naphtha, kerosene, and others) to heavy fuels. The fuel selection depends strongly on the CPI application. Heavy fuels often bring reliability problems, higher emissions and fast degradation. In some cases, a 10–15% reduction in the produced power has been reported for some gas turbines using heavy fuels within a few weeks after startup. However, users should note that aero-derivative gas turbines cannot use heavy fuels.

The fuel — whether gas or liquid — should be injected at a pressure of about 3–5 bars above the air-compressor discharge pressure. The fuel compression and pumping systems — particularly the fuel-gas compressor systems are important and require close attention when designing the overall gas turbine packaging. It is important to select the right, oil-free compressor for such applications, with correct compression characteristics and proper pressure capabilities.

The fuel-treatment system also plays a critical role for many gas turbines, since unwanted components in the fuel stream can cause performance or reliability issues (such as the formation of deposits or corrosion) or high emissions.

Modern gas turbines that use low-NOx technologies tend to be particularly sensitive to liquid or dirt carryover within the fuel gas. Thus, they generally require a clean and heated fuel gas. Superheating is the only certain method for ensuring the elimination of any liquid carryover in fuel gases. Generally, a well-designed fuel system — one that has all of the required separators, multiple filtration stages, a knockout drum, heater(s), accessories, auxiliaries, instruments and monitoring devices — is a good investment that will provide payback over time by helping to ensure trouble-free operation of the turbine.

FIGURE 3. The modern, horizontally split gas turbine casing shown here is an example of a large and modern gas turbine. Today's advanced turbines are sophisticated and complex systems that allow for overall efficiencies above 50% (Photo used with permission from Siemens)

Filtration at the air inlet

A proper filtration system for the inlet air is also important; otherwise unwanted particulate matter in the inlet air can cause erosion and blade contamination or fouling. The minimum requirement should be a high-efficiency, multistage, air-filtration system to remove particles down to 1 µm (or less) from the inlet air.

Old-fashioned filters only remove particles above 3 µm in dia. However, in any cases, small particles (below 3 µm in dia., and even as small a 1 µm) are to blame for gas turbine fouling and other issues, and such particles are often able to evade capture by old-fashioned filters. Some advanced filters are now available to remove particles down to 0.3 µm from the inlet air.

Starting device

The sizing of the starting device for the gas turbine is an important consideration for any gas turbine. In a free-power turbine design (including many aero-derivatives and some heavy-industrial type machines, such as twin-shaft and multi-shaft designs), the starting device does not need to rotate all turbine shafts and driven equipment. Rather, it only needs to be designed to overcome the torque needed to start the gas generator section.

In a single-shaft, gas turbine design (including many heavy industrial machines), the total train torque should be considered when sizing the starting device, as the starting device should rotate the single-shaft and coupled driven machines and equipment. A speed-torque curve of the gas turbine (and machineries coupled to it during the startup) should be respected during this sizing and proper safety margins should be considered. The starting device is often to blame for reliability issues, inefficient sizing, low availability, and so on, so be sure to give this critical component the proper attention during the specification of any gas-turbine package.

Gas turbine auxiliaries

Standards for gas turbines and gas turbine auxiliaries (such as API-616, API-614, ASME and others) have tried to note the minimum requirements for the specified applications in the code. The major problem is that some useful requirements are listed as optional in the gas-turbine-related codes. As a rule-of-thumb, users should follow all requirements (both mandatory and optional requirements) for the gas turbine packaging. Sometimes, requirements should be specified beyond the codes, to achieve a high level of performance and reliability. Consider the following:

- Codes are usually updated only every 5–10 years and recent technologies, innovative designs, latest observations or new experiences typically need several years to come to the attention of (and be accepted by) code task-force team(s) and then be incorporated into the codes

- The teamwork that is involved should have representatives from different groups, vendors and others, with various backgrounds and goals, to prepare for compliance of relevant codes. Note: the main focus of the codes should not necessarily be the best performance and reliability (for the operators); rather, the final (or agreed-upon) specification should be an optimized set of requirements (or sometimes compromised ones). In other words, any user should know that some items specified in codes are not necessarily the best possible technology for operators and often it is necessary to specify some requirements in addition to the codes

There is always a great concern about the lubrication oil system (generally called "the oil system"). A design that involves having the primary oil pump driven by the main machinery shaft is usually not acceptable for any high-speed turbomachinery (including the gas turbine). The high speed itself is one reason; it is not usually matched with lower speeds of oil pumps. The use of a gear unit to connect the oil pump to the turbomachinery shaft is often a poor solution, because an oil pump failure can mandate shutdown of the turbomachinery unit.

Horizontal oil pumps are always preferred. The oil pump selection and packaging should be in a way to minimize maintenance and operation efforts. For instance, oil-suction pipes should be arranged to provide positive suction head on the oil pumps, with a slope toward the pump. Cast-iron casing is usually not desirable for any equipment (or machinery) in the machinery package or auxiliary systems, because it is a brittle material and can fail very quickly in emergency situations, particularly in the event of fire.

Generally, an auxiliary skid arrangement should be optimized to balance performance objectives and reliability goals, while maintaining easy access and maintenance requirements, and compact design. Heat exchangers are needed to cool the lubrication oil, which is often heated during operation. TEMA C shell-and-tube heat exchangers (with removable bundles) are well-known for auxiliaries, including lubrication oil skids. The oil pressure should be greater than the cooling-water pressure, to avoid the potential for water leakage into the oil in the case of an unexpected problem (such as exchanger tube crack or leakage). Water is on the tube side and oil on the shell side.

Plate-type heat exchangers are not popular in turbomachinery assemblies since they might clog or experience some other operational problems. An exception is for revamp projects with limited available footprints; but tubular heat exchangers may be used for small packages.

FIGURE 4. A example of a very large gas turbine installation. The air inlet filter and the exhaust gas stack are also shown.

Gas turbine heat recovery

For some gas-turbine packages, heat recovery is the source of many problems and issues. One reason may be that in spite of the gas turbine, which is offered in standard models, the heat-recovery unit is usually a custom-designed system. The performance and reliability of the gas turbine package depend on the heat-recovery system. The design, fabrication and operation of such a heat-recovery system as an integrated part of the overall gas turbine package system. In the most common form, the exhaust gases from the gas turbine enter the heat recovery steam-generating (HRSG) system, where the energy from the hot exhaust is used to heat the water to produce steam.

Many HRSGs are designed in different modules and sections. In many cases, each HRSG has a preheater, an economizer and a superheater. The steam for modern steam turbines is usually superheated. Both vertical and horizontal HRSGs are commonly employed.

By contrast, once-through steam generators (OTSGs) are used in some applications because they are cheaper, simpler and more compact compared to other HRSG designs. OTSG systems do not have defined economizer, evaporator or superheater sections. In simple terms, in an OTSG system, water enters at one end and steam leaves at the other end. There is no need for drums, various sections and many other auxiliaries (or accessories).

Typically, the hot gas exhaust from a gas turbine has ample oxygen. Therefore, the gas exhaust can be used in another combustion process to increase its temperature for a better heat recovery arrangement. The supplementary firing at the waste-heat recovery unit could be a feasible option to achieve the maximum possible efficiency. This design is also becoming popular in modern CPI plants, which require a better operationall flexibility since, theoretically, supplementary firing can offer some operational flexibility.

However, this complex design (supplementary firing and HRSG) requires special care. For example, the transfer duct (between the gas turbine exhaust and the waste-heat recovery unit) should have a sufficient length to ensure complete combustion and avoid direct flame contact on the heat-transfer surfaces. On the other hand, the duct system length should be optimized, in order to limit the heat loss, manufacturing costs and overall system footprint.

Control and monitoring

The temperature of the turbine blade metal must be monitored to ensure reliability of the first row of turbine blades and other hot sections. The use of pyrometers to sense the blade metal's temperature is offered for some gas-turbine packages for CPI units. Very high pressures in air-axial compressors of gas turbines have caused these compressors to have a very narrow operating range between the surge and the choke. The axial compressors of gas turbines tend to be very sensitive to dirt and fouling, and even slight modifications to the blade (vane) angle.

Dynamic pressure transducers that detect the surge and other flow instabilities in the air axial-compressor are an important element for some gas turbine packages. The stability in the combustion process could also be monitored by the same method. The application of dynamic pressure transducers in the combustion sections, especially in modern, low-NOx combustors, could ensure that each combustor section is burning evenly without any issue, problem or instability.

Lubrication oil for gas turbine

The lubrication oils for gas turbine are subject to a wide range of harsh conditions, such as extreme heat, high contamination, inadvertent mixing with different substances and more. These effects can degrade the integrity of the oil base stock and deplete any additives, causing irreversible molecular changes and hence changes in the lubrication oils.

Most gas turbine trains use a relatively low-viscosity oil (compared to that used by gear units and reciprocating machines), for example, ISO viscosity grade (VG) 46.

A lubrication oil with optimum viscosity reduces the power waste for operation because frictional power involved in bearings and other lubricated parts would be reduced. The usual expectation by users is relatively low makeup oil for the gas turbine lubrication oil (say on average below 5–10% oil added per year). This low makeup requirement is a factor that encourages high-quality, long-life lubricant applications for a gas turbine. Usually, the oil in a gas turbine train (without a gear unit), if selected properly and maintained correctly, does not need to be drained and replaced with much frequency and thus could last for a relatively long time. It is hard to note an expected life, but it could be a matter of years. The gas turbine oils should be well-maintained (such as avoiding possible contamination by water and other fluids, using good seals, and so on) to extend their service life and simultaneously provide the maximum machinery performance.

Generally, for gas turbines operating at high temperatures, oxidation of lubrication oil could be an important issue. High temperature directly affects the oxidation. Heat also reduces the oil life. For high-temperature applications, the oxidation rate is usually doubled for every 10°C increase in the oil temperature.

Lubrication oils can also fail because of contamination. A good solution is to use the correct sealing system to eliminate the potential for gas leakage to the oil.

Any additives used in a gas-turbine lubrication oil should extensively be verified and tested. The oil and additives must be carefully formulated in a tightly controlled process. The key to an excellent lubrication oil is to retain the desired properties. Successful (long-term satisfactory operation) references are important. In other words, it is important to check if proposed lubrication oil were used in similar gas turbines in more or less the same conditions successfully.

Integration is the key for gas-turbine packaging.

The lubrication oil in most modern aero-derivative gas turbines and advanced high-efficiency gas turbines could be in contact with metal surfaces above 200°C. These high temperatures, and the possibility of cyclical operation, can result in significant thermal and oxidative effects on the oil. For these applications, sophisticated synthetic oils are the only available options. Mineral oils used in old-fashioned gas turbines are not usually suitable for modern gas turbines.

Instead of degradation occurring in an orderly, predictable fashion, many lubricants that are used in modern gas turbines fail rapidly. And some of the standard oil-analysis tests offer little indications as the gas turbine lubricant starts to degrade. Thus, it is critical to study previous lubrication oil behaviors in similar gas turbines and operating situations.

"Ferrography" is a technique that provides valuable information about wear evolution in machinery through analysis of a representative lubrication oil sample. In an analytical ferrography study, the solid debris suspended in a lubricant sample is separated. The solids are then passed across a bipolar magnetic field. After that, a solvent "wash" cycle removes any lubricant remaining on the substrate, resulting in a "ferrogram" where the particles are all arranged by size and permanently attached to the slide for optical analysis using a bichromatic microscope. The particles are then examined and classified by size, shape, concentration and metallurgy. The information carried by the wear particles is valuable for the identification of the wear mode and mechanism.

Analytical ferrography can be particularly effective in the detection of soft contaminants and in the identification of their nature. This can be a powerful technique to identify the oil-related issues of the machinery, root-cause analysis, the morphology and characteristics of the insoluble particles, and the progressive mechanism of varnish formation. While the ferrography test procedure is lengthy and requires highly skilled analysts, the benefits can outweigh the costs. This is a recommended test if any abnormal wear is observed.

Fourier transform infrared (FTIR) analysis can be useful to measure organic molecular components, monitor additive depletion and identify organic degradation byproducts (oxidation). FTIR is the preferred method of IR spectroscopy. In IR spectroscopy, IR radiation is passed through a sample. Some of the IR radiation is absorbed by the sample and some of it is passed through (transmitted). The resulting spectrum represents the molecular absorption and transmission, creating a molecular fingerprint of the sample. Like a fingerprint, no two unique molecular structures produce the same infrared spectrum. ■

Edited by Suzanne Shelley

Author

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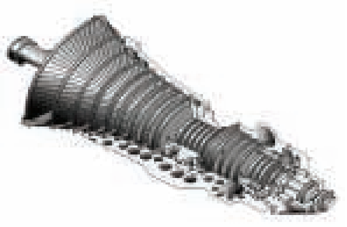

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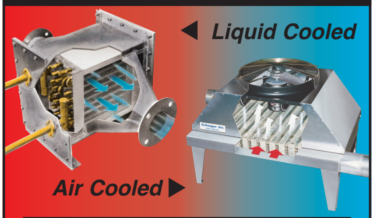

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Pipe, valves & fittings	845.6	858.5	874.5
Process instruments	402.1	404.0	408.8
Pumps & compressors	958.4	953.5	937.3
Electrical equipment	511.9	513.5	514.4
Structural supports & misc	741.7	745.9	767.3
Construction labor	323.8	321.8	320.4
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Engineering & supervision	319.5	319.0	322.4

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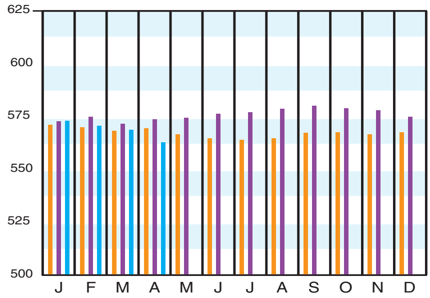

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CPI value of output, $ billions	Apr. '15	=	1,909.5	Mar. '15	=	1,902.6	Feb. '15	=	1,911.4	Apr. '14	=	2,199.0
CPI operating rate, %	May '15	=	77.3	Apr. '15	=	77.5	Mar. '15	=	77.3	May '14	=	76.4
Producer prices, industrial chemicals (1982 = 100)	May '15	=	237.3	Apr. '15	=	238.5	Mar. '15	=	245.4	May '14	=	289.1
Industrial Production in Manufacturing (2002=100)*	May '15	=	101.3	Apr. '15	=	101.5	Mar. '15	=	101.4	May '14	=	99.5
Hourly earnings index, chemical & allied products (1992 = 100)	May '15	=	158.7	Apr. '15	=	158.2	Mar. '15	=	157.6	May '14	=	155.2
Productivity index, chemicals & allied products (1992 = 100)	May '15	=	107.9	Apr. '15	=	108.5	Mar. '15	=	108.4	May '14	=	106.9

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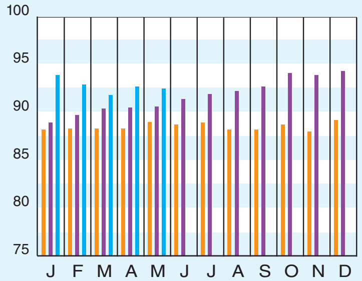

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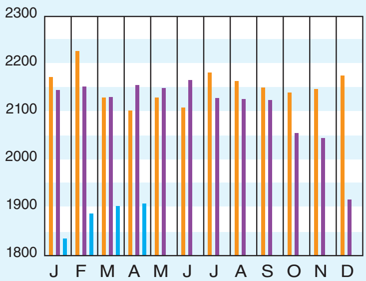
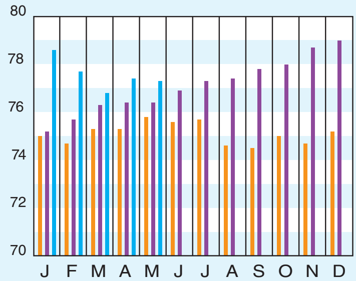


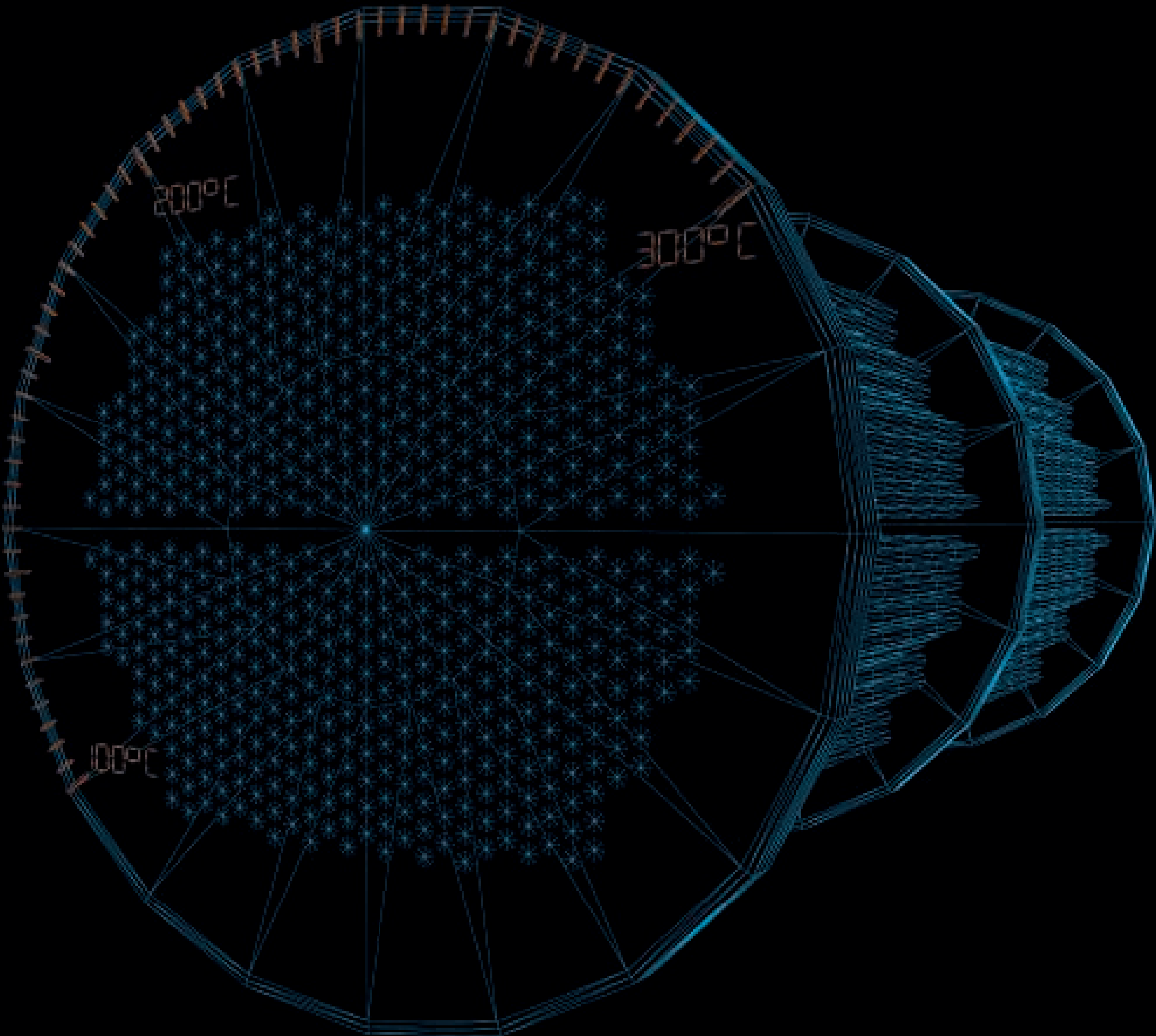
CPI OPERATING RATE (%)



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

CURRENT TRENDS

The preliminary value for the April 2015 *CE* Plant Cost Index (CEPCI; top; the most recent available) continued the trend of small monthly declines since the beginning of the year. The April CEPCI is 1.8% lower than the corresponding value from a year ago at the same time. For the second consecutive month, the preliminary value for the Equipment subindex in April decreased, while the Construction Labor subindex was higher. For April, the Buildings subindex saw a very small decline, while the Engineering & Supervision subindex was slightly higher. Meanwhile, the latest Current Business Indicators (middle) numbers generally were similar to the previous month's values, but the CPI value of output index for May 2015 remains below the corresponding value from 2014.


200°C
300°C
100°C