CHEMICAL ENGINEERING

December 2012

GASIFICATION DOUBLE FEATURE

STARTS ON PAGE 34

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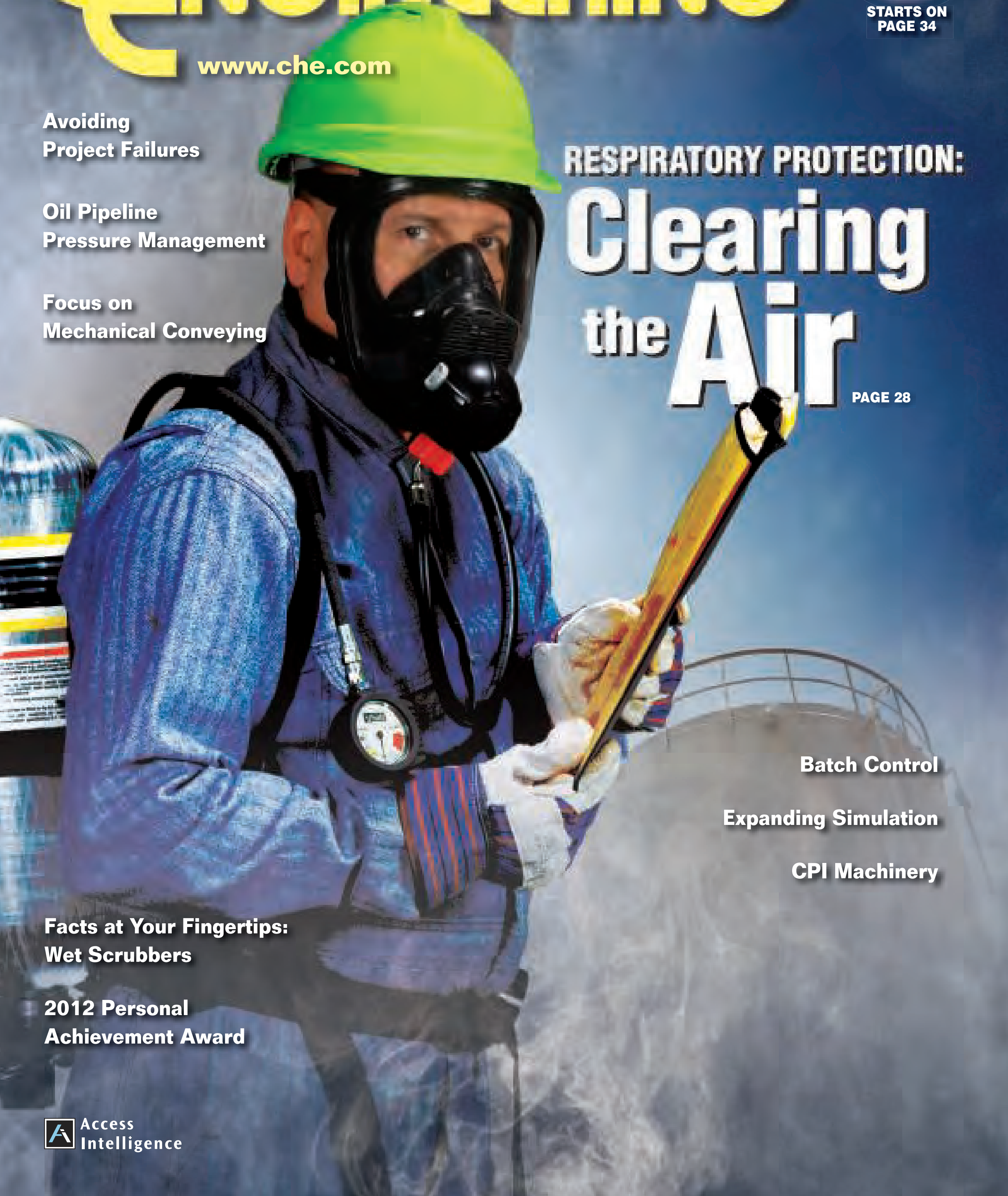

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Oil Pipeline Pressure Management

Focus on Mechanical Conveying

RESPIRATORY PROTECTION:

Clearing the Air

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Expanding Simulation

CPI Machinery

Facts at Your Fingertips: Wet Scrubbers

2012 Personal Achievement Award

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Cut Your Cost 9 Ways with One Ultra-Economical Conveyor

1 Cut installation cost
Easy conveyor routing at any angle (over, under or around obstructions, through small holes in walls or ceilings) conforms to process layouts, drastically cutting installation costs, while consuming minimal floor space.

2 Slash initial cost
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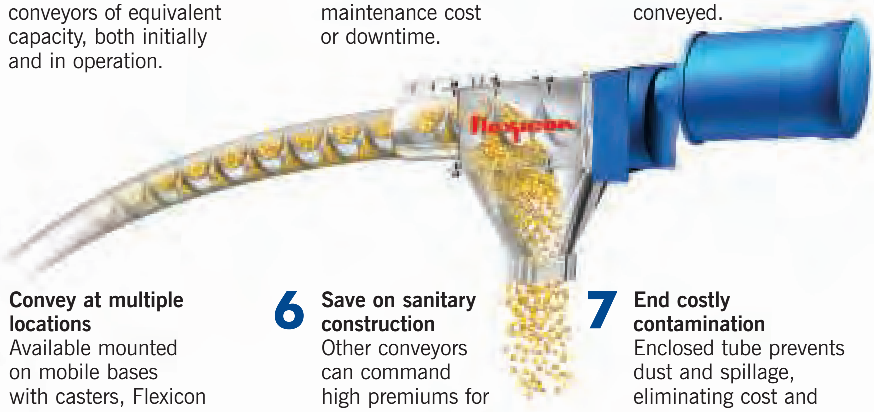
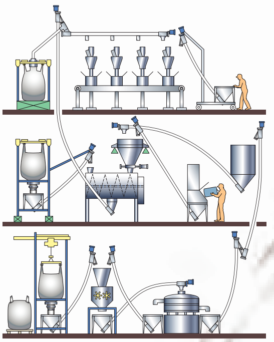
4 Use less energy
Low horsepower motors, simple gear reducers and ultra-efficient operation significantly cut energy cost per volume of material conveyed.





5 Convey at multiple locations
Available mounted on mobile bases with casters, Flexicon conveyors with hoppers, dust collectors and other accessories can operate at multiple locations, eliminating the need for dedicated conveyors.

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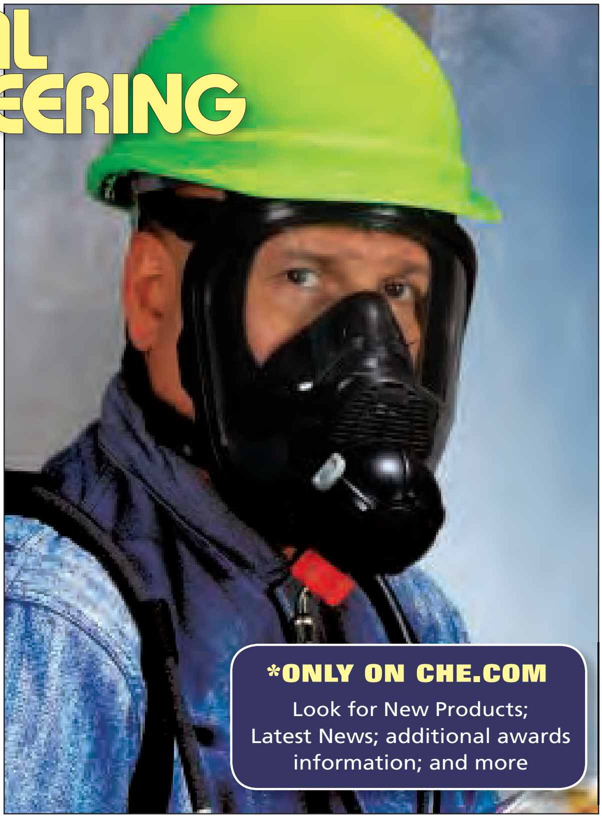

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55 The Fractionation Column I drink tap water The author prefers tap water to bottled, citing the environmental effects of the disposable container

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COMING IN JANUARY

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CHEMICAL ENGINEERING

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Superstorm's impact on CE

Many readers of this magazine are familiar with the impact of a hurricane — both professionally and personally. Plants along the U.S. Gulf and the southern Atlantic Coasts, for instance, live with a high probability that one of these storms cross their paths, and therefore are generally prepared for such storms. Last month, however, the force of a hurricane hit a most unlikely place, the Northeast U.S. *Chemical Engineering's* editorial headquarters are located in New York City, specifically lower Manhattan, which was one of the hardest-hit areas. While we are grateful that all of our employees are safe, several of them experienced major utility outages, and our offices are still not operational. We sincerely thank those of you who have expressed concern, and apologize to any of you who might have experienced delays or other problems in communicating with us.

Our office building, which ironically has its entrance on Water Street, suffered severe flooding in the basement and lobby. Like many buildings in New York City, the basement houses the building's main power systems. As a result of that power outage, which was still in effect at *CE* press time, our email server, phone systems and some other IT systems became unavailable. Luckily, within a few days our IT department was able to restore a month or so worth of email backups, but many emails during the month of November did not reach us. Also, much of our mail has been stranded at the post office. So if you have tried to contact one of us and have not received a response, we urge you to try again.

On a more personal note, three of our key staff members were impacted by major utility outages. One associate editor weathered the long storm at his home, along with his wife and two small children. But within about 24 hours or so, he was able to relocate to his parents' home, where they had power and utilities. Within hours of that relocation, he was setup to work and tackle the challenges we were facing on the professional side.

Our art director and editorial production manager (the person who handles all of our graphic design and layout of the magazine, plus the design of our covers) was actually blocked inside his own neighborhood by downed trees, utility poles and power lines for at least a couple of days. Once he was liberated from that situation, he was able to visit local coffee shops and make attempts to charge up his computer and hop onto internet hotspots. But given that the rest of the local community was in the same boat, his attempts were not always successful, and did not provide internet speeds sufficient for most of the production work involved in magazine publishing. Fortunately, his power was restored within about a week, as was his internet service. Over the next couple of weeks, he worked tirelessly to produce and reproduce some lost work, so that this issue could arrive on time in your mailbox.

Worst hit on our staff, was our managing editor, who was also stranded within her immediate neighborhood. While that state of affairs was soon relieved, services at her home — power, heat, water, telephone — were out for almost two weeks. She weathered those conditions through a cold front that dropped about eight inches of snow on her community. Even her local cellular telephone tower was down, so she could not be reached for most of that time. I recall receiving an email from her, via her neighbor's iPhone, letting me know that she had not been injured. Finally, she regained power — just in time to give her light to pack her suitcase and join the rest of the editorial team in New Orleans for ChemInnovations.

We are very grateful to these individuals, who put forth great effort under very difficult circumstances to assure that we deliver the quality editorial that you expect. ■

Rebekkah Marshall

Letters

Submitting manuscripts to CE

Practical information. First and foremost, our readers look to us for practical information. These individuals want concise factual information that aids in solving real problems. They do not look to us for abstract theoretical treatises, vague general discussions or reviews of previously published material. In other words, we prefer and accept "how to" articles rather than purely descriptive ones. Most of our articles fit in one of the following categories:

- Process equipment selection, design or specification
- Plant operations and maintenance
- Process and equipment optimization
- Economic evaluation
- Project management
- Regulatory compliance and safety considerations

Broadly applicable. *CE* articles should appeal to a relatively wide section of our readers, who are chemical engineers working throughout the chemical process industries, as opposed to just one sector of them.

Non-promotional. Outside authored articles must make no mention of nor show favoritism toward specific products or vendors.

Exclusive. We only publish manuscripts that are offered to us exclusively. In other words, submit your manuscript to only one magazine at a time!

How to submit your idea

Manuscripts should be emailed to manuscripts@che.com

Artwork. Please include all artwork and tables with your manuscript and obtain any necessary legal clearance beforehand. Photographs must be at least 300 dpi or greater.

Length. We generally look for manuscripts in the 2,000–5,000 word range.

Date. The timing depends on what your schedule allows.

Questions to consider as you write

- Is the idea or manuscript timely or interpretive, rather than just a rehash of old material?
- Is the idea or manuscript aimed at helping the non-specialist become conversant with the subject, rather than being written for another expert?
- Does the material help readers in decision-making, in technical administration, or in policy formulation?
- Will it enable readers to accelerate their professional development?

If so, then you're on the right track.

Do you have —

- Ideas to air?
- Feedback about our articles?
- Comments about today's engineering practice or education?
- Job-related problems or gripes to share?

If so — Send them, for our Letters column, to
Rebekkah Marshall
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88 Pine St., 5th floor
New York, NY 10005; letters@che.com

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NORTH AMERICA

21st Winter Fluorine Conference. American Chemistry Soc., Div. of Fluorine Chemistry (ACS; Washington, D.C.). Phone: 614-447-3776; Web: fluorine.sites.acs.org/21stwfc.htm
St. Pete Beach, Fla. **January 13–18, 2013**

NACE Nuclear Power Plant Coatings Symposium 2013. National Assn. of Corrosion Engineers (NACE; Houston). Phone: 281-228-6200; Web: events.nace.org/events
Orlando, Fla. **January 15–16, 2013**

Informex. Informex Holdings, LLC (Hamilton, N.J.). Phone: 609-759-4700; Web: informex/com
Anaheim, Calif. **February 19–22, 2013**

ARC Advisory Group Forum. ARC Advisory Group (Boston, Mass.). Phone: 781-471-1000; Web: arcweb.com
Orlando, Fla. **February 11–14, 2013**

Corrosion 2013. National Assn. of Corrosion Engineers International (Houston). Phone: 800-797-6223; Web: events.nace.org/events
Orlando, Fla. **March 17–21, 2013**

American Fuel and Petrochemical Manufacturers (AFPM) Annual Meeting. American Fuel & Petrochemical Manufacturers (AFPM; Washington, D.C.). Phone: 202-457-0480; Web: afpm.org
San Antonio, Tex. **March 17–19, 2013**

American Chemical Soc. National Meeting and Exposition. American Chemical Soc. (Washington, D.C.). Phone: 202-872-4600; Web: acs.org
New Orleans, La. **April 7–11, 2013**

Interphex 2013. Reed Exhibitions (Norwalk, Conn.). Phone: 203-840-5648; Web: interphex.com
New York, N.Y. **April 23–25, 2013**

AIChE 2013 Spring Meeting and 9th Global Congress on Process Safety. AIChE (New York, N.Y.). Phone: 800-242-4363; Web: aiche.org
San Antonio, Tex. **April 28–May 2, 2013**

7th Annual ACEEE Energy Efficiency Finance Forum. American Council for an Energy-Efficient Economy (Washington, D.C.). Phone: 202-507-4000; Web: aceee.org/conferences/2013/eeff
Portland, Ore. **May 13–15, 2013**

15th Annual Electric Power Conference & Exhibition. Tradefair Group, an Access Intelligence LLC Co. (Houston). Phone: 832-242-1969; Web: electricpowerexpo.com
Chicago, Ill. **May 14–16**

AFPM Reliability & Maintenance Conference and Exhibition 2013. American Fuel & Petrochemical Manufacturers (AFPM; Washington, D.C.). Phone: 202-457-0480; Web: afpm.org/conferences/
San Antonio, Tex. **May 22–25**

Risk Management of Corrodible Systems. National Assn. of Corrosion Engineers International (Houston). Phone: 281-228-6200; Web: event.nace.org
Orlando, Fla. **June 18–20, 2013**

AWMA Annual Conference. Air & Waste Management Assn. (AWMA; Pittsburgh, Pa.). Phone: 412-232-3450; Web: awma.org
Chicago, Ill. **June 25–28, 2013**

EUROPE

Powtech. Nuremberg Messe (Nuremberg, Germany). Phone: +49-911-86-06-83-55; Web: powtech.de/en/
Nuremberg, Germany. **April 23–25, 2013**

21st European Biomass Conference and Exhibition. ETA-Florence Renewable Energies (Florence, Italy). Phone: +39-55-500-2280, ext. 221; Web: conference-biomass.com
Copenhagen, Denmark **June 3–7, 2013**

ASIA & ELSEWHERE

World CTL 2013 Conference — Natural Gas, Liquid Fuels and Petrochemicals from Coal, Petcoke and Biomass. World CTL (Paris). Phone: +33-607-28-5247; Web: 2013.world-cti.com
Shanghai, China **April 16–19, 2013**

AchemAsia 2013. Dechema e.V. (Frankfurt am Main, Germany). Phone: +49-69-7564-277; Web: achemasia.de/
Beijing, China **May 13–16, 2013**

The 13th China International Environmental Protection Exhibition & Conference. Goodwill Exhibition & Promotion Ltd. (Hong Kong). Phone: +852-2893-4338; Web: goodwill-exh.com.hk/ciepec2013/
Beijing, China **June 11–14, 2013** ■

Suzanne Shelley

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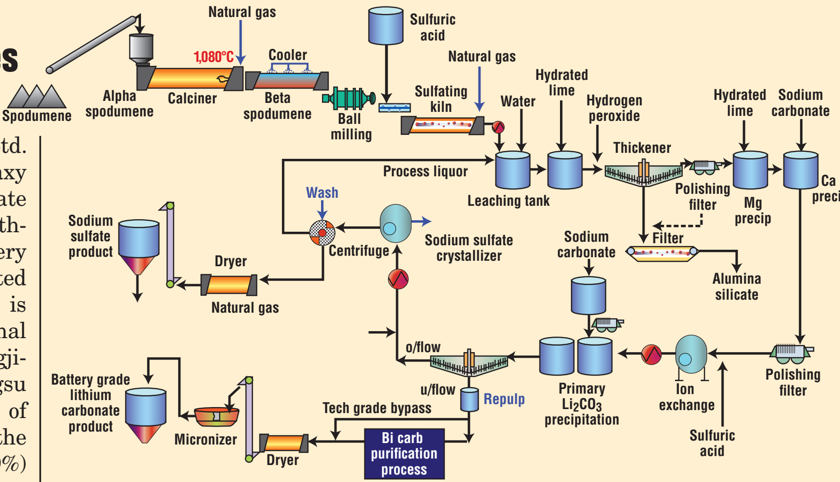
CHEMENTATOR

Edited by Gerald Ondrey December 2012

A patented process produces battery-grade lithium



Lithium producer Galaxy Resources Ltd. (Perth, Western Australia; www.galaxylithium.com) says that lithium carbonate product from its wholly owned Jiangsu Lithium Carbonate Plant has achieved battery grade quality using the company's patented process (flowsheet). The Jiangsu plant is located in the Yangtze River International Chemical Industrial Park of the Zhangjiagang Free Trade Zone in China's Jiangsu Province. It has a production capacity of 17,000 ton/yr of lithium carbonate and the capability of producing high-purity (99.9%) electric-vehicle-grade lithium carbonate.

The lithium originates from Galaxy's Mt. Cattlin mine at Ravensthorpe, Western Australia. Galaxy mines lithium pegmatite ore and processes it onsite to produce spodumene concentrate and tantalum byproduct.

According to the company, the latest testing at Jiangsu showed that sodium levels have dropped from 117 ppm to 20 ppm (battery specification is less than 250 ppm). For lithium cathode and lithium-ion battery (LIB) makers, sodium is one of most troublesome impurities, causing oxidation and gassing in the final product. Excessive sodium levels can also cause reduction in charging and discharging capacity in lithium-ion batteries, as well as reducing battery life.

The company says similar quality improvements have been recorded in sulfate levels. A typical battery specification is less than 800 ppm, and the latest testing showed a level of 530 ppm. Excessive sulfate impurity can lead to gassing and leakage in lithium-ion batteries.

Calcium, magnesium and iron have also remained well below specification levels. These elements can reduce the capacity of lithium-ion batteries and have an effect similar to that of high sodium levels.

Galaxy plans to build an LIB plant near the existing lithium carbonate facility. Proposed Phase 1 production is 620,000 battery packs per year, primarily for the eBike market.

Low-cost production of PHA from air and greenhouse gases

Newlight Technologies (Irvine, Calif.; www.newlight.com) has launched commercial production of a polyhydroxyalkanoate (PHA) thermoplastic made from air and greenhouse gases, such as methane, that can be manufactured less expensively than conventional petroleum-derived alternatives, using a novel high-efficiency biocatalyst and bioreactor system.

While considerable effort has previously been directed toward developing a viable PHA process using greenhouse gases as inputs, the production costs have been prohibitively high because the conversion efficiencies of previous biocatalysts have been on the order of a one-to-one ratio, explains Newlight co-founder and CEO Mark Herrema. Newlight has been able to raise conversion efficiencies for producing PHA from greenhouse gases by 500%, he says.

To accomplish the dramatic jump in conversion efficiency, and thereby allow lower production costs, Herrema's company focused on controlling the epigenetic profile of a microorganism used to generate its proprietary biocatalyst. By doing so, Newlight was able to boost the conversion efficiencies that were attainable. Epigenetics refers to those factors that regulate the expression of genes. "We can change the conditions around the microbe's DNA and selectively turn on or off particular genes," remarks Herrema, "so the biocatalyst the microbe produces can generate much more PHA than it would naturally." Newlight has also developed a unique reactor to handle multiple gases simultaneously while achieving high mass-transfer rates into the reactor medium.

Further lowering costs for Newlight's process is the simplified downstream processing, and the fact that its epigenetic

(Continues on p. 12)

Rotary atomizer

Engineers at Dedert Inc. (Homewood, Ill.; www.dedert.com) have developed a high-speed rotary atomizer for a spray-dryer system that features a motor with permanent rare-earth-metal magnetic bearings. The centrifugal rotary atomizer can achieve peripheral speeds 30 to 40% higher than traditional rotary atomizers. The Dedert technology allows users to atomize more viscous materials, as well as those with higher solids content. The improved performance of the atomizer means potentially higher production capacities in spray dryers. Mechanically, the spray dryer has a simple design that reduces maintenance, says Colin Crankshaw, Dedert CEO. For example, the rotary atomizer requires no oil lubrication. Also, "the magnetic bearings have a two-year lifetime," he says, versus changing bearings every three to six months with a traditional gear-driven motor. The company recently installed the first commercial application in a food production facility in the U.S.

Recycling rubber

Researchers at the Fraunhofer Institute for Environmental, Safety and Energy Technology (Umsicht: Oberhausen,

(Continues on p. 12)

Note: For more information, circle the 3-digit number on p. 60, or use the website designation.

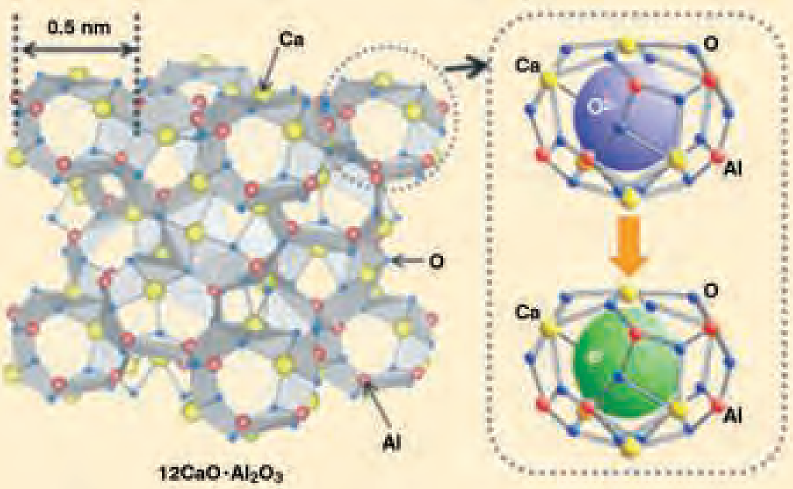
A highly active catalyst for making NH_3

The research groups of Hideo Hosono and Michikazu Hara at the Materials and Structures Laboratory, Tokyo Institute of Technology (TiTech; Yokohama, Japan; www.msl.titech.ac.jp) have developed a high-performance catalyst for the synthesis of ammonia. In the laboratory, the catalyst is found to be an order of magnitude more efficient than commercial ruthenium-based catalysts because it cuts the energy barrier for the reaction of H_2 and N_2 in half. The researchers believe their achievement will contribute to a more environmentally friendly route to NH_3, with milder reaction conditions compared to the conventional Haber-Bosch process, which requires high temperatures and pressures, and consumes more than 1% of the world's power. The researchers are already collaborating with a Japanese company, and aim to commercialize the technology in 5–10 yr.

The catalyst is made by attaching ruthenium atoms to nano-sized cages of a calcium aluminate electride, which confines electrons within the cage. The electride — $12CaO \bullet 7Al_2O_3$ (hereafter C12A7; diagram) — is a component found in cement. Hosono's group developed the C12A7 electride system and Hara's group applied the electride as a catalyst for NH_3 synthesis. The researchers report that Ru-loaded electride, (Ru/C12A7:e^-) is a strong electron donor, and is chemically stable.

Kinetic analysis with infrared spectroscopy revealed that Ru/C12A7:e^- markedly enhanced N_2 dissociation on Ru by the back donation of electrons, and that poisoning of the Ru surfaces by adsorption of hydrogen can be effectively suppressed because of the ability of C12A7:e^- to store hydrogen reversibly. At pressures of 0.1–1.0 MPa (N_2-to-H_2 ratio of 3) NH_3 was 10 times faster with Ru/C12A7:e^- than for a catalyst of Ru on a Cs-doped MgO support.

The chemists are working to enhance the performance by increasing the surface area of the C12A7 electride, and accelerate the development of an industrial catalyst. They also plan to clarify the detailed reaction mechanism in order to find a less-expensive alternative metal to Ru.



LOW-COST PRODUCTION OF PHA

(*Continued from p. 11*)

modification technology can be run as a non-sterile process. Since the PHA produced contains fewer byproducts, less downstream processing is required, and Newlight was able to develop low-cost technology to render a high-performance end-product, Herrema says.

Newlight is now producing and selling its PHA-based plastics at a capacity of over 100,000 lb/yr. The company is preparing to build a larger plant in California, to be completed in 2013, that will produce a few million pounds per year of PHA for markets including durable goods, packaging and consumer disposables.

While Newlight primarily uses air and methane-based greenhouse gases, such as biogas and natural gas, as production inputs for its bioprocess, the company has also operated its technology using air and CO_2-enriched air, and is working on increasing its use of those inputs as feedstocks.

(*Continued from p. 11*)

Germany) have developed a new material, called elastomer powder modified thermoplastic (EPMT), which can be processed into products. EPMTs contain up to 80 wt.% residual rubber (from used tires, for example) and 20 wt.% of a thermoplastic, such as polypropylene. EPMT can be processed in conventional injection-molding machines and extruders into products that can themselves be recycled. The physical and mechanical properties of EPMT, such as elasticity, breaking strain and hardness, can be modified to meet the requirements of the application.

To make the EPMT, rubber residue is first granulated into 3-mm sized particles. The particles are then cooled with liquid nitrogen and ground into powder. This powder is then fed to a melt-mix process where it is combined with the thermoplastics and additives.

The institute has developed three different recipes, and can produce 100–350 kg/h. A spinoff company has been formed — Ruhr Compounds GmbH — to produce and commercialize EPMT materials. The work was sponsored by the Federal Ministry for Economics and Technology (BMWi; Berlin) under the Exist Research Transfer project.

U.K. bio projects

LanzaTech (Roselle, Ill.; www.lanzatech.com) is working with the U.K.'s University of Nottingham Center for Biomolecular Sciences on a project to make low-carbon fuel. The university has been awarded funding of £2.9 million (approximately $4.65 million) for the project by the U.K. Biotechnology and Biological Sciences Research Council (BBSRC). It is one of six synthetic biology projects selected by BBSRC, with total funding of £20 million ($32 million).

The six projects focus on biotechnology and advanced bioenergy and will use synthetic biology to investigate major global challenges, such as producing low-carbon fuel and reducing the cost of industrial raw materials. The funding is also expected to help build a world-leading synthetic biology research community in the U.K. In the case of the University of

(*Continues on p. 14*)

Scaleup for a microbial process that produces acetic acid from offgases

A demonstration plant for the production of acetic acid from the carbon dioxide in industrial offgases will be built at an operating plant of Petronas (Kuala Lumpur; www.petronas.com.my), Malaysia's national oil company, under an agreement with LanzaTech (Roselle, Ill.; www.lanzatech.com), developer of the process. Scheduled for startup in late 2013, the plant will be similar in size to a demonstration unit for a LanzaTech process that produces ethanol and 2,3 butanediol (2,3-BD) from the carbon monoxide in offgases, says Mike Schultz, the company's vice-president of engineering. That plant started up last April at a Bao Steel (Shanghai) steel mill and produces 100,000 gal/yr (300 ton/yr) of ethanol (see *CE*, December 2010, p. 12).

The CO_2 process is similar to the CO technology in that it uses fermentation media containing naturally occurring bacteria that have been optimized to obtain a product (acetic acid in the case of CO_2). Raw offgases are sparged into the solution, and the CO_2 reacts with hydrogen at 35–40°C to yield acetic acid, plus water. The rest of the components in the gases are inert and pass through the reactor.

Schultz says that, unlike CO, CO_2 is readily soluble in water, which makes the CO_2 process more effective. LanzaTech plans to recover the acid from the solution by countercurrent solvent extraction (the CO process uses distillation to obtain ethanol). He notes that CO_2 is present in the offgases from many industrial processes and can account for as much as 50–60% of raw natural gas. Hydrogen for the process can be provided from various low-value sources, such as coke oven gas, hydrogen plant offgas, and refinery fuel gas. Schultz points out that these gas sources are typically not at the hydrogen concentration and pressure required for chemical and refinery use, and would be expensive to upgrade for this purpose.

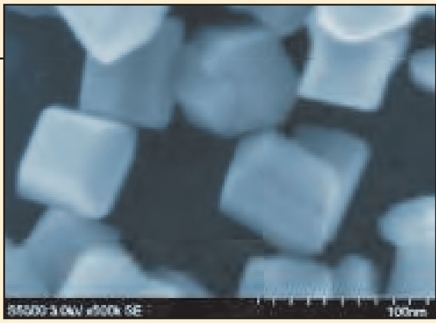
A boost for bio-butanol production

Lately there has been much renewed interest in fermentative production of *n*-butanol from renewable biomass as an industrial solvent and liquid fuel superior to ethanol that could be used as a substitute for gasoline. An improved butanol production through the reinforcement of the direct butanol-forming route in *Clostridium acetobutylicum* has been reported by a Korean team, which includes scientists from: the Dept. of Chemical and Biomolecular Engineering, Korea Advanced Institute of Science and Technology (KAIST; www.kaist.ac.kr); GS Caltex (Daejeon; www.gscaltex.com), a petroleum-refining company; and BioFuelChem (all from Daejeon, South Korea), a startup butanol company.

The key metabolic pathways and the biphasic fermentation model for acetone-butanol-ethanol production by *C. acetobutylicum* have been well studied. Acetate and butyrate first formed during the acidogenic phase are reassimilated to form acetone-butanol-ethanol (cold channel).

(*Continues on p. 14*)

A new photocatalyst for VOC destruction . . .



A process for manufacturing fine particles of titanium dioxide that exhibits a high level of photocatalytic activity has been developed by Showa Titanium Co., a subsidiary of Showa Denko K.K. (SDK, Tokyo; ww.sdk.co.jp). The product has been developed in collaboration with professor Bunsho Ohtani at Hokkaido University with support from the New Energy and Industrial Technology Development Organization (NEDO, Kawasaki, Japan; www.nedo.go.jp). Showa Titanium is now conducting tests for volume production at its pilot plant, aiming to commercialize the product by the end of 2013.

When used as photocatalyst, these titanium-oxide particles cause strong oxidation and reduction reactions in the presence of ultraviolet (UV) light, thereby decomposing a variety of volatile organic compounds (VOCs). The TiO_2 particles also exhibit ultra hydrophilicity, causing water to spread as a thin film, a property that makes the material useful for solar-powered air purification in applications such as antifogging window glass and antifouling coatings for exterior surfaces of buildings.

Although it is well known that the photocatalytic properties of TiO_2 improve as the particle size gets smaller, conventional methods for making fine TiO_2 particles often develop crystal defects, which lowers the photoconversion efficiency as well as the catalytic activity. To avoid this problem, Showa Titanium has developed a gas-phase production process to make decahedral titanium-oxide fine particles (photo) with minimal defects. In addition to the improved photocatalytic properties, these low-defect TiO_2 products have potential for other applications as functional materials, such as for ceramic capacitors.

. . . and another photocatalyst for destroying viruses

Meanwhile, professor Kazuhito Hashimoto at the University of Tokyo (Japan; www.light.t.u-tokyo.ac.jp) has developed new photocatalyst materials based on copper-titanium oxide, which exhibits superior antiviral effectiveness and enhanced antibacterial properties compared to existing systems. Developed with support from NEDO (see story above), this new catalyst system is capable of reducing the number of viruses in air by four orders of magnitude without light in 1 h — a 99.99% viral deactivation — and by seven orders of magnitude in the presence of visible light. The research group also observed similar effectiveness against bacteria, such as *E. coli* and *Staphylococcus aureus*. A system using this photocatalyst has undergone field testing at airports and hospitals in Japan.

Together with Showa Titanium, the scientists have started to develop a mass-production process for the photocatalyst system. Also under the NEDO project, applications development are underway at Seiwa Kogoyo Co. (for air-cleaning systems); Sekisui Jushi Corp. (for construction materials for interiors); Toto Ltd. (for tiles and paints); Nippon Sheet Glass Co. (for glass); at Panasonic Corp. (for films); and Taiyo Kogyo Corp. (for tent canvas materials).

A Boost for Bio-butanol Production

(*Continued from p. 13*)

Butanol can also be formed directly from acetyl-coenzyme A (CoA) through butyryl-CoA (hot channel).

The team claims to have reported, for the first time, the results of systems metabolic-engineering studies of the two butanol-forming routes and their relative importance in butanol production. It also claims to have developed a metabolically engineered *C. acetobutylicum* strain capable of producing butanol with high yield and selectivity, by reinforcing the direct butanol-forming flux.

By reinforcing the direct butanol-forming flux in the bacterium, 18.9 g/L of butanol was produced, with a yield of 0.71 mol butanol/mol glucose by batch fermentation. Those levels are 160% and 245% higher than those obtained with the wild strain. By fed-batch culture of the engineered strain with in situ recovery, 585.3 g of butanol was produced from 1,861.9 g of glucose, with the yield of 0.76 mol butanol/mol glucose and productivity of 1.32 g/L/h. The team believes this makes the process cost-competitive.

(*Continued from p. 12*)

Nottingham, researchers are working to maximize the use of sustainable forms of energy by harnessing the ability of certain bacteria, such as *Clostridium ljungdahlii* to consume carbon monoxide and convert it into useful chemicals and fuels.

Na-ion batteries

To overcome some of the limitations of lithium-ion batteries, such as the relative scarcity and high cost of lithium and the flammability of the organic electrolyte currently used, a group from Murdoch University (Perth, Western Australia; www.murdoch.edu.au), led by Manickam Minakshi, has developed an alternative aqueous NaOH battery. The idea was to replace LiOH with abundantly available aqueous NaOH electrolyte, and couple this electrolyte with a Zn anode and an MnO_2 cathode.

Existing sodium technologies work at high temperatures, using an anode of molten sodium and a cathode of molten sulfur. The group aimed for a low-temperature storage device.

Minakshi says that simply replacing the Li^+ with Na^+ ions probably does not work well, because Na^+ ions are 70% larger than Li^+, and do not fit well in empty spaces of the electrode's matrix. Only materials with 2D layered structures, or a 3D structure with corner sharing matrix, or a crystal structure forming large-size tunnels can reversibly accommodate Na^+ ions, he says. Hence, MnO_2 was selected as the cathode material. As sodium is not involved in the anodic process, this system is not a "rocking-chair sodium-ion cell" but rather a NaHO cell — MnO_2|NaOH|Zn — with sodium insertion on the cathode and zinc dissolution from the anode.

The discharge capacity of the MnO_2 cathode for the NaOH cell is 225 mAh/g (300 Wh/kg), compared with 142 mAh/g (210 Wh/kg) for the LiOH cell using a 1 V cut-off voltage.

Minakshi says the reversibility of the NaOH cell needs to be enhanced for practical applications by incorporating oxide additives to the host MnO_2 matrix. He says the aqueous sodium battery could find application in large-scale energy storage systems, such as a smart grid.

A new way to obtain hydrogen from heavy oil

The volume of heavy, sour crude oil processed by North American refineries is steadily increasing, and along with it a commensurate demand for hydrogen to upgrade that oil. A steam-reforming process that would allow refiners to produce their own H_2 from heavy oil and residuum is being developed by TDA Research, Inc. (Wheat Ridge, Colo.; www.tda.com).

Currently, refiners make a lot of their own hydrogen by steam-reforming methane or coke gasification. However, while natural gas is now plentiful and inexpensive in the U.S., naphtha is the heaviest feed that can be processed by conventional steam-reforming, says Girish Srinivas, principal engineer for TDA. He adds that TDA's process will be less expensive than coke or heavy oil gasification, except for very large plants.

Srinivas explains that TDA's process converts heavy oil and residuum to a hydrogen-rich syngas with a H_2-to-CO ratio of 4–6, using a conventional nickel steam-reforming catalyst. However, unlike conventional steam reforming, the process uses a fluidized-bed rather than a fixed-bed reactor, and is in the form of a loop with two reactors: one for reforming and one for catalyst regeneration. Heavy oil/residuum and steam are fed into the reforming reactor and reacted at 870°C and 50–100 psig. The catalyst flows around a reactor-regenerator loop, and since the contact time with the feed is relatively short, the amount of carbon buildup on the catalyst is not enough to cause irreversible deactivation.

From the reforming reactor, the catalyst goes to a regenerator, where the coke is burned off with air and the catalyst is reheated to 870°C, using a small amount of heavy oil feed as additional fuel. The catalyst returns to the reactor as inactive nickel oxide, but is quickly reduced back to catalytically active Ni metal by the hydrocarbons in the feed. In laboratory tests, using about 300 grams of catalyst and steam-to-carbon ratios of 3–5, the process has achieved 70% selectivity for H_2, says Srinivas. The process has been demonstrated using both atmospheric tower bottoms (ATB) and vacuum tower bottoms (VTB) as feedstocks. TDA is working on a preliminary scaleup design for eventual pilot plant testing. ■

Phase separator

Biotage AB (Uppsala, Sweden; www.biotage.com) has commercialized its new Universal Phase Separation columns, which are alternatives to traditional glass funnels for separating immiscible liquids in laboratory applications. The new columns are cartridges that are fitted with a concentric, selectively permeable insert. As the mixture flows down the column, the organic phase passes through the internal frit, leaving the aqueous phase inside the separator.

Anethole: A new flavor

Les Dérivés Résinques & Terpéniques (Dax, France; www.drt.fr) has developed a process for producing anethole, a natural derivative of anise. The synthetic anethole can be used in beverages, toothpaste, perfumery and pharmaceuticals. ❑

CAB grows higher in October

The American Chemistry Council's (Washington, D.C.; www.americanchemistry.com) leading macroeconomic indicator known as the Chemicals Activity Barometer (CAB) rose 0.6% in October, marking the fourth consecutive month of gains. Also, the September and August CABs were upwardly revised, and the index stood at 90.7 in October.

"The pattern thus far in 2012 has been similar to that in 2011 and 2010 — a strong start to the year, followed by deterioration in the 2nd quarter, and from all appearances thus far, a recovery in the fourth quarter," ACC said in a recent Weekly Chemistry and Economic Report.

Production-related indicators were positive, ACC says, including rising activity in construction-related plastic resins, coatings, pigments and other chemistry, which suggests the recovery in housing and light vehicles is strengthening. "In summary, the CAB is signaling economic growth during 2013," the report says.

The weekly ACC report also noted that the U.S. Chemical Production Regional Index (CPRI) was flat overall for September, with the Gulf Coast and Ohio Valley regions posting gains, but all other regions showing declines in production.

Meanwhile, the Global CPRI rose 0.3% in September, marking the 10th month of gain. The pace, however, has slowed since last year, the ACC report says.

"Overall trends . . . continue to point to softening activity as the world economy slows and political uncertainty persists in the U.S.," the report says.

Chesar to be a means to achieve chemical safety report compliance

The European Chemicals Agency's (ECHA; Helsinki, Finland; echa.europa.eu) Chemical Safety Assessment and Reporting tool (Chesar) contains additional functionalities to assist registrants in carrying out their chemical safety assessments (CSAs). As a new functionality, the exposure estimation tool for consumers — targeted risk assessment (TRA), developed by the European Center for Ecotoxicology and Toxicology of Chemicals (ECETOC) — is embedded.

In addition, Chesar users can now report releases of waste in a structured form and better describe the assessment approach taken for health hazards resulting from flammability, explosiveness or oxidizing potential of a substance. With these new functionalities, registrants can use Chesar to make a comprehensive chemical safety report (CSR), including exposure scenarios for all uses to document and control possible risks to workers, consumers and the environment.

Chesar 2.1 also offers the possibility to start preparing exposure scenarios for communication in the supply chain. The tool includes a library of standard phrases, which can be used to communicate the relevant results of the chemical safety assessment to downstream users. Chesar 2.1 is ready to import standard phrase catalogs, such as ESCom phrases developed by the European Chemical Industry Council into this library, once these are available in a format compatible with Chesar. The next update of ESCom scheduled before the end of the year is expected to provide this format.

The next Chesar version (2.2) is expected to be released in the first quarter of 2013. ■

EPA STAYS CHEMICAL MANUFACTURING AREA SOURCES RULE

The U.S. Environmental Protection Agency (EPA) issued a 60-day administrative stay of the Chemical Manufacturing Area Sources (CMAS) rule. Affected sources originally faced an imminent October 29 deadline to comply with the 2009 final rule, but with EPA still in the process of finalizing its reconsidered CMAS rule, the agency noted that a stay of the rule was warranted. The stay ends on December 24, 2012.

On January 30, 2012, EPA published a proposed reconsideration of this rule in order to re-evaluate certain provisions, some of which would affect applicability. Since the final reconsideration is not yet completed, EPA stated that a short stay of the final rule is appropriate to allow the agency the time necessary to complete the reconsideration action. ❑

Agreement designed to improve hazmat response

Chemtrec (Washington, D.C.; www.chemtrec.com) and the National Registration Center for Chemicals (NRCC; Qingdao, China; en.nrcc.com.cn) have entered into a memorandum of understanding (MOU) for mutual assistance.

The partnership will enhance the capabilities of both organizations to effectively respond to hazardous materials incidents occurring within China, as well as those that occur outside the country.

Companies transporting hazardous materials to locations within China, as well as between China and other areas, will receive the greatest benefit when registered with both organizations for their emergency-response information needs.

The MOU recognizes the capabilities of each organization and their mutual goal to assist emergency responders during incidents involving hazardous materials. The MOU provides the framework for the organizations to share and leverage their respective information resources during hazardous materials emergencies, 24 hours a day, seven days a week.

Chemtrec, a part of the American Chemistry Council, was established in 1971 by the chemical industry as a public service hotline for emergency responders, including fire fighters and law enforcement, to obtain information and assistance for emergency incidents involving chemicals and hazardous materials.

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2012 PERSONAL ACHIEVEMENT AWARD

UOP's Gautam is named the winner, and four merit awards are honored along with the 2012 ChemInnovations Awards

FIGURE 1. After CE's Rebekkah Marshall, presented him with the top award, Gautam cited the many benefits that the chemical engineering profession brings to society, including environmental progress

Last month, in New Orleans at an award ceremony to kick-off ChemInnovations (www.cpievent.com), *Chemical Engineering* unveiled the results of its 2012 Personal Achievement Award. The first prize was presented to Rajeev Gautam, the President and CEO of UOP LLC (Des Plaines, Ill.; www.uop.com), a Honeywell company, while merit awards were given to four other individuals:

- Diane Dorland, retired dean and professor emeritus in the chemical engineering department at Rowan University (Glassboro, N.J.; www.rowan.edu)
- Fabio Bravo, process engineering technical manager at The Dow Chemical Co. (Midland, Mich.; www.dow.com)
- Steve Donen, vice president for process development and engineering at renewable-chemical company Rivertop Renewables (Missoula, Mont.; www.rivertop.com)
- Charles Easley, senior process engineer at BSI Engineering (Cincinnati, Ohio; www.bsiengr.com)

Established in 1968, and presented biennially since then, the Personal Achievement Award highlights the fact that the influences that teach us, inspire us and drive us to succeed in professional life, tend to come more from individuals than corporations. The 2012 winner and honorees were narrowed down from fifteen finalists (*CE*, July 2012, p. 5). For more about the award, see the online version of this article at www.che.com.

Also at the award ceremony, results of the 2012 ChemInnovations Awards recognized both technologies and individuals in a number of categories (see box, p. 18).

1st prize: Rajeev Gautam

Rajeev Gautam serves as president and chief executive officer of Honeywell's UOP, a strategic business unit of Honeywell Performance Materials and Technologies. UOP is a leading international supplier of process technology, catalysts, engineered systems, and technical and engineering services to the petroleum refining, petrochemical, chemical and gas processing industries.

Gautam is known internationally in the petroleum refining and petrochemical industries. Before being named to his current post, he served as vice president and chief technology officer of Honeywell Specialty Materials. During the last 30 years he has held key positions within UOP — spanning research and development (R&D), engineering and marketing — including vice president and chief technology officer of UOP; director of the Process Technology & Equipment business; technology director for Platforming and Isomerization Technologies; senior manager of Adsorption Technology; and manager of Molecular Sieve Process Technology.

As noted in the award nomination submitted by Jeffery C. Bricker, research director, R&D, at UOP, Gautam has been a champion of R&D and the creative process. "Under his leadership, UOP has made remarkable advances in intellectual property. UOP filed 523 patent applications and was granted 300 patents within the past two years."

Highlights of the breakthrough technologies that UOP has introduced under Rajeev's leadership include the following:

- The first methanol to olefins (MTO) process (*CE*, January 2006, p. 13) was licensed in China and will allow the conversion of coal to valuable

chemical intermediates, ethylene and propylene
- The first high-conversion Uniflex Heavy Oil conversion process (*CE*, March 2012, p. 12), which was licensed in the Middle East and will allow valuable ultra-low sulfur diesel to be produced from the bottom of the barrel with less coke byproduct and better utilization of crude oil, Bricker says
- Technology for conversion of biomass to jet fuel and diesel fuel, significantly lowering the carbon dioxide footprint for these key fuels (CE, May 2010, p. 11)

Gautam began his career with Union Carbide in 1978, which became part of a joint venture with UOP in 1988. He holds a B.S.Ch.E from the Indian institute of Technology and an M.S.Ch.E. from Drexel University. He also holds a Ph.D. in chemical engineering from the University of Pennsylvania and an MBA from the University of Chicago. He is a Fellow of AIChE and served in key roles in program development in its Computing and Systems Technology Division.

Honoree: Dianne Dorland

Dianne Dorland is currently professor emeritus in the Chemical Engineering Dept. at Rowan University. She was the first woman elected president of AIChE (elected in 2003) and is the first woman recognized as a winner of this award.

Dorland is recognized for using her process engineering experiences at Union Carbide and the U.S. Dept. of Energy's Morgantown Energy and Technology Center in W. Va. to bring hands-on and interactive approaches into the engineering curriculum. She was dean of engineering from July 2000 to August 2010 and has been a professor of chemical engineering since September 2010.

Dorland served as president of AIChE during a period of economic decline. According to Doug Kreibel, 2011 Delaware Valley Engineer of the Year, Dorland initiated several policies to reorganize and restructure the organization and bring it back to financial stability.

As dean of engineering, Dorland strengthened and brought continuous improvement to the internationally recognized Rowan Engineering Clinic Program. According to Z. Otero Gephardt, who submitted a nomination on behalf of the AIChE Delaware Valley section, Dorland has been instrumental in the use of students' learning styles data to enhance student learning. She is also credited for encouraging professors to become student-centered in their teaching and research. Meanwhile, she was responsible for the development and establishment of workshops and programs to attract middle- and high-school students to engineering, including the Attracting Women to Engineering Summer Program, Engineering Clinics for Teachers and Project Lead the Way.

Dorland's technical achievements, her inspiring attitude and clear understanding of what is important in technical and professional excellence make her a deserving candidate for this award.

Honoree: Fabio Bravo

Fabio Bravo works for The Dow Chemical Co. as the process engineering technical manager for the Sadara project, which is the largest petrochemical project in history. Sadara is a grassroots project to simultaneously build 26 chemical plants in Jubail (Saudi Arabia) as a joint venture between Dow and Saudi Aramco.

Bravo's chemical engineering career has focused mainly on process design for projects and mega projects around the world. He participated in all the phases, from conceptual design to startup, of the Optimal Mega project in Kerteh (Malaysia), and he lived in Malaysia for about three years for the detailed design, construction and startup of the project. Bravo also worked in the conceptual design and front-end engineering and design (FEED) for the Direct TMS project in Termoli (Italy), which received this magazine's prestigious 35th Kirkpatrick Award.

Bravo is very passionate about chemical engineering, especially about plant design, and he is well known in the industry and in the process engi-

2012 CHEMINNOVATIONS AWARDS

The annual ChemInnovations Awards are a cooperative effort between *Chemical Engineering* and the ChemInnovations Advisory Committee. An industry-wide call for nominations is issued early in an award year and announced in *Chemical Engineering*. Once the nomination period has closed, award nominations go through two rounds of judging. First, the ChemInnovations Advisory Committee will review nominations and rate each based on specific and measurable criteria. After receiving ratings, the editors of *Chemical Engineering* complete the second and final round of judging.

Safety Investment Award. Braskem S.A. (Sao Paulo, Brazil; www.braskem.com) won the Safety Investment Award for its work in developing a method for providing actionable measurements of toxic fugitive emissions. The Braskem approach, which goes beyond regulatory safety requirements, combined a mass spectrometer and a total hydrocarbons detector to monitor very low levels of target compounds and the total concentration of organic materials at 90 different locations. The system allows fast location of toxic emissions and results in a more leak-tight plant.

Community Service Award. The Community Service Award was given to LyondellBasell (Houston; www.lyondellbasell.com) for its Global Care Day, a volunteer activity that executed 70 single-day projects in local communities. The projects are focused on education, environmental conservation and community prosperity.

Innovative Energy Use Award. For its energy-saving technology for turbo-charging air-oxidation processes, Perstorp AB (Perstorp, Sweden; www.perstorpformox.com), formerly known as Formox AB won the Innovative Energy Use Award.

Plant Manager of the Year Award. The Plant Manager of the Year award went to Chris Witte, head of the BASF SE (Ludwigshafen, Germany; www.basf.com) facility in Freeport, Tex. for his proactive management approach and inspirational attitude.

Education Outreach Award. The Education Outreach Award was awarded to UOP for its program to foster mathematics and science education in the Chicago metropolitan area and around the state of Illinois. Highlights of the diverse program include the "You Be the Chemist Challenge," an innovative educational competition for students in grades five through eight, revolving around chemistry concepts, laboratory safety and scientific discoveries.

Early Adopter Award. The Early Adopter Award was awarded to Dow Chemical, for its use of *ab initio* modeling in engineering design. The Dow-developed mechanistic kinetic model of chlorination and cracking chemistry associated with allyl chloride production was used in the design and optimization of a novel allyl chloride reactor.

Unit Operations Award. The Unit Operations Award was presented to Jerry R. Johanson, a pioneer in the solids processing field whose work has help prevent solids flow problems.

Best Plant Improvement Award. The Best Plant Improvement award went to Houston Community College's Suhas Divekar, who invented a new process dynamics system-identification algorithm for industrial applications. ❑

Scott Jenkins

neering community. He is very proud of the contributions that chemical engineers make to society and understands the role that chemical engineers play in solving some of the biggest issues of our time — supply of water, food and goods for a growing and more demanding population around the world and related environmental impact, to just mention a few. Bravo's passion for chemical engineering and specifically for plant design is contagious, and as such he has coached and mentored many process engineers during his career, including not only Dow process engineers, but also engineers from engineering and petroleum refining companies. For several years he has been involved with organizations that have a vision to promote scientific careers in underserved communities.

Bravo has about 28 years of chemical engineering experience and is the author of several papers in a variety of chemical engineering topics. He holds a B.S.Ch.E from Universidad Pontificia Bolivariana (Colombia) and an M.S.Ch.E. from Rice University.

Honoree: Steve Donen

Currently serving as vice president for process development and engineering at renewable chemical company Rivertop Renewables, Steve Donen has more than 30 years of experience in the chemical process industries (CPI), including executive leadership positions in manufacturing, engineering and technology development. Throughout his extensive career, Steve has led numerous teams to look for and bring innovative, efficient and effective engineering solutions to the CPI

In early 2012, Donen led the successful scaleup of Rivertop's proprietary platform oxidation technology (*CE*, January 2010, p. 16) from the laboratory to contract manufacturing. He will continue directing these efforts to enable Rivertop to produce 10 million pounds of contract-manufactured glucaric acid products per year for use in the corrosion inhibition and detergent builders markets. Also, Rivertop is currently constructing a semi-works facility at the company's headquarters in Missoula, Montana, which will allow Rivertop to prove the company's continuous low-cost process technology at a size scalable to a world scale manufacturing plant.

Prior to joining Rivertop in January 2011, Donen served as director of process development and engineering at Segetis, a startup company that is developing bio-based industrial materials in the areas of adhesives, additives and polyols. There, he lead construction of the company's first-ever ketal-technology semi-works facility, which at full capacity can produce up to 250,000 lb/yr of renewable chemicals and products and has successfully demonstrated the new technology at a capacity that can be easily scaled to a world-scale manufacturing plant.

Prior to Segetis, Steve spent 13 years with NatureWorks LLC (previously known as Cargill Dow LLC) as director of Manufacturing Technology & Engineering. At NatureWorks, he led the cross functional team in developing, designing, constructing and starting up the first-ever world-scale polymer plant that makes plastic from corn and garnered this magazine's 2003 Kirkpatrick Award.

Honoree: Charles Easley

Charles (Chuck) Easley is a senior process engineer at BSI Engineering. After graduating from Purdue in 1961 with a B.S.Ch.E., he began his long career not with chemistry, but with military service in Rickover's nuclear Navy. He left the mid-West to work on the world's first nuclear-powered aircraft carrier, the USS Enterprise. That was his first foray into what would later be considered "alternative fuels."

Following his military duty, he joined Proctor & Gamble. While a full time product development engineer, he received his M.S.Ch.E., attending evening classes at the University of Cincinnati. He then joined Raphael Katzen Associates, earned his professional engineer certification, and has spent a lifetime helping design and start up dozens of chemical plants. Meanwhile, Easley is a past chair of the Ohio Valley AIChE Chapter.

His career reflects the diversity of the ChE profession itself. In designing different chemical plants, Easley has worked on a broad range of technologies, including pharmaceuticals, hydrogen cyanide, molten phenol and partially polymerized acrylic syrup. He was instrumental in developing a design for the recovery of sulfur dioxide from fluegas. However, where he really excelled was in alternative fuels.

Easley played a key role in developing the modern large-scale fuel-ethanol industry. While at Katzen Associates, where he eventually rose to vice president, Easley designed some of the first grassroots plants for production of ethanol from corn. His other fermentation work included designing a pilot plant system for evaluating fed-batch mode for conversion of waste cellulosic fiber to ethanol using simultaneous saccharification and fermentation technology. In the last few years, his work has included barley to ethanol, wood cellulose to butanol, plasma conversion of spent coal to syngas, heterotrophic algae to biofuel, and new technology using iodine for the purification of polysilicon for solar cells.

Easley's technological contributions alone warrant merit. However, it is his attitude and willingness to mentor others that sets him apart, says his colleague Jim Daly, process dept. manager at BSI Engineering. "In my 30-year career, I've never worked with a more dedicated, erudite engineer." ■

Rebekkah Marshall

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SIMULATION FOR THE MASSES

AspenTech

FIGURE 1. With it's most recent simulation tools, AspenTech has taken leads from Microsoft, and switched from toolbars and menus to ribbon-type formatting because it makes the software faster and easier to use

Simulation tool use expands beyond design and into day-to-day optimization projects

While almost all chemical processors employ simulation software during the early design stages of new plants or new lines, simulation vendors say best-in-class facilities take the powerful tools further and use them for improving operations and profitability. And, across the board, software providers are working hard to make their most recent applications more user-friendly and accessible, so that more engineers and operators can take advantage of these available and advanced engineering tools.

"What we see and hear from others in the industry is that 80% of users of simulation software tend to use only 20% of the capability of the software," says Steve Brown, executive vice president and chief operating officer with Chemstations Inc. (Houston; www.chemstations.com). "All software providers are adding great new features that can do powerful things, but the adoption rate of those features is slow, so we're all trying to address that."

For example, Chemstations' newest product CHEMCAD 7, which is slated for launch in the summer of 2013, will include a ground-up rebuild of the graphical user interface. "We've learned a lot about the chemical engineering computing environment and workflow in the last 25 years and we'll be using the latest software-development tools to take advantage of computing power and operating system efficiencies. Chemstations has spent a lot of resources to address making the tool easily understood and used."

Invensys Operations Management

FIGURE 2. This image shows the transparent view of a gasifier operation from IGCC 3D, virtual immersive-training system

AspenTech (Burlington, Mass.; www.aspentech.com), too, is working toward these same goals. Their latest release, in February of 2012, offered a completely new user interface. "Our goal was to make it much easier for the average process engineer to use a process simulator," says David Tremblay, senior director, product management with AspenTech. "Traditionally simulators were made for folks with a background in programming, but we are really working hard to make it more accessible to people with an understanding of engineering, but not programming."

He says they've taken leads from Microsoft, which switched from toolbars and menus to ribbon-type formatting because it makes the software faster and easier to use. Software is now divided into different environments for different types of users to make it less complex, less busy and less confusing.

Very soon, AspenTech expects to release a newer version, which promises an extremely close integration between simulation and other types of analysis like energy-use optimization and economic optimization.

Similarly, Tobias Scheele, vice president of advanced applications with Invensys Operations Management (Houston; iom.invensys.com), says not only are they working on ease of use but also on "making software fit for a purpose."

"You don't always need a sledgehammer to get the nail into the wall," he says. "So we are focused on providing the right level of sophistication for each user. Not everyone uses this type of software every day, so we're trying to simplify it for engineers with more generic backgrounds who will only use it on occasion."

Invensys Operations Management

FIGURE 3. Emergencies such as gas leaks can be simulated to improve operator response and increase safety

Simulation beyond design

So, why the push to bring simulation to the chemical engineering masses? Vendors say there is much more to these tools than designing a process. "When talking about simulation, there are really two areas: design and operations/optimization," says Scheele.

While the design stage is obvious, that area, too, is becoming more detailed as software advances. "In the past it was used for quick optimization for process economics, to maximize return on investment or optimize the capital investment," says Chemstations' Brown. "But now process designers can use it during this stage to optimize energy efficiency and environmental impact along with process economics, thanks to more powerful tools used at earlier stages of design."

But, because there are many processes already existing in the world, the use of simulation tools shouldn't stop following design. "Dynamic simulation is the next step," notes Invensys' Scheele. "Key equipment and key process areas require constant studies to make sure engineers have an understanding of how each piece of equipment impacts the rest. They should know how the operating envelope is performing. He says strong dynamic simulation packages allow users to test control systems in a safe environment. They can also be used for operator training.

A very crucial area these days is in optimization of the plant and its processes, say the experts. "The latest tools allow you to connect a simulation directly to process control, SCADA and DCS systems, which opens up a whole new world of capabilities for performance monitoring and online optimization," explains Brown. For example, if you have an existing process and you have a flowsheet in one of the simulators where you know the optimum conditions, you can compare it to the field and see if the process is diverging from design specs online in realtime.

Scheele agrees that this is a very important tool for today's chemical processors. "The reality of today's operating environment is that processors need to squeeze out the process so they can be profitable, and that's all about optimization," he says. He says often engineers can examine a few process variables to see if they are running optimally, but because there are potentially hundreds of variables related to setpoints, flowrates and such, it's nearly impossible to understand the complete impact of one variable on the entire process. "Optimization tools can do this. It takes all the plant data, provides error detection, steady state detection and optimizes against an objective function such as quality, price point, or anything else you want to define; and then it tweaks the variable you want to tweak within the boundaries you allow," explains Scheele. "From there it gives you an optimal point to say what variables you can change to get a more optimized process or earn more money on the process."

The benefits of using simulation for process optimization can be remarkable. Ron Beck, product marketing director for engineering products at AspenTech, says some of their customers who have had debottlenecking or process-line improvement projects and have made use of the ability of today's simulation tools found solutions that they hadn't even considered as a possibility in just a few days' time. In one case a cost savings of tens of millions of dollars was achieved from one process unit, and in another, $100 million was saved. "We're talking about decisions that could not and would not have been made without simulation. And the fact that these decisions were made on a such a shortened cycle demonstrates the ability of simulation to provide both major savings and significant process improvements for chemical companies," notes Beck.

With potential like that, software providers say that simulation tools should be used more widely throughout the plant. "Everyone needs to know how to use these tools and use them effectively if the plant wants a sustainable future. So we are working on making tools that can and will be used up and down the organization, not just one that will be used once to design a process and put on a shelf." ❑

Joy LePree

SIMULATION PRODUCTS

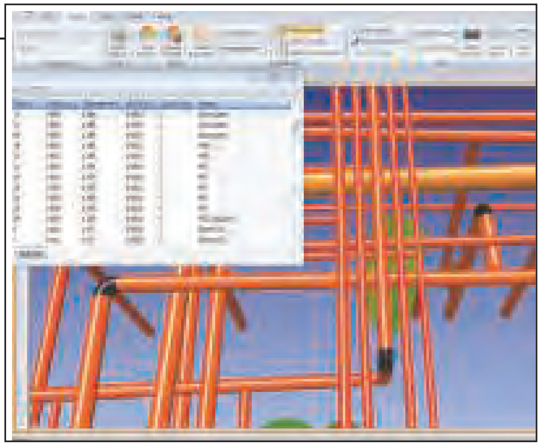
Design software uses symbolic components and computation

Wolfram SystemModeler provides a high fidelity modeling environment that uses symbolic components and computation to drive design efficiency. The program integrates with the Wolfram technology platform to enable modeling, analysis and reporting to achieve a fully agile design-optimization loop. Many of today's tools are limited in their fidelity by their foundations: using block diagrams that poorly represent key components, and product models just for simulation and not engineering analysis. Computation is numerics-only or not integrated. The SystemModeler approach of versatile symbolic components, backed by the computation environment, enables an all-in-one integrated workflow. — *The Wolfram Group, Champaign, Ill.*
www.wolfram.com

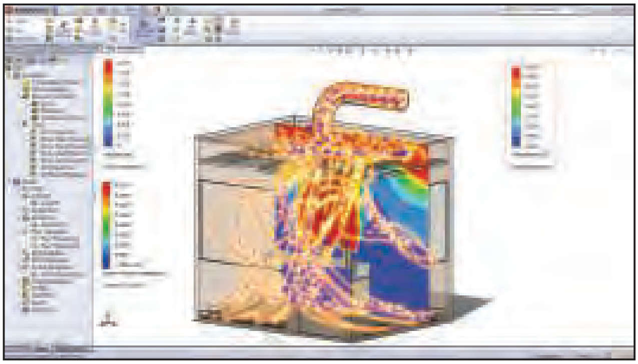
Simulation simplifies liquid and gas analysis

SolidWorks Simulation provides a complete range of tools for analyzing the structure, motion and multiphysics of parts and assemblies or exploring fluid dynamics and heat

ClearEdge 3D



Dassault Systemes SolidWorks



flow around and through a design. SolidWorks Flow Simulation software provides powerful computational fluid-dynamics tools that allow users to quickly and easily simulate fluid flow, heat transfer and fluid forces that are critical to a successful design. The software allows users to inspect and optimize complex flows, find the best dimensions or flow conditions, detect turbulences and re-circulation issues with animated bands, 3D arrows, pipes or spheres using flow-trajectories visualization, understand the flow of non-Newtonian fluids and include sophisticated effects like porosity, cavitations and humidity. — *Dassault Systemes SolidWorks Corp., Waltham, Mass.*
www.solidworks.com

Software enables realtime monitoring and prediction

PlantPAx ModelBuilder enables real-time monitoring and prediction of process characteristics that are critical to peak performance. The result is improved production efficiency, reduced product variability and waste and increased profitability. This empirical and modeling data-analysis tool was designed to create Soft Sensors for use in industrial control applications. A Soft Sensor is a model that predicts process values based on realtime process data. Soft Sensors provide virtual measurements of variables that are difficult to measure by physical devices due to the limited reliability and associated costs. This model supplements traditional laboratory measurements by reducing the time interval needed to supply results from hours to minutes. ModelBuilder can also be used in “offline mode” to better understand process behavior by analyzing complex linear and nonlinear processes. Using the historical process data, the analysis tools can extract, clean and model historical process data to gain insight into the key process variables that most affect quality. — *Rockwell Automation, Milwaukee, Wis.*
www.rockwellautomation.com

Cloud-based dynamic simulators for access & agility

These Virtual Dynamic Simulators bring the value of the Virtual Plant, using MiMiC Simulation Software, into the world of cloud computing. Using the same technology implemented in public cloud enterprises, the private cloud implementation allows flexible access and agility, but behind the security of the end user’s firewall. Simulators using VMWare virtualization technology provide reduced training- and development-system hardware requirements, protection of dynamic simulation to control system simulator communications through the use of virtual LAN implementations, one-button startup of training or development systems, greater security and availability for the training and development system, flexibility to handle multiple control-system implementations and dynamic models in the same system, flexibility to allow training of development systems from any networked PC or thin client, and the ability to handle system expansions and upgrades with minimal hardware investments. — *Mynah Technologies, Inc., Chesterfield, Mo.*
www.mynah.com

Software provides enhanced pipe extraction

EdgeWise Plant 3.0 has new features that optimize and accelerate 3D modeling workflows. The software automates the extraction of complex CAD pipe geometry from 3D laser-scanned data, reducing time to create accurate, as-built, 3D models of process plant facilities. Features include 64-bit multicore processing that extracts pipes up to 12 times faster than previous releases; quality assurance tools that allow firms to validate the accuracy and fit of every pipe; improved extraction algorithms that identify nearly all pipes in the scene; automated finishing tools to quickly connect pipe runs and fit any missed pipes to the point cloud; SmartSheet technology that extracts key pipe intelligence such as OD, length and bend into a worksheet and exporting of pipes to layers or levels in AutoCAD, MicroStation or Cyclone. — *ClearEdge 3D, Herndon, Va.*
www.clearedge3d.com

Calculate pressures when pipes are submerged

AFT Fathom is a fluid dynamic-simulation software for engineers, used to calculate pressure drop and flow distribution in liquid and low-velocity gas piping and ducting systems. AFT Fathom accurately simulates individual system components and their interaction, tightly integrates equipment characteristics, analysis and output with a system’s schematic representation and improves the quality of systems engineering, leading to less costly, more-efficient and more-reliable piping systems. AFT Fathom 8 offers new features such as a heat transfer model that models simultaneous convective and constant heat-flux loads, and the ability for engineers to specify ambient pressures, which vary with elevation, allowing more precise gauge pressure predictions. — *Applied Flow Technology, Colorado Springs, Colo.*
www.aft.com ■

FOCUS ON

Mechanical Conveying

Volkmann

Anver

GEA Wiegand

This weighing system can incorporate up to three loadcells

The Conweigh (photo) weighing system complements this company's VS and PPC Series of vacuum conveyors, and can accurately weigh powders, granules, food particles, pellets, capsules and other bulk materials that are being transferred into and out of production processes. The unit registers weight to within ±1% or better, allowing adjustments to be made to avoid weight gain or losses during transfer. Conweigh can work with one, three or four load cells, depending on the production application. For weighing into vacuum conveyors, Conweigh is available in two configurations: a single loadcell to accompany the company's VS or PPC200 and 250 conveyor models, and three load cells for the VS or PPC350 and 450 models. — *Volkmann, Inc., Hainesport, N.J.*

www.volkmannusa.com

A better, safer way to lift bags

The vacuum-tube (VT) Series Bag Lifter (photo) is said to provide an ergonomically sound alternative to manual lifting, for loading and unloading bags and sacks from skids, pallets and conveyors. Developed for production use, this vacuum-operated bag or sack lifter provides 100% duty cycle, features instant attach and release, and speeds bag-handling operations. The Bag Lifter is constructed from stainless steel for washdown environments, and has an ergonomic handlebar with fingertip controls. The vacuum pad attachments have foam-rubber sealing rings, and the housing is available in plastic or stainless steel. The lifter is suitable for 50-, 100- and 125-lb bags. — *Anver Corp., Hudson, Mass.*

www.anver.com

A liquid helps move solids with this jet pump

Liquid-jet solids pumps are jet pumps that, with the help of a motive liquid, can convey flowable granular material. The motive liquid (usually water) flows at high velocity out of the motive nozzle into the mixing chamber of the pump, thereby entraining the material that is present in the mixing chamber. The mixture of liquid and solids can be conveyed directly to the point of application, by pipe or hose, without the need of another pump. Liquid-jet solids pumps are used for conveying sand, gravel, activated carbon, ion-exchange resins and other solids. They can also be used for filling and emptying reactors, in the decarbonizing and neutralizing units of water plants and for mixing in precipitating agents during the treatment of sludge and effluent. These pumps can also be supplied as mobile units complete with hopper and rinse-water connection (photo). — *GEA Wiegand GmbH, Ettlingen, Germany*

www.gea-wiegand.com

Dust-free handling of empty bags without product waste

The Manual Dump System collects dust generated during manual dumping, compacts empty bags and conveys bulk material downstream. The dust-free system consists of a receiving hopper, dust collector and flexible-screw conveyor. A bag infeed chute through the sidewall of the hopper hood allows the operator to pass empty bags directly into the compactor, causing dust generated from both the dumping and compaction to be drawn into the system's two cartridge filters. An automatic reverse-pulse filter-cleaning system releases short blasts of compressed air regularly, causing dust buildup on the outer surfaces to fall into the hopper, thereby conserving usable product. The compactor ac-

Note: For more information, circle the 3-digit number on p. 60, or use the website designation.

Modern Process Equipment

commodates 50 to 80 bags. The hopper discharges into an enclosed, flexible screw conveyor, designed to handle a wide range of materials, including free- and non-free-flowing bulk materials from large pellets to sub-micron-sized powders. — *Flexicon Corp., Bethlehem, Pa.*
www.flexicon.com

Gentle conveying of heavy loads
The Chain-Vey tubular drag conveyor (photo) has been proven to convey hundreds of different products, including ingredients for cement. The system transports products gently and efficiently, both vertically and horizontally, in a dust-tight environment without product degradation or declassification, says the manufacturer. Other features include a case-hardened carbon-steel link chain to convey high bulk densities (cable systems cannot handle the load) and XP (explosion-proof) rating upgrading capability. Systems are available for handling 650, 1,000 and 1,400 ft^3/h. — *Modern Process Equipment (MPE), Chicago, Ill.*
www.mpechicago.com

Eriez Manufacturing

These feeders handle up to 850 ton/h
The Heavy Duty Electromagnetic Vibratory Feeders (photo) are suitable for handling coal, ore, aggregates, slag or whenever high-volume, controlled feeding is required. The feeders feature an energy-saving intermeshed a.c./permanent magnet drive. The feeders are available in nine models with capacities of up to 850 ton/h, and can be supplied with overhead drives, multiple-drive arrangements, "grizzlie" decks and dust covers to meet users' application requirements. They feature an electromagnetic design that has no moving parts, such as shafts, cams or bearings, thus eliminating the need for lubrication. Controls come standard in NEMA 12 enclosures for dusty environments; other enclosures are also available. — *Eriez Manufacturing Co., Erie, Pa.*
www.eriez.com

David Round

A jib crane for pharmaceutical manufacturing
These new all-stainless-steel articulating jib cranes (photo) are ideal for lifting bulk bags or other materials (up to 1,000 lb) in cleanroom environments. Explosion-proof models of these jib cranes are available to meet electrical standards required in hazardous-environment processing areas. The cranes feature fully enclosed mechanical components, including wire-rope hoist, gearbox and motor drum. Lift height and boom/knuckle configurations can be varied to meet user specifications. Structural components are prepared with a glass-bead finish that is applied in a dedicated, in-house metal-treatment facility. This results in smoother, more hygienic surfaces that are free of imperfections, such as weld scars, says the manufacturer. — *The David Round Co., Streetboro, Ohio*
www.davidround.com

These sanitary receivers are easy to clean
The P-Series Sanitary Receivers are designed to convey difficult powders for continuous conveying applications, such as hopper loading and loss-in-weight feeder refill applications, that require a high level of sanitary design and frequent cleaning. The receiver body is made of stainless steel (DIN 1.4404, AISI 316L), with internal and external electro-polished surfaces. Modular design allows for easy disassembly and cleaning. Tri-Clover fittings allow for quick disconnection from the conveying and vacuum piping. All units have reverse-jet filter cleaning. Models available include P-10, P-30 and P-100 with conveying rates of up to 4,000 kg/h (8,800 lb/h). — *K-Tron, Salina, Kan.*
www.ktron.com ■

Gerald Ondrey

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Wet Scrubbers

Wet fluegas desulfurization (FGD), also known as wet-scrubbing, is a popular pollution-abatement technique for removing acid gases, such as SO_2 and HCl from fluegas produced during coal-fired power generation and industrial combustion processes. Wet scrubbing is used in association with power generation, thermal oxidizers, kilns, incinerators, boilers, foundries and other combustion units. Also, wet-scrubbing can be used to treat other sulfur- or acid-laden fluegas streams produced in petroleum refining, metal smelting, gas processing and other chemical and pharmaceutical operations. The reliable operation of wet scrubbers has a direct impact on a facility's ability to ensure regulatory compliance with mandated SO_2 limits. Problems with the mist eliminators can lead to unplanned or excessive downtime of the wet-scrubbing system.

Operation

In a wet-scrubbing system, an incoming sulfur-laden exhaust stream is contacted by a circulating stream of an alkaline solution (most often a slurry of caustic reagents). Contact between the two streams converts the acid gases in the exhaust to neutral salts and other solid byproducts that are eventually removed. The pH of the resulting fluegas is 7–8. The most widely used reagents are lime and limestone. With such an approach, calcium hydroxide or calcium carbonate is used to convert SO_2 to calcium sulfate or calcium sulfite, which precipitate out of solution as a sludge.

There are different scrubber configurations available, but most involve multiple sprayers with high-pressure nozzles that atomize the scrubbing liquid into a fine mist of reactive droplets. The extreme surface-area-to-volume ratio of the droplets maximizes contact between the acid-laden fluegas stream and the alkaline scrubbing solution, which promotes mass transfer of the pollutants from the gas phase to the liquid, and thus promotes the neutralizing reactions.

Mist eliminators

Wet scrubbers are notoriously capital- and maintenance-intensive. An integral part of most wet FGD systems are the mist eliminators, and the ongoing maintenance and frequent replacement of these components is to blame for a large portion of the overall operating costs of a wet scrubber system.

The role of the mist eliminators (which are installed near the top of the spray tower) is to remove the fine droplets of alkaline reactant that become entrained in the fluegas stream inside the tower during operation. Chevron-shaped mist eliminators take the fluegas stream on a convoluted path, forcing the entrained droplets to contact the baffle plates and coalesce into larger droplets, which then fall back into the vessel.

TABLE 1. MIST ELIMINATOR PERFORMANCE PROFILE

	Polypropylene	Vinyl ester FRP	Polysulfone	Stainless steel
Relative installed cost	1.0	2.3	2.8	4.8
Melting/softening point*	320°F	212–260°F	365°F	2,550°F
Oxidative stability (longterm temperature)	149°F	266°F	284°F	Not a limitation
Relative ease of cleaning	Difficult	Most difficult	Easiest	Most difficult
Failure modes	Melting and loss of strength	Delaminating and damage from cleaning	Loss of ductility	Pitting

*FRP materials maintain significant mechanical properties above their softening point, polysulfone gradually and polypropylene forms a viscous melt.

Material selection

Wet scrubbers create hot, corrosive conditions, such as sulfuric acid attack, as well as the presence of fluorides and chlorides. Because of these conditions, material selection is important. The presence of flyash and other particulate matter makes the environment erosive as well. Solids buildup occurs for all choices of alkaline.

Mist eliminators are available in a variety of materials, including polypropylene (PP), fiber-reinforced polymer (FRP), stainless steel (SS) and polysulfone. Each material has distinct advantages and disadvantages.

Polypropylene is the lowest-cost option (on a material cost basis). It has broad chemical resistance to both acidic and alkaline substances present in a wet scrubber. It is the most widely used among the polymer-based options for mist eliminators.

Fiber-reinforced plastic consists of a vinyl ester or polyester resin matrix, to which continuous glass fibers are added for structural reinforcement. FRP has lower costs than corrosion-resistant metals, and possesses broad corrosion and chemical resistance. The material is also lightweight, but with good rigidity and load-bearing capabilities.

Polysulfone is a engineering polymer that has higher costs than PP and FRP, but a number of factors justify the higher cost over the course of its lifetime. These factors include broad resistance to hydrolysis and oxidation in the hot, moist and acidic environment, plus toughness and other mechanical properties.

Polysulfone has performance advantages over the other materials, including improved short-term thermal properties, greater long-term load-bearing capacity and stiffness at elevated operating temperatures, and better resistance to fouling and oxidative attack by the alkaline-scrubbing reagents and acid gases found inside the wet scrubber.

Polysulfone also has lifecycle cost advantages over the competing materials. Extensive use of polysulfone for wet scrubber mist eliminators has been shown to significantly reduce the number and duration of routine cleaning cycles, trim operation and maintenance costs, and to extend the overall service life of the mist eliminator components, and improve the longterm reliability of wet scrubbing systems.

Stainless steel is the most costly material for mist eliminators, although it does confer additional mechanical strength and rigidity. Stainless-steel mist eliminators are perceived to be easier to clean because the water blasters used to remove solids buildup can be set at higher pressures. However, the ease of cleaning can be somewhat of a misperception because stainless steel is susceptible to oxidative attack and pitting.

Common failure modes for the prevailing materials are melting and distortion from loading (PP), pitting and corrosion (SS) and delamination and overall degradation (FRP).

Fouling

Mist eliminators experience problems mainly in two categories: A) fouling and corrosion; and B) heat-related damage to the mist eliminator components. Fouling occurs when solids and salts produced in the wet-scrubbing process accumulate on the chevron mist eliminators. Solids buildup on the surfaces of the mist eliminator can close off the available open area within the chevron baffles, leading to increased pressure drop and reduced collection efficiency. Material accumulation can also result in excessive mechanical loads, which can present problems for polymeric materials that lose mechanical strength in hot, corrosive conditions. For example, PP can experience softening and melting when exposed to prolonged high temperatures.

Acid gases in combustion fluegas are converted to calcium sulfate ($CaSO_4$) and calcium sulfite ($CaSO_3$), which precipitate and accumulate on the surfaces of the mist eliminator. Calcium sulfite is relatively easily washed from any surface, but calcium sulfate tends to form a harder precipitate. Periodic manual cleaning of mist eliminators is necessary despite measures to reduce scaling and fouling.

Corrosion occurs as a result of oxidative and chemical attack to the surfaces and crevices of mist eliminator components.

Editor's note: This edition of "Facts at Your Fingertips" was adapted from the article "Controlling SO_2 Without Corroding the Bottom Line," by Bill Looney, Brian Baleno and others, appearing in the January 2008 issue of *Chemical Engineering*, pp. 30–37.

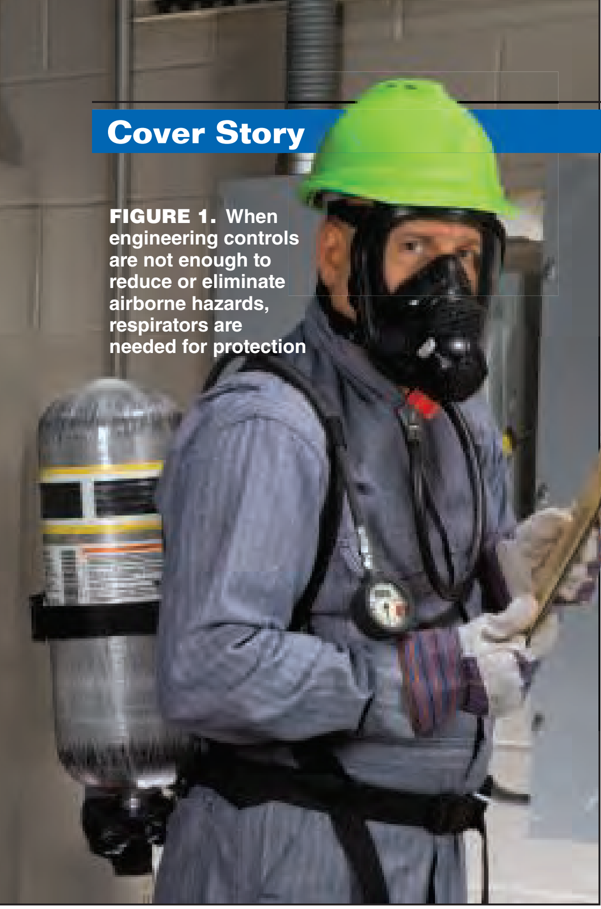


FIGURE 1. When engineering controls are not enough to reduce or eliminate airborne hazards, respirators are needed for protection

Clearing the Air About Respiratory Protection

Learn the basics about selection and regulatory compliance for these potentially life-saving devices

Dennis Capizzi
MSA Safety

Airborne respiratory hazards are a very real threat in the chemical process industries (CPI). Existing in a variety of forms including gases, vapors, dusts, mists, fumes, smoke, sprays and fog, such hazards can cause illnesses including cancer and lung impairment, or even death. Examples of respiratory hazards include combustion byproducts; toxic fumes or dust created by metal melting; ozone and nitrogen oxides from processes involving an electric discharge in air; and dust particles released by grinding (notably dry grinding such as blasting) and crushing applications, and the transport, sieving, mixing or screening of any dry material.

The specific hazardous gases present in a workplace will, of course, vary according to the processes of the facility, but commonly include chlorine, chlorine dioxide, ammonia, nitrogen dioxide, nitric oxide and volatile organic compounds (VOCs). Some hazardous gases, such as carbon monoxide, act rapidly and can cause unconsciousness or death within minutes, while other toxic gases can take years to produce noticeable harm.

Where toxic substances are present in the workplace and engineering controls (such as enclosing or confining the contaminant-producing operation, exhausting the contaminant, or substituting with less toxic materials) are inadequate to reduce or eliminate them, it is time to turn to respirators (Figure 1).

What is a respirator?

A respirator is a protective device that covers the nose and mouth or the entire face or head to guard the wearer against hazardous atmospheres. Respirators may be either tight-fitting or loose-fitting. There are two types of tight-fitting respirators: "half masks" cover the wearer's mouth and nose, while "full facepieces" cover from the hairline to below the chin (Figure 2). Loose-fitting respirators include hoods and helmets that cover the head completely.

The OSHA standard

The appropriate use of respiratory protection is not only important for worker health and safety — in the U.S., it is the law. The U.S. Occupational Health and Safety Administration (OSHA) is the main federal agency charged with the enforcement of safety and health legislation in the U.S. Much of this legislation is written in the form of standards. OSHA standards are rules designed to provide a work environment free from known dangers or hazards. They require the use of certain safe practices and equipment, and assign employers the responsibility of monitoring hazards and keeping records of workplace injuries and illnesses. Compliance with OSHA's standards is mandatory and is stringently enforced.

In 2011, "Respiratory Protection, General Industry (29 CFR 1910.134)" was OSHA's fourth most frequently cited standard violation. Standard 29 CFR 1910.134 covers the respiratory protection division of the personal protective-equipment category. Essentially, it details the requirements for compliance in workplaces where respiratory hazards are a potential threat (Figure 3). The aforementioned statistic reveals that too many workers are not employing appropriate protection from respiratory hazards on the job. According to OSHA, an estimated 5 million workers are required to wear respirators in 1.3 million workplaces throughout the U.S.

FIGURE 2. This is an example of a full-facepiece respirator that covers the wearer's face from the hairline to below the chin

The role of ANSI

In addition to OSHA, another driving force in the regulatory arena is the American National Standards Institute (ANSI). As a voice of the U.S. standards and conformity assessment system, ANSI's mission is to enhance both the global competitiveness of U.S. business and quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems, and safeguarding their integrity, in an effort to protect workers.

ANSI thus provides a neutral forum for the development of policies on standards issues and serves as a watchdog for standards development and conformity assessment programs and processes [*2*]. ANSI/AIHA Z88.2 "Standard Practices for Respiratory Protection" is a voluntary consensus standard drafted by the ANSI Z88 Committee on Respiratory Protection [*3*]. This standard is significant, as it addresses the issue of assigned protection factors (APFs). APFs are the main factor used by many employers when they select respirators for worker protection from airborne hazards. The ANSI standard recommends protective factors that are very similar to those of OSHA, except for a more conservative APF for filtering facepieces (disposable respirators). The standard also addresses other key issues regarding the proper use of respiratory protection in the workplace, including the following:

- Respiratory protection program requirements
- Standard operating procedures for programs
- Respirator selection, limitation and use
- Training
- Fit testing
- Maintenance, inspection, storage and disposal
- Breathing air and oxygen-deficient atmospheres
- Recordkeeping

Establishing a program

The fundamental goal of any respiratory protection program is to control occupational diseases and injuries caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smoke, sprays and vapors. The defense against these contaminants is simple: keep them out of the worker's breathing air.

Engineering and administrative controls, which have the potential to completely eliminate the hazard, must always be implemented first. These include actions such as enclosing or confining the contaminant-producing operation, exhausting the contaminant, or substituting the contaminant with a less-toxic material. Work practices such as limiting employee exposure should also be considered. If these controls do not eliminate the hazards, then employers must provide appropriate respiratory protection for every employee who might be exposed to them.

Whenever OSHA standards or employers require respirator use, there must be a complete respiratory protection program in place. Employers must have written operating procedures to ensure that employees use the respirators safely and properly. Users must be familiar with these procedures as well as the types of respirators available and their limitations.

A qualified program administrator. First of all, a qualified program administrator must be responsible for the program. This person must know enough about respirators to supervise the program properly. Larger plants or companies with industrial-hygiene, in-house medical, safety-engineering or fire-prevention departments should administer the program in liaison with the program administrator. In smaller plants that do not have specialists, an upper-level superintendent, foreman or qualified person must serve as the program administrator.

Employee training. Any respirator program should stress thorough training of all respirator users. Employees must be aware that a respirator does not eliminate the hazard. If the respirator fails, the user will be overexposed to dangerous substances. To reduce the possibility of failure, the respirator must fit properly and be maintained in a clean and serviceable condition. Employers and employees must understand the respirator's purpose and limitations. Users must not alter or remove the respirator even for a short time, regardless of its potential discomfort.

Regular evaluation. Employers must evaluate the effectiveness of their company's respirator program regularly and modify the written operating procedure as necessary to reflect the evaluation results. Workplace conditions that affect respiratory hazards and respirator use may change over time. This would include new work processes or techniques, the use of new or different materials or chemicals, changes in the amount of a respiratory hazard present in the workplace and changes in the types of respirators being used. The written program must therefore be updated as necessary to reflect and address these changes. Employees should always notify their employer if a change in the workplace occurs that conflicts with, or may not be covered by, the existing respirator training or established workplace policies or procedures.

Choosing the correct respirator

Selecting the right equipment is a three-step process:

1. Define the hazard and determine its extent.
2. Evaluate user factors that affect respirator performance and reliability.
3. Select an appropriate respirator that is certified by the National Institute for Occupational Safety and Health (NIOSH) [*1*]. Note that equipment

must always be used in accordance with the specifications accompanying the NIOSH certification.

When selecting respirators, employers must consider the chemical and physical properties of the contaminant, as well as the toxicity and concentration of the hazardous material and the amount of oxygen present. Other selection factors are the nature and extent of the hazard, employee work rate, the size of the area to be covered, worker mobility, work requirements and conditions, and the limitations and characteristics of the available respirators.

Air-purifying respirators use filters or sorbents to remove harmful substances from the air. They range from simple disposable masks to sophisticated devices. They do not supply oxygen and must not be used in oxygen-deficient atmospheres or in other atmospheres that are immediately dangerous to life or health (IDLH).

Atmosphere-supplying respirators are designed to provide breathable air from a clean air source other than the surrounding contaminated work atmosphere. They include self-contained breathing apparatus (SCBA) units (Figure 4a) and supplied-air respirators (SARs; Figure 4b).

The time needed to perform a given task, including the time necessary to enter and leave a contaminated area, is an important factor in determining the type of respiratory protection needed. For example, SCBAs, gas masks, or air-purifying chemical-cartridge respirators provide respiratory protection for relatively short periods. On the other hand, an atmosphere-supplying respirator that supplies breathable air from an air compressor through an air line can provide protection for extended periods.

If the total concentration of airborne particulate matter is low, particulate-filter air-purifying respirators can provide protection for long periods without the need to replace the filter. Where there are higher concentrations of contaminants, however, an atmosphere-supplying respirator such as the positive-pressure SAR offers better protection for a longer time.

Since they use an independent air source, SARs eliminate the need for concern about filter breakthrough times, change schedules, or the use of end-of-service-life indicators (ESLIs) for airborne toxic materials — factors that must be considered when using air-purifying respirators.

Respirators must not impair the worker's ability to see, hear, communicate or move as necessary to perform the job safely. For example, atmosphere-supplying respirators may restrict movement and present other potential hazards. SARs, with their trailing hoses, can limit the area the wearer can cover and may present a hazard if the hose comes into contact with machinery. Similarly, a SCBA that includes a back-mounted, compressed-air cylinder is both large and heavy. This may restrict climbing and movement in tight places, and the added weight of the air cylinder presents an additional burden to the wearer.

Another factor to consider when using respirators is the air-supply rate. The wearer's work rate determines the volume of air breathed per minute. The volume of air supplied to meet breathing requirements is very significant when using atmosphere-supplying respirators, such as self-contained and air-line respirators that use cylinders, because this volume determines their operating lives.

Peak airflow rate is also important in the use of a constant-flow SAR. The air-supply rate should always be greater than the maximum amount of air being inhaled in order to maintain positive pressure in the respiratory enclosure.

The increased breathing resistance of air-purifying respirators under conditions of heavy work may cause the user breathing difficulty, especially in hot, humid conditions. To avoid placing additional stress on the wearer, use the lightest respirator possible that presents the least breathing resistance.

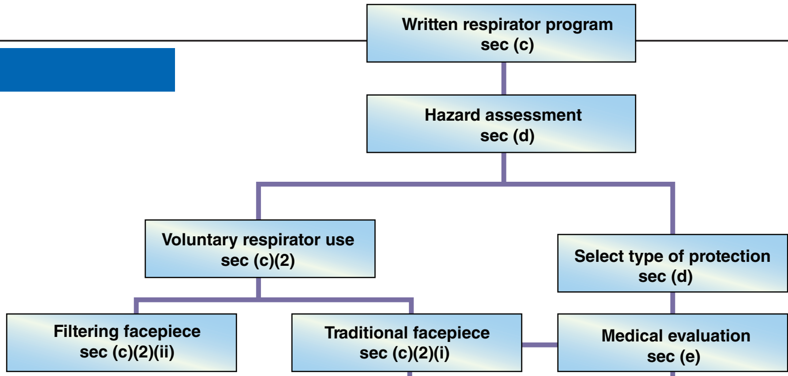
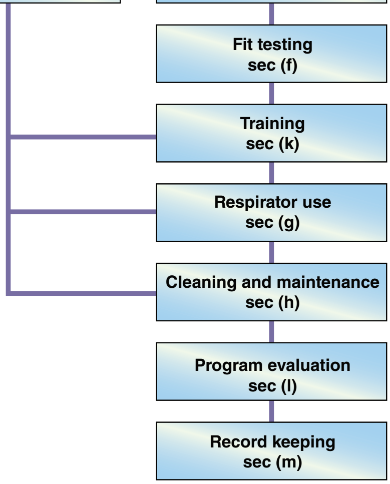



FIGURE 3. This simplified illustration shows the requirements that employers must follow to comply with the 29 CFR Part 1910.134 Standard

SCBAs and some chemical canister respirators provide a warning of remaining service time. This may be a pressure gage or timer with an audible alarm for SCBAs or a color ESLI on the cartridge or canister. The user should understand the operation and limitations of each type of warning device. For the many gas masks and chemical-cartridge respirators without ESLI devices, the employer must establish and enforce a cartridge or canister change schedule. Employees should begin each work shift with new canisters and cartridges.

Ensuring proper fit

Different types of respirators, and even different brands of the same type of respirator, have different fit characteristics. No one respirator will fit everyone. Some employees may be unable to get an adequate fit with certain respirator models of a particular type of respirator. This is why employers must provide a sufficient number of respirator models and sizes to ensure

ADDITIONAL RESOURCES

Additional information on protecting yourself from airborne hazards can be obtained from the U.S. Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety (NIOSH), and the American National Standards Institute (ANSI). Safety product manufacturers' websites can also be a helpful resource. Here are a few useful website links:

- www.osha.gov/law-regs.html — For OSHA's standards
- www.cdc.gov/niosh — The home page for the and Health's National Personal Protective Technology Laboratory, which contains a variety of information and links related to respiratory protection and other personal protective equipment
- www.ansi.org — The home page for ANSI
- www.osha.gov/dte/library/materials_library.html — OSHA Directorate of Training and Education's Training and Reference Materials Library. Provides outreach training materials (such as slide presentations) for OSHA's respiratory protection standard, as well as links to additional resources about respiratory protection
- webapps.msanet.com/ResponseGuide/ — Website from author's company that contains two interactive tools: Chemical Database & Respirator Selection and Cartridge Service Life Calculator, as well as a complimentary download entitled "Managing a Respiratory Protection Program", a guide to simplifying compliance with 29 CFR Part 1910.134
- www.osha.gov/dts/shib/respiratory_protection_bulletin_2011.html — OSHA bulletin, "General Respiratory Protection Guidance for Employers and Workers" (2011), which provides basic information to employers and workers who may find themselves using respiratory protection for the first time. It also provides information on what respirators are, how they work, and what is needed for a respirator to provide protection
- www.osha.gov/SLTC/etools/respiratory/index.html — OSHA's eTool, Respiratory Protection (1998), which provides employers with instruction on the proper selection of respiratory protection and the development of change schedules for gas/vapor cartridges
- www.osha.gov/Publications/OSHA3079/osha3079.html — OSHA guidebook, "Respiratory Protection", publication no. 3079, (2002). This booklet clarifies key provisions of the respirator protection standard, which was revised in January 1998. It also provides specific guidance on respirator selection, fit testing, hazard evaluation and medical evaluation
- www.osha.gov/Publications/3280-10N-05-english-06-27-2007.html — OSHA quick card, Respirators Quick Card, publication no. 3280 (2005), which provides employees with a brief description of the different types of respirators available
- www.cdc.gov/niosh/npptl/topics/respirators/disp_part/RespSource.html — NIOSH Web page, "NIOSH Respirator Trusted-Source Information Page", which provides information to understand the types of respirators, how to identify approved models and outlets for purchase, a listing of all NIOSH-approved and U.S. Food and Drug Admin. (FDA) -cleared surgical N95 respirators, a listing of recently revoked respirator approvals and relevant user notices. It also contains information on how to implement the use of respirators in the workplace and use them appropriately, including commonly asked questions and answers (fact sheets), respirator myths, the science of respirator function and performance, and respiratory protective devices not approved by NIOSH ❑

that every employee can select an acceptable respirator that fits properly.

Corrective eyeglasses worn by employees can also present a problem when fitting respirators. Special mountings are available to hold corrective lenses inside full facepieces. A qualified individual must fit the facepiece and lenses to provide good vision, comfort and proper sealing.

Tight-fitting respirators cannot provide proper protection without a tight seal between the facepiece and the wearer's face. Consequently, beards and other facial hair, the absence of normally worn dentures, facial deformities, jewelry or head gear that projects under the facepiece seal can also seriously affect the fit of a facepiece. To ensure proper respiratory protection, check the facepiece each time you wear the respirator. You can do this by performing either a positive-pressure or negative-pressure user-seal check. Detailed instructions for performing these checks are in Appendix B-1 of OSHA 29 CFR 1910.134.

Qualitative versus quantitative fit testing. Fit testing is required for tight-fitting facepiece respirators. You can test the effectiveness of the fit of the facepiece two ways: qualitatively and quantitatively.

Qualitative fit testing involves the introduction of a harmless, but strong, smell or irritating substance into the breathing zone around the respirator being worn. If no odor or irritation is detected by the wearer, then this indicates a proper fit.

Quantitative fit testing offers more accurate, detailed information on respirator fit. While the wearer performs exercises that could induce facepiece leakage, a fit-testing instrument numerically measures the amount of leakage into the respirator. This testing can be done either by generating a test aerosol as a test atmosphere, using ambient aerosol as a test agent, or using controlled negative pressure to measure any leakage. Detailed instructions for performing both qualitative and quantitative fit testing are contained in Appendix A of OSHA 29 CFR 1910.134.

Proper inspection and care

It is important to inspect all respirators for wear and tear before and after each use, giving special attention to rubber or plastic parts that can deteriorate or lose pliability. All parts including the facepiece, headband, valves, connecting tube, fittings and cartridges, canisters or filters must be in good condition. A respirator inspection must include checking the tightness of the connections.

SCBAs should be inspected at least monthly, and air and oxygen cylinders should be fully charged according to the manufacturer's instructions. This inspection should include a check of regulator and warning devices to ensure proper functioning. Employers must keep a record of inspection dates and results.

Chemical cartridges and gas mask canisters should be replaced as necessary to provide complete protection, following the manufacturer's recommendations. Additionally, mechanical filters should be replaced as necessary to avoid high breathing resistance.

Only an experienced person is permitted to make repairs, using parts specifically designed for the respirator. This person must consult the manufacturer's instructions for any repair, and no attempt should be made to repair or replace components or make adjustments or repairs beyond the manufacturer's recommendations.

Employers must ensure that respirators are cleaned and disinfected as often as necessary to keep them sanitary. In addition, the employer must have emergency-use respirators cleaned and disinfected immediately after each use.

Respirators should be washed in

a detergent solution and then disinfected by immersing them in a sanitizing solution. Cleaner-sanitizers that effectively clean the respirator and contain a bactericidal agent are commercially available. Strong cleaning and sanitizing agents and many solvents can damage rubber or plastic respirator parts. Use these materials with caution or after consultation with the respirator manufacturer.

Store respirators in a manner that provides protection against dust, sunlight, heat, extreme cold, excessive moisture and damaging chemicals. When packed or stored, each respirator should be positioned to retain its natural configuration. Facepieces and exhalation valves should rest in a normal position to prevent the rubber or plastic from deforming.

FIGURES 4a and 4b. Supplied-air respirators are designed to provide breathable air from a clean air source other than the surrounding work atmosphere. They include self-contained breathing apparatus units (left) and air-line respirators (right)

Manufacturers' tools

There are three especially valuable tools that can assist in the development, administration and maintenance of a workplace respiratory protection program:

- Respirator selection guide
- Cartridge life expectancy calculator
- Manufacturer training programs

Many respirator manufacturers' websites contain these tools. OSHA's website contains a respirator selection guide.

Respirator selection guide. A respirator selection guide is designed to help users identify the proper respirator solution to meet their individual needs. Choices include everything from SCBAs to half- and quarter-type facemasks. In addition to selecting the proper respirator, a respirator selection guide also helps users choose the correct filtering element if their exposure situation allows for the use of an air-purifying respirator. The following steps should be taken to use a respirator selection guide.

Step 1: Assess your environmental conditions to determine the hazard(s). To determine an atmosphere's oxygen content or concentration level of gaseous contaminants, proper air sampling must be conducted. The results of this sampling will determine what level of protection is required. Generally, respirator and cartridge selection is based on three factors:

1. The results of the atmospheric monitoring or sampling program
2. The accepted American Conference of Industrial Hygienists (ACGIH), OSHA or NIOSH exposure limits for the substance(s) present
3. The maximum use concentration of a substance for which a respirator can be used

An additional part of the hazard assessment process is determining whether the contaminant has adequate warning properties. This affects respirator selection because chemical cartridge respirators and gas masks should only be for routine use against gases and vapors with adequate warning properties, unless the cartridge is equipped with an end-of-service life indicator.

Step 2: Check chemical exposure limits. After finding out what hazards exist, compare the chemical concentration at your facility (determined by air sampling) with the chemical's exposure limits. Note that most respirator selection guides use the lowest exposure limit published by ACGIH, OSHA or NIOSH as a baseline to determine the need for respiratory protection. One exception to this rule is when an OSHA substance-specific standard exists with applicable respirator use limitations for protection against the chemical of interest. In this case, the OSHA requirement is specified.

Step 3: Select a respirator and cartridge. Now it is time to select a respirator and cartridge. During this process it is important to note that recommendations in a respirator selection guide are typically based on appropriate levels of respiratory protection. If you choose, a higher level of protection can be used by selecting a respirator with a higher maximum-use concentration or, if applicable, a higher cartridge-filter efficiency. This is advisable if the atmosphere in the work area is prone to changes, since the contaminant concentration has the potential to become higher.

Cartridge life-expectancy calculator. Let's assume that you determined that the respirator of choice should be a full-facepiece with a multi-gas cartridge. It is now time to use the cartridge life-expectancy calculator. This tool is interactive and is designed to provide guidance as to how long a specific cartridge should be used before it needs to be replaced. The determination is called "time of breakthrough" and refers to the point at which a hazardous chemical will begin to break through the cartridge or filter without being absorbed or collected by the protective barrier. OSHA requires that respirator cartridges be replaced at pre-determined intervals based on worksite-specific usage conditions [*4*].

A cartridge life-expectancy calculator is very easy to use. Simply answer a minimal number of questions by entering key environmental and usage factors. The calculator then provides a suggested maximum service time for the cartridge(s) being used in that specific environment. Although cartridge calculators may vary somewhat, they all require the same basic input:

- Chemical hazard and concentration
- Temperature
- Relative humidity
- Atmospheric pressure or altitude
- Type of respirator and cartridge
- Type of work and average breathing rate (light, moderate or heavy)
- Breakthrough concentration preference
- Safety factor

When using a cartridge life-expectancy calculator you must remember that this tool provides a guideline for your final decision on cartridge replacement. Several other factors should also be considered, such as changes in conditions during the work shift, changing climate conditions (seasonal changes), condition of the cartridge or respirator, cartridge storage conditions, accuracy in determining the ambient conditions and user training experience. Ultimately, the appropriate change-out schedule must be developed by a qualified professional.

Manufacturer training programs. The third tool is the training programs that are available from respirator manufacturers. In addition to onsite training, some respirator manufacturers offer online programs through their websites. As part of an effective training program, the user may be required to pass a test about the respirator, including how to wear and maintain it. An employee training program is required by OSHA. ■

Edited by Dorothy Lozowski

References

1. A list of NIOSH-approved respirators can be found at http://www.cdc.gov/niosh/npptl/topics/respirators/cel/
2. About ANSI Overview, http://ansi.org/about_ansi/overview/overview.aspx?menuid=1 (accessed September 18, 2012)
3. The ANSI/AIHA Z88.2 "Standard Practices for Respiratory Protection" is available on the ANSI website, www.ansi.org
4. Federal Register, p. 1272, col.1 OSHA 1910.134(d)(3)(iii)

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Coal Gasification For Chemicals

Richard Beaman
and Cliff Reese
SSOE Group

Numerous cost and processing challenges surround coal gasification, but the technology is becoming more prevalent in petroleum-poor areas

Compared to petroleum refining, the coal gasification process appears less complex. The chemistry behind the primary gasification reactions have been well known for around 100 years, and coal is more plentiful than petroleum in the U.S. and in some other areas. So why then, are petroleum refineries common and coal gasification plants so rare?

There are a host of reasons for why petroleum has historically been the feedstock of choice for making chemicals, and coal has been used mostly as a fuel for steam and electricity production. These include the comparative ease with which petroleum can be extracted, transported and processed. However, another set of conditions, including growing world demand for energy and transportation fuels, has renewed interest is coal gasification as a starting point to produce chemicals and liquid fuels.

Fossil fuels in the future

Increasing demand for energy, especially in the developing parts of the world, combined with high and fluctuating petroleum prices has generated momentum for coal gasification as an industry. Some estimates project that by the year 2035, the global demand for energy in all forms, including for transportation, will increase by at least 36%, and some studies have even suggested an increase of as much as 50%. Because of this rising world demand, fossil fuels will need to remain a critical source of energy and fuels production, despite the development of renewable energy technologies. This is particularly true in oil-poor areas of the world that have relatively easy access to coal, such as eastern and southern Asia.

For example, gasification is proving to be especially marketable in China. Ranking number three in the world with 114 billion tons of coal reserves, China has its feedstock readily available. The Gasification Technologies Council (Arlington, Va.; www.gasification.org), which promotes gasification technology worldwide, stated that between 2004 and 2012, China could claim 42 gasification plant startups. The overwhelming majority of China's production of synthesis gas (syngas; largely CO and H_2 gases) via coal gasification leads to the manufacture of chemicals.

Petroleum versus coal

Coal has been used as a fuel for many centuries. It has historically been mined and minimally processed to remove the larger rocks and shipped to the end user, who may pulverize it to powdered coal to improve combustion. Some users, such as steel producers or their suppliers, further process the coal by heating it in a reduced oxygen atmosphere to drive off the volatiles — water and light hydrocarbons — leaving predominantly carbon and ash. Today, coal is mainly used as a fuel for stationary steam and electricity production, which allows for the installation of the required large, cumbersome coal handling and processing equipment. Until recently, coal has generally not been used to produce chemicals other than the recovered off-gases from coke production.

Petroleum is processed using separation techniques, such as distillation, as well as thermal and catalytic reactions, to produce a range of hydrocarbon products by thermally and catalytically breaking larger petroleum molecules into smaller ones, and by removing the undesirable components such as sulfur. Also, some of the smaller gaseous molecules from the early separation steps are combined with large molecules to optimize the product quality and demand requirements.

Historically, petroleum refineries started out as distillation plants, where the petroleum was separated into different boiling range fractions; this was a much simpler process than today. Over the years, incremental technical advances were made, by adding many reaction steps (both thermal and catalytic) to the refining process, causing it to become more and more complex. However, processing coal to make chemicals, beyond what was necessary for creating steam or coke, was so much more difficult than the early petroleum refining process, that it was abandoned and is only now being revisited on a large scale.

Coal gasification

Gasification uses partial combustion of the coal to thermally break the coal into carbon monoxide, hydrogen, carbon dioxide, water vapor and a mixture of impurities, such as hydrogen sulfide and mercury, and some minor amounts of nitrogen compounds. The resulting gas stream is treated to adjust the ratio of hydrogen to carbon monoxide (through a catalytic water-shift reaction) and to remove the impurities, carbon dioxide and water. The syngas can then be used as a clean

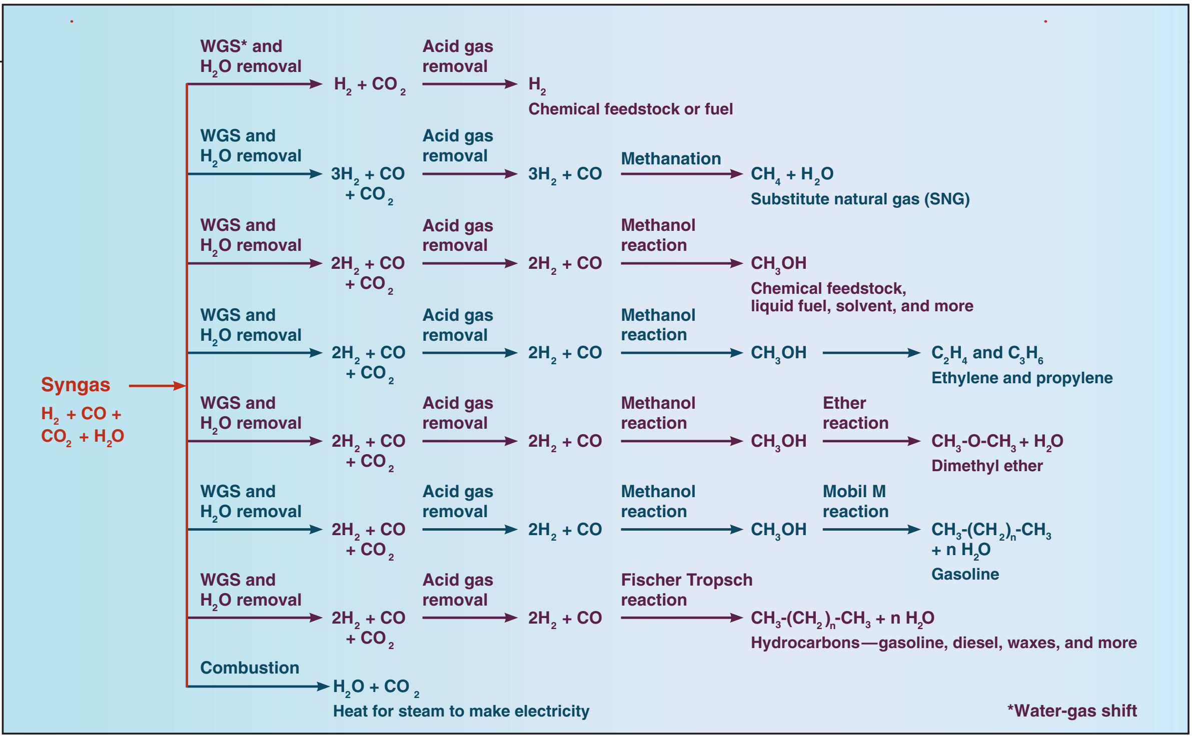

FIGURE 1. Synthesis gas can be used to generate a wide variety of reaction products

fuel or processed into other chemicals, including the following (see Figure 1):

1) Low- or medium-Btu fuel gas
2) Methanol
3) Straight-chain hydrocarbons
4) Hydrogen
5) Methane

Methanol can be further processed into other chemicals, including ethylene, propylene, dimethyl ether and liquid hydrocarbon fuels.

Coal processing challenges

Coal appears mainly as a solid hydrocarbon, with hydrocarbon gases found in the pores and voids. Petroleum, on the other hand, is a mixture of heavy liquid hydrocarbons, with hydrocarbon gases dissolved in it. Often, some of the lighter gases separate from the oil and form a vapor space above the liquid petroleum deposit. These differences dictate how the two naturally occuring substances are processed, refined and used.

Because it is a solid, coal is more difficult to extract from the ground, and more difficult to transport and process than crude petroleum, which can be pumped out of the ground, transported through pipelines, and pumped through process equipment. Coal is also considered relatively "dirty," since it typically contains high levels of ash, sulfur, and mercury.

In petroleum refining, it is relatively simple to break the larger oil molecules into smaller, more useful molecules, such as cracking heavy fuel oils (atmospheric gas oil, vacuum gas oil) into lighter fuels — gasoline, diesel and so on — and also into lighter chemicals, such as ethylene and propylene. Cracking is accomplished by thermal heating or by catalytic reactions, and is usually done in the liquid phase.

By comparison, when coal is heated, the smaller hydrocarbon molecules present in the voids of the solid coal are driven out. Many of the short side chains or single-ring structures break off the main coal structure, which is predominantly made up of multiple aromatic rings that are highly resistant to thermal degradation and remain in the solid phase.

Cost factors in coal gasification

The process differences between coal gasification and petroleum refining described above also result in cost challenges for the burgeoning coal-gasification industry. These include higher costs for capital, development, engineering and operation. All of the methods needed to make chemicals from coal require relatively expensive catalysts, in larger-volume vessels than a "liquid"-phase petroleum catalytic vessel. The large-volume vessels are needed because the gases are far less dense than the liquids in the petroleum process. This significantly increases the capital costs of coal gasification. Also, many of the reactions needed to make the useful chemicals and some of the processes to remove the undesirable components, such as carbon dioxide and hydrogen sulfide, require very high pressures. It is much more difficult to compress gases than to pump liquids up to high pressure — another factor that adds to the operating costs.

Gasifier considerations

Another major (capital) cost associated with coal gasification is the gasifier itself. Those familiar with petroleum refining know that from time to time, a refinery will need to switch to a different feedstock, due to the maturation of the oil fields it is currently using. This new feedstock may have significantly different properties. When this occurs, the petroleum refinery may need to modify parts of the plant to adjust to the new feedstock.

Similarly for coal gasification, different types of coal may require changing out the main part of the process — the gasifier — if the original one was not designed to handle certain properties of the new coal supply. When changing or designing a new gasifier, many properties of the coal need to be accounted for including the following:

- Caking characteristics
- Ash content
- Reactivity
- Sulfur content and type of sulfur (organic or pyritic, also known as inorganic)
- Coal rank (bituminous, sub-bituminous, lignite and so on)

For example, when certain types of coal are heated to high temperatures, the coal softens and fuses together. This can cause plugging problems in the process equipment. Gasifier operators should consult the manufacturers of their unit to determine if their design addresses all the properties of the coal to be gasified.

Gasifier classifications

There are a growing number of gasifier types. They can typically be grouped into two classes: fluidized bed and packed bed. In a fluidized bed gasifier, the coal particles are "floated" by the gas flow. The floating can be mild (where the particles are floated enough to expand the bed above its stagnant volume) or more energetic, to the point where the bed is expanded greatly and the turbulence creates areas of recirculation. This causes the particles that have been in the bed for a longer time to mix with those that have just entered the bed. If this is taken one step further, the gas velocities can be high enough to actually entrain the particles and carry them away from the particle injection point. This is called a "transport reactor." Transport reactors are among the more recent developments in the gasifier industry.

In packed-bed reactors, the gas flowrates are low enough that the particles are quite stationary relative to the reactor walls. The only movement occurs when the particles near the bottom of the reactor become smaller, causing the particles above to fall down to fill the voids, as well as when the ash is removed from the bottom of the reactor.

There is a difference in the gas flow capabilities between the two classes of gasifier reactors. The fluidized-bed class must have the gas flow and the particle flow co-current with respect to the net particulate-matter flow direction. Whereas the packed-bed gasifiers can have either a co-current or counter-current flow configuration. Also, it is relatively easy to recycle any unreacted or underreacted solids in the fluidized-bed reactors, either within the reactor or externally, after some size separation. This is useful in eliminating bypassing of the unreacted or under reacted particles.

Underground coal gasification

Underground coal gasification (UCG), which converts unworked coal into combustible gas via gasification, is also a growing industry. The difference between surface gasification and UCG is that instead of the coal being extracted, the cavity itself becomes the reactor. With more than 80% of the world's coal currently unmineable, it makes sense for companies to stop bringing the coal up and instead, bring the process down to the coal. According to the World Coal Assoc. (London, U.K.; worldcoal.org), China has about 30 UCG projects underway. Stone Horn Ridge LLC is currently in the testing phase of a large UCG project in Cook Inlet, Alaska and plans to go commercial by 2015.

It is interesting to note that some studies show that demand for energy may actually decrease due to developments in energy efficiency. If this proves to be true, it could affect the focus of these technology advancements — making their environmental impact a bigger factor. ■

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Selection of an Optimum Gasification Product

Determine the optimum product for a given composition of gasification-derived synthesis gas

Armen Abazajian
WorleyParsons

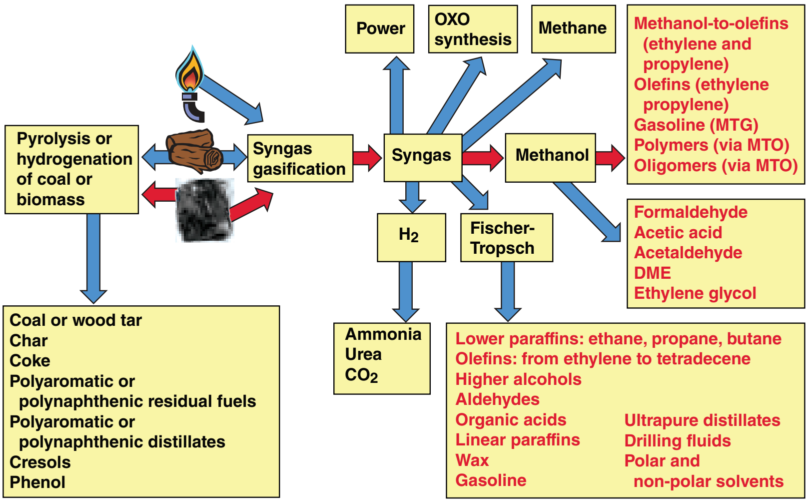

FIGURE 1. The synthesis gas resulting from gasification of various feedstocks can be used to manufacture a wide range of chemicals and fuels

Equipment for generating synthesis gas (syngas; mostly CO and H_2) is typically the most expensive part of an overall gasification complex. Understandably, the owners of gasification assets seek the highest value for the syngas produced by these assets. The methodology used in this study describes which gasification products may yield the highest value for the resulting syngas, given certain input data and assumptions.

For the purposes of the study, treated syngas means dry, purified, non-shifted synthesis gas. The main variables in these calculations were the following:

- The chemical composition of the raw syngas (itself a function of the raw material being gasified)
- The chemical and elemental composition of the final products or their energy content
- Capital cost of the syngas conversion technology
- Operating costs for the syngas conversion

From these variables, a value-ranking of nine different final gasification products was developed.

Gasification fills demand gap

To most individuals in the petroleum and petrochemical industries, it is clear that the production of onshore or shallow offshore conventional petroleum (so called "cheap oil") is not meeting the world's demand for carbon and hydrogen for use in energy, transportation fuels and petrochemicals applications. As the supplies of cheap oil dwindle, the utilization of more expensive substitutes is increasing. Without near-future supply shocks, most analysts say that the oil demand will continue to grow, thus bringing non-conventional petroleum substitutes, such as natural gas, oil sands, bitumen, shale oil and gas, coal, petroleum coke and biomass into increasing use.

The mention of natural gas as a non-conventional petroleum substitute merits an explanation. Although natural gas is a "conventional" feedstock for energy production, as well as for a range of petrochemical products, it is an unconventional petroleum substitute when it comes to its use in natural gas vehicles (NGVs), liquid fuels, such as dimethyl ether (DME) and Fischer-Tropsch (F-T) fuels.

Gasification is one of the technologies by which carbon and hydrogen-containing non-conventional feedstocks can be converted into energy, fuels and petrochemicals (Figure 1). However, the non-conventional feedstocks have a chemical and elemental composition that may be considerably different from the familiar variations of compositions of oil and gas.

Given the differences in feedstock composition, the question is whether the synthesis paths developed over the years for oil and gas feedstocks remain optimum, or if the basket of economically viable petrochemical products derived from conventional carbon and hydrogen resources should stay unchanged.

The methodology for determining the optimum product for a syngas generation project demonstrated in this study may be used to find such a desirable product, or a number of desirable products, for a given gasification feedstock.

Some of the steps in the method for determining an optimum gasification product can be time-consuming and expensive. This study uses reasonable assumptions and publically available

TABLE 1: ILLINOIS #6 COAL COMPOSITION	
Component	Proximate analysis wt.% dry
C	71.72
H	5.06
N	1.41
S	2.82
O	7.75
Cl	0.33
Ash	10.91
Total	100
Moisture (as received)	11.12
HHV*, Btu/lb	11,666

*HHV is higher heating value

TABLE 2: SYNGAS COMPOSITION	
Component	Mole fraction
H_2	0.2732
CO	0.6837
CO_2	0.0071
CH_4	0.0071
N_2	0.0091
Ar	0.0027
H_2S	0.0105
COS	0.0048
HCN	0.0002
NH_3	0.0006
HCl	0.0011
H_2/CO	0.3995

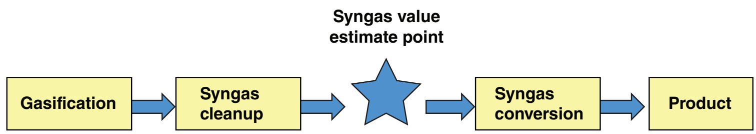

FIGURE 2. By determining a value-ranking for syngas generated by gasification, operators can choose the optimal chemical products

data to demonstrate the method.

The results of the study are highly dependant on the input data as well as the assumptions. The example shown below should not be assumed to be generic for all feedstocks or for any coal feedstock. Other input data, for example, the price relationship between the products chosen for the study during the time period considered in the study, contemporary capital costs and local markets can have a large effect on study results.

Study methodology

As a starting point for this study, an Illinois #6 coal composition shown in a National Energy Technology Laboratory (NETL; Morgantown, W.Va.; www.netl.doe.gov) study [*1*] (Table 1) is used.

Various gasification technologies are identifiable by the compositions of syngas they produce. Examples are a greater or smaller amount of shift, methane production, and carbon dioxide produced.

For the purposes of this study, a generic composition of synthesis gas was calculated based on the elemental composition of the coal. The following assumptions were made: very low CO_2 content; low water-gas shift and low methane production; as well as reasonably low assumptions of other key impurities, similar to what would be expected to be produced by entrained-flow gasification as part of GE, Shell, ConocoPhillips or Siemens gasification technologies (Table 2).

In a targeted study using this methodology, it would be preferable to use a composition based on a particular feedstock from a given gasification technology vendor, which would result in a better estimate of syngas composition. Of course, in addition to using a number of possible coals as a feedstock, synthesis gas may be a product of natural gas or possibly naphtha reforming, or petroleum coke, biomass, residual fuel oil or even municipal solid or slurry waste. Syngas produced from each of these feedstocks, as well as different quality coal, may be very different from the composition in Table 1 and yield an entirely different value-ranking of the products.

A U.S. Gulf Coast location with implied reasonable access to power and large markets for the final products is assumed. Also, the price impact of additional capacity of the final product is assumed to be negligible. Practically, this would also imply that a capacity addition is in step with market expansion, or that an expansion is significantly less than 20% of the size of the market. The products investigated in this study are shown in Table 3.

The manufacture of all of these products from syngas via known commercial routes is technically feasible. To avoid misinterpretation of the results, a randomly assigned list of products is used to show value rankings of different products.

For the purposes of this generic study, raw material utilizations reported in the publically available literature were included in the material balance calculations. Where raw material utilizations were not available from literature references, reasonable assumptions were made. A more detailed study would use raw material quotations from providers of particular syngas conversion technology. Alternatively, better estimates from industry, scientific and patent literature can be used.

The 2009 or 2010 average U.S. product prices from various publically available market reports [*3,4*] were used for economic calculations. Where average annual prices were not available, 2010 November to December spot values were used [*2*]. The F-T hard wax price is based on a 2010 year-end verbal quote from an industry participant.

Clearly, while some of the products can be shipped worldwide and have transportation- and duty-modified global price parity, other products cannot feasibly be moved long distances and reflect local or regional market conditions. Also, energy, commodity and, subsequently, chemical prices over the last three to four years experienced wide fluctuations. A market price projection over the lifespan of the planned facility would be a better input to the study. North American energy and petrochemical valuations have experienced large fluctuations in the last four to five years. The prices used in the study are based on energy and petrochemical price scenarios consistent with $62/bbl oil and $5.37/million Btu natural gas. The outcomes of the study will be different at $100/bbl oil and $4.40/million Btu natural gas.

"Unencumbered" syngas values were calculated given product pricing and syngas utilizations in making the product. In this context, "unencumbered" syngas values are those that do

TABLE 3. LIST OF PRODUCTS FROM SYNGAS
Substitute natural gas
Acetic acid
Ethanol
Fischer-Tropsch (F-T) fuels*
Hard wax (also via F-T)
Methanol
Hydrogen
Electricity
Ammonia
*Given the typical F-T LPG/naptha/deisel composition of products

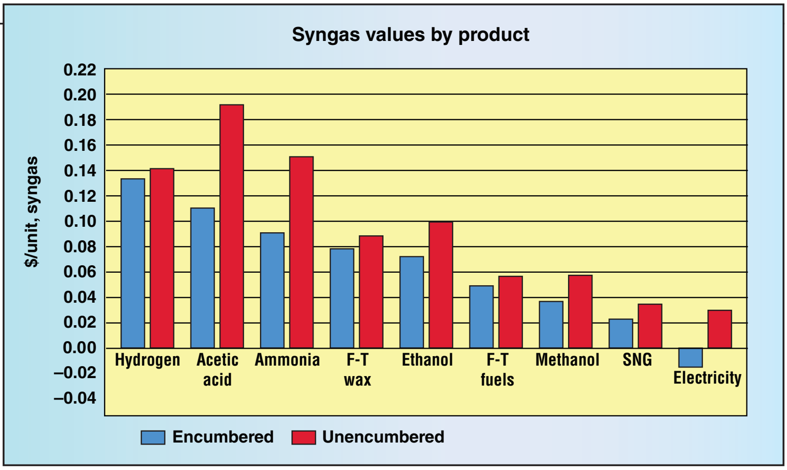

FIGURE 3. Unencumbered syngas values refer to those that do not take into account the capital and capital-related operating costs of converting the syngas into final products

not take into account the capital and operating costs of converting the syngas into the final products. Unencumbered values — illuminating though they may be — may distort the conclusions of the study. For example, they may overstate the value conferred on syngas by an expensive product, but one that is also very expensive to make from syngas.

Methanol synthesis can be considered as an example. The main methanol synthesis reaction is:

$CO + 2H_2 \longrightarrow CH_3OH$

Thus, approximately 2 mol of hydrogen are required per mole of CO. In practice, the synthesis gas fed to the methanol reactor contains some CO_2 and the ratio used is R = (mol H_2 – mol CO_2)/(mol CO + mol CO_2) = 2.05. The synthesis gas composition in Table 2 is clearly short of the required hydrogen. Assuming that the coal feedstock with the composition in Table 1 is the only feedstock available, the deficiency in the stoichiometric hydrogen must be made up by a shift reaction:

$CO + H_2O \longrightarrow CO_2 + H_2$

Therefore, approximately 1.6 mol of additional hydrogen are necessary.

Assume that the mass yield of methanol from the combination of the above methanol synthesis reactions is approximately 0.90. Thus, utilization of the synthesis gas of the given composition is approximately 2.26 lb syngas per pound of methanol product.

Global methanol supplier Methanex (Vancouver, B.C.; www.methanex.com) reported the 2009 annual average price of methanol to be approximately 0.115 ¢/lb. The "unencumbered" value of the syngas converted into methanol is approximately 0.051 ¢/lb. Both the methanol and the shift reactions above are exothermic. Taking credit for the waste heat, the "unencumbered" value of the syngas was estimated to be slightly higher, at 0.053 ¢/lb.

Capital investments and operating costs to convert synthesis gas into the nine products in Table 3 were extracted from a number of publically available sources [*5,6*]. The accuracy of these sources is unknown. Better capital investment estimates supplied by technology vendors or by engineering companies from their extensive project databases is desirable for better results.

"Encumbered" syngas values were calculated by adding capital-related operating costs and capital-related charges to "unencumbered" syngas values. No carbon sequestration or carbon offset costs are assigned to any of the products.

To calculate the "encumbered" value of synthesis gas used to make methanol, a total installed cost (TIC) capital cost of $0.16/lb of annual production was assumed. This value was available from an online source [7]. Generally, annual capital-related operating costs and other capital-related charges (or "encumbrance" in this study) equal approximately 27% of the TIC. The "Encumbered" value, (*E*) was calculated as follows:

$$E = (0.115 - 0.27 \times 0.16 + 0.0024) \div 2.26 = \$0.033/\text{lb syngas}$$

Similar calculations were carried out for the other eight products. It should be noted that the calculations shown here are greatly simplified to allow quick screening analysis. More detailed calculations would be necessary to improve the accuracy of the analysis.

Syngas product-value rankings

The results of the study show that the three most important parameters in determining the optimum product from a gasification project are the final product price, the capital and operating costs of syngas conversion to products and the mass-balance considerations in making the product from a given syngas. These conclusions are not surprising. However, the method discussed here offers a systematic way of selecting a gasification product.

The products are ranked in the order of diminishing "encumbered" syngas value. As discussed previously, the difference between the "unencumbered" and "encumbered" product value is the influence of the syngas conversion capital and capital-related operating costs. The main factor in the high encumbered and unencumbered value of acetic acid and ammonia is the relatively low utilization of synthesis gas per unit of product. Hydrogen and F-T wax are there because of their high market value despite relatively unfavorable syngas utilization. Ethanol has relatively low syngas utilization due to its oxygen content (although higher than methanol, for example), while F-T fuels, despite having somewhat low utilization, are assisted by the $0.50/gal U.S. subsidy available in 2009. The relatively low methanol price in 2009 brought down the value of syngas despite relatively high syn-

(*Continues on p. 54*)

Managing Pressure while Pigging an Oil Pipeline

Pressure control valves can manage pressure in oil pipelines, but pigging the line presents a challenge

Seyedamir Hosseini
National Iranian Oil Co. (NIOC)

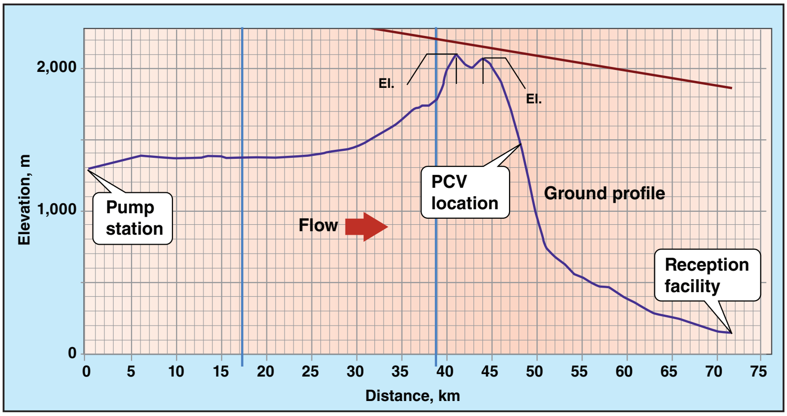

FIGURE 1. The ground profile shows the relative elevation of the pipeline pump station and reception, as well as the placement of the pressure-control valve

TABLE. 1: VALVES POSITION IN DIFFERENT OPERATION STATUS

Different operation mood	Valve 1	Valve 2	Valve 3	Valve 4	Valve 5	Valve 6
Normal operation	Open	Close	Close	Open	Close	Open
Shutdown case	Close	Close	Close	Open	Close	Open
Pigging operation before unloading the PCV manifold	Open	Close	Close	Open	Close	Open
Pigging operation for unloading from the PCV manifold	Close	Open	Open	Close	Open	Close

How to utilize a pipeline inspection gauge (pig) in a crude-oil pipeline that requires a pressure control valve can be a bewildering question for process engineers, especially in cases where the oil pipeline does not have any pig-launcher and receiver facilities.

The challenge becomes how to keep the pressure profile unchanged along the length of the pipeline. This task is complicated when the pipeline route has significant elevation changes. Following the experience this group had in negotiating the challenge helps illustrate several strategies that are important to operating pressure control valves (PCV) and managing pressures in pipes.

Varying elevations

Crude-oil products are often transferred from pump station to reception facilities that are located at different elevations. In some cases, such as the one described here, the pipeline route passes over a mountain peak, and the reception facility is located at significantly lower elevation than the pump station (Figure 1). Because the oil must be moved over this peak point, the pump station must produce high specific pressure to transmit liquid to the summit. Thus the pressure of the recovered oil will be higher than that at the pump station discharge. High pressures in the reception facility can increase the risk of pipe rupture. Moreover, due to high pressure loss in the reception facility's control valve, the valve seat and plug are exposed to excessive erosion, so valve failure is possible. For valve maintenance, its internal components are changed to work correctly afterward.

To reduce the risk associated with these conditions, our group installed one pressure control valve at a specific point on the upstream side of the reception facility along the pipeline. In this way, the high pressure of the discharge pump station can be reduced in the reception facility. This strategy decreases mechanical fatigue, vibration and erosion at the pressure-reducing station (reception facility).

Although this new design eliminates the problem of high pressure, using a pig inside the pipeline raises another problem. One possible solution is to position the pressure control valve on a bypass line and move the pig through the main pipeline. However, in that case, the pressure control valve should be overridden, and downstream pressure buildup is inevitable.

The most appropriate way to solve this problem while maintaining the ideal pressure profile comes from a special piping arrangement and from introducing motorized or manual valves on either side of the pressure control valve. When pigging the pipeline, a

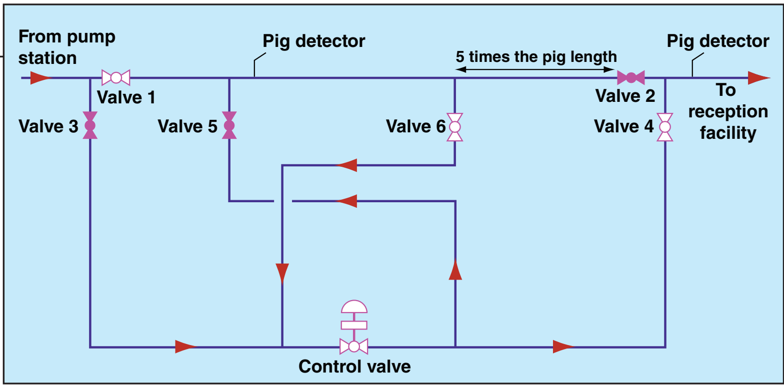

FIGURE 2. By following a sequence of opening and closing the network of valves in the pipeline, pigging the line can be achieved without extra capital costs

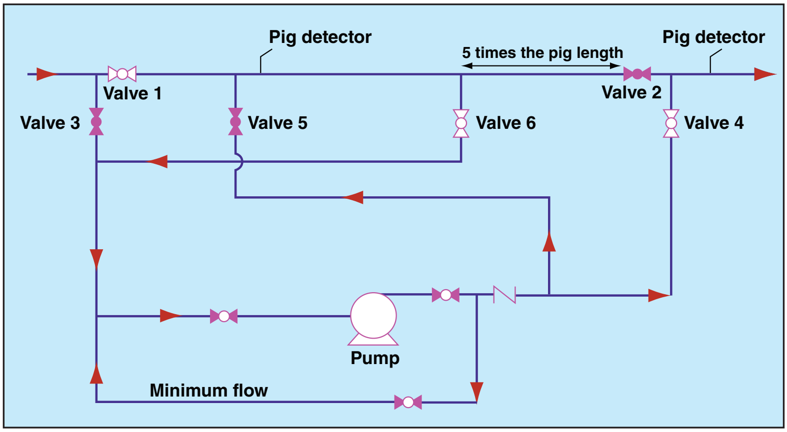

FIGURE 3. The layout of pump-station piping is shown without the pig launcher and receiver

predefined sequence of valve openings and closings should be implemented (Figure 2) in which the main pipeline is used as a pig launcher and receiver.

Operating conditions

The different operating conditions of the pipeline that should be considered are as follows:

Normal operation case: In normal operation, the pressure control valve is adjusted with a pressure transmitter, and all motorized valves are closed, except for valves 1, 6 and 4.

Shutdown case: In the case of a shutdown in the pump station, gravity can contribute to the pressure buildup at the reception facility. By closing valve 1, this problem can be eliminated.

Pigging case: In this case, the most important factor is keeping the pressure profile unchanged in the pipeline via the pressure control valve, while accounting for the new reception and launching facility.

When the pig is moved through the pipeline from the pump station in our pressure reduction station the following sequence should be applied:

A) Valves 1 and 6 should stand in their open position and valve 3 should be closed exactly as in the normal operation case. So the pig passes only through valve 1, and because of the liquid flow, the pig is trapped between the valve 6 connection and valve 2. Under such conditions, because of the liquid flowing through control valve, the pressure will be controlled via PCV. Placing the pig detector after the valve 1 and valve 5 connection helps users remain informed about pig position.

B) When the operator has been made aware of the pig position with the pig detector and its situation before valve 2, then valve 3 should be opened and valve 1 should be closed. For unloading the pig from the pipeline, valves 2 and 5 will be opened and valves 4 and 6 will be closed. In this condition, oil flow comes from valve 3, and after passing through the control valve and valve 5, provides enough pressure to move the pig through the pipeline. So the pig passes from valve 2.

C) After unloading the pig from this station, all the valves' positions will be returned to normal operating conditions.

All valve positions are provided in Table 1, according to the different operation states.

This piping arrangement greatly reduced the operating and capital costs because the pipeline itself was used as a pig launcher and receiver, and because the pressures found in the reception facility were reduced. This piping layout has been developed and constructed in other pump stations that are located between two large pump stations in order to reduce discharge pressures in the previous pump station and to handle higher liquid flowrates.

The piping arrangement method in such pump stations, as discussed here, led to simpler operation and prevented waste of capital costs.

It should be noted that in remote locations for which operators could not take proper actions to change the valve positions in pigging cases, installation of an additional pig detector after valves 2 and 4 on the main pipeline can be performed in order to take the appropriate signal from both pig detectors. In this way, all mentioned valve sequencing can be carried out to pass the pig through these stations. ■

Edited by Scott Jenkins

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Batch Control:

Controller- Versus Server-Based Sequencers

The size of the batch operation is not the sole deciding factor. Follow this guidance to select the best control strategy for your system

John Párraga
Rockwell Automation

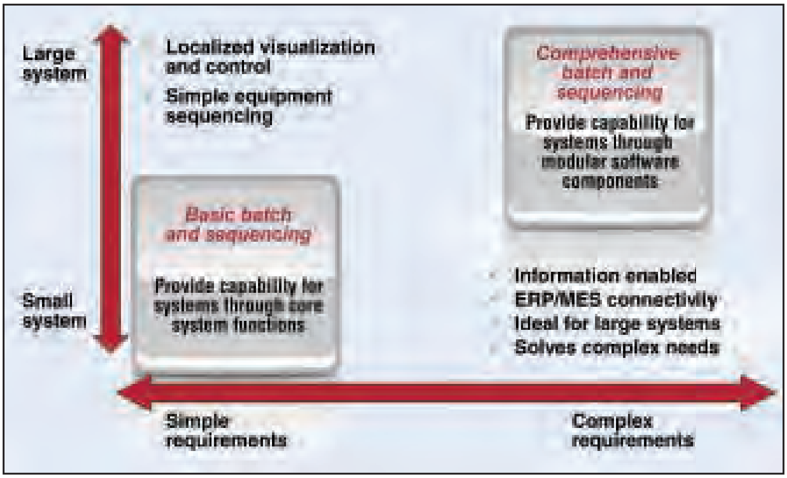

FIGURE 1. A small system usually requires a relatively small amount of equipment, but can be accompanied by simple or complex requirements

When designing a batch system, engineers often select the control solution based on the size of the system. It is traditionally thought that small batch systems require a controller-based sequencing solution, while larger systems require a server-based solution. However, despite traditional practices, the size of the system is not always the best indicator of an appropriate solution. A small application or single-unit system may have complex requirements. For example, it may need to be capable of managing hundreds of recipes or may contain complex decisions or paths based on process conditions.

To identify the right solution, users should consider the three types of batch and sequencing solutions:

- *A hard-coded solution* — Fixed sequences are programmed as applications in a controller
- *A configurable, controller-based solution* — Flexible sequences are programmed as applications in a controller
- *A server-based solution* — An off-the-shelf software product that is specifically designed to solve sequencing requirements, often referred to as a comprehensive solution

Very few systems can leverage custom, hard-coded solutions, as this typically only allows for formula values (setpoints) to be downloaded to a fixed sequence. As a result, when the sequence must change, users are forced to change the code. This adds risk to the process and can add significant costs in terms of design, implementation, testing and validation requirements for the new system.

Due to the rigidity of a hard-coded solution, many engineers prefer to use a configurable, controller-based solution for their small batch needs. This is appropriate if the application requires modular sequence-management capabilities, but the complexity of the process may not be great enough to warrant a server-based software package.

But how does one know if the complexity of the process calls for a controller-based solution? To determine whether or not a given system has simple or complex requirements we must consider the following questions:

1. Does the system have the ability to store the number of recipes required?
2. Does the complete batch occur in a single (S88) unit?
3. Can the system provide the recipe branching and loop backs required?
4. Can the batching system capture and log the amount of data required?
5. Does the system have the ability to specify the type and amount of formula values required?
6. Does the system have enough memory to store the application and number of recipes required?
7. Will the system provide for safekeeping of recipe intellectual properties?

If the answer to all of these questions is yes for a given batch application, then a configurable, controller-based solution may be a suitable choice. The Table contains some of factors

TABLE 1. SYSTEM CAPABILITIES: PROS AND CONS			
Costs			
Controller-based		**Server-based**	
Pros	**Cons**	**Pros**	**Cons**
• Low-cost or free-sequencing engine human-machine interface (HMI) and controller application code	• Requires HMI software • Requires a controller	Includes: • Sequencer engine • Operator electronic work instructions • Materials management • Batch campaigning • Formulation management • Electronic journal • Web-based reporting • No controller required for manual processes • No HMI required	• Higher upfront investment due to costs of implementing and maintaining a server
Equipment requirements			
Controller-based		**Server-based**	
Pros	**Cons**	**Pros**	**Cons**
• Does not require a server operating system	• Requires a controller • Requires HMI software	• Works with a variety of user interfaces • Does not require a controller • Enables multi-controller interface and coordination	• Requires a server operating system to run batch service • Requires an operating system to run clients
Robustness			
Controller-based		**Server-based**	
Pros	**Cons**	**Pros**	**Cons**
• Recipe will continue to run in the controller without an HMI or network	• Recipe will continue to run without HMI or network; no operation view if loss of network • Loss of power will cause loss of current or sequence state	• Components detect loss of network or server and bring recipe and phases to held safe state • Upon system restore, the recipes reconstruct and recipes continue where they left off after operator restart	• Requires the PC and the network in order to continue sequence • No built-in redundancy, relies on third party
Reporting capabilities			
Controller-based		**Server-based**	
Pros	**Cons**	**Pros**	**Cons**
• Reporting available on some systems	• Custom reporting required • High cost of implementation • Only "Real" value type data is captured, no string or enumerations	• Comprehensive data collection performed by batch service • Ability to move data to multiple data bases • Free predefined reports • Interaction with historical data-tracking software provides the ability to correlate batches with historical trend data	• Requires an operating system

(Continues on p. 44)

to be considered during the selection of a controller- or server-based batching solution.

A controller-based solution

Pros: Controller-based solutions typically require no additional upfront licensing investment beyond the human-machine interface and a controller. In addition, a controller-based solution solves simple batching needs; it allows for flexible recipe management and enables local, single-unit supervision and control.

Cons: Limited numbers of recipes, steps per recipe, parameter values and reported values per phase.

This approach typically requires more recipe upkeep in maintaining consistency among similar units.

A server-based solution

Pros: A server-based solution enables maximum flexibility and can be used from simple to the most-demanding batch requirements. Server-based solutions solve higher-level requirements — such as class-based recipes, audit/diagnostics, extensive data collection and reporting, analysis and optimization, equipment arbitration, integration with manufacturing execution (MES) and enterprise resource planning (ERP) systems, manual work instructions, recipe safe-keeping and active material management — all while supporting multi-unit coordination across multiple controllers if required.

Cons: Such systems require the purchase of software silencing.

Case examples

1. Pharmaceutical manufacturer implements new batch and sequence management. AMPAC Fine Chemicals (AFC), one of North America's largest custom, small-molecule

TABLE 1. SYSTEM CAPABILITIES: PROS AND CONS (Continued)			
Equipment definition and specification			
Controller-based		**Server-based**	
Pros	**Cons**	**Pros**	**Cons**
• All equipment model configuration performed via HMI • Ability to add equipment phases to definition without affecting running recipes • Simple to understand and deploy • Controller memory usage tool available • Ability to add or remove units, phases, parameters and report values on-the-go • Only requires HMI and controller know-how to maintain	• Limited to four parameters and four report values • No strings or enumerations parameters or report values • All equipment definitions require the same controller memory overhead to be reserved whether it is in use or not • Maximum of 32 phases per unit • Consumes controller processor memory (estimating tool available)	• Unlimited number of parameters and report values • Each equipment definition can be different for units, phases, parameters and reports • Parameters and report data types: integer, real, strings, enumerations • Unit attributes allow equipment to be automatically selected based on equipment conditions • Phases have the ability to acquire shared resources • Equipment allocation and arbitration is performed by batch server not in controller code • Does not require controller to run if manual process • Equipment phase logic can be distributed among multiple controllers or varying types • Unit and phase class definition	• Addition of new equipment requires stopping and restarting batch service, no online equipment definition changes allowed

(Continues on p. 45)

manufacturers of active pharmaceutical ingredients (API), weighed its batch configuration options and migrated its hard-coded control system to a controller-based solution. "AFC really needed a flexible control solution that offered easier system updates to accommodate its highly-varied manufacturing schedule," said Neal Yates, senior project engineer at Banks Integration, AFC's long-time automation partner.

"The project was originally scoped only for the control-equipment upgrade so there was no funding available for the addition of batch capabilities," Yates explained. After considering several alternatives, AFC decided that a controller-based solution would be an ideal alternative to a traditional server-based batch solution.

The controller-based batch and sequencing solution that was selected is independent of application servers and software. As a result, Yates and the Banks Integration Group team were able to deliver a flexible, controller-based solution without the need for costly, engineering-intensive custom code or additional server infrastructure associated with large-scale batch solutions. In addition, the AFC team is now able to configure recipes and formulas directly in the controller using dedicated, user-friendly software that does not require code changes to the system. This important advance helps users streamline the implementation of any approved changes.

With the new system, plant operators at AFC have reduced their use of manual, paper-based batch sheets for detailed processing instructions, thanks to an automated solution embedded directly into the control system. "Many of our production processes require a high level of detail — for example, if we remove a kill solution that deactivates a volatile chemical too soon, it could significantly impact the entire process," said Mike Ryan, director of Automation Systems and Calibration at AFC. "With the automated batch solution we're improving the quality and consistency of our APIs, and avoiding the delays that naturally occur during manual operations."

2. Leading personal-wash company benefits from improved asset and production performance while meeting stringent quality standards. Although a controller-based batch solution was evaluated as an option for AFC, PZ Cussons, a leading personal wash company based in the U.K., had a successful experience implementing a server-based batch solution into its high-speed, liquid-manufacturing process.

As part of a complete overhaul and modernization of its U.K. supply chain, PZ Cussons decided to take advantage of the control and visibility capabilities offered by a modern process-capable automation infrastructure. While establishing the justification for a new U.K. manufacturing facility, the company realized that much of its existing process equipment at its old site was not meeting demands of a modern manufacturing environment.

Starting from a clean slate, PZ Cussons identified many areas where savings could be made and unnecessary costs that could be removed. The company wanted to adopt leaner manufacturing procedures to enable further savings in stock holding and deliveries. The primary challenge was to obtain visibility of all steps in the process and keep all parameters within operational tolerances. This operational goal required extremely

TABLE 1. SYSTEM CAPABILITIES: PROS AND CONS (Continued)			
Recipe definition and usability			
Controller-based		**Server-based**	
Pros	**Cons**	**Pros**	**Cons**
• Intuitive user interface for operator and formulators • Ability to modify existing running recipes on the go • Ability to save running recipe as master recipe • Simple to step forward or backward to predefined pausing points • All recipe definition is performed via HMI • All recipe definitions reside in the controller	• Single-unit recipes • No class-based recipes, each one needs to be maintained individually • One (S88) operation per recipe • No recipe structure reusability • Maximum of 32 steps per recipe • Maximum of 32 recipes per unit • All recipes reserve the same amount of controller memory, regardless of number of steps or recipes per unit • Recipe step transitions are based on phase completion • No looping or branching in recipe; always performs the same steps of a sequence • Risk of losing recipe intellectual property by exposing controller code to anyone working in the controller	• Multiple-unit recipe coordination • Recipe operations and unit procedures can be reused by other recipes • Ease of creating, saving and replicating recipes • Class-based recipes allow one recipe to run in multiple units at the same time, simplifying recipe management and control • Number of recipes virtually unlimited, recipes may contain many steps • Recipes do not reside in the controller and do not consume controller memory • Recipes are transportable (copy/paste) • Recipe changes are audited • Phase parameters and reports can be calculations that reference other parameters and report values, unit tags, and so on • Recipe step transitions can be configured to be the result of calculated values, unit conditions, recipe conditions, reported values, parameters, equipment states, and more, or simply phase complete • Looping and branching can be performed	• Changes made to running recipe cannot be stored as the master recipe • Steps cannot be added or removed from running control recipes

accurate batching, mixing and metering systems that could not only communicate with each other, but could also communicate with the master control system within the offices, and within external suppliers, via a secure extranet.

An entirely new processing and production operation was developed. The implementation of the project made full use of the diagnostic data that the fieldbus devices provide. This has given PZ Cussons a level of process visibility and control far beyond what its older plant had. And the new approach is helping the company to attain many of the savings it envisaged, while also removing many of the process variables that had introduced unwanted costs.

PZ Cussons also has effectively been able to simplify some processes that took operators many years to learn. Even then, each operator had his or her own way of doing things on each of the machines, which led to some of the process variability.

With the old approach, all the recipes were hard-coded into the programmable logic controllers so there was no easy way to test new recipes and mixes without a significant recoding exercise. By comparison, the new technology has allowed the company to pilot test new recipes on a small scale prior to mass production. Similarly, using the old approach, there was a need for specialist operators, but due to the scalability and portability of the new software, any operator can now run any line. This allows operators to become multi-skilled — and add value to the areas where their intervention really counts.

Conclusion

The selection of a batch-sequencing system should not only be based on the amount of process equipment, but also on the equipment and procedures level of complexity and the system flexibility. ■

Edited by Suzanne Shelley

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Engineering Practice

CPI MACHINERY: Commissioning, Startup and Piping

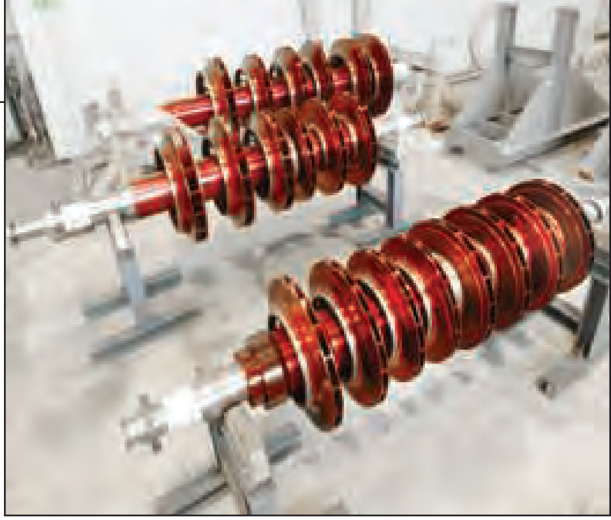

FIGURE 1. Shown here are examples of centrifugal compressor impeller assemblies (rotor assemblies) ready for shop balancing

Practical notes on installation, piping, support, layout, nozzle-loads, stress analysis, pre-commissioning, commissioning, startup and operation of rotating machinery

Amin Almasi
WorleyParsons Services Pty. Ltd.

When it comes to rotating machinery (pumps, compressors, gas turbines, steam turbines, turbo-expanders, and others) operating in the chemical process industries (CPI), installation, piping, support, pre-commissioning, commissioning and startup play crucial roles. Machinery maintenance and repair can be quite costly, and perhaps because of shortages of skilled manpower, particularly at remote site locations, CPI plants have given less attention to technical details for machinery installation, piping and commissioning.

When one considers that the initial investment costs for a rotating machine can be in range of $200–2,000/kW ($0.2–2 million/MW), whereas daily production loss can exceed $1–2 million for many modern (and large) CPI plants, one can see that it is necessary to protect these machines by doing an adequate installation, piping, commissioning and startup job.

Machinery piping design

Although there are rules and practices adopted for the design of general CPI plant-piping in order to facilitate the design and to avoid common errors, there are usually some special rules or exceptions when it comes to piping associated with CPI rotating machines; failure to properly handle these exceptions and special rules can cause difficulties in the installation and create problems during the operation of the rotating equipment.

The piping between a rotating machine and suction or discharge equipment (such as suction or discharge vessel or cooler) is critical, particularly when the operating temperature is very different than ambient temperature, and when the piping sizes are large. Sometimes both the rotating machine and the peripheral equipment are located on the same side of the pipe-rack. In that case the connecting pipe is supported on the pipe-rack and during operation, and because of the thermal difference, the piping generally moves away from both pieces of equipment. This layout and piping design offers relatively smaller loads on the equipment nozzles.

In some CPI units where space is constrained, the rotating machine and the equipment (suction or discharge equipment) are situated on opposite sides of the pipe-rack. In this case, the center point of the line running on the pipe-rack acts like a pivot point. The connecting line on both sides of this center point will move toward the equipment. This arrangement induces marginally more loading on the equipment nozzle compared to having equipment on the same side of the pipe-rack.

In many CPI plants, the discharge of a rotating machine (compressor, pump or others) is usually routed to an air-cooler or a heat exchanger (intercooler or after-cooler). Usually the rotating machine is offset from the air-cooler (or the heat exchanger). In this case, the vertical thermal expansion is absorbed by the deflection of the horizontal legs and similarly, the thermal expansion of the horizontal legs is absorbed by the deflection of the vertical legs. Another arrangement is when the machine and the air-cooler (or the heat exchanger) are located in the same line and relatively close to each other. In such case, it is necessary to provide enough flexibility to absorb the thermal movements. Loop(s) should be provided. To support a loop, it should be routed on a nearby pipe-rack (if possible), or else a proper structural support should be provided. The offset location of the machine to the air-cooler (or the heat exchanger) provides better piping flexibility.

Steam turbines or turbo-expander turbines (whether cryogenic or hot-gas type) are strain sensitive and operate at very high temperature difference with relatively low allowable nozzle loads. Usually, numerous layout details should be considered to provide the maximum possible flexibility. Even a good layout can create a problem if proper supporting is not considered. Good recommendations for the turbine piping are as follows:

1. A flexible piping arrangement may encircle the turbine.
2. Line stops may be located in such

a way that they match the turbine centerlines. This line stop arrangement can nullify the thermal movement effects and help in reducing the nozzle loads.

3. Supports near turbine nozzles should have low friction. Spring supports with minimum variability are recommended. They can be supported with hanger rods and rigid struts that reduce the friction at the support.

For parallel rotating machines (two or more identical machines working in parallel), the piping of each two identical trains could be mirror imaged in order to get a common maintenance area (an easy access).

Piping system vibration

The most obvious effect of piping vibration or pulsation — particularly sustained vibrations — is fatigue failure, especially at critical high-bending stress regions. The existence of such vibration suggests three approaches:

- Provide mechanical restraints to prevent the movement of the piping system (a damping solution)
- Elimination or control the vibrations or pulsations at their source (particularly those from rotating machines)
- Eliminate the coupling. Elimination of the transmission routes that excite the piping system vibrations or pulsations (for example, eliminate the excitations by changing the natural frequency of the system to avoid a resonance)

While each of these three approaches can be valuable, no single one will necessarily be the optimum for all cases of the rotating machine piping. Some of them could be excessively expensive, impossible, impractical or ineffective for a specific case. For example, the cost of mechanically restraining a large-size overhead piping could be very high.

Many criteria have evolved for the control of piping vibration or pulsation (from different points of view such as noise, safety, environmental and others). The fact is, the amplitude of the vibration or pulsation is not the biggest problem. The real danger is the dynamic stress level in the piping system, and this stress should be limited to below the destructive levels. Whenever the vibratory stress exceeds the endurance level of the piping, a failure can occur. By this argument, any vibration-amplitude criteria for CPI piping system should be applied very carefully. Special considerations should be given to the configuration of the piping system being studied. In other words, vibration amplitude criteria for a piping system should consider the piping configuration involved. The stress level in a piping configuration is mainly a function of the physical distortion.

The dynamic stress generated in a cantilever span due to a certain vibratory deflection is different than in that generated in another complex configuration by an equal vibratory deflection. A lower stress is generated in a long (straight) piping span compared to a short complex one (such as "L" shape, "U" shape, loop shape and similar) as a result of the same dynamic deflection. An investigation into the dynamics of different piping configurations shows that the variation in the dynamic stress per unit of vibratory deflection tracks rather directly with the natural frequency for a given piping. For example, a long (straight) flexible span has relatively low stress and a relatively low natural frequency. This natural frequency variation could be used to normalize allowable dynamic stress criteria (of course, it is just an approximation).

Based on this approach, the vibration velocity criteria can be specified for each piping configuration. As a rule of thumb, the vibration velocity limit can be stated as 6–9 mm/s for a long piping span, and 3–6 mm/s for a short complex piping (such as "L" shape, "U" shape, loop shape and others). These values are just rough estimates, and higher vibration values may be acceptable for some cases.

Piping support and flexibility

Piping-support systems are generally designed according to two major rules. First, the support locations are determined by the guidance of the maximum allowable spans. Secondly, the support types are selected based on the expected thermal displacement, dynamic situations, stress analysis and similar operational effects.

Flexibility studies (or a piping stress analysis) are intended to verify that stresses in CPI plant piping and the loads on the equipment nozzles (forces and moments at the fixed equipment or rotating machine nozzles) are within the acceptable limits through all anticipated phases of normal and abnormal operation. All possible situations, including the installation at ambient temperature, various operating conditions, the startup, the normal shutdowns, the emergency shutdowns, upsets and others, should be considered.

The piping of rotating equipment should be designed and supported so that equipment can be dismantled or removed without adding temporary supports (that means, by only removing spool pieces).

Rotating machine piping should be supported on integral extensions of the equipment support structure or independent structure (or support), and not be anchored to the equipment or its base-plate.

Alignment

Improper machinery alignment can cause excessive vibration, premature wear and early failure. Proper alignment can greatly improve bearing and seal life, reduce vibrations and boost reliability and overall performance. Adequate clearance for each machine casing (for example, driver, gear unit and driven equipment) is important to permit a proper alignment. Some authorities recommend the rotating-machine shaft-interface fit (the alignment tolerance) with a tolerance of around 0.0005 times of the shaft diameter (approximately 0.01–0.02 mm for typical 25–50 mm shaft diameters). Some textbooks recommended an alignment tolerance of around 0.01 mm overall, regardless of the shaft diameter. Special rotating-machine trains may need tighter alignment tolerances. Some ordinary machinery trains with flexible couplings (such as flexible couplings that transmit torque through elastomeric materials) may tolerate higher interface fits than those mentioned above. The coupling spacer length is also important since the parallel misalignment accommodation is directly proportional to that length.

Alignment tolerances given by coupling manufacturers may perhaps be only true for the coupling itself and could be excessive for coupled rotating machines.

The real criterion for alignment are the vibrations from the machinery when running. If excessive, particularly at twice the running speed (or axially), further alignment improvement is required. Analysis of failed components such as bearings, couplings and seals can be used to indicate the need for an improved alignment. Commonly-used alignment methods fall into three broad categories: reverse-indicator; face-and-rim; and face-face-distance.

Reverse-indicator. The reverse-indicator is the preferred setup for aligning modern CPI rotating machinery. The accuracy of this method cannot be affected by the axial movement of the shafts in sleeve bearings (hydrodynamic bearings). Both shafts should turn together (generally both shafts should be rotatable and coupled together), so coupling eccentricity or surface irregularities do not reduce the accuracy of the alignment readings. Geometrical accuracy is usually better using this method, compared to other methods.

This method is very convenient and generally implemented without disconnecting the coupling. For complex alignment situations, where thermal expansion or multi-casing trains are involved, the reverse-indicator method could be used quite readily. Usually, single-axis leveling is sufficient for machines using rolling-element-bearings, and two-axis leveling could suffice for machines employing sleeve-bearings.

There are some limitations for the reverse-indicator alignment method. If the coupling diameter exceeds the available axial-measurement span, the geometrical accuracy could be poor using the reverse-indicator alignment method compared to other methods. (such as the face-and-rim). Nowadays, the general trend is toward high-torsional-stiffness couplings (metallic, flexible spacer-type couplings), and the reverse-indicator method is nearly always the selected alignment setup for modern CPI installations.

Face-and-rim. The traditional face-and-rim method was popular decades ago. It can be used on large and heavy rotating machines whose shafts cannot be turned (of course, some run-out error may occur due to shaft or coupling eccentricity). It may offer a better geometrical accuracy than the reverse-indicator method for couplings with short spans (a small span-to-diameter ratio). Generally, this method is better and easier to apply on short coupling spans (or small non-critical machines). If this method is used on a machine with sleeve bearings, the axial float error could be significant, and a special procedure is usually required. As a general rule, a two- or three-axis leveling is required for rolling-element bearings and sleeve bearings, respectively (The reverse-indicator method requires leveling in one less axis for each). For long spans, this method requires spacer removal to permit the face mounting.

Face-face-distance. The face-face-distance alignment method is introduced for very long spans (such as trains that use a long transmission shaft instead of a coupling). This method is usable without an elaborate long-span bracket or other special considerations. The geometrical accuracy of this method is normally lower than the other two methods. It has no advantage over other commonly-used alignment methods for anything except the long spans (the long connecting shafts).

Laser alignment. Nowadays, methods using laser optic alignment have become very popular. Devices usually use a semiconductor emitting a laser beam in the infrared (IR) range (the wavelength around 800 mm) along with a beam-finder incorporating an IR detector. Physical contact is not required (it is replaced by the laser beam). Typical accuracy is one micron using the modern laser alignment methods. With the data automatically obtained from the sensor, the system can instantaneously yield the horizontal and vertical adjustments required for the alignment of the machine.

Many machinists make alignment corrective movements by trial and error (some may spend one or two days aligning a machine this way). However, by knowing how to calculate the corrections or using an advanced laser-lignment module, the time could be cut to two hours or less.

The thermal expansion (or contraction) of machines can often be significant for the alignment purposes (depending on the machine configuration). The movement of one machine casing relative to others is the main concern (absolute movements cannot affect the alignment). Movements caused by the pipe loads, the fluid forces and the torque reactions usually have important effects. The vibration can give an indication of whether thermal movements or other operational effects are causing misalignment problems during the startup or during operation. It may be necessary to consider the thermal-operational movement correction in the machinery alignment during the commissioning. One of the best methods can be mechanical measurements on a machine during the operation at the site with the job foundation and the final piping. Another useful recommendation is to make the machine and piping adjustments while the machine is operating, using vibration measurements as the primary reference.

Balancing

Imbalance can be caused by a variety of reasons, including tolerances in fabrication (or assembly), variation within materials (such as voids, porosity or similar), any non-symmetry, distortion, deflection, dimensional changes, degradation, and other manufacturing or operational problems. Manufacturing processes are the major source of imbalance. However, improper shipment, assembly, installation and commissioning can also lead to imbalance of the rotating assembly.

Often, field balancing is required at the CPI site during commissioning or startup. If the danger of this imbalance vibration is not recognized, costly damages could occur after a very short operation time. This may result in the destruction of the bearing, seal damage, cracks in various components, foundation damage, mounting system problem or other issues.

With a simply supported rotor assembly (bearings at both ends), vibrations due to the imbalance will be

FIGURE 2. This photo shows a typical piping arrangement for a pumping system

mainly in the radial plane. In the case of an over-hung rotor, high axial vibrations may also occur (the amplitude of axial vibrations could be comparable to those measured radially).

An unbalanced rotor assembly can cause high stresses in the rotor itself, in its support structures and in the entire machine-foundation system. Balancing of the rotor may be necessary to increase the bearing and seal life, minimize the vibration (and the stresses), minimize the noise, minimize the effects and risks of fatigue, minimize the power losses and increase safety. Imbalance can be of four basic types: static, couple, quasi-static and dynamic.

Static. Static imbalance exists when the principal axis of inertia is displaced parallel to the shaft axis. With a statically unbalanced rotor, the amplitude and phase of the vibration at both ends of the rotor are the same. This type of imbalance is found primarily in narrow, disc-shaped rotating parts such as flywheels or machine wheels (for example, thin impellers). It can be corrected by a single mass correction. Static balancing is satisfactory only for relatively slow-revolving, disc-shaped components or for parts that are subsequently assembled onto a larger rotor that is then balanced dynamically as an assembly.

Couple. Couple imbalance arises when two equal unbalanced masses are positioned at opposite ends of a rotor and oriented 180 deg. from each other. A couple imbalance needs another couple to correct it.

Quasi-static. The quasi-static imbalance represents the specific combination of static and couple imbalance where the angular position of one couple component coincides with the angular position of the static imbalance.

Dynamic. In the case of a dynamic imbalance, the central principal axis of inertia is neither parallel to, nor intersects the shaft axis. It is the most frequently occurring type of imbalance and can only be corrected by the mass corrections in at least two planes perpendicular to the shaft axis.

If the rotor support system is rigid, the unbalanced dynamic force is usually larger than if the rotor support system is flexible (except at the resonance). In practice, rotor support structures are neither entirely rigid nor entirely flexible, but somewhere in between.

A field-balancing package usually provides sensing and monitoring instrumentation needed to measure the balancing of a rotor while the rotor runs inside the machine at the site (in its own bearings and under its own power). Basically a field-balancing system consists of combinations of proper transducers and measurement devices that provide an imbalance indication proportional to the vibration magnitude. A suitable calculation module is used to convert the readings (usually the vibration, in several runs with the test masses) into the magnitude and phase angle of the required correction masses. The vibration measurements at one end of a machine could be affected by the imbalance vibration from the other end.

To determine accurately the size and the phase angle of needed correction masses, at least three runs are required. One to identify the "current" condition, the second with a test mass in one plane and the third with a test mass in anther correction plane.

Nozzle flange connection

To minimize loads on the machinery nozzle and facilitate the installation of piping, the rotating machine nozzle flanges should be parallel to the plane shown on the machinery drawing to within 0.1–0.5 deg. (depending on the equipment details). It is very important to correctly align flanged joints (the equipment nozzle flange and the piping flange). Flanges that are bolted up unevenly, in extreme cases, can cause some bolts to be nearly loose, while others are so heavily loaded that they locally crush the gasket. This can lead to leakage.

Flanges are designed to accommodate specific sizes and types of gaskets. For a given bolt load, a narrower gasket will experience a greater unit load than a wide gasket. A gasket with proper type, sizes and width should be employed. The gasket thickness determines its compressibility and the load required to seat it. The thicker the gasket, the lower the load necessary for seating. A proper thickness assures sufficient compressibility to accommodate slight facing irregularities while having a sufficiently high seating load. For a stud larger than 1 in. (25 mm), a proper hydraulic wrench should be used.

Bolting at operating conditions during the startup and the operation runs can be an important factor in minimizing flange-connection problems. During operation, the temperature change can cause the bolts and gaskets to deform permanently, which may cause a loss of bolt stress. Bolting at the operating condition helps correct this effect. The objective is to restore the original bolt stress that has dropped (or changed) due to yielding or creep of the flanged joint components. The bolting procedure should start at the point of the relative peak of the gap and proceed in a crisscross pattern.

Inlet strainer

It is very important to start up any CPI rotating machine with clean piping, particularly on the suction side. Any dirt, rust, welding beads or scale that is carried to the machine can cause serious problems. Even though cleaning procedures have been carefully followed, a temporary strainer should be installed in the suction line of each CPI rotating machine casing. Provisions should be made in the piping to check the pressure drop across the strainer and to remove the strainer element for cleaning. The machinery CPI piping should be fabricated with sufficient flange joints so that the piping, the permanent filters and the temporary strainers can be dismantled easily for cleaning. It is better to clean piping in sections before the actual erection.

Installation and commissioning

Electrical equipment. Electric machine problems appear in two major forms: 1) Mechanical, particularly rotor or bearing difficulties; and 2) Electrical, mainly electric winding or electrical-system problems.

Usually, a large portion of reported electric-machine issues are bearing problems. Other common electric-machine problems are misalignment, lubrication problems, excessive shaft loadings and environmental issues (ice, snow, sand or dirt).

There can be operational problems if the center of gravity of the electric-machine rotor assembly is different than the magnetic center. In this condition, the rotor continually hunts for the position it wants to run in. This can manifest itself in high axial vibrations. The phase and frequency of these vibrations may or may not prove to be synchronous. A proper magnetic alignment is required to solve this issue.

If dampness in the insulation of the electric machine is suspected as the result of shipment, storage or installation, the insulation resistance of the windings or other electrical components should be measured before the site commissioning.

Lubrication system. The cleanliness of a lubrication system used in a CPI plant is extremely important. When flushing at the site, the same lubrication oil should be used for flushing as that specified for operation. Any dirt or debris in a lubrication system should be collected at the lubrication filter (or additional strainers) during the flushing. Sufficient time is needed for a proper flushing (usually several days).

The cleaning capacity of the lubrication oil is better at relatively high oil velocities, a relatively high temperature and low viscosity. The transportation capacity of the lubrication oil is best when the oil is relatively thick at a relatively low temperature and high viscosity. The temperature of the lubrication oil should be varied within the specified low and high limits, several times, to achieve a proper flushing of the lubrication system.

Seal system commissioning

During the commissioning and startup of a rotating machine, the damages of mechanical seals occur particularly often. Modern mechanical seals are usually supplied as cartridge units (pre-mounted) and most often do not require adjustment during the machine assembly, installation or commissioning. Increased imperfections of concentricity and run-out in the shaft can lead to high vibrations and decrease significantly the service life of the seal. Stainless-steel pipes should be used for entire seal services with sufficient cross-section to ensure that the mechanical seal can be supplied with required clean seal fluid at any operation situation.

Dry-gas seal system. The warning limit for a dry-gas seal leakage is often five times the expected (normal) leakage value. The leakage should be carefully controlled during the startup and the initial period of the operation.

During operation, the dry gas seal needs a positive differential pressure (usually minimum 1–3 bars) in order to provide for a sufficient cooling of the dry gas seal. The commissioning or startup with too-low differential pressures may lead to damage of the dry gas seal by means of overheating, hang-up, wear or contacting sliding faces. The pressure change rate should usually be limited for reasons of operational safety (often in the range of 10–20 bars/min). The supply of the bearing lubrication oil should only be started when the bearing sealing system is provided with the separation gas (usually nitrogen gas). The operation of the dry gas seal requires minimum values of the rotating machine speed. If the machine does not rotate, a minimum differential pressure is required to ensure that the sliding faces lift off statically. In the case of rotating machine trains with very long startup or shutdown times, the operation with contact (contact of the seal faces) during every start/stop cycle has to be expected, depending on the operating parameters. This is an important consideration in the startup.

Operation and maintenance

The foundation and mounting systems beneath rotating equipment will often deteriorate over time. When this happens, the dynamic forces or deflections in the system can go beyond permitted levels. Very costly foundation (or mounting) system repair and re-grouting may be implemented, if downtime can be accepted in the CPI plant. Successful alternative approaches to the repair (or renewal) of mounting systems (such as renovation methods based on "shimming") without requiring downtime are also available and have recently become very popular.

For many rotating machines, the tight manufacturing clearances and complex geometry make refurbishing difficult in a case of major damage or catastrophic component failure, such as a bearing failure. As another example, the rotor may end up digging and melting into the casing. If bent, the rotor should be replaced. If not bent, it may be refurbished, which is usually a difficult process. For example, the rotor's sealing edges can often be sprayed in case of damage. Repair of the machine's casings is both difficult and risky — for machining and even more for welding. ■

Edited by Gerald Ondrey

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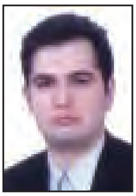

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Avoiding Project Failures

Recognize these key project-failure modes, so that corrective action can be taken

Jeffrey Harding
CH2MHILL

Companies in the chemical process industries (CPI) spend billions of dollars every year on capital projects. Most are successful, yielding the desired results. Some projects are only partially successful (and therefore partial failures), in that they are ultimately completed and work as desired, but only after a budget or schedule overrun. And some projects fail completely, sometimes spectacularly, never providing the desired results. This article discusses some of the key reasons for project failures. The intent is to assist the reader in recognizing some of the failure modes, so that corrective action can be taken and project failure — even partial failure — can be avoided. The article assumes some basic knowledge of capital projects and is intended for the novice project manager or capital manager. Project professionals will recognize many of these failure modes, and could probably contribute many more.

The three basic components of a project, the so-called "iron triangle" of projects, are scope (what is supposed to be provided by the project; for example what is to be built), budget (how much it is supposed to cost) and schedule (how long it is supposed to take) [*1*]. Several of the failure modes, as might be expected, involve these three items. There are, however, also other ways that projects can fail. Some of these involve "softer" issues, such as human factors.

Poorly scoped project

Most project professionals would probably agree that the leading cause of project failure is a poorly scoped project. As mentioned above, the scope of a project is what it is supposed to provide. In the case of a CPI project, in its most simple form, the scope is the equipment that is to be installed. While this sounds pretty simple, one would be surprised how often projects are initiated without a clear idea of what the scope is.

Note that scope is different from objectives. The objective may be to produce 100,000 tons/yr of a certain product with a certain specification. Often objectives are easier to define than scope, as scope is much more detailed. Scope gets down to the "nuts and bolts" — exactly how are we going to produce that 100,000 tons/yr [*2*]? Every project should have a clearly written scope that defines what the project is providing and sometimes states what it is not providing. Not doing so almost guarantees a partial project failure in term of budget and schedule — as the project team tries to figure out what it is really trying to do, or has to do in order to meet the overall project objectives — if not a larger failure.

Scope changes

Another failure mode involving project scope is poor scope control. Once the scope of a project is defined and established, scope changes become the enemy. Often, the process engineers on the project will come up with ideas to improve the process. While this may seem like a good thing, it can still be detrimental to the project, as every change has a ripple effect.

For example, say the process change is to change a heat exchanger from a shell-and-tube to an air-cooled fan exchanger. New equipment specifications must be developed, the piping design will have to be modified, the supports and foundations will need to be modified, and now electric power will be required for the motor(s).

If the project is still in the design phase, the only cost is engineering rework, and there will be an associated schedule delay. But obviously, the later in the project a scope change occurs, the more impact it has in terms of both cost and potential schedule delay. If equipment has been bought, and especially if installation of the equipment has begun, the cost impact increases tremendously. Once the scope of the project is defined, avoid changes like the plague. Improve and optimize the process after the project has been completed.

Poorly budgeted project

Another often-repeated fatal error on projects is arbitrarily setting the budget. One might think, "Who would do that? How could that happen?" Well, it usually happens like this: a manager asks a project manager, "How much will this cost?" The project manager goes off and develops a project cost estimate to the best of his or her ability using whatever resources are available and presents it to the manager, who then says, "Well that's too much. We only have X dollars available, so you'll have to do it for X."

Project costs typically consist of equipment costs (for not only process equipment, but also utility equipment, electrical equipment, instrumentation, control systems and so on), bulk material costs (for example, piping, wiring, concrete and steel), and services costs (such as engineering and construction labor). Within a given market or region, there is only so much variability in those costs. The only way to significantly reduce costs is to reduce scope.

And, if you reduce scope, by definition you are not getting the same project you originally intended. That may be acceptable, but it needs to be well thought through. Every project should have a well-documented budget (based on a well-defined scope) to serve as a basis for cost control. Not doing so almost guarantees a partial failure in terms of a budget overrun.

Poorly planned and scheduled

Another way that projects can fail is to have an inadequately thought-out schedule and plan for execution. Again, sometimes schedules are set arbitrarily: "We must have this by the end of the year," or even better, "We need this ASAP!" ASAP is not a schedule.

A well thought-out project schedule allows time for items such as permitting, safety reviews, detailed design, tie-ins, bidding cycles, equipment deliveries, construction durations and so on. It also needs to be properly sequenced to assure that required tasks are completed before moving on to the next task, and that nothing needs to be "undone" and then "re-done." Every project should have a well-developed, documented schedule. Not doing so almost guarantees a partial project failure in terms of a schedule delay.

New or ill-defined technology

This could also be considered a subset of a poorly scoped project, but the root cause is different. Attempting to implement new technology (such as a new process) is one of the highest-risk types of projects. Due to scaleup issues, these types of projects are even more risky if a typical step in the development of a process (for example from laboratory to pilot plant to semi-works to full-scale production plant) is skipped. Scaleup can be tricky business. Sometimes things don't behave the same in a plant as they did in the laboratory.

A project that implements new technology requires even more diligence and attention than some other types of projects. While the rush to market may provide additional schedule pressures, it is advisable to have additional time built into the schedule for commissioning and startup for these types of projects. It is also advisable to have additional budget contingencies for unforeseen issues. New technology and scaleup projects are probably the most likely candidates for a total project failure.

The most spectacular project failure I have ever witnessed (fortunately not as a direct participant) involved a chemical company that wanted to build a production-scale unit of an R&D process to make a new product for one of its major customers. The process was not very well developed, but the project proceeded. An engineering firm was hired, detailed design was performed, equipment was bought, construction contracts were awarded and a plant was built.

The project was budgeted at around $20 million. When construction was completed and startup began, numerous problems were encountered, such as plugging and corrosion issues that limited operations to short runs before shutdowns were required for cleaning and repairs. After months of delays and another nearly $20 million of capital investment, the company finally pulled the plug on the project. The process never ran successfully. It was the most complete project failure I have ever witnessed. I think this could have been prevented by taking the typical scaleup steps mentioned above, instead of trying to go from laboratory to production scale in one step. But that could have taken a couple of years and the company was not willing to do that.

Poorly selected manager

The key person on any project is the project manager. Although the project manager does not have to know everything, he or she must "know what they don't know." Even an inexperienced project manager will likely succeed if he or she has a support network of project management and subject matter (such as process engineering) experts that they can call upon. But an inexperienced project manager with no support system will likely fail.

Another consideration for assigning a project manager is compatibility. When you get right down to it, projects are accomplished by people who must work together as a team. That doesn't mean that they all have to be best friends, but if there are compatibility, personality, communications or similar issues between the project manager and the internal or external project-team members, this puts the project at risk. One of my favorite articles about projects is called Keep Attila the Hun off of Your Project [*3*]. As the title implies, you don't want that

ADDITIONAL PROJECT MANAGEMENT RESOURCES

A number of organizations provide resources and information for managing and executing projects. Here are a few of them:

Project Management Institute (PMI;14 Campus Blvd., Newtown Square, Penn., 19073-3299; Phone (toll): 610-356-4600; Phone (toll-free): 855-746-4849; Website: www.pmi.org) — PMI is the world's leading professional organization for project management. PMI offers general project management information across many industries that is documented in many standards and in the Project Management Body of Knowledge (PMBOK). It also offers certification programs, such as the Project Management Professional (PMP).

Construction Industry Institute (CII; 3925 West Braker Lane (R4500), Austin, Tex., 78759-5316; Phone: 512-232-3000; Website: www.construction-institute.org) — CII is a consortium of over 100 leading owner, engineering/contractor and supplier companies. It does research and disseminates knowledge on project execution to improve the project delivery process. CII offers books and training on project management, many of which have a slant toward CPI projects.

Independent Project Analysis (IPA; 44426 Atwater Drive, Suite 100, Ashburn, Va., 20147; Phone: 703-729-8300; Website: www.ipaglobal.com) — IPA is a consulting company that uses quantitative techniques to analyze projects and rate project performance to help companies improve their project delivery systems. Many large oil and chemical companies use IPA to independently audit and grade their project performance. IPA also offers training on all aspects of project development and execution through the IPA Institute. ❑

type of person on your project team — you need team players.

Inadequate project support

Projects require resources, mostly human, but of other types as well. One of the biggest mistakes companies can make is not committing the necessary resources to a project. Assigning a project manager is only the start. Other resources, such as process engineers, plant liaison people (for example, for electrical and controls interfaces), operations and maintenance people, procurement people and so on, may be required — even if only on a part-time basis — to provide input and assistance for the project to be successful.

While an engineering firm is often engaged to provide project support [*4*], there are some things that you cannot assign or contract to third parties. If corporate or plant management persons do not make a commitment of these resources, it will put the project in jeopardy. And, providing input late can sometimes be as bad as not getting it at all — see scope changes above.

Poor stakeholder consideration

The Project Management Institute (PMI; Newtown Square, Penn.; www.pmi.org) defines a project stakeholder (paraphrasing) as anyone involved with or affected by the project [*1*]. So obviously, the project team members are stakeholders, as is the "customer," meaning for example, the business unit for whom the project is being built. But there are also other stakeholders, such as the unit operators, the maintenance personnel, and even people outside the fenceline, such as neighbors and community members.

In the case of large, grassroots plants, these external stakeholders can be key to even allowing a project to be built (you have probably heard of "NIMBY" — not in my back yard). So careful consideration of all project stakeholders is critical, or the project may fail before it even gets started.

Inadequate communication

The PMI says that 90% of a project manager's time is spent on communication [*1*]. This includes communicating goals, objectives, plans and directions to team members; communicating progress and status to management; communicating with outside entities such as vendors and contractors; and more.

Communications can be so complicated that a communications matrix can be set up to establish the required communications channels and assure that nothing is missed. A sure-fire way for a project to fail is by a lack of communication. If the project team is not sure of its goals or direction, if management is not aware of the status of the project, or if outside entities are not aware of their responsibilities, you can be assured that you will have at least a partial failure in terms of scope, schedule or budget.

Inadequate risk management

Every project involves risk. The PMI defines risk as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives [*1*]. At the beginning of every project, a risk management exercise should be done to identify potential risks and put together plans on how these risks would be handled.

For example, say your project involves a pressure vessel to be fabricated from an exotic alloy that is experiencing wild price fluctuations and limited availability. It is not known what the price or delivery time will be at the time the order for the vessel will be placed. Your project-risk-management plan should address these risks in terms of budget and schedule contingency, and perhaps include approaches such as alternative suppliers and alternative materials of construction. On larger projects, formal risk-management plans are a good idea (actually a requirement in many companies), but even on smaller projects a risk management plan is a good idea. Failure to consider risks could easily lead to a partial project failure in terms of schedule and/or budget.

Poorly chosen engineering firm

As mentioned earlier, an engineering firm is often engaged to provide the necessary resources for detailed design, including drawings and specifications needed for buying equipment and getting the project built. I suggest engineering firms be evaluated on five Cs: capability, competency, capacity, commitment and compatibility.

Capability involves technical capabilities. Consider if the firm has all of the necessary skill sets that you need for the project (such as process, piping, instrumentation, electrical, civil, structural, architectural and other areas of expertise).

Competency is harder to judge, but can often be assessed by checking references.

Capacity is essentially "do they have enough of the right kinds of people to execute the project?"

Commitment is the firm's willingness to assign the right people, and right numbers of people, to the project and work with you through any obstacles that might be encountered, toward a successful completion.

And compatibility is often the key: is the firm the right size, is it organizationally compatible, does it seem to share the project team's values, does it understand the project objectives, is it a good fit for the project? Obviously the answers to these questions can be pretty subjective, and these issues can begin to be assessed in meetings with the firm.

One of the worst things that can happen is for an adversarial relationship to develop with the engineering firm. While this may not cause the project to fail, it is guaranteed to make the project a miserable experience. And remember, if you must bid engineering services, the low bidder is not always the best choice [*5*].

Poorly chosen contractor(s)

Likewise, as with engineering firms, the same "C" questions should be asked of potential construction contractors. In my experience, if you have pre-qualified the construction contractors based on the five Cs, and done a good job of developing construction bid packages in detailed design, lump-sum competitive bidding is still an appropriate way to select a construction contractor. However, the five Cs should still be evaluated and the low bidder may not be the best choice.

The selection of construction contractors can make or break a project. Contractors who do not have adequate resources, are not committing the needed resources, or are more interested in generating change orders than in building the project, almost certainly guarantee partial failure in terms of schedule and budget.

Final thoughts

Large operating companies and engineering and construction (E&C) firms have processes and procedures in place to prevent many of these failures from happening. The front-end loading (FEL) process that many companies employ is designed to prevent many of the scope, budget and schedule problems from occurring. They emphasize up-front planning and require approvals at various "stage gates" to confirm that the appropriate scope, budget, and schedule development has occurred. If your organization does not have these processes and procedures for executing projects, hopefully you will be able to recognize some of the warning signs, raise a flag and get some help.

It is often the "softer," people issues that are harder to immediately identify and harder to rectify, but these will cause project failure just as surely as any other issue. Be on the lookout for them, and be prepared to deal with them if you must.

There are many organizations available that provide resources and information on managing and executing projects (see box). There are also many consultants available to assist with projects.

Successful capital projects are a key to the overall success of companies in the CPI. If you and/or your organization are inexperienced in executing projects, hopefully this article will help you recognize some of the potential ways in which projects can go astray, so that corrective action can be taken, and failure — even partial failure — can be avoided. ■

Edited by Dorothy Lozowski

References

1. Project Management Institute (PMI), "Project Management Body of Knowledge," 4th ed., PMI, Newtown Square, Penn., 2008.
2. Harding, J. S., A Crash Course in Project Engineering," *Chem. Eng*., July 1995.
3. Horowitz, B. A., Keep Attila the Hun off of Your Project, *Chem. Eng. Prog.*, April 1995.
4. Harding, J. S., Use Contractors Effectively, *Chem. Eng*., November 1994.
5. Harding, J. S., Preparing a Request for Proposal, *Chem. Eng*., January 1997.

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SELECTION OF AN OPTIMUM GASIFICATION PRODUCT (*Continued from p. 39*)

gas utilization. SNG suffers because of both very high syngas utilization and low price of competing natural gas.

Finally, electricity as a product even shows negative "encumbered" value because of the low electricity price in the U.S., and relatively low heating value of syngas as compared to natural gas. Therefore, it has a higher capital outlay per unit of energy produced.

The ranking of products is likely to be different at varying relative values of oil and gas in North America. While some of the products shown above compete with products typically derived from natural gas, others compete with the petroleum-derived products. Thus, the relative valuations of the different products are expected to be significantly different today, which most likely will influence the ranking of the products.

In addition to determining an optimum product from a gasification process, the methodology used in this study also can be applied to determine the optimum feedstock or an optimum technology path. A gasification project developer may be a feedstock owner (for example, a coal company), a gasification or syngas technology owner, or a final-product market participant. Clearly, feedstock owners would be interested in optimizing product mix and technology path. Technology owners may be interested in optimizing feedstock and product value. Final-product market participants would look to optimize feedstock and technology fit with the target final product.

The keys to an accurate assessment of syngas value are:

1. In-depth knowledge of a wide range of gasification and syngas conversion processes.
2. Knowledge of product markets, prices and understanding of market dynamics.
3. Extensive and accurate capital cost reference databases.
4. Optimization tools for product and energy price sensitivity studies. ■

Edited by Scott Jenkins

References

1. National Energy Technology Laboratory (NETL; U.S. Dept. of Energy). Cost and Performance Baseline for Fossil Energy Power Plants study, Volume 1: Bituminous Coal and Natural Gas to Electricity, May 2007.
2. ICIS website. http://www.icis.com/home/default.aspx, Accessed January 2012.
3. Energy Information Agency (U.S. Dept. of Energy) website. http://www.eia.doe.gov/steo/, Accessed January 2012.
4. BASF SE website. http://bericht.basf.com/2009/en/managementsanalysis/businessdevelopment/globaleconomy/chemicalindustry.html, Accessed January 2012.
5. NETL. Task 2 Topical Report Coke/Coal Gasification With Liquids Coproduction Volume 1, DOE NETL Contract No. DE-AC26-99FT40342 Gasification Plant Cost and Performance Optimization, September 2003.
6. Mitretek. Polygeneration of SNG, Hydrogen, Power, and Carbon Dioxide from Texas Lignite. Technical Report, DOE NETL Contract No.: DE-AM26-99FT40465, December 2004.
7. Barranon, Diana C.C., Methanol and hydrogen production, energy and cost analysis. Master's thesis. Lulea University of Technology, Sweden, Dept. of Applied Physics and Mechanical Engineering.

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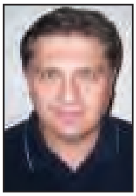

Armen Abazajian is a senior supervising process engineer at WorleyParsons (6330 West Loop South, Bellaire, TX 77401; Phone: 713-407-5000; Email: armen.abazajian@worleyparsons.com) with over 25 years of experience in design, technology development and plant engineering. Abazajian's expertise is in syngas conversion technologies including Fischer-Tropsch synthesis and synthetic crude upgrading, OXO synthesis, methanol, MTO, methanol derivates, ammonia synthesis and IGCC as well as other aspects of gas, coal, and biomass-to-liquids and chemicals processes. Abazajian has been granted 12 U.S. patents. He graduated *cum laude* with a degree in chemical engineering from the University of Houston in 1986.

Fractionation Column

I drink tap water

I drink tap water! There, I finally said it. I am out of the closet — the water closet. My two sons are now cowering with shame, wondering how they can possibly ever face their Dasani-drinking friends again.

It was maybe 20 years ago when I first encountered the concept of bottled water. What a strange idea! Why would anybody want to pay for something that's free — and everywhere — including public drinking fountains? I regarded it as a fringe product for fringe people. Now, 20 years later, I seem to be in the minority.

As we all know, the biggest problem with bottled water is...the bottles. The statistics are staggering — and worsening. In 2006, Americans sent 38 billion plastic water bottles to landfills.* If laid end-to-end, those bottles would go to the Moon 20 times. Speaking of the Moon, in Stillwater, Okla. there is possibly no more beautiful sight than a Full Moon hovering over Water Bottle Mountain, just northeast of town.

Several years ago, a Penn & Teller cable-television episode contended that "plastics recycling" is mostly mythical. Based on a recent literature search, at most, only 28% of plastic water bottles are actually recycled. How long does it take a plastic water bottle to biodegrade? It depends on whether the bottle is exposed to sunlight. If so, 400 years; if not, 1,000 years.

Obviously, governments need to do something. In the U.S., they did! Last year the House of Representatives spent about $750,000 on bottled water. I guess the Capitol building has no drinking fountains.

So what is the big attraction? In 2007, two controversies made the headlines. Aquafina bottle labels were found to include the acronym "PWS." The makers of Aquafina were forced to change the labels to "Public Water Source." At just about the same time, in the UK, the makers of Dasani were forced to admit that the source of the water was the "municipal" supply. I just looked up the word "municipal" in three dictionaries. None said "virgin mountain streams."

Generally, bottled water is filtered and purified, but the producers of bottled water do not contend that U.S. tap water is undrinkable. In the U.S. and in Western Europe I always drank tap water. However, there are countries where I never (knowingly) drank it. An excellent list of countries where the water is considered to be high, moderate and low risk is provided on the Website TravelerIndependent.com.

I should be a big fan of plastic bottles. After all, a very significant fraction of the monomers that comprise the bottles went through distillation devices that I helped develop. Nevertheless, I am not a fan. I will admit that bottled water is both potable — and portable — but the damage that bottled water does to the environment far exceeds the convenience of having it at your fingertips, everyday and all day. If you ever see me carrying a plastic water bottle, the odds are very high that I just filled the bottle from a tap somewhere. ■

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

* I thank Ms. Joella Redden for her research work, most of which would not fit into this editorial.

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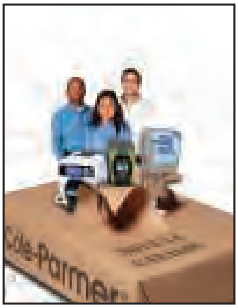

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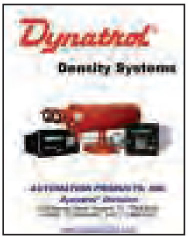

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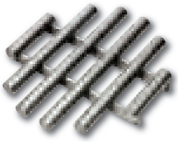

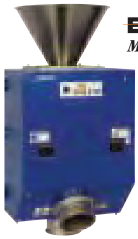

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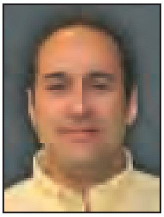
People

OCTOBER WHO'S WHO


Engel


Widmann


Subramanian


Wright


Kleinhans

Jonathan Foster becomes CFO of **LS9, Inc.** (South San Francisco, Calif.), a developer of renewable and sustainable fuels and chemicals.

David Engel becomes president of the American Filtration and Separations Soc., Southwest Chapter. He is the managing director of **Nexo Solutions** (The Woodlands, Tex.), which focuses on process efficiency and technology development, and is co-founder and lead consultant at **Sulphur Experts,** Filtration Div., a sulfur-recovery engineering company.

Martin Widmann, senior vice president at **BASF** (Ludwigshafen, Germany), now leads the company's global Fuel and Lubricant Solutions business unit.

Ravichandran Subramanian joins **Koch Membrane Systems** (Wilmington, Mass.) as regional commercial manager for Southeast Asia.

Industrial Scientific Corp. (Pittsburgh, Pa.), makers of gas-detection systems, names *Larry Kilian* senior director of sales.

Strongwell Corp. (Bristol, Va.), a maker of pultruded, fiber-reinforced polymer composites, names *Tracy Wright* director of Virginia manufacturing operations (including the company's Bristol and Abingdon facilities).

Matthias Kleinhans, managing director of **Sandvik Process Systems GmbH** (Fellbach, Germany), has taken on an additional role as managing director of **Sandvik Materials Technology GmbH**. ■

Suzanne Shelley

BUSINESS NEWS

PLANT WATCH

BASF building production plant in Poland for emissions catalysts

November 6, 2012 — BASF SE (Ludwigshafen, Germany; www.basf.com) is investing approximately €90 million in the first step to build a mobile emissions-catalysts production facility in Sroda Slaska, near Wrocław, Poland. Construction of the new 40,000-m^2 facility — BASF's largest in Europe — will begin before the end of the year. The plant will start production in the 1st Q of 2014. Additional expansion will follow, raising the total investment volume for the project to approximately €150 million. All ten planned light-duty and heavy-duty production lines are expected to be operating at full capacity by 2016.

Uhde wins mega contract for fertilizer plants in the U.S.

November 5, 2012 — CF Industries has selected ThyssenKrupp Uhde GmbH (Uhde; Dortmund, Germany; www.uhde.eu) through its U.S. business partner, Uhde Corp. of America (Pittsburgh, Pa.), to provide engineering and services for two fertilizer complexes in the U.S. At its complex in Donaldsonville, La., CF Industries will construct a 3,300-metric tons per day (m.t./d) ammonia plant, a 3,500- m.t./d urea plant, a 1,520-m.t./d nitric acid plant and a urea-ammonium nitrate (UAN) plant with a capacity of 4,500 m.t./d of UAN solution. The ammonia, nitric acid and UAN plants will be based on Uhde processes, while the urea plant will employ the process belonging to Stamicarbon of the Netherlands. The urea and UAN plants are scheduled to come onstream in the 2nd half of 2015 and the new ammonia plant in 2016. In Port Neal, Iowa, the company plans to build an ammonia plant with a capacity of 2,200 m.t./d, a urea plant with a capacity of 3,500 m.t./d and a urea granulation unit with a capacity of 3,500 m.t./d. These plants are scheduled to come onstream in 2016. Overall expenditure on the projects will total $3.8 billion.

Evonik builds new plant for personal- and household-care ingredients in Brazil

October 24, 2012 — Evonik Industries AG (Essen, Germany; www.evonik.com) is moving ahead with its plans to build a new production facility for cosmetics and consumer goods in the Brazilian state of São Paulo. The mid-double-digit million euro investment will go on stream in 2014. The total production capacity is around 50,000 m.t./yr, spread across different technologies, such as surfactants, conditioning agents, emollients, emulsifiers, thickeners and others.

Dow plans EPDM rubber plant for the U.S. Gulf Coast

October 24, 2012 — The Dow Chemical Company (Dow; Midland, Mich.; www.dow.com) says that it plans to build a new world-scale plant for the production of metallocene, ethylene propylene diene monomer (EPDM), sold under the trademark of Nordel IP Hydrocarbon Rubber. The new facility, when operational in 2016, will incorporate the use of Dow's newest proprietary catalyst technology. The manufacturing site will be located on the U.S. Gulf Coast. This production facility will leverage Dow's investment plan to increase ethylene and propylene production in the U.S. Gulf coast and will connect the company's U.S. operations into feedstock opportunities available from increasing supplies of U.S. shale gas.

Algeria plans construction of solar-tower power plant in North Africa

October 22, 2012 — The first solar-tower power plant in North Africa will be built in Algeria. The People's Democratic Republic of Algeria Ministry of Higher Education and Scientific Research and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit; BMU) have agreed to collaborate on this project. The aim is to build a solar-gas hybrid power plant with an output of up to 7 MW. Important components of power station technology were, to a great extent, developed by the German Aerospace Center (DLR; Cologne; www.dlr.de) with partners. The power plant will be constructed in Boughezoul, on the northern edge of the Sahara desert. It will be able to operate using only solar energy or as a hybrid power plant fuelled by a combination of solar power and gas.

Solvay doubles PVDF production capacity in France

October 18, 2012 — Solvay S.A. (Brussels, Belgium; www.solvay.com) says it is starting up new production capacity for polyvinylidene fluoride (PVDF) at its Tavaux plant in France. Solvay invested €26 million to increase the PVDF production capacity at the plant by 50%.

Uhde Inventa-Fischer to build Europe's biggest PET plant

October 17, 2012 — Uhde Inventa-Fischer (Domat/Ems, Switzerland; www.uhde-inventa-fischer.com) is to build a polyethylene terephthalate (PET) plant for its Indian customer JBF Industries Ltd. The plant, with a total nameplate capacity of 432,000 m.t./yr, will be located in Geel, Belgium, and will produce PET for bottling and packaging applications, based on Uhde Inventa-Fischer's patented Melt-To-Resin (MTR) technology.

Clariant expands production capacity for dehydrogenation catalysts

October 15, 2012 — Clariant (Muttenz, Switzerland; www.clariant.com) plans to expand production capacity for its Houdry dehydrogenation catalysts. The expansion will be achieved by a low double-digit million Swiss-francs investment at its current Louisville, Ky. plant. Production is planned to start in September 2013. Houdry catalysts are part of the product portfolio from Clariant's business unit Catalysis & Energy (formerly Süd- Chemie), which is headquartered in Munich, Germany.

MERGERS AND ACQUISITIONS

Siemens to reorganize its water business to focus on automation and drives

November 11, 2012 — Siemens AG (Munich, Germany; www.siemens.com) has decided to reorganize its activities in the water business. The company intends to focus on automation and drive solutions for the control of water applications for municipalities and industry. The Business Unit known as Siemens Water Technologies, which offers solutions for municipal and industrial water purification and wastewater treatment, is to be sold along with the corresponding service activities. Siemens Water Technologies is active predominantly in the North American market and recently underwent a comprehensive restructuring. The products and services provided by Water Technologies comprise a number of different biological, chemical and mechanical methods for the treatment of water and wastewater.

Clariant and Wilmar establish JV for amines and selected amines derivatives

October 26, 2012 — Specialty chemicals manufacturer Clariant Ltd. (Muttenz, Switzerland; www.clariant.com) and Wilmar International Ltd. (Singapore; www.wilmar-international.com), an Asian agribusiness group, have, through their respective subsidiaries, agreed to establish a 50-50 joint venture (JV) as the global platform for production and sales of amines and selected amines derivatives. The JV will be headquartered in Singapore. Subject to regulatory approvals, including merger clearances, the JV is expected to be operational in spring of 2013. ■

Dorothy Lozowski

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

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

2010 2011 2012

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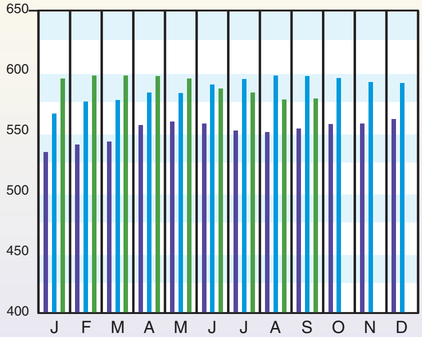
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Sept.'12 Prelim.	Aug.'12 Final	Sept.'11 Final
***CE* Index**	577.4	576.6	596.0
Equipment	700.8	700.1	727.6
Heat exchangers & tanks	643.9	641.6	692.4
Process machinery	662.3	663.3	677.4
Pipe, valves & fittings	895.7	899.2	912.6
Process instruments	424.0	420.1	439.4
Pumps & compressors	929.0	929.0	909.9
Electrical equipment	510.6	511.3	510.1
Structural supports & misc	742.3	741.2	772.5
Construction labor	324.8	323.6	330.7
Buildings	527.2	524.5	520.4
Engineering & supervision	328.7	328.6	330.9

Annual Index:

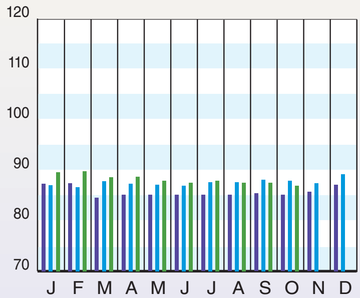
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7



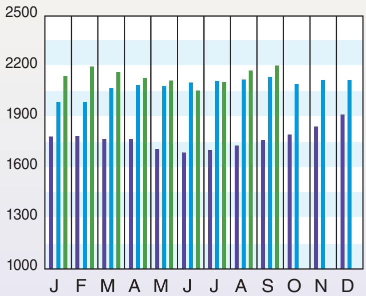
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS			YEAR AGO	
CPI output index (2007 = 100)	Oct.'12	= 86.9	Sep.'12 = 87.3	Aug.'12 = 87.5		Oct.'11 = 87.9	
CPI value of output, $ billions	Sep.'12	= 2,207.8	Aug.'12 = 2,175.3	Jul.'12 = 2,108.8		Sep.'11 = 2,137.7	
CPI operating rate, %	Oct.'12	= 75.0	Sep.'12 = 75.3	Aug.'12 = 75.5		Oct.'11 = 75.9	
Producer prices, industrial chemicals (1982 = 100)	Oct.'12	= 299.7	Sep.'12 = 300.1	Aug.'12 = 292.9		Oct.'11 = 325.2	
Industrial Production in Manufacturing (2007=100)	Oct.'12	= 93.0	Sep.'12 = 93.8	Aug.'12 = 93.7		Oct.'11 = 91.5	
Hourly earnings index, chemical & allied products (1992 = 100)	Oct.'12	= 157.6	Sep.'12 = 158.3	Aug.'12 = 157.7		Oct.'11 = 156.8	
Productivity index, chemicals & allied products (1992 = 100)	Oct.'12	= 103.1	Sep.'12 = 103.2	Aug.'12 = 102.8		Oct.'11 = 105.9	

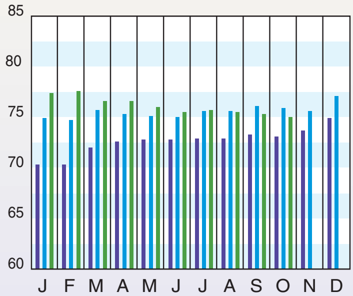
CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



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

CURRENT TRENDS

Capital equipment prices, as reflected in the *CE* Plant Cost Index (CEPCI; top), dropped 3.12% from August to September (the most recent data). Meanwhile, the Current Business Indicators from IHS Global Insight (middle), show less than a 0.5% decrease in the operating rate and output index, from August to September. At the same time there was a 1.49% increase in the value of output over the same time period, and a 0.13% average decrease in the producer prices, industrial chemicals. Year over year, there is a 1.17% decrease in the output index, a 3.28% increase in the value of output, a 1.23% decrease in the operating rate and a 7.84% decrease in the producer prices, industrial chemicals.

According to the American Chemistry Council's (ACC; Washington, D.C.; www.americanchemistry.com) latest weekly economic report at *CE* press time, The Organization for Economic Co-operation and Development (OECD) composite leading indicator (CLI) for September points to weak growth in many major economies, but signs of stabilization are emerging in Canada, China and the U.S.

For more on capital cost trends and historical CEPCI data, visit: www.che.com/pci ■