
CHEMICAL ENGINEERING
December
2011
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Consider more than the fluid
Access Intelligence

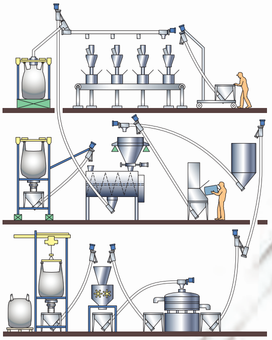
Cut Your Cost 9 Ways with One Ultra-Economical Conveyor

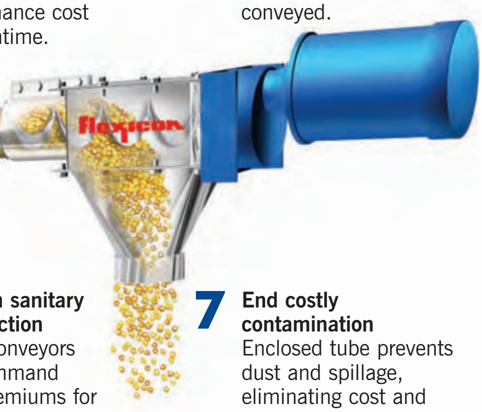
1 Cut installation cost
Easy conveyor routing at any angle (over, under or around obstructions, through small holes in walls or ceilings) conforms to process layouts, drastically cutting installation costs, while consuming minimal floor space.

2 Slash initial cost
Flexicon conveyors cost far less than drag chain conveyors, bucket elevators, pneumatic conveying systems and other conveyors of equivalent capacity, both initially and in operation.

3 Save on maintenance
Rugged inner screw is the only moving part contacting material (no internal bearings) yielding ultra-high reliability with little maintenance cost or downtime.

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.

6 Save on sanitary construction
Other conveyors can command high premiums for food, 3-A dairy and pharmaceutical models, but Flexicon conveyors can meet sanitary requirements at comparatively low cost.

7 End costly contamination
Enclosed tube prevents dust and spillage, eliminating cost and quality concerns associated with contamination of your product and plant environment.

8 Reduce cleaning costs
Removable end cap allows reversing of screw for evacuation of material, in-place flushing of crevice-free interior, or quick removal of screw for sanitizing—all with minimal labor or downtime.

9 Convey disparate materials
Handle sub-micron powders to large pellets including non-free-flowing products that pack, cake, seize, fluidize, abrade or smear, with no separation of blends, often eliminating the need for multiple units.

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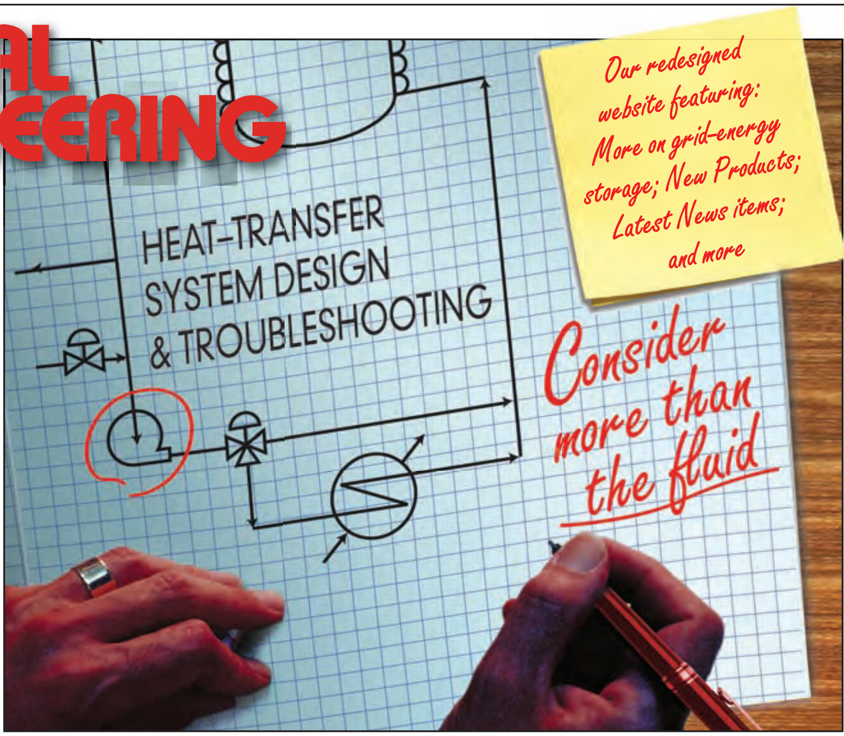

COMING IN JANUARY

Look for: **Feature Reports** on Total Cost Analysis; and Heat-Transfer; **Engineering Practice articles** on Project Management Mistakes; and Lubrication for Rotating Machines; **News articles** on Ammonia; and Centrifuges; and more

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Access Intelligence

BPA

Editor's Page

CE's growing LinkedIn presence

For over 109 years now, readers have looked to *Chemical Engineering* for practical how-to information that can be used directly on the job, plus the latest about what's happening in, or will be affecting, the chemical process industries (CPI). While our editors put a lot of time and effort into identifying what the most important and timely issues are, finding good sources of information and assimilating it all in an unbiased, authoritative, clear and concise format, the truth is that the sources of much of that information come from within our readership itself. In a sense, one of our most important missions as editors is simply to facilitate the sharing of best practices, concerns, solutions and so on.

Our latest venture into social networking follows that same mission, and one might say it even takes it a step further. Approximately eight months ago *CE* launched its first LinkedIn group. The group has grown rapidly, and at press time it was already crossing the milestone of 2,000 members. That is a relatively quick ramp-up to such a critical mass of participants, and it underscores how eager chemical engineers are to share information.

The group is made up of a very diverse mix of CPI professionals from across the globe. About 32% of our members are from the U.S (4.4% of which are from Texas alone). The next most-represented geographical area is India (9%), followed by the E.U. (8%), Canada (5%), the U.K. (4.6%), Brazil (3.5%), Pakistan (2.9%), Australia (2.5%), Indonesia (2%) and Saudi Arabia (2%).

Meanwhile, the most-represented employers so far are what you might expect from our readership, the CPI's engineering and operating companies: Worley Parsons, DuPont, Sabic, Fluor, Air Products, LyondellBasell, Nalco, Dow Chemical, Dow Corning, BASF, Jacobs Engineering, ExxonMobil, Shell and Chevron. By industry group, approximately 28% of members identify themselves with chemicals, 25% with oil and energy, 4% with mechanical or industrial engineering, 4% with mining and metals and 3% with environmental services. As for general job function, 34% work in engineering, 8% in operations, 6% in program and project management, 4% in consulting and 4% in research. (Note: Only the most significant categories are listed.)

Another interesting representation of the group's membership is that of seniority: 34% of the current membership identifies themselves as entry level, 23% are senior level, 17% manager level, 6% director and around 6% are top (executive) level management (3% each for vice president and C levels).

While it is safe to assume that many of the group's statistics will change over time, the current demographics fit perfectly with our vision for the group. First and foremost, the group is not a venue for promotions. The purpose of the group is to provide a platform where our readers can interact more frequently and directly with each other to share their best practices and expertise. Similarly, we see the group as a way for us to connect with our readers and their needs more directly.

For instance, one of the discussions that has received the most comments is a question we posed to the group asking them what types of technologies they would like to see covered in an upcoming *CE* news feature. The most popular responses included the following: Incorporating renewable energy into CPI facilities, biotechnology for producing building block chemicals, technology to recover and purify CO_2, advances and optimization of separation technologies (such as membranes, pervaporation, multi-phase separation, and so on), process intensification, debottlenecking and more.

If you have not joined the group already, we invite you to do so today and give us your feedback. The group name is Chemical Engineering Magazine, and a direct link to it is available at www.che.com. ■

Rebekkah Marshall

Letters

Better styrene science needed

The U.S. Dept. of Health and Human Services' (HHS) flawed and unwarranted ruling that styrene poses a health hazard continues to stir opposition from respected scientists, manufacturing leaders, the hundreds of thousands of American workers whose jobs depend on a viable styrene industry, and a broad-based bipartisan coalition on Capitol Hill. Fifty members of the U.S. House of Representatives last week — including a dozen Democrats — sent a strongly worded letter to the Obama White House urging the Administration to commission a National Academy of Sciences (NAS) review of HHS's action. Only an independent and rigorous NAS review can resolve the confusion caused by HHS's 12th Report on Carcinogens (RoC). Moreover, only an NAS review — the gold standard of scientific assessments — can help the federal government make informed regulatory decisions and provide responsible guidance about hazard identification.

As noted epidemiologist Dr. Julie Goodman of Gradient Technologies and other veterans of NAS reviews have pointed out, HHS' RoC was based on cherry-picked science and an unsound process. HHS chose to ignore the weight of scientific evidence, which clearly shows no causal link between styrene and human cancer. Among the studies HHS failed to adequately consider are:

- Its own Agency for Toxic Substances and Disease Registry
- International Agency for Research on Cancer's 2002 review
- Comprehensive studies recently conducted by the European Union, Canada and Japan
- A 2009 review conducted by a blue-ribbon panel of internationally recognized epidemiologists

HHS' staffers must have known that the latest science did not support their conclusions about styrene's health effects. Yet the agency insisted on issuing a ruling with the potential to frighten workers, plant neighbors and consumers — with no public health benefit whatsoever.

Left unchallenged, the listing of styrene as a carcinogen could have the longterm effect of moving manufacturing jobs to countries that have not taken such an ill-informed position. Indeed, the only [other] place a manufacturer has to worry about styrene liability is Sweden.

Styrene-dependent composite manufacturers, many of them second- or even third-generation family companies, are already suffering the consequences of HHS's peremptory action. Workers' compensation liability costs have skyrocketed, certain companies are delaying investments and worker expansion due to marketplace uncertainty and many worry that the HHS ruling will ultimately force them to move their facilities out of the U.S. This domino effect may well effectively kill the industry. U.S. composite companies help produce everything from better roads and bridges to recreation boats and pollution controls to the ballistic shields that protect our military.

Styrene has been used safely for more than 60 years. We cannot let a misguided federal ruling jeopardize such a critical industry — and some 750,000 sorely needed American manufacturing jobs. For more information, please consult www.youknowstyrene.org ■

Tom Dobbins, chief staff executive
American Composites Manufacturers Assn.

Calendar

NORTH AMERICA

IFPAC 2012 — International Forum & Exhibition for Process Analytical Chemistry. IFPAC (Grayslake, Ill.). Phone: 847-543-6800; Web: ifpacpat.org
Baltimore, Md. **January 22–25, 2012**

Molding 2012 — 22nd International Conference. Executive Conference Management (Plymouth, Mich.). Phone: 734-737-0507; Web: executive-conference.com
Miami, Fla. **January 22–25, 2012**

16th Annual ARC Annual Forum. ARC Advisory Group (Boston, Mass). Phone: 781-471-1175; Web: arcweb.com
Orlando, Fla. **February 6–9, 2012**

Informex USA 2012. Informex Holdings LLC (Princeton, N.J.). Phone: 508-743-8543; Web: informex.com
New Orleans, La. **February 14–17, 2012**

2012 NPRA Annual Meeting. National Petrochemical & Refiners Assn. (Washington, D.C.). Phone: 202-457-0480; Web: npra.org
San Diego, Calif. **March 11–13, 2012**

Pittcon Conference & Expo 2012. The Pittsburgh Conference (Pittsburgh, Pa.). Phone: 412-825-3220; Web: pittcon.org
Orlando, Fla. **March 11–15, 2012**

ACS National Meeting. American Chemical Society (Washington, D.C.). Phone: 202-227-5558; Web: acs.org
San Diego, Calif. **March 25–29, 2012**

2012 International Petrochemicals Conference. National Petrochemicals & Refiners Assn. (Washington, D.C.). Phone: 202-457-0480; Web: npra.org
San Antonio, Tex. **April 1–3, 2012**

The 2012 National Symposium on Market Transformation. American Council for an Energy-Efficient Economy (Washington, D.C.) Phone: 202-507-4043; Web: aceee.org
Washington, D.C. **April 1–3, 2012**

6th International Workshop on Characterization of Porous Materials (CPM-6). Rutgers University, Dept. of Chemical and Biochemical Engineering (Piscataway, N.J.). Fax: 732-445-5728; Web: cpm6.rutgers.edu/
Delray Beach, Fla. **April 30–May 2, 2012**

Interphex. Reed Exhibitions (Norwalk, Conn.). Phone: 203-840-5648; Web: interphex.com
New York, N.Y. **May 1–3, 2012**

PTXi International Powder and Bulk Solids 2012. WHO UBM Canon Trade Shows (Los Angeles, Calif.). Phone: 310-445-4200; Web: powdershow.com
Chicago, Ill. **May 8–10, 2012**

Electric Power Conference 2012. The Tradefair Group (Houston), an Access Intelligence Co. Phone: 832-242-1969; Web: electricpowerexpo.com
Baltimore, Md. **May 15–17, 2012**

2012 ACEEE Hot Water Forum. American Council for an Energy-Efficient Economy (ACEEE; Washington, D.C.) Phone: 202-507-4043; Web: aceee.org
Berkeley, Calif. **May 21–23, 2012**

EUROPE

Interplastica, 15th International Trade Fair on Plastics and Rubber. Messe Düsseldorf North America (Chicago, Ill.). Phone: 312-781-5185; Web: mdna.com
Moscow, Russia **January 24–27, 2012**

Global ManuCHEM Strategies 2012. We.Conect Global Leaders (Berlin, Germany). Phone: +49-30-52-10-70-3-21; Web: manu-chem.we-conect.com
Berlin, Germany **February 13–14, 2012**

Energy Storage — International Summit for the Storage of Renewable Energies. Messe Düsseldorf North America (Chicago, Ill.). Phone: 312-781-5185; Web: mdna.com
Düsseldorf, Germany **March 13–14, 2012**

Silicone Elastomers 2012 — 5th International Conference. Smithers Rapra Technology Ltd. (Shropshire, U.K.). Phone: +44-1939-250383; Web: ismithers.net
Berlin, Germany **March 27–28, 2012**

High-Performance Elastomers & Polymers for Oil-and-Gas Applications — 6th International Conference. Smithers Rapra Technology Ltd. (Shropshire, U.K.). Phone: +44-1939-250383; Web: ismithers.net
Aberdeen, Scotland **April 17–18, 2012**

11th World Filtration Congress. Filtech Exhibitions Germany (Meerbusch, Germany). Phone: +49-2132-9357-60; Web: wfc11.at
Graz, Austria **April 16–20, 2012**

Hannover Fair. Deutsche Messe (Hannover, Germany). Phone: +49-511-89-0; Web: hannovermesse.de
Hannover, Germany **April 23–27, 2012**

IFAT/Entsorga. RIGK GmbH (Wiesbaden, Germany). Phone: +49-611-3086-00-0; Web: rigk.de
Munich, Germany **May 7–11, 2012**

ASIA & ELSEWHERE

PlastIndia 2012. Messe Düsseldorf North America (Chicago, Ill.). Phone: 312-781-5185; Web: mdna.com
New Dehli, India **February 1–6, 2012** ■

Suzanne Shelley

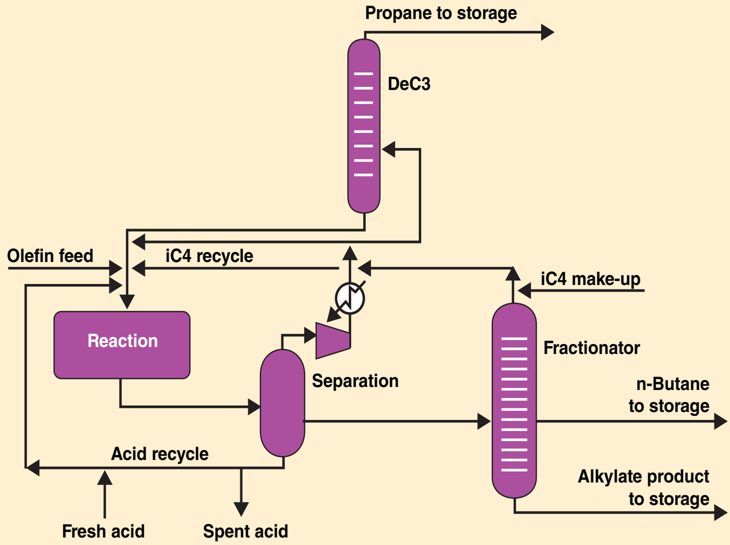
Commercialization is set for a new alkylation process

An improved sulfuric-acid alkylation process that reduces acid consumption by up to 50% from that of conventional processes will make its commercial debut in China. Developed by Lummus Technology, a CB&I company (The Woodlands, Tex.; www.cbi.com), the technology will be used by Ningbo Haiyue New Material Co. in a grassroots alkylation plant to be built near Ningbo City, Zhejiang Province. Scheduled for startup at the end of 2013, the plant will produce 600,000 metric tons (m.t.) per year of alkylate.

The process is similar to standard sulfuric acid alkylation methods in that it uses H_2SO_4 to react light olefins (C_3–C_5) with isobutane to produce motor fuel alkylate (predominantly C_8 material). The innovation is a contactor for mixing the acid and hydrocarbons. Conventional alkylation units use large impellers to mix the reactants, then separate the alkylate product from the acid emulsion. The product is purified by a series of acid and alkaline washes. In contrast, Lummus carries out the reaction in a large, vertical column, using proprietary packing to achieve efficient contacting between the components.

The design of the contactor improves mass transfer over conventional alkylation and enables an easier separation of the reaction products, says Todd Vogt, Lummus Technology's director of operations for refining. "We have eliminated the acid and alkaline water wash and use advanced coalescers for cleanup," he says. Also, the contactor allows the process to be done at around 27°F, versus 40–50°F for mechanical mixing. The colder temperature improves selectivity and produces a higher-octane product, with low acid consumption, says Vogt, noting that mechanical impellers are unsuited to low-temperature operation because of the viscosity of the acid emulsion. Another benefit is that the process is readily scaled up — the Ningbo plant will use only two vertical reactors in parallel, versus about eight reactors for conventional alkylation.

"We have come up with a simplified process that eliminates a lot of equipment, so we expect to cut capital costs by 20–30%," says Vogt. "Also, we estimate that operating costs will be reduced, primarily through reduced acid consumption and lower maintenance cost."



Bio bisabolene

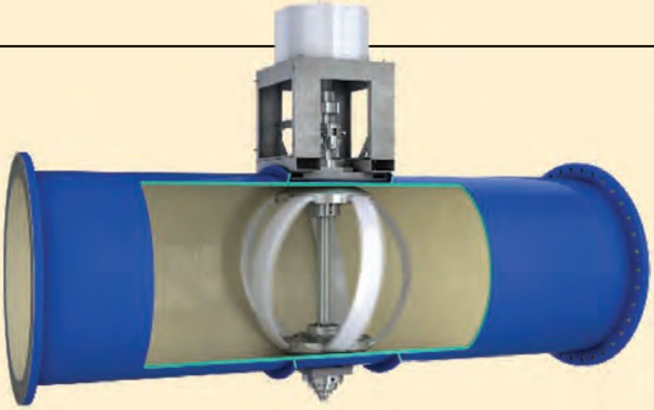
Through genetic engineering of microbes, scientists from Lawrence Berkeley National Laboratory's (Berkeley, Calif.; www.lbl.gov) Joint BioEnergy Institute (JBEI) have coaxed both bacteria (*Escherichia coli*) and yeast (*Saccharomyces cerevisiae*) to produce a chemical precursor to bisabolane — a critical step toward an improved renewable diesel alternative. The precursor can be converted to bisabolane when treated with hydrogen gas under pressure. Bisabolane, a plant-derived hydrocarbon chemically related to turpentine, was discovered to deliver comparable performance to standard D2 diesel fuel and superior cold weather performance. With continuous yield improvements, biosynthetic bisabolane could initially serve as a cold weather additive to diesel and biodiesel formulations and, at higher yields, could substitute for these fuels. The JBEI team inserted a gene from the Grand Fir tree into *E. coli* bacteria, and made genetic adjustments designed to optimize the production of bisabolene, boosting the yield of that chemical tenfold.

Making amides with high yield, less waste

A catalyst for making amides from alcohols and amines under aerobic conditions has been developed by Professor Shu Kobayashi and his research group at the University of Tokyo (Tokyo, www.chem.s.u-tokyo.ac.jp/users/synorg/index_e.html). The catalyst — nano particles (2.4-nm dia.) of gold and cobalt — is said to produce amides with higher yield, less side reactions and almost no waste, compared to alternative routes based on carboxylic acids and amines, which require a condensation agent that generates a lot of waste. Yields of more than 90% have been achieved in the laboratory for amides that are typically used for synthesizing proteins and textile chemicals.

For example, a targeted amide has been produced from benzyl alcohol and benzyl amine with a 96% yield using a 1-wt.% Au/Co catalyst on a polymer-incarcerated, carbon-black (PICB) support. The reaction required 12 h in a tetrahydrofuran-water solvent at room temperature. Over 30 other reactions using alcohols and amines — including ammonia and amino acids — have been studied, with yields of over 90% for the corresponding amide. The catalyst can be recovered and reused several times without loss of activity, says Kobayashi. The group plans to work with industrial partners to develop commercial processes.

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



An in-pipe turbine system generates energy from water effluent

Hydrofoil turbines mounted inside gravity-fed water-effluent conduits can generate significant electrical power without impeding flow, a demonstration project has shown. The in-pipe turbine systems offer chemical process industries (CPI) companies a way to extract emission-free energy from flowing wastewater discharge pipes.

Based on hydropower research by Northeastern University professor Alexander Gorlov, and developed into a circular, in-pipe format by Lucid Energy (Portland, Ore.; www.lucidenergy.com), the lift-based turbines (photo) turn as water flows through the pipe, producing torque on the shaft. The rotating shaft turns a permanent-magnet generator that induces electrical current. The marine-grade fiberglass composite blades of the turbine work bi-directionally, and are coated with a corrosion-resistant material.

To work cost-effectively, the system requires a minimum of 10 ft of head, pipes of greater than 24-in dia., and water volumes of at least 10 million gal/d, explains Josh Kanagy, director of business development at Lucid Energy. One turbine unit extracts between 2 and 5 ft of head from the flowing water, depending on conditions. Multiple units can be mounted in the same length of pipe, as long as they are separated by at least two or three pipe diameters, Kanagy adds. Depending on the amount of head, flow velocity and volume, each turbine unit can produce between 10 and 100 kW of electricity, which translates to 90,000 to 900,000 kWh per year.

This month, the company will begin operation of the fourth version of its demonstration pipe-turbine system at a municipal water facility in Riverside, Calif. The unit is identical to the company's planned commercial unit, which will be available in mid-2012. By installing such a turbine system in their wastewater discharge, companies are eligible for certain tax credits for green energy, Kanagy points out.

A car company moves closer to making cellulosic ethanol ecomomically

Using gene recombination technology, Toyota Motor Corp. (TMC; Toyota City, Japan: www2.toyota.co.jp/en) has developed a new strain of yeast that achieves one of the highest ethanol-fermentation density levels in the world — approximately 47 g/L with 87% yield (based on the feed sugar). In addition to the high yield, TMC's yeast is highly efficient at fermenting xylose, which is normally difficult to ferment for naturally occurring yeasts. The new yeast is also highly resistant to fermentation-inhibiting substances, such as acetic acid.

TMC is focusing on cellulosic ethanol, which is produced from non-edible plants that have significantly less impact on world food supplies. Aiming to achieve production-cost parity with other liquid fuels, such as gasoline, TMC hopes to achieve a stable supply of raw-material plant fibers as well as technologies that reduce production costs. Napier Grass from Indonesia is a promising raw material because it not only thrives on land unsuitable for growing crops, but has a production volume and cultivation cost of 50 ton/ha/yr and ¥4/kg, respectively, which is very competitive compared to rice straw from Japan (26 ton/ha/yr, ¥7/kg); Acacia from Malaysia (21 ton/ha/yr, ¥6.3/kg); and Switch Grass from the U.S. (7 ton/ha/yr, ¥15/kg).

To reduce the production costs, TMC is also developing a pre-treatment process that combines crushing and steaming with diluted acid, and an integrated, simultaneous saccharification and fermentation process, which enables the reduction of equipment cost and improves the yield. The company is working to further improve production yields and to cooperate with liquid-fuel-producing companies to realize its goal of commercializing cellulosic ethanol by 2020.

Raceways *and* cables

Last month, Bentley Systems, Inc. (Exton, Pa.; www.bentley.com) launched the first and only comprehensive, integrated software developed specifically to design, model and deliver both raceway and cable systems. The Raceway and Cable Management V8i software tool integrates functional design with detailed physical design and includes a wide range of 2D and 3D design tools. By providing users with early and accurate material requirements via automated intelligent functions and highly realistic 3D design simulation, the software is said to improve quality, lead to increased safety in construction and enhance operations management through the integrity of a comprehensive as-operated model across constant retrofits.

Circle 24 on p. 62 or go to adlinks.che.com/35072-24

Detecting steam-trap leaks gets easier

Steam traps are designed to allow condensate, but not steam, to escape from a steam line. When they malfunction, however, numerous costly consequences can result including energy losses, insufficient heating to processes, maintenance issues and more. At its Global Users Exchange in late October, Emerson Process Management (St. Louis, Mo.; www.emersonprocess.com) introduced a new wireless device that continually monitors steam traps for leaks, making them easier to find and thus promptly repair.

Currently, some leaky steam traps are only repaired when someone notices they are leaking. A better approach to steam trap monitoring is periodic manual inspections, but this also has its drawbacks. The Rosemount 708 Wireless Acoustic Transmitter combines temperature and sound measurements that can continually monitor and detect a leaky steam trap, and also analyze for other problems, such as a possible plug in the line. Each unit is strapped onto the steam pipe near the steam trap to be monitored. This same technology and device can also be used on pressure relief lines to detect when a pressure relief valve has opened.

Control the fuel-to-air ratio in combustion with varying fuels

In combustion, the ratio of fuel to air is key to efficiency, emissions control and stable performance of the combustion system. Adjusting this ratio to accommodate variability in fuels — due to the use of different fuels, and the variability that naturally occurs with some of the lower-cost fuels and renewable fuel sources — is a difficult task. Emerson Process Management (St. Louis, Mo.; www.emersonprocess.com) has introduced a technology, called True BTU, which is a patent-pending innovation for calculating the actual Btu values of fuel sources to make energy production predictable and repeatable. At the company's Global Users Exchange in late October, Chip Rennie, director of Industrial Energy for Emerson, called True BTU combustion control a "game changer." He further said that this platform "reinvents the current model of combustion management, which has been around since the 1920s and is still in practice today."

To compensate for the variability in fuels, excess air is typically used in combustion systems. This means that most of the time the fuel-to-air ratio is not ideal. With True BTU, the change in O_2 level in the outgoing gas stream is measured, and using a stoichiometric equation for combustion, the fuel-to-air ratio is instantaneously adjusted. This technology allows companies to interchangeably use the most available and affordable renewable or waste fuels to consistently create steam to power their operations, says the company.

Recover oil from messy spills with this mesh

A novel mesh for oil-water separation with opposite wettability to traditional materials has been developed by a group of researchers from Beijing, China — the Beijing National Laboratory for Molecular Sciences, Institute of Chemistry, Chinese Academy of Sciences (www.iccas.ac.cn); School of Chemistry and Environment, Beihang University (ev.buaa.edu.cn); Dept. of Chemistry, Tsinghua University (www.tsinghua.edu.cn); and Graduate School of the Chinese Academy of Sciences (gucas.ac.cn).

The new material is a superhydrophilic and underwater superoleophobic hydrogel-coated mesh in an oil/water/solid three-phase system. It consists of rough nanostructured hydrogel coatings and microscale porous metal substrates. The researchers claim the new material can selectively and with an efficiency of better than 99%, separate water from oil-water mixtures, such as vegetable oil, gasoline, diesel, and even crude-petroleum oil-water mixtures without any extra power. The underwater superoleophobic interface prevents the coated mesh from fouling by oil, making it easy to recycle the oil and the materials.

Hydrogel consists of a cross-linked network with interstitial spaces that fill up with water, making it a typical hydrophilic material. The trapped water molecules greatly decrease the contact area between oil droplet and solid surface. The three-phase system presents a discontinuous contact line, allowing an oil droplet to easily roll off the surface, and the oil-adhesion on the surface is extremely low.

The research group chose polyacrylamide (PAM) as the coating material, where N,N'-methylene bisacrylamide (BIS) served as the chemical cross-linker. Stainless steel meshes with diameters between 340 and 380 µm were used as substrates. The cleaned stainless-steel mesh was carefully immersed in the mixed pre-gel solution, then drawn out horizontally and slowly

(Continues on p. 16)

Green standards

In late October, NFS International (Ann Arbor, Mich.; www.nsf.org) and the American Chemical Soc. Green Chemistry Institute (ACS GCI; Washington, D.C.; www.acs.org/gci) developed an American National Standard that provides a standardized way to define and report the environmental and human health hazards associated with a chemical product and its manufacturing process impacts. The standard, known as NSF/GCI/ANSI 255 Greener Chemicals and Process Information Standard (www.nsf.org/info/nsfgci355), establishes standardized criteria for comparing chemicals and processes that help manufacturers and their customers make "greener" choices. As a third-party certifier, NSGF International will certify reports to this standard. ❑

Optical cavity furnace can boost solar cell efficiency

Using an array of lamps inside a highly reflective chamber, the optical cavity furnace (OCF) takes advantage of photonics effects to help manufacture solar photovoltaic cells with higher efficiency than those made by conventional rapid-thermal-processing (RTP) methods. In addition, the OCF can reduce cost and raise efficiency of the manufacturing process itself.

Scientists at the U.S. Dept. of Energy's National Renewable Energy Laboratory (NREL; Golden, Colo.; www.nrel.gov) developed the OCF to harness the ability of photons to effect atomic-level changes that are important to solar-cell process outcomes, such as avoiding iron and other impurities, creating junctions and improving electronic properties. NREL engineer Bhushan Sopori remarks, "Optics can make a lot of things happen at the interfaces in a cell, where, for example, metal can reflect the light and speed the diffusion of impurities." The photonics effects offered by the OCF-based manufacturing process could boost cell efficiency by up to four percentage points, Sopori adds.

Aside from the photonic effects on the cells, the OCF allows a lower cost, lower-energy process. An OCF costs half or less than an RTP furnace, and uses half as much energy. Heat losses are virtually eliminated with highly insulating and reflective ceramics on the oven walls. The visible- and infrared-wavelength light used in the OCF uniformly heats crystalline silicon wafers, especially at the edges, which are prone to heat loss and cooling, with unparalleled precision.

The NREL team is working with an industry partner (AOS Solar Inc.; Los Angeles, Calif.; www.aossolar.com) to build a manufacturing-size OCF capable of processing 1,200 silicon wafers per hour.

OIL RECOVERY *(Continued from p. 15)*
with the solution adhered on the surface of the steel wires. After photoinitiated, in-situ radical polymerization for 90 to 120 min., the PAM hydrogen-coated mesh was obtained.

The group says the coated mesh is easily cleaned for reuse, even high-viscosity oils are easily washed away. The meshes retain their underwater superoleophobic and low-oil adhesion properties after 50 uses.

Alfa Laval

Heat-exchanger ‘fusion’

Last month at the Brau Beviale 2011 Exhibition (November 9–11; Nuremberg, Germany), Alfa Laval AB (Lund, Sweden; www.alfalaval.com) launched a new plate heat exchanger, which combines the energy efficiency, accessibility and modularity of plate technology with the viscous and particulate-handling capabilities of tubular technology. The so-called FusionLine features a 4–6-mm open-channel on the product side (diagram, red), which is easy to clean-in-place and is fully accessible. The open-channel design — with no contact points — is made possible by bonded plate cassettes on the media side (diagram, blue), which are bonded using the company’s patented AlfaFusion technology, which bonds two stainless-steel plates together into one piece with no joints.

AlfaFusion technology allows the use of thin plates for optimal heat transfer, and also maintains a high resistance against product pressure. The channel geometry ensures gentle product treatment, and the plates can be easily added and removed, enabling quick reaction to changes in production volume. The footprint is also 30–40% smaller than a tubular heat exchanger, says the company.

The FusionLine is suitable for viscous and particulate-containing products, such as juices, prepared foods, soups and sauces, which have traditionally been processed in tubular heat exchangers, says the manufacturer.

First working FDI prototype

Last month at the Namur Annual General Meeting in Bad Neuenbahr, Germany, the first working prototype of FDI (field device integration) was demonstrated. FDI device packages were used to integrate Foundation Fieldbus, HART and Profibus field devices of various manufacturers within an ABB process control system. Typical applications, such as parameter assignment, configuration, diagnostics and maintenance were demonstrated. The system makes use of prototypes of FDI standard host components developed by the FDI Cooperation, LLC (Karlsruhe, Germany; www.fdi-cooperation.com). The working prototype was developed to verify the FDI concepts, apply the standard host components in a system context and to demonstrate FDI functionality.

The first draft of the FDI specifications is expected to be published by the end of this year. Conformance Test concepts are planned to be completed by mid 2012, and completion of the FDI standard host components, such as EDD Engine and User Interface (UI) Engine will be completed by the FDI Cooperation by the end of 2012. ■

Newsfront

TRANSPORTING ENERGY THROUGH TIME

FIGURE 1. Integration of wind power is a major application for grid energy-storage technologies, such as the planned Li-ion battery facility shown here

A portfolio of new energy-storage technologies is poised to tackle applications on the next-generation power grid

Modernizing the world's power grids represents a key infrastructure goal for economic growth. Large-scale, energy-storage technologies offer the opportunity to optimize the efficiency of the next-generation power grid and extend its capabilities. Renewed attention on energy storage systems for the grid has given rise to a host of emerging technologies aimed at more effectively transmitting electricity not only across space, but also through time.

Several factors have fostered development of new electrochemical and mechanical strategies for large-scale energy storage systems that can collect generated electricity and store it for discharging to the grid when needed. Among the major drivers are the high capital costs associated with managing peak power demand, as well as the increase in grid modernization initiatives. Meanwhile, deployment of wind and solar power are increasing, making the grid more sensitive to the variability inherent in nature, and thus strengthening the need for energy storage systems.

Currently, 99% of existing grid-energy storage is achieved through "pumped hydro," a term used to describe the strategy of pumping water to higher elevations at times of low demand, and releasing the water through turbines to produce electricity when demand is higher. Pumped hydro has been relatively effective for years, but its use has specific site requirements, and plants are highly capital-intensive and may have environmental drawbacks.

These drawbacks, coupled with grid modernization and renewable energy growth, have spurred considerable effort by engineers in many disciplines to commercialize newer storage technologies — such as flow batteries, lithium-ion batteries, compressed-air energy-storage systems and flywheels — that are more broadly applicable and offer higher performance for specific applications. Meanwhile, questions remain about which storage technologies can be deployed cost-effectively, how best to match technologies to a variety of grid applications, and about how the economic and regulatory environment can be adjusted to allow storage technologies to fulfill their potentials (for more, see the online version of this article at www.che.com).

Grid-storage needs are varied

Energy storage systems have the potential to provide a range of benefits to the entire electrical system, from power generation to transmission and distribution, an ultimately to the end-user. According to U.S. Dept. of Energy (DOE; Washington, D.C.; www.energy.gov) and independent analysts, the size of the grid-energy storage market may be over $1.5 billion today, and has been forecasted to grow to more than $35 billion by 2020.

The evolution of the modern power grid, as well as the degree to which renewable energy technologies are deployed, is highly intertwined with the development of economical grid-energy storage systems. Among the most frequently discussed applications of energy storage involving power generation is off- to on-peak shifting, where storage devices would be charged at the site of intermittent renewable energy sources, and discharged into the grid during on-peak periods. This would enable increased penetration of wind and solar power into the power grid. Another key generation-related application is in grid frequency regulation, where short-term fluctuations in energy supply and demand are smoothed by storing energy when supply exceeds demand, and discharging when the reverse is true. This allows traditional fossil-fuel power generators to operate at more consistent levels, where they are most efficient, and produce lower emissions. Other potential applications of energy storage include energy arbitrage, support of electricity transmission and distribution systems, and backup power. With the large number of applications possible for maximizing grid reliability and asset utilization, it is likely that multiple energy-storage technologies that meet cost, performance and durability requirements will find significant uses.

The needs of a particular application can often be characterized by the power and energy matrix, an assessment of the level of power required over a period of time. A significant engineering challenge for energy storage technology developers is broadening the capabilities of a technology to handle a wide range of energy versus power demands. Extending the versatility, while reducing costs for energy storage technologies, represent the main goals for developers.

Until costs for deploying energy storage technologies come down, technologies that can perform well for several applications may have the inside track on commercial uptake. "Energy-storage technologies will play a critical buffering role in the next-generation power grid," but costs remain high, says Chris Kuhl, an applications engineer at ZBB Energy Corp. (Menomonee Falls, Wisc.; www.zbbenergy.com). "The industry still has a long way to go to get down to $500 and $250 per kWh installed," the cost points put forth by engineers at Sandia National Laboratory and DOE as the target for economic competitiveness of commercially sited and grid-scale (utility-owned) energy storage assets, respectively.

New compressed air approach

After pumped hydro, the next most common energy-storage technology is compressed-air energy-storage (CAES). Classical CAES uses electric motors to pump air into underground caverns adiabatically. When electricity is needed, air is released, driving a turbine to generate power. Disadvantages of classical CAES include its requirement for specific geologic sites,

DOE SPURS ENERGY STORAGE ADVANCES

With series of research grants, conferences and projects at its network of national laboratories, DOE has fostered development of energy storage technologies for the grid. In addition to the flow battery and Li-ion battery projects mentioned in the main text, the DOE is supporting work on many types of grid-energy storage technologies, from grid-scaleable lead-acid batteries to a low-cost, rechargeable iron-air battery.

Aside from batteries, DOE is also supporting development of advanced flywheel technology, a mechanical means of energy storage whereby energy from a motor is used during a charging phase to accelerate a rotor assembly to high speed with minimal friction. For discharging, energy can be extracted from the spinning rotor, which is attached to a generator. The inertial energy of the spinning rotor drives the generator, which can inject power back to the grid, rather than by electrochemical means. Startups like Amber Kinetics (Fremont, Calif.; www.

amberkinetics.com) received awards for demonstrating improved flywheel devices. Amber is planning on a commercial prototype flywheel in 2012 that features magnetic bearings, a low-cost rotor, and a high-efficiency motor-generator.

Another approach with DOE support is superconducting-magnet energy storage (SMES). A public-private team led by Brookhaven National Laboratory (Brookhaven, N.Y.; www.bnl.gov) and Superpower Inc. (Schenectady, N.Y.; www.superpower-inc.com), is developing a SMES system that uses magnetic fields in superconducting coils to store energy with virtually zero energy losses.

In other DOE public-private partnerships, Argonne National Laboratory (Lemont, Ill.; www.anl.gov) has formed a collaborative arrangement with Dow Chemical Co. (Midland, Mich.; www.dow.com) to develop new battery materials. Argonne has also established a facility specifically for supporting the the scaleup of production processes for battery-related materials, with the goal of moving products into commercial production. ❑

and its heat losses during the compression and expansion.

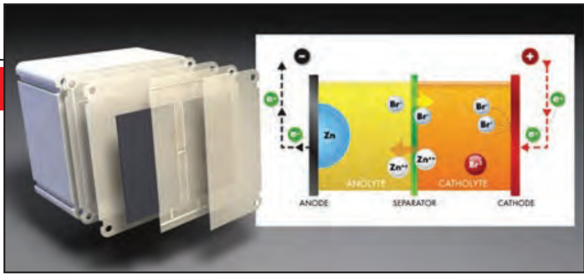
A new CAES technology developed by SustainX Inc. (Seabrook, N.H.; www.sustainx.com) uses isothermal compression and expansion to increase the efficiency of the operation. SustainX overcomes the difficulties of classical CAES by using a reciprocating engine, as opposed to a turbomachine, and sealed-pipe storage tanks, rather than underground caverns or aquifers, for the compressed air. An electric motor compresses air isothermally using a mechanical crankshaft to store air at 3,000 psi. When electricity is needed, the compressed air is expanded isothermally, running the same crankshaft, which in turn, drives a generator.

The company has engineered a proprietary method to control the temperature of the air during compression and expansion, so that its temperature never deviates by more than 10 to 15°F. The result is a highly efficient cycle that minimizes heat loss. To achieve the isothermal compression and expansion cycle, SustainX engineers had to devise an effective method to transfer heat to and from the air. To accomplish this task, the company developed a system to efficiently aerosolize water. The high surface area of the droplets, and their proximity to air molecules, enables efficient heat transfer during compression and expansion. Company cofounder Dax Kepshire says the company's aerosolization method consumes little energy, helping to make the technology economically viable.

SustainX has demonstrated a 40-kW CAES system at its New Hampshire facility, and plans to build (with power company AES) a megawatt-scale system next year. SustainX is pursuing grid applications that require electricity for durations of 1–6 h, although Kepshire says the power and energy are independently scalable, allowing the technology to potentially be applied elsewhere. For now, SustainX sees its technology as a more efficient solution than the combustion-engine "peakers" that are commonly used at power plants for balancing supply and demand.

Flow batteries advance

Flow batteries employ pumps to move electrolyte solutions past electrode



ZBB Energy

FIGURE 2. Flow battery chemistries, like the one shown here from ZBB Energy, use pumps to circulate electrolyte solutions within cell stacks

plates where reduction-oxidation reactions occur. Several flow-battery electrochemistries are under investigation in an effort to capitalize on their advantages — including the ability to store electricity in a modular design, fast response rates and the ability to vary durations of discharge.

An example in this area is ZBB Energy, which has developed a zinc-bromine flow battery that is currently in commercial production. The electrochemical cell consists of a zinc anode and a bromine cathode, separated by a microporous membrane. Aqueous electrolyte solutions of zinc and bromide ions are circulated through the cell stacks. The battery design employs a replaceable cell stack of high-density polypropylene spacers, and 60 bipolar electrodes. As the battery charges, zinc metal is plated onto the anode in the cell stacks, and bromide is converted to bromine, which is stored in a phase-separated manner.

ZBB's technology targets applications that require power discharge in the 2–8 h range. "The ZBB flow battery is ideal for time-shifting renewable energy," says ZBB's Chris Kuhl. "It is also useful as a ramp-control device to stabilize power demand peaks," he says. Among the advantages of the ZBB flow battery is its ability to operate at full output over a wide temperature range (–30 to 50°C). The electrolytes never need replacing, and although the high-surface-area anode will wear out, it can be changed out with the stack after five years.

In a DOE-funded project, flow batteries using a different chemistry are under development by United Technologies Corp. (UTC; East Hartford, Conn.; www.utc.com), along with partners including the University of Texas (Austin; www.utexas.edu). The team of scientists has designed a unique flow-battery cell that offers power densities an order of magnitude higher than those published so far for flow batteries. "The electrochemical cell stacks dominate the cost of batteries," says UTC engineer Craig Walker, so if we can increase power output, the batteries can produce the same power at smaller cell sizes, which lowers costs.

The flow battery, which is targeted at improving power quality from wind farms and time-shifting off-peak power, has been demonstrated at small scale, and could be described as a hybrid between a fuel cell and a conventional battery. Liquid reactants flow over electrodes separated by an ion-exchange membrane. Leveraging UTC's expertise in fuel cells, the cell stack was designed for higher performance and optimized efficiency. The team plans to complete a 20-kW prototype of the battery in late 2012.

Primus Power (Hayward, Calif.; www.primuspower.com) is also developing a flow battery — one based on zinc-halogen chemistry. Key differentiators for the Primus technology include high-conductivity electrodes, which increase power capacity, and a carefully designed flow architecture to reduce capital cost. Primus cells are housed in 20-kW, 60-kWh units that can be linked together for utility-scale installations. Primus plans a demonstration-scale system in 2012, and a commercial-scale project in 2013.

Li-ion for storage

Li-ion batteries are common in portable electronic devices and newer electric vehicles, but they can also be a viable grid-energy storage technology. A123 Systems Inc. (Waltham, Mass.; www.a123systems.com) has been a player in the electric vehicle area, but is also utilizing its technology for grid-power applications, such as smoothing out the supply and demand variations as renewable energy is integrated into the power grid.

"With some grid-energy storage solutions, there are few [non-grid] applications, so it's more difficult to reduce costs," says Andy Chu, vice president for marketing and communications for A123 Systems. "With Li-ion technology, we can leverage the technology, manufacturing and logistics infrastructure that has been developed for Li-ion batteries in devices and vehicles, and apply that to power-grid applications." A123's Chu envisions costs coming down significantly compared to flow batteries because of the existing infrastructure.

Technology licensed and developed by A123 relies on nanoparticles of a doped form of lithium-iron-phosphate for its cathode material. The cathode structure allows lithium ions to move more easily into and out of the material than with other Li-ion materials, which reduces physical expansion and lengthens the lifetime of the battery and the number of charge-discharge cycles the battery can handle.

Among the advantages of A123 batteries used in grid-storage applications are the ability to site facilities anywhere, explains Chu. Also, Li-ion batteries don't require water or emit pollutants, so there are fewer requirements for permitting and siting.

As part of a DOE demonstration program, A123 is building an 8-MW Li-ion battery for storing energy at a wind power site in Tehachapi, Calif. The project's purpose is to demonstrate the flexibility of Li-ion batteries for grid storage, and to "test whether the same battery system could be appropriate for multiple grid storage functions in which several hours of power are needed," says Chu. ■

Scott Jenkins

Editor's note: For additional information on emerging technologies for grid-energy storage, visit www.che.com for the expanded version of this article.

SIMULATION SPREADS ITS WINGS

FIGURE 1. Honeywell's UniSim will soon be linked to a 3D visualization technology, providing a virtual environment that can be used to design, analyze, and verify plant operations, as well as to prepare operations teams for safe, reliable and efficient operations

Simulation software is not just for designing plant layouts anymore. Enhancements and integration capabilities allow it to help out in any number of ways around the facility

Because the benefits are many, roles for simulation software tools exist from planning and design of facilities through operations and everything in between. And thanks to enhancements, it's becoming easier to use simulation alongside other software packages, while niche simulation tools are making complex processes easier and less expensive to implement.

In general, process simulation software lets users solve problems faster than would be possible by hand. "There are many problems that are not feasible or even possible to solve by hand without these tools," notes David Hill, manager of technical support with Chemstations (Houston). "For example, rigorous distillation-column modeling could take months without these tools because there's so much math involved. For this reason, the biggest benefit process simulation brings to the table is time savings. Hundreds of man hours could be spent using paper and pencil or trying to make a large calculator for process engineers to use."

And, this time-saving potential leads to lower costs when using simulation to design a facility or process or manage functions beyond design, says Peter Henderson, UniSim product manager with Honeywell (Morristown, N.J.). In process and equipment design, before the plant is built, simulation provides an environment where you can make a lot of decisions based on reflection of design requirements that allow you to build an optimal plant virtually before you spend any money on construction or equipment purchases. "If you can imagine, debottlenecking and optimizing plants before you even build ensures you have the lowest capital costs to build."

Another objective, he says is to have the ability to increase yield and plant performance before you purchase the equipment. "The cost savings is in buying the right equipment for each process, which allows the operating company to produce a product economically right from the start," explains Henderson.

Simulation meets control

"At this early level, chemical engineers are looking at the entire process in one glance, every step from raw materials to finished products," says Scott Thibauld, vice president of sales and marketing with CPFD Software (Albuquerque, N.M.). "For these purposes, 1D process simulation tools are typically employed. Since the design is very conceptual at this point, there is less that can be done to affect things such as energy costs, capital expenses or operating expenses, though the type and number of specific steps required will provide insight into this."

However, advanced simulation users are adding simulation tools to their process control system, data historian or other software tools that let them use the simulator as a software-based sensor, says Hill.

The benefits of this type of action are many. "By using a dynamic simulation of the process with an emulated online control system, users can test their automation system through various scenarios, whether it's the start up of a [petroleum] refinery or running through all the cycles in a batch plant," says Martin Berutti, president and COO of Mynah Technologies, LLC (Chesterfield, Mo.). "Testing in this way allows them to be sure all controls and automation strategies are linked and designed correctly to provide effective control of the process."

This allows users to cut down on the time required to make process control changes or recover from process control changes or validate a control system change without affecting the process.

Simulation models can also be used as a virtual instrument to predict things that may be hard to measure in a real plant, says David Tremblay, director of product management with AspenTech (Burlington, Mass.). Chemstation's Hill agrees: "Simulation provides the ability to calculate hard-

SIMULATION SOFTWARE VENDORS

Vendor	Website	Vendor	Website
AspenTech	www.aspentech.com	CPFD Software	www.cpfd-software.com
Bentley	www.Bentley.com	Honeywell	www.Honeywell.com
Bryan Engineering & Research	www.bre.com	Mynah	www.mynah.com
Chemstations	www.chemstations.com	Process Systems Enterprise	www.psenterprise.com

to-measure values that processors should know, such as purity coming out of a distillation column or reactor, based on data they couldn't otherwise measure," says Hill.

The control system will send easy-to-measure values into a process simulation model, and based on that information, the model can predict what is happening in the process. This lets engineers have control systems that respond quicker to change and provide earlier warnings, while making it easier to optimize energy use.

And, even more benefits can be had by using simulation to model energy and utility use. "Quite often users will model how cooling water or steam are being used in a facility and find ways to save money," says Hill. "We also see a number of our customers using simulation to find changes and scenarios they can rule out as they try to find better uses of energy or better or less costly ways to operate their equipment."

Another value of linking control and simulation is that it provides training and a reliable, safe and simple method for transferring and building knowledge of plant control and operations.

"If you listen to the people who study human factors engineering, they will state that you have to build a mental model of the process and interaction of that process with the control system," says Berutti. "A good, experienced operator has a sophisticated mental model of how everything works, so when he starts to see an excursion in how the process is supposed to go, he, by reflex, knows what needs to be done to get back on track."

However, building that type of mental model can only be developed by working on the real process with the real system; so how, when hiring someone who may not have seen these conditions on this control system or process, do you provide him with that experience and help him build the reflexes to handle those incidents? How do you provide the opportunity for him to develop his own mental model to the point where he's sophisticated enough to handle and operate the process under these conditions? According to Berutti, by giving him a complete replica of the plant and control system, offline, in a simulated, virtual plant. "He can develop that necessary mental model without affecting the real plant and accelerate his ability to become more effective when controlling the process," says Berutti (Figure 1).

Mynah's MiMiC product makes this possible because it has a realtime dynamic simulation engine along with the separate service environment of a Microsoft server. The secondary service is a simulated I/O system that is designed to read and write to an offline control system. "MiMiC comes in and writes to the I/O system of this offline control system so the control system now, for all practical purposes, thinks it has a real working process and I/O with transmitters, sensors, pumps, motors, and other equipment in the field, working together. We have a rich library of dynamic modeling objects and functions so users can build unit operations models quickly," he says. "This integration of realtime dynamic simulation with online control works together to create a functioning virtual plant that can be used for training purposes. It's like a flight simulator for the process industries."

Honeywell's Henderson explains how valuable simulation for training can be. "Operator training is intended to prepare the operator for a process or control issue he's not seen. Simulation prepares him around competencies that are required before he enters the control room of a $2-billion facility by reproducing the control environment or operations environment," he says. "This allows him to do plant startups, shutdowns and respond to operations challenges because failure in simulation prepares him for his job in the control room.

"This type of training allows for faster startups and higher plant reli-

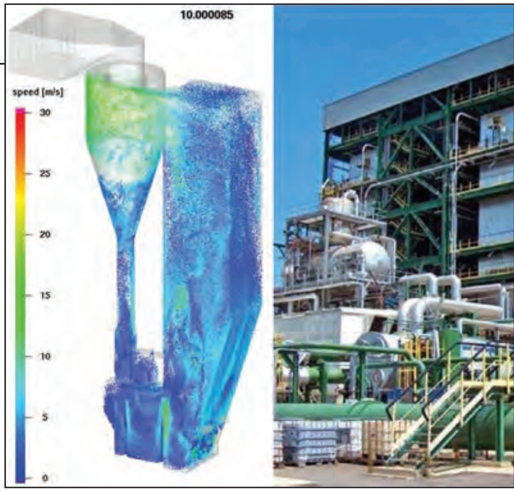


FIGURE 2. Full-scale CPFD model (left) and operating plant (right) for the Biomasse Italia CFB biomass-fired power plant in Strongoli, Italy

ability. It permits training on more than operational set points and allows operators to consider the optimal operation of a plant that generates better yield, quality and utility use. There is a very strong economic benefit for training operators via simulation."

Simulation integration

One of the reasons this type of training is possible is because simulation products are increasingly able to interact and interoperate with control systems, as well as other software tools. "No one product can be the best at all things," says Gavin McIntyre, manager of process applications/customer service with Bryan Research & Engineering (Bryan, Tex.). "You will find that most simulation tools are good at many things and some specialize in particular areas, but none of them can do everything. Numerous opportunities exist to incorporate specialty tools from a variety of vendors, and incorporation allows the user to have the best available technology accessible through one package," he says.

Integration of third party software today is possible with current programming technology. "It can be done through a standard interface, such as Cape-Open, by inserting program languages, calling a custom dynamic link library or through a simple spreadsheet routine," explains McIntyre.

Integration and interoperability save both the vendor and the user time and money. "We don't intend to be all things to all applications," says Henderson. "But we do intend to take advantage of best in class solutions to extend our tool set. We allow customers' or third-party physical properties or chemical systems to be loaded into the system, which minimizes the product development we have to do.

"We are open to third-party properties and equipment, as well as third party 3D visualization tools and learning management systems for training. This is possible because we have adopted common interface standards so we can integrate with many common applications and our control system can integrate with many control systems as well. Powerful software becomes more powerful with openness to other technologies and software tools," says Henderson.

Anne-Marie Walters, global marketing director with Bentley (Exton, Pa.) says that her company also strives to make their simulation products interoperate with information "no matter where it comes from instead of relying on people to be able to re-draw or re-input information."

"We've put a lot of investment into the ability to interoperate so that users can get to accurate 3D models quicker via an interoperable link with other systems. This means that if something changes, users will automatically see what impact that has on what they are trying to assess," she says.

"This is possible because Bentley supports international standards for interoperability. Not just with our software, but with third-party design and analysis tools as well. It's our job to make sure we can pick up all the information and make sure the systems work together so that all the engineers can focus on their own jobs.

"This makes the project quicker, compresses project time scales and avoids human errors due to out-ofdate models. It allows users to base decisions on better, more timely information and ultimately make safer plants, much faster."

And interaction with other tools can also allow people who may not be using simulation on a daily basis to become simulation experts. For example, AspenTech's Simulation Workbook can link to an Excel spreasheet. "The beauty in this is that where traditionally users had to build custom interfaces using programming, now they can copy and paste links between the simulator and Excel," says Sanjeev Mullick, director of industry marketing with AspenTech. "This environment allows users to quickly crate tables of input and output data, charts, graphs and pictures of the plant so people who aren't experts can point and click and change numbers and see the power of simulation at work.

"Using Excel allows people who aren't familiar with simulation tools to perform 'what-if' studies," says AspenTech's Tremblay. "They can bring in plant data and change some variables in the model using Excel and see how the rest of the process is affected. In that fashion they can experience the cause and effect and get insight that allows them to make better decisions.

Specialty simulations

However, there are times when simulation needs to go beyond training and creating "what if" scenarios, and that is where more complex tools come into play. For example, when building actual equipment, computation fluid dynamics (CFD) tools can be used to model and understand the behavior of a piece of equipment, such as a gas-solid chemical reactor, in detail. They will typically need to model the equipment in full 3D and in a time-transient way, since the phenomena to be modeled and understood are time-transient themselves. The objectives of the modeling are ultimately to ensure that the chemical reaction to be run and controlled will be safe, efficient, repeatable, stable, reliable and as energy efficient as possible, says CPFD Software's Thibauld. "Such details as how the equipment will be started up and shut down must be studied if a practical process is eventually to be designed and deployed.

His company's Barracuda software is a niche CFD software package based on a unique numerical method called Computational Particle Fluid Dynamics, which is an implementation of a method known more generically as multiphase particle-in-cell. It is designed for performing simulations that involve particles, either gas-particle or liquid-particle flows, which is an application area that general purpose CFD packages do not serve well, he says. "The CFPD method and Barracuda software work very well because they can model the particle size distribution and its effects on fluid-particle flows in detail, plus handle solids loadings from dilute to dense packed at the same time and in the same domain."

Barracuda can model gas-gas, gas-solid, and solid-solid chemical reactions in detail and at a discrete particle level while still being able to model very large devices at full scale within a reasonable calculation time. In the chemical and petrochemical industries, it is often used for modeling fluidized systems such as fluidized bed reactors (Figure 2).

Likewise, Bryan Engineering & Research offers ProMax, which has extensive enhancements to allow simulation of more complex processes. In particular, it offers a very specialized electrolytic thermodynamic package for modeling ionic systems, such as amine treating and sour water strippers, and a special reactor and thermo package for modeling sulfur recovery systems. The thermo models for traditional hydrocarbon systems have been expanded to allow modeling of a wider range of conditions and also include special data for associated systems such as glycol dehydration and methanol injections. ■

Joy LePree

Lessons I've learned in R&D

In the movie "Jerry Maguire," Mr. Cuba Gooding, Jr. said it first — "Show me the money!" In 1999, Ms. Jane Li said it to me many times — "Show me the money!" Ms. Li was my Six Sigma for R&D instructor when I worked at UOP. After she said it for about the tenth time, I finally got it. I had been working in R&D for almost 25 years. Some of the products and technologies that I had worked on had brought profits to my companies. Nevertheless, the profit motive of R&D was not yet totally ingrained in me.

My Six Sigma training provided many lessons. The marketing department must be involved in R&D projects — early and often. What good is a new product if there is no market for it, or, if there is no significant profit? Also, the manufacturing and production department must similarly be involved. What good is a new product if the shop cannot produce it at a reasonable cost? Meanwhile, R&D projects require regular reevaluations. R&D managers need to be willing and able to stop projects at any time. All R&D projects do not need to be completed. Conversely, some R&D projects deserve extra attention and funding.

Ralph Waldo Emerson is generally attributed with saying, "Build a better mousetrap and the world will beat a path to your door." This R&D philosophy is not as true as R&D engineers would like to believe. Even the best mousetraps need to be marketed. It is never easy to sell new mousetraps. (In fact, when I look back on the first 12 new products that I was involved in, 11 of those had to be launched outside the U.S. because none of our U.S. customers wanted to be the guinea pig.)

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

My long list of personal experiences has taught me some other things. Expect the unexpected — and enjoy it. Surprising laboratory results often provide great starting points for further study. Some, but not all, "bad ideas" are worth further evaluation. What, indeed, might happen if a developing product was installed upside down or if a test program was run in reverse. What might be learned? You would sometimes be surprised.

Every R&D project requires a plan — a plan that begins with inception and funding and ends with selling and startup. That plan, however, should consider that many experiments need to be done wrong the first time. Some experiments begin with an inadequate vocabulary, or a data collection sheet that does not have enough variables listed. As Albert Einstein said, "If we knew what it was we were doing, it would not be called research, would it?"

R&D directors are encouraged to provide their managers with discretionary funds, maybe 15% of the total R&D budget. R&D engineers are inspired by the freedoms that such funding provides, and by the faith that their directors are exhibiting. Expect 115% efforts regarding discretionary projects.

R&D engineers are encouraged to perform design, manufacturing and selling work when such opportunities arise. R&D engineers should not spend too much time riveted to their computers, while the real work is being performed by technicians in the laboratory in another building.

Finally, but most importantly, frontiers can be unsafe places. If you are an R&D worker, and if safety is not your number-one priority, know that it someday will be — and must be. ■

Mike Resetarits

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Using Rupture Disks with Pressure Relief Valves

Protecting process systems from overpressurization is a critical task in the chemical process industries (CPI), and rupture disks and safety relief valves are routinely used for this purpose. In certain situations, using rupture disks in combination with safety relief valves offers advantages that can increase safety and lower costs. The advantages include a significant lengthening of the service life of the relief valve, as well as prevention of process leakage.

What considerations should be made when combining devices? And how can you decide when the combination is appropriate versus when it may not be useful?

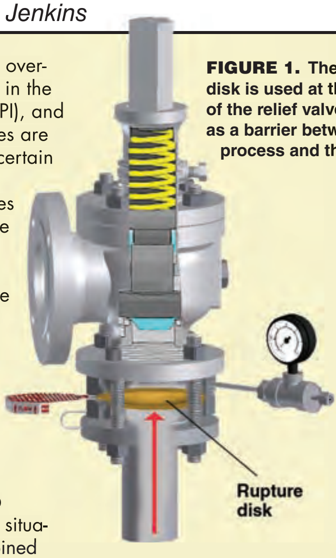


FIGURE 1. The rupture disk is used at the inlet of the relief valve, acting as a barrier between the process and the valve

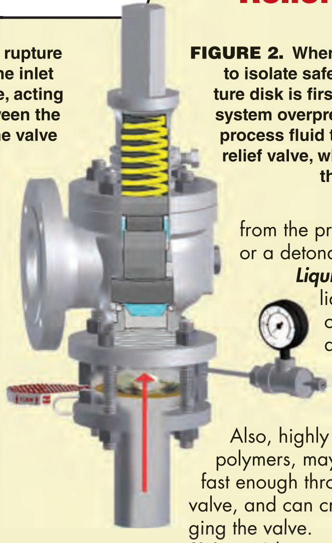


FIGURE 2. When rupture disks are used to isolate safety relief valves, the rupture disk is first to open in the event of system overpressurization. The vented process fluid then contacts the safety relief valve, which releases the fluid if the pressure is excessive

Reasons to combine the two

When overpressurization occurs in situations where rupture disks are combined with safety relief valves, the disk bursts and a valve release follows. Once the pressure drops to a safe level, the safety valve reseats itself and continues to protect the system (Figures 1 and 2). There are several situations in which using the two systems together can lead to significant benefits.

Isolation of relief valve. Rupture disks can isolate a safety relief valve from process fluids and materials, so that, under normal operating conditions, the safety valve does not encounter the process chemicals. Since the safety valve is isolated, its internal mechanics will not come into contact with any caustic process chemicals or viscous materials that might interfere with the valve's operation. Because valve internals are not routinely exposed to process materials, they remain in almost new condition, which allows longer periods between major overhauls. Also, since the valve is isolated, it is not necessary to have the valve constructed in a material designed for continuous contact. For example, if the process fluid requires that Hastelloy be the preferred material of construction for continuous contact, a carbon-steel valve (with Hastelloy trim) combined with a Hastelloy rupture disk can be used. This will save a significant portion of the valve cost.

Leak prevention. Another major advantage of combining rupture disks with relief valves is leak prevention — under normal operating conditions, the rupture-disk barrier prevents process fluids from escaping into the atmosphere. An example described in Ref. 1 illustrates the savings that can be realized by the combined arrangement: For conventional safety valves, American Petroleum Institute (API) standard 527 (Seat Tightness of Pressure Relief Valves) allows for an orifice size of F or smaller to have a maximum allowable leakage rate of 40 bubbles per minute (approximately 6 ft^3 over a 24-h period, or 2,190 ft^3/yr). This leakage is either lost, eroding profits and potentially harming the environment, or requires the installation of a system to recover the leakage.

Test-in-place. Combining rupture disks with safety valves allows the safety valve to be tested in place in the field. With a suitable, reverse-buckling rupture disk installed at the valve inlet, the safety relief valve can be field-tested by a single person with a portable pressure source. To accomplish this without opening any process piping, air (or nitrogen or another fluid) is injected from the pressure source into the chamber between the rupture disk and the safety valve inlet. The test pressure is increased until the valve releases, and should be within the set pressure tolerance of the valve.

What to consider

What factors should be considered when deciding whether to use rupture disks in combination with pressure safety relief valves or to use a rupture disk alone? There are likely many, depending on the particulars of the application, but here is a set of basic considerations with which to begin.

Cost. Rupture disks are considerably less expensive than safety relief valves, particularly when the valve needs to be constructed from exotic materials.

Process materials. A rupture disk alone is a good choice for overpressure protection in cases where process contents are inexpensive, nonhazardous and environmentally safe. A rupture-disk and relief-valve combination should be the choice when a leak-tight seal of the pressurized system is needed, and when the conservation of product within the pressurized system is important, because it contains a corrosive, hazardous or expensive substance.

Speed. The quick-bursting action of a rupture disk makes it a first consideration when the potential for runaway reactions exists. Safety valves alone will not react quickly enough to protect a process system from the pressure of a deflagration or a detonation.

Liquid properties. Some liquids may freeze or cause icing under rapid depressurization, leading to blockage within a safety valve, and rendering it ineffective. Also, highly viscous liquids, such as polymers, may not relieve pressure fast enough through a safety relief valve, and can create a danger of plugging the valve.

Sizing. When sizing a relief valve, engineers need to determine the required fluid-flow capacity, and simultaneously to analyze the possible emergency scenarios, such as fire, loss of process cooling and equipment failure. The capacity requirements are then entered into a sizing equation to determine the relief valve area. For a rupture-disk-safety-valve combination, the flow capacity of the combination must be confirmed to support the selection of both the valve and the disk. A combination capacity factor (CCF), which is often determined from ASME-certified capacity testing, can be used to support the decision. The CCF is calculated as the ratio between the capacity of the disk-valve combination over the relief valve capacity alone. CCFs should not exceed 1.

Pressure drop. The proper function of a relief valve requires that the pressure drop between the vessel it protects and the valve inlet is not more than 3% of the valve's set pressure. Relief valves that are isolated by a rupture disk contribute to piping pressure drop, but by selecting rupture disks having low flow-resistance values, the pressure-drop target is usually reached.

Differential pressure. In a rupture-disk-safety-valve combination, the differential pressure across the rupture disk must be monitored. The assembly shown in Figures 1 and 2 contains an excess flow valve to maintain atmospheric pressure in the space between the rupture disk and the safety valve, as well as a pressure gage on the relief valve to provide local confirmation of pressure status.

References

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Editor's note: This edition of "Facts at your Fingertips" is adapted from the article referenced above.

Thermal Fluid Systems: Design Considerations

Single-fluid heat-transfer systems that both heat and cool a process require special considerations for trouble-free operation

Jay Hudson
J.G. Hudson & Associates

FIGURE 1. This packaged single-fluid system heats fluid directly with the two electrically heated heat exchangers in the foreground. The cooling heat exchanger (horizontally mounted behind the heating units) cools fluid that is diverted through it by a control valve. Fluid is motivated by a pump that is not visible in this image. When installed, this unit will have an expansion tank mounted, either to the unit or nearby

Heat Exchange and Transfer

Thermal fluid systems that both heat and cool are often utilized in batch processes. They are also often found in continuous processes where heating is required at one point in the process and cooling (often for the purpose of heat recovery) is required in a different part of the process. Because these systems utilize the same fluid for both the heating and cooling process, they are collectively referred to as "single fluid systems." This article discusses considerations specific to the design and operation of single fluid systems, although some of these considerations are more widely applicable.

Single fluid systems can operate in an efficient and trouble-free manner or they can subject the owner to operational inefficiencies and maintenance problems, depending on whether or not certain design and operational pitfalls are avoided. These heat-transfer systems can operate over a wide range of temperatures, from as high as 400°C (750°F) to temperatures well below –40°C (–40°F). A few heat-transfer fluids can actually accommodate most of this broad temperature range.

In this article, I discuss pitfalls and considerations for the very hot and very cold aspects of single fluid systems with the understanding that, as operating temperatures trend closer to ambient temperatures, operational concerns will be lessened; however attention paid to these considerations for all systems can improve performance and reliability.

Single fluid systems can be heated directly, as with electrically heated systems (Figure 1) or indirectly, as with secondary loop designs that receive heat, normally by direct injection of hot thermal fluid from a central source (Figure 2). Careful attention to the components of the system can contribute to reliable operation with good performance and low maintenance costs.

Thermal fluid selection

I have maintained for a long time that the selection of the thermal fluid is the most-important single decision to be made in the design and specification of a thermal fluid system, and nowhere is it more important than in single fluid systems.

For heating-only systems, it is common practice to evaluate potential thermal fluids by comparing maximum-allowable bulk- and fluid-film temperatures. The fluid's vapor pressure should be considered for expansion tank and pump NPSH (net positive suction head) considerations. Resistance to oxidation is also important.

The evaluation of the thermal fluid for low temperature operation is also extremely important. Here, we are looking beyond the basic lowest temperature where the fluid is "pumpable". Pumpability is a consideration for start-up in heating-only systems, but when the system is expected to efficiently cool the process, the fluid should be significantly warmer than its minimum pumpability temperature. The consideration here is viscosity. A fluid may be pumpable at a viscosity of one hundred to several hundred centistokes viscosity, but high viscosity makes for a low Reynolds number and a poor fluid-film heat-transfer coefficient. Significant attention should be paid to the viscosity and flow characteristics of the fluid at the minimum temperature that the fluid is expected to cool the process.

Careful attention to the fluids available, and evaluation of fluid properties as compared to the individual

FIGURE 2. This packaged single-fluid system is heated indirectly by direct injection of hot fluid from a central source. The cooling heat exchanger (horizontally mounted behind the pump) cools fluid that is diverted through it by a control valve. The pump maintains alignment by having the casing supported at its centerline. The pump is also air-cooled (note the fins), and the mechanical seal is protected from extreme temperatures by being located at the rear of the pump

Temperature range of various heat transfer fluids

Fluid type	Temperature range, °C	Flashpoint
Petroleum fluid (46CST)	40 – 300	FP 227 °C
Terphenyl / biphenyl	-9 – 380	FP 132 °C
Diphenyl ethane	-50 – 315	FP 146 °C
Diethyl benzene	-70 – 315	FP 57 °C
Methyl cyclohexane	-115 – 175	FP –7 °C
Silicone (high temperature)	-40 – 400	FP 160 °C
Silicone (medium temperature)	-150 – 260	FP 47 °C

FIGURE 3. This chart shows the temperature range of a typical petroleum-based "hot oil" plus several synthetic aromatic fluids and two silicone-based fluids (FP is flashpoint)

demands of the single fluid system can have a significant effect on the longterm performance of the system (Figure 3). Classes of fluids include the following:

Petroleum-based fluids: The so-called "hot oils" are widely used in industry and can be used successfully in single fluid systems. There is a cost advantage to using these fluids, but most are limited (at the hot end) to 300°C (572°F) and do not give good cooling performance below 40°C (100°F). There are petroleum fluids that perform well above 300°C and other formulations that perform at lower temperatures.

Synthetic aromatic fluids: These fluids are manufactured rather than refined, and offer extended temperature performance at both high and low temperatures. Some of these fluids have very low viscosities at low temperatures, which allows high Reynolds numbers (and relatively high heat-transfer coefficients) to be maintained at low temperatures. Low temperature performance can be extended to as low as –115°C (–175°F) with these fluids. At the high-temperature end of the spectrum, these fluids can be more stable at high temperatures and allow heating to temperatures as high as 400°C (750°F). There is no fluid that can achieve heat transfer performance at both –100°C and +400°C, but aromatic fluids are available with usable temperature ranges as broad as 400°C (720°F). These fluids are often more expensive than petroleum-based fluids, but their extended performance and higher thermal stability offer value to many users.

Silicone fluids: Silicone fluids offer advantages of very wide, useable temperature ranges and low toxicity. One fluid has a range of almost 800°F (–40 to +750°F). Silicone fluids are high performance fluids and carry a price to match. They are very manageable in properly designed systems. Silicone fluids can develop significant vapor pressure at high temperatures and, in the author's experience, can be more prone to leakage than other fluids. However, proper system design and a good piping-material specification can help make a very reliable and robust system.

There are other classes of fluids, including glycol-based fluids and fluorocarbon-based fluids, but they are not discussed in detail in this article.

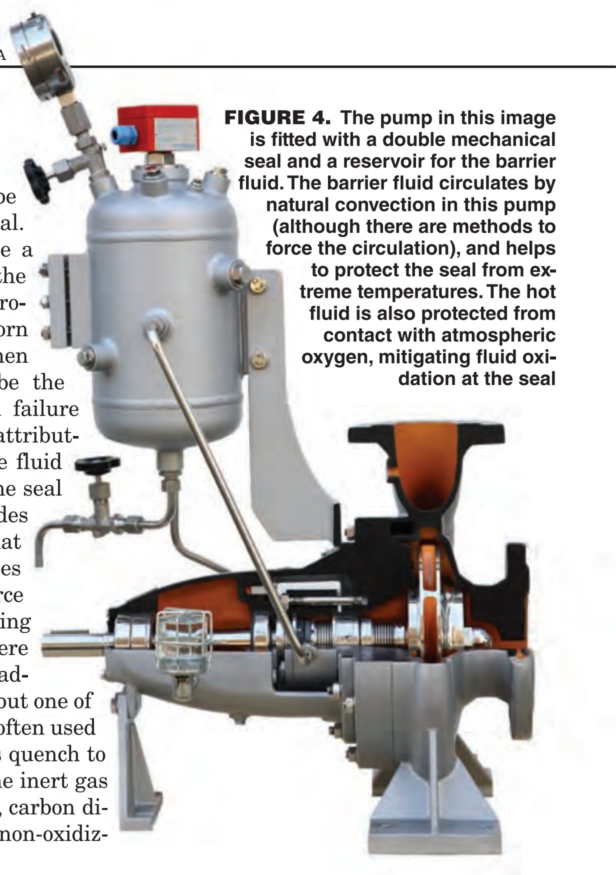
Pumps

The pump is almost always the component requiring the most maintenance in a thermal fluid system, and is deserving of considerable attention when a new single-fluid system is being specified, or an existing system is being upgraded.

There are three pump applications in single fluid systems:

1. The heating (or hot- fluid-circulating) pump
2. The cooling pump, which may circulate thermal fluid or cooling water, depending on temperatures and system design
3. The single fluid pump, which will undergo the temperature swings associated with heating and cooling the process

Not all single-fluid systems have three pumps, because the applications are often combined. For instance, on smaller systems, the hot-fluid pumping application and the single-fluid



Dickow Pumps, USA

FIGURE 4. The pump in this image is fitted with a double mechanical seal and a reservoir for the barrier fluid. The barrier fluid circulates by natural convection in this pump (although there are methods to force the circulation), and helps to protect the seal from extreme temperatures. The hot fluid is also protected from contact with atmospheric oxygen, mitigating fluid oxidation at the seal

pump application can be combined into one pump.

This article concentrates on the single fluid pump, because it has the most demands placed on it due to the fact that it is in a constantly changing temperature environment. The items that should be taken into consideration when specifying a single fluid pump are explained here.

Thermal stress: As the pump changes temperature, the metal components of the pump will expand or shrink, according to the direction of the temperature change. Different parts may change at different rates, depending on the weight of the particular casting and the percentage of its surface directly in contact with the pumped liquid. Rapid temperature changes can cause different components to press against each other unevenly. Over time, this will result in maintenance problems or out-and-out failures.

Materials of construction: Construction materials are important in specifying a single fluid pump. While cast iron may be adequate for water pumps and even some light-duty chemical pumps, it is too brittle for heat transfer duty, as rapid temperature changes could cause a cast-iron casting to crack. Ductile iron, cast steel or stainless steel are better choices for materials of construction.

Alignment: Mechanical alignment is critical for long bearing and mechanical seal life. If a (end suction) pump has a conventional foot mount under the casing, the expansion of the casing under heating can push the centerline of the pump out of alignment with the motor. This allows vibrations that can shorten bearing and seal life.

To counteract these problems, pumps are available with "centerline mounts", where the pump casing is supported from the horizontal centerline. This supports the casing at the shaft centerline and maintains alignment by allowing the casing to expand both up and down when temperature increases.

Mechanical seals: Mechanical seal specification and installation is deserving of considerable attention in single fluid pumps (Figure 4). Most pump "failures" exhibit themselves as mechanical seal failures, although the failure may not be the sole fault of the seal. If — when you remove a mechanical seal — the carbon face (or other rotating face) is not worn back to the shoulder, then the failure may not be the fault of the seal. Seal failure on hot pumps is often attributable to oxidation of the fluid as it migrates across the seal faces. The fluid degrades to carbon particles that either score the seal faces or agglomerate and force the faces apart, allowing the fluid to leak. There are many methods for addressing this problem, but one of the simplest and most-often used is to apply an inert gas quench to the back of the seal. The inert gas can be steam, nitrogen, carbon dioxide or another inert, non-oxidizing gas.

Seals that operate at cold temperatures (below 0°C) can leak as well, but not from fluid oxidation. Water can condense, and ice can form at the seal faces of cold seals, which can eventually force the seal faces open and allow a fluid leak. This problem can be a challenge to troubleshoot, because when the pump is removed from service for maintenance, the ice in the seal melts and the faces go back together. As with hot seals, an inert gas quench goes a long way toward mitigating the problem. Obviously, steam is not a good choice here, but nitrogen is used successfully in many cases.

Seals that operate near the pumped-fluid temperature can also wear abnormally if the temperature range of the system is large. This problem can be mitigated by environmental controls on the seal that stabilize the seal temperature, or by choosing a pump that locates the seal away from the pumped fluid.

Flange leaks: Low viscosity, high vapor pressure and low surface tension cause thermal fluids to be prone to leaking. A well-thought-out piping materials specification will go a long way toward reducing the possibility of leaks. One way to minimize leakage opportunities is to weld valves and fittings into the pipe, and to use bellows-sealed valves. Threaded connections on pipe and fittings are the least acceptable type of pipe joining in these systems. Where connections cannot be welded, as with pumps, the specification of 300-lb raised face flanges and the use of carbon- and stainless-steel spiral-wound gaskets significantly reduces the possibility of fluid leakage.

Sealless pumps

Mechanical seal problems can be avoided by using sealless pumps. The rotating assembly of a sealless pump is completely sealed from the outside, in a canister at the rear of the pump. The rotating-assembly bearings are lubricated and cooled by the pumped liquid.

Magnetic drive pumps employ a rotating magnet outside the can that is driven by a conventional electric motor. (Figure 5) The magnetic field of the driving magnet penetrates the metal of the can and couples with an internal magnet, which is part of the rotating assembly and drives the pump.

Canned motor pumps use a rotating assembly similar to those in magnetic drive pumps, except the internal magnet is replaced with a motor rotor winding (Figure 6). A three-

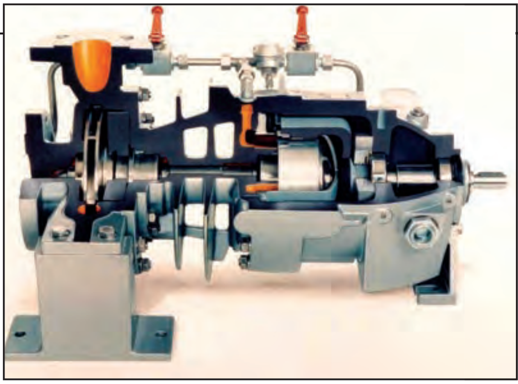
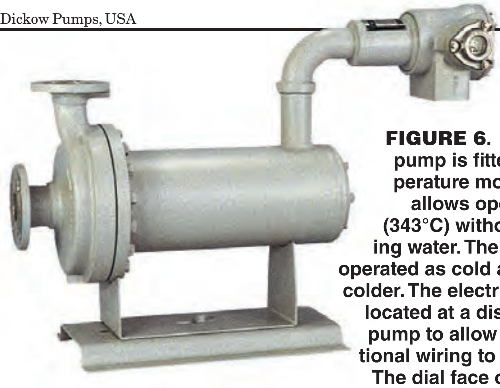


FIGURE 5. **This cutaway of a magnetic drive pump shows the outer magnet, isolation can and the interior rotating assembly. The impeller and interior magnet are supported by ceramic sleeve bearings — that are wetted by the fluid — inside the pump. The outer magnet is supported by the ball bearings seen on the right. The containment shell prevents fluid from escaping from the pump, but is permeable to the magnetic field allowing the outer magnet to drive the inner magnet and impeller assembly. The pump casing is supported by pedestals connected to a centerline mount to help maintain alignment. The magnetic drive assembly is separated from the hot end of the pump by an extended adapter with cooling fins. Properly fitted, this pump can operate from –60 to 400 °C**

Dickow Pumps, USA



Teikoku Pumps, USA

FIGURE 6. **This canned motor pump is fitted with a high-temperature motor winding, which allows operation up to 650°F (343°C) without the use of cooling water. The pump may also be operated as cold as –40°C (–40°F) or colder. The electrical junction box is located at a distance from the hot pump to allow the use of conventional wiring to connect the pump. The dial face on the junction box monitors wear of the internal bearings**

phase motor winding is wrapped around the can. When the winding is energized, the pump operates like an electric motor. As with magnetic drive pumps, the rotating-assembly bearings are lubricated and cooled by the pumped fluid.

Sealless pumps (both canned-motor and magnetic-drive) have the advantage that they do not leak, but the user should be mindful of certain other aspects of sealless pump use. Sealless pumps use special materials of construction and have a significantly higher first cost than conventional pumps with mechanical seals. However, if they are properly specified, installed and operated, sealless pumps can enjoy a long service life that helps to offset their initial high cost.

Sealless pumps are more sensitive to suction conditions than their mechanically sealed cousins. They do not tolerate cavitation, slugging or dry running, and can fail quite dramatically if subjected to a significant diet of these conditions. Repair costs for failed sealless pumps can be quite costly. For these reasons, an installation utilizing sealless pumps should be carefully evaluated to avoid instances of cavitation, slugging or dry running.

Cooling protection

Cooling problems increase as the temperature difference (ΔT) between the thermal fluid and the cooling media increase. The cooling heat exchanger is normally a liquid-to-liquid heat exchanger where thermal fluid is cooled by water, although there are different approaches. The exchanger is generally rated at a temperature below the maximum temperature anticipated in the system in order to have an acceptable cooling rate at lower process temperatures. This presents a few interesting problems when the thermal fluid is at maximum temperature and the system transitions over to cooling mode.

If the heat transfer fluid is hot enough, and the ΔT is very high, the heat exchanger will operate at a heat transfer rate well above its specified rating. If the temperature is high enough, the cooling water can actually boil on (or in) the tubes. Depending on cooling water quality, this can allow scaling to occur on the tubes and eventually lower the efficiency of the heat exchanger and require expensive chemical cleaning. Another possibility, again depending on water quality and condition, is to have corrosion on the tubes, which will eventually lead to a tube leak.

When operating at high thermal-fluids temperatures, and above the specified rating of the heat exchanger, it is also possible to overheat the water returning to the tower. This problem is particularly important if the user goes to a dedicated cooling tower, because the cooling-water-return temperature can exceed the maximum temperature rating of the tower. If the tower has a plastic fill, the plastic can actually soften and sag in the tower. More than one tower has been rebuilt as a result of high cooling-water-return temperatures.

Chillers are sometimes used to directly cool the thermal fluid, particularly if cold temperatures are required to finish the batch. Chillers are also used to avoid maintaining a cooling tower. Again, serious (and sometimes expensive) problems can surface if fluid supply temperature exceeds the maximum allowable temperature of the chiller. Problems can range from reduced service life of the chiller to out-and-out catastrophic failure.

To avoid these pitfalls, consideration needs to be given to methodologies that guard against extreme temperatures. This can generally be accomplished by the use of flow-control and recirculation strategies, along with careful specification of heat exchangers, cooling towers and chillers. The benefits realized will be reduced maintenance and longer life of critical equipment. ■

Edited by Dorothy Lozowski

Author's note:
Pictures included in the article are printed with the permission of the manufacturer. Use of these pictures does not constitute an endorsement of the product. When specifying equipment for thermal fluid systems, the reader should employ experienced resources, either internal or external, to insure that recognized and generally accepted good engineering practice is followed and that local and national codes and standards are complied with.

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Troubleshooting Heat-Transfer Fluid Systems

Real examples demonstrate how to analyze problems in heat transfer systems. The culprit is oftentimes not the thermal fluid

FIGURE 1. A very high viscosity thermal fluid can be a reason for failure of a heat-transfer system

Jim Oetinger
Paratherm Corp.

Articles about thermal fluid systems often start with a variation of the statement that "thermal fluid systems typically require little ongoing maintenance for the first few years of operation" and then go on to extol the various advantages of indirect thermal-fluid process heating over competitive heating methods, such as direct heat, steam and so on. The corollary to that statement, however, is that by the time there is a problem, the operating personnel that were trained on the system have moved on, been excessed or promoted. As a result, when things do go wrong, the guessing begins. And, unless there is an obvious cause like a geyser from the expansion-tank vent or a pump that sounds like it's moving ball bearings, someone will likely blame the thermal fluid for the problem.

There are several problems that seem to occur with some frequency. This article reviews a number of real examples and describes how the symptoms can be misinterpreted. The suspected fluid properties and the testing procedures necessary to determine which of the fluid properties (if any) is responsible for the problem are examined (Figure 1). Finally, recommended corrective actions are proposed.

Decrease in production rates

The following three examples explore production-rate problems, with the analyses and findings that resulted. A simple flowchart that can help in this type of analysis is given in Figure 2.

Example 1: A large facility experienced reduced productivity from its thermal fluid system that was operating at 450°F. The heater outlet temperature was increased to maintain throughput on several pieces of equipment, but the process was still losing ground. (Note: this is an excellent reason to log the heater outlet temperature so that you know when changes started, should you have a problem.) Previous test results had indicated the presence of carbon sludge in the fluid, so plans were made to activate a sidestream filter to remove the carbon. Before the plan was implemented, however, a sample of thermal fluid was taken that immediately identified the problem.

The fluid property that has the greatest effect on heat transfer rates is viscosity. Because the fluid heat-transfer coefficient (which controls the rate of heat transfer between the heat exchange surface and the fluid) is only one element of the overall heat-transfer coefficient, changes in the viscosity at elevated temperature (350°F or more) have to be significant (on the order of 200%) to cause a noticeable change in system performance. In this case, the problem was obvious and required no testing — a sample that was extracted at operating temperature went almost solid when it cooled. This put the fluid well above the 200% threshold.

Example 2: A chemical plant requested a sample kit to test its thermal fluid because one of its vacuum reactors was taking too long to heat. Even though the fluid had been in the system for many years and had recently been tested, it was assumed that the fluid must have gone "bad". This situation is probably one of the more common scenarios for heat transfer systems. The problem comes to light when someone realizes that the heater temperature has to be increased to keep production on schedule. In this case, the evidence against the fluid was further strengthened by the relatively "normal" heater pressure and temperature readings. This prompted the request for the sample kit and a quotation for a complete fluid changeout. While the latter course of action is appealing to the fluid supplier, it was unlikely to solve the problem since the problem wasn't the fluid.

The overriding evidence in this specific situation was that there had been no maintenance required on the system since the fluid had been tested. Fluid had not been removed or added (which eliminates contamination as a suspect) nor had any of the operating conditions changed. It turned out that there was a leak in

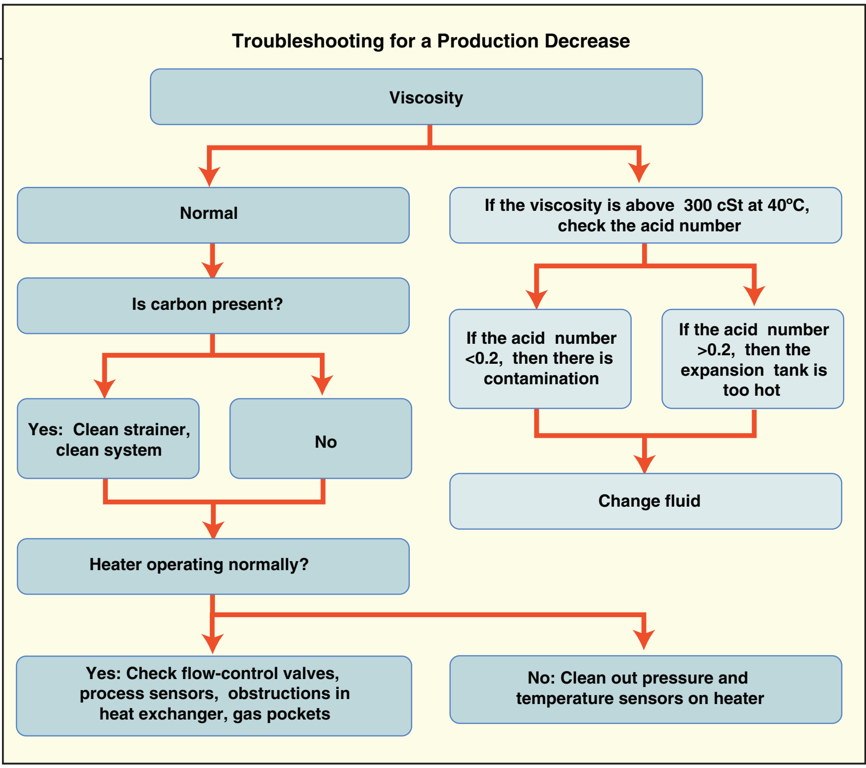

FIGURE 2. A simple flowchart can help analyze the symptom of production decreases

the vacuum system, undetected by a faulty sensor, which resulted in an increased heat load required for distilling the product.

Example 3: A poultry processor was experiencing reduced throughput in a continuous convection oven. The heater and pumps were checked for problems, and all temperature and pressure sensors were replaced. Someone suggested cleaning the heat-transfer fluid system. Since the fluid had been in service for a number of years, it was assumed to have degraded and formed blockages in the coils because the temperature drop across the heat exchanger was much lower than when the unit was new. The fact that the fluid had been tested routinely and found to be in good condition was totally ignored in the evaluation. Management personnel wanted to clean the system and then change the heat transfer fluid. A lube-oil additive-type cleaner was added to the system with the expectation that the problem would be solved. When there was no progress, a thermal-fluid sample kit was requested along with a request to estimate the cost of replacement fluid. Once again the viscosity of the sample was found to be well within the normal range. The plant manager was very disappointed with the results showing that the fluid was not the problem, because he had to send the maintenance staff back in to keep looking for the real culprit. Eventually it was discovered that an air damper inside the oven had a broken weld that allowed it to flip up into the air stream, effectively blocking the coils. Throughput was reduced because insufficient heat was getting to that section of the oven.

Pressure fluctuations

In one chemical plant, personnel noticed that the discharge pressure of the main circulating pump began to fluctuate as the fluid temperature approached 350°F after an extended shutdown. Thermal fluid was added to the system through the expansion tank, which made the situation worse for a period of time. Since the system had been kept under a nitrogen blanket during the downtime, water absorption through the expansion-tank vent was ruled out. Convinced that the fluid had degraded during the shutdown, personnel made plans to take another outage and replace the fluid. To pacify management, a fluid sample was taken and tested. The test results indicated high water levels (greater than 150 ppm, versus the normal level of less than 50 ppm).

Pump-discharge pressure fluctuations in a closed-loop heat-transfer system are always the result of entrained gas. Aeration of the fluid is often blamed for such fluctuations, particularly if fluid is added through the expansion tank. However, entrained air doesn't abruptly become gaseous, but instead it causes problems from the start. While it is true that overheating a fluid can produce more volatile molecules that will theoretically vaporize, in practice the relatively low liquid-to-vapor expansion rate (which is about 20) pretty much rules this out as the source of gas.

The real culprit is most often water, which has an expansion rate of 1,000. Until water is either drained from the system or flashed off through the vent, it remains in the bottom of the thermal buffer tank or the expansion tank. In fact, tanks have been known to rust through at the bottom because water has been in the same place for many years. When the heat-transfer fluid flows out of the tank as the system cools, the water is carried into the system piping, and then is dispersed into the circulating fluid when the pump starts. As the system temperature reaches about 220°F, the water droplets become steam bubbles and the pressure fluctuations begin. What causes confusion is that the pressure problems don't appear at the expected 212°F. Depending on the system pressure and design as well as the amount of water present, symptoms may not begin until the heater temperature reaches 280–300°F. If the pump is operating at a slightly negative suction head, even lower water concentrations can result in pressure fluctuations.

Figure 3 shows a simple chart that can be used to help troubleshoot pressure fluctuation problems.

Pump seals

A hot-roll calendering operation was experiencing repeated rotating joint-seal failures. The seal faces were being scored severely enough from the inside out to create fluid leakage. Two of the oldest seals were experiencing

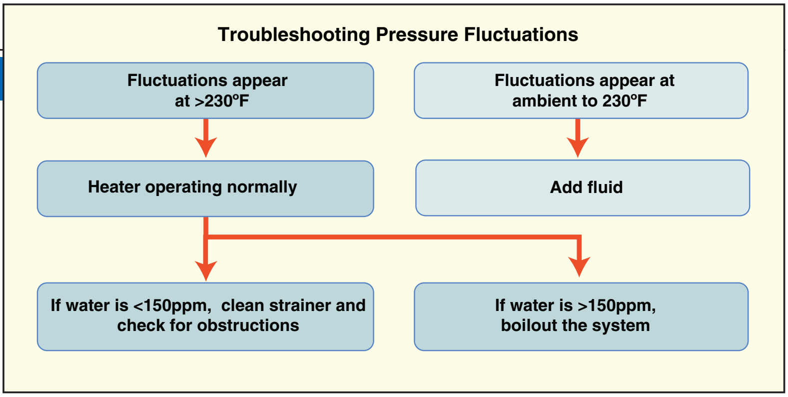

FIGURE 3. When pressure fluctuations occur, this simple chart can guide a first analysis of the problem

the greatest number of failures. While the fluid tests showed no significant change in the fluid condition, there was visible residue of a previous brand of insoluble fluid. The most compelling evidence of what the problem might be was that particles were collecting on the sidestream filter elements. To prevent further problems from what was suspected to be carbon (from degraded heat-transfer fluid), the user began to evaluate a system flush and fluid change.

The majority of carbon particles produced by fluid degradation are the result of fluid oxidation (as determined in fluid analysis by the total acid number). These acids are formed when hot fluid is exposed to air in the expansion tank. They are thermally unstable (compared to the fluid itself) and thereby degrade into carbon at relatively low temperatures (375 to 400°F) once the concentration has reached an acid number of 0.3 or so. If the expansion tank continues to run hot, the acid number will either stabilize or continue to increase. If the cause of the oxidation has been corrected, the acid number will decrease as the acids are consumed.

The carbon that is formed is similar to "soot" in appearance and will remain suspended in the fluid, which causes the fluid to appear to be black. The particles will drop out of suspension in stagnant fluid and form sediment (sludge). However, individually these particles are extremely fine (<0.5 micron) and as such are incapable of damaging rotating seals because they pass between the rotating faces. However, they will clump on 25-micron filter elements, which can be misleading during troubleshooting. In this case, the solution required analysis of the filter. The particles were analyzed and found to contain over 90% iron. This information was transmitted to the user, who then shelved the plan to flush the system and replace the fluid. Instead, he concentrated on improving his filtration system to eliminate the metallic particles.

Erratic production

A food processor began experiencing sporadic production problems with a multiple-user heat-transfer system that was used to heat tanks. Once again, the pump pressures and temperatures were all within the expected ranges. Because the fluid had been in service for a number of years, the likely solution was deemed to be fluid replacement. The shutdown was planned and quotes were obtained.

After the costs of the fluid and lost production were totaled, cooler heads prevailed, and it was decreed that the fluid should be tested by the current fluid suppliers to be sure it really did need to be replaced. Although the fluid had not been tested for a number of years and actually was a blend of several fluids, the supplier was able to determine that the fluid was in acceptable condition. Now that the "easy solution" was not applicable, the real investigation started. Particularly confusing, but overlooked when the fluid was the prime suspect, was the fact that the most significant decline in production occurred when there was the least demand on the heater. Fluid velocity has even more effect on heat transfer performance than viscosity, so whenever there is a drop in heat transfer, it's time to look at the flowrate.

Liquid-phase heaters require continuous flow to prevent fluid degradation. Hence these systems need some way to bypass the heat users when heat is not required. There are two ways to accomplish this: 1) A backpressure control valve that maintains flow when the two-way control valves are closed; and 2) One or more three-way control valves (depending on the number of users) with a manual pressure-equalization valve on the bypass port.

Theoretically three-way valves are superior to a backpressure valve arrangement because they provide a constant flow through the heater — a concept that is favored by the purists — if the balancing is done rigorously. This exact balance is difficult to maintain over time due to changes in equipment and the ever-present potential for third-shift adjustments. In this particular case, it was discovered that the bypass valves on the least-used leg of the system had been fully opened so that when that system was not operating, a substantial amount of fluid was bypassing. When the unit was operating, the bypass volume was reduced, which in turn increased the pressure and thus flow to the other units bringing production rates back up. Instead of attempting to balance all of the bypass valves (which would have required the installation of multiple pressure gages) the solution was to install a backpressure valve between the feed and return header and then close all of the bypass valves, effectively turning them into two-way valves. While this control scheme did allow the heater flow to vary, it made the system much easier to control since each user was independent of the others. ■

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Feature Report

TURNAROUNDS: Shorter, Safer, Simpler

John Barth
Apprion, Inc.

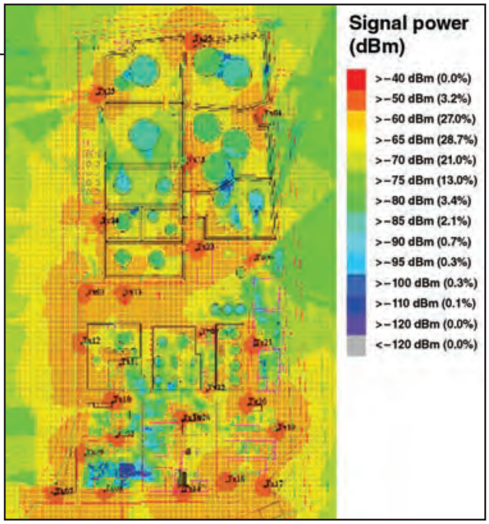

FIGURE 1. This 802.11a wireless grid simulation output offers signal power levels as one reading of many in a live wireless site survey analysis

Wireless networks are easily justified in a turnaround budget, and keep paying off after startup

Today's plant turnarounds bear little resemblance to those of the past: Last-minute preparations and procurements combined with hurried work plans penciled into a notebook often led to undisciplined procedures, incidents and equipment that still operated with defective parts.

Those bygone practices have been cleaned up and replaced with clearer processes as turnarounds have become critical to a plant's longterm sustainability and to a company's compliance with increasingly strict government regulations. Indeed, in this age of litigiousness and first-class environmental expectations, the difference between a sloppy and a successful turnaround can impact the very reputation and viability of a company in the chemical process industries (CPI).

Nonetheless, it's common knowledge that the vast majority of turnarounds still don't meet all performance standards. In fact, about 25% significantly underperform in more than one success criteria. It's also no secret that labor costs, capital budgets and preplanned time frames are still regularly exceeded.

One particularly cost-effective solution that can narrow the gap in turnaround performance is industrial wireless technology. New, yet proven, state-of-the-art tools are helping CPI leaders turn around their turnarounds by keeping them on track and bringing them in under their planned financial and time budgets. On top of that, the same investment that paid for itself in streamlining the turnaround, can also be used after startup to improve operations throughout the lifecycle.

From a technology perspective, what has happened is this: As more and more CPI companies have turned to a new generation of automated intelligence tools for project management, procedure execution and other key tasks, most of the tools have also advanced to run as wireless applications. These tools are especially effective when they can tie into network-wide information systems and can provide necessary information to turnaround personnel exactly when and where they need it. This improved availability of information can help overcome some of the enduring challenges associated with turnarounds to help cut costs and time and to improve efficiency, accuracy and productivity.

Just like the turnaround itself, proper preparation, planning and processes are integral to reaping the most rewards from an industrial wireless solution. As with almost any relatively new technology in the CPI, however, proven success and lessons of what to expect go a long way in making the decision to take the plunge at all.

CPI wireless adoption so far

In addressing this burden of proof, let's look at the growing trend toward wireless technology in the CPI and why it's happening. In "State of Industrial Wireless 2010," a year-long research effort, key findings from process manufacturing respondents showed the following:

- 64% of process manufacturing facilities reported having at least one wireless application installed at their facility
- A 23% increase in wireless adoption and an 85% increase in those considering wireless applications
- Compliance applications for security, safety and workforce productivity were the key drivers for adoption in 2010, with over 50% of respondents considering one of these applications
- Condition monitoring and asset management applications led wireless adoption with a year-over-year increase of 56%
- Video, communications and mobility are the applications driving the next wave of adoption

Significantly, the same survey found that the number one barrier to implementing wireless applications is that imposed by cost and budget constraints. I believe cost and budget constraints are easily overcome when we consider the benefits and timing of a wireless deployment as a part of turnaround planning.

Balancing the cost equation

As a percentage of the cost of a turnaround, an all-inclusive wireless infrastructure (networking, instrumentation and mobile devices) is miniscule. For ex-

FIGURE 2. The Huntsman wireless mobility application includes mobile handhelds, RFID (radio frequency identification) tags and wireless infrastructure

ample, if a $400,000 investment in plant infrastructure for wireless is required for a $50 million turnaround, that amounts to less than 1% of the budget. Usually, turnarounds are the largest part of any company's capital budget process or, in some cases, turnarounds are done as a completely separate budget process. Either way, the company is able to add a very small cost to a very large budget and get an enormous return.

In fact, in most cases, the cost of the infrastructure fits within the ±5% margin for project success. Often, the ability to make decisions via realtime wireless data reduces the turnaround by two or three days. If a turnaround is scheduled for 45 days with a budget of $45 million and the use of wireless data allows for the project to come in one day early, the cost for wireless infrastructure of $450,000 (1%) has immediately paid for the infrastructure more than two times. If the company can then add another application (post turnaround) for operational, maintenance, reliability, compliance or other improvements, the financial returns can be dramatic and recurring.

It's worth mentioning that getting executive sponsorship and buy-in from various functional areas within the facility sometimes can be the most challenging part of launching an industrial wireless solution. However, by tying the initial deployment of wireless infrastructure to a turnaround, the discussion becomes a cross-functional one by default.

The capital budgeting process for a large turnaround requires that operations, maintenance, reliability, instrumentation, safety and so on, all have input in the months (and even years) before the turnaround occurs. As a result, when a wireless infrastructure is added into the cost of the turnaround, it facilitates a cross-functional conversation about how to use that infrastructure during and after the turnaround is completed. It also brings visibility into the area of industrial wireless at the plant manager level and above, which means there is executive sponsorship from the beginning.

Cases in point

What are some of the specific reasons that companies are using wireless technology, whether for turnarounds or other daily operations? In general, the realtime data from wireless solutions allow for "on the fly" decisions, which can lower the number of overtime hours required by adjusting or rescheduling "slower" shifts during turnarounds and reducing costs of delivery for services and equipment. Safety or process incident rates also can be reduced because of realtime wireless access to shutdown and startup procedures via handheld devices.

Access to realtime data also allows for comparison between "as is" situations versus "planned for" situations. In other words, if your P&IDs have discrepancies — and they all do — your team can bring them up-to-date and make necessary adjustments in realtime for equipment procurement and tradesman time requirements. (For more, see the box, p. 39).

One recent illustration was announced several months ago around the completion of a wireless site plan at BASF FINA Petrochemicals LP (BFLP) facility in Port Arthur, Tex. Initially, the site survey focused on a wireless application for mobile handheld devices to improve the management of the facility's turnaround planning and scheduling. The site plan included expansion to cover implementation of a more comprehensive wireless infrastructure to support future additional wireless applications for condition monitoring, security and productivity.

The survey included measurements and data gathering to determine strategic placement of radio frequency (RF) transceivers and network devices to comprise a facility-wide wireless infrastructure. The plan called for 802.11 industrial WiFi access points and condition monitoring sensors positioned at key locations throughout the plant in anticipation of the future facility-wide wireless infrastructure and applications including backhaul for gate readers, condition monitoring, remote operator handheld devices, communications and video applications. Performance measurements, including area coverage and network connectivity, were taken within each zone of the plant.

"We wanted a full wireless application site plan across the entire facility to determine the most cost-effective and efficient implementation possible," James Skoruppa, senior I&E controls engineer at the Port Arthur facility, said in the announcement. "Plus, we did not want to create various individual, 'one-off' systems — a common mistake when implementing new technology in a phased approach."

Similarly, at a field site of the Huntsman Corp., a global manufacturer and marketer of differentiated chemicals, a wireless network was installed and leveraged with mobile handhelds and software to help speed the process of capturing defects and enabling operators to initiate maintenance work requests directly from the field, as part of a program called Project Zero. They also used the wireless-based system to provide field access to step-executable standard operating procedures and standard operating conditions. This enabled them to centralize and manage this safety information in one place rather than building the data into each round, checklist or procedure. The new system was found to reduce the time between defect detection and a maintenance work order from hours to a matter of seconds.

According to a case study by the ARC Advisory Group, entitled, "Huntsman Extends IT to its Field Operations", "An industrial mobility central data base engine also was built to provide immediate access to critical operating limits, consequences of deviation and corrective actions, for any operating procedure, maintenance procedure, operator round or safety verification being performed by the operator at the point of decision-making in the field. Legacy information, such as process

TURNAROUNDS ARE EASIER WITH WIRELESS

Dramatic cost savings opportunities:
One day saved in a major turnaround can equal as much as $1 million.

Improved project execution in realtime:
Realtime data allow for more accurate, up-to-date scheduling of contractor and tradesmen hours, equipment delivery from vendors and prioritization of tasks. This accuracy leads to reduced downtime for contractors and on-time delivery of equipment, which drives cost savings into the project plan.

Preventative maintenance:
Realtime access to equipment checklists and mechanical integrity procedures (MIPs) allows for more efficient execution of planned maintenance and also access to data regarding unplanned equipment-maintenance requirements. Less time spent finding information in paper format equals more time spent executing in completing the turnaround. Timely completion equals cost savings.

Increased equipment uptime (post turnaround):
Any equipment identified as a potential challenge (so-called bad actors) can be monitored post turnaround utilizing the wireless infrastructure paid for by the turnaround. Increases in equipment uptime have proven to be both more cost-effective and safer for the workplace employees.

Management of change (MOC):
During the turnaround, plant personnel always identify procedures or P&IDs that are either outdated or require some change. Realtime access to procedural data and management of change software allows the MOC process to be streamlined.

Process improvement opportunities throughout the facility:
Because the turnaround typically involves a cross functional team (operations, process control, maintenance, safety, instrumentation and so on), each team member will be able to give input on how to further utilize the wireless infrastructure for efficiencies after the turnaround has been completed.

One time investment, perpetual return:
The investment made in the wireless infrastructure for a major turnaround can be utilized for any number of critical safety, security, field instrumentation monitoring or other application. For example, post turnaround, your company can utilize the same infrastructure for wireless cameras for site surveillance, field mobility devices for rounds, readings and realtime work-order execution, or even to enable a new emergency notification system. ❏

and instrumentation diagrams, process flow diagrams, drawings, procedures, incident reports and so on, were also made available on demand."

The report said that Huntsman was able to make such resources available in the field — which extended over 3,000 acres through a wireless network combining Wi-Fi and WiMAX equipment — providing a high quality of service to the mobile operators "in order to support their use of the new software."

"The most challenging task for Project Zero is that chemical plants are designed, built, run and maintained by humans and humans make mistakes," John Prows, vice president of manufacturing excellence for Huntsman's performance products div., stated in the ARC case study. "Mistakes in EHS [environmental, health and safety] performance can damage what we value most — human life. With accurate and timely information we can all make better decisions. Realtime field access to information levels the playing field for everybody. The most or the least experienced Huntsman associate can immediately access anything on any plant server while in the field, without the difficulty or embarrassment of carrying paper. If you truly value your people, then give them accurate and timely information in the field at the point of decision making."

These two examples give you a taste for both the motives and experience that other CPI companies have had in leveraging wireless tools to improve crunch-time turnarounds as well as ongoing day-to-day operations. If you are considering implementing wireless to help improve your next turnaround, the next section helps put the most important planning criteria into perspective. A CPI application, after all, is a complex, industrial installation requiring technical and domain knowledge — not a simple remote control entertainment system in your family room. For the CPI, setting up an effective wireless system takes a lot more than a wireless device, receiver and remote control handheld.

Planning for wireless

While you certainly do not need to be a wireless expert yourself, at the very least you should understand the following ten criteria as you traverse the first steps of defining what you might expect your wireless application to achieve and selecting a vendor to help you design and implement a system.

1. Proven partner experience. As with any vendor selection process, make sure your wireless partner has plenty of reliable and proven real-world experience, not only in the CPI but also with turnaround work in particular. You want to work with a "battle-tested" vendor who has customers you can reference. Be sure it has domain expertise in your field, whether you're retrofitting pipe, checking the integrity of welding, tracking the status of craftsmen or ensuring that processes are followed on time and in budget.

2. Site planning. One of the most critical aspects of implementing a wireless system is to conduct a methodical, thorough and detailed site plan that takes into account your business objectives. As with a turnaround project itself, preparation cannot be emphasized enough. This is particularly critical if the wireless infrastructure encompasses a facility-wide or network-wide scope that increases the complexity of technical, logistical and collaboration issues. Placement of transceivers, network devices and monitoring sensors must be carefully assessed for one-time and everlasting project success.

3. Networked capabilities. The most value of a wireless infrastructure is realized when it's extended across a network, what some call "the network effect". You want to make sure that you and your vendor clearly understand the complexity of your network and how communications can be facilitated across it. Wireless can overcome multiple communications systems or integrate with them, depending on the application needs. In either case, the vendor must have the expert resources to tie in realtime wireless data with existing or new information systems across an entire network.

FIGURE 3. A centralized dashboard provides a view of multiple wireless locations and applications and enterprise-wide events and exceptions

FIGURE 4. To be useful in both turnarounds and operations, an industrial wireless gateway should have an open protocol and be "device neutral" so that it can leverage multiple types of devices — handhelds, wireless instrumentation, video, communications and more

4. Centralized platform. Your wireless vendor should have deep experience with tying wireless data to middleware, enterprise-class software, application or tablet software, either by providing its own or with integrating into existing information systems. Ideally, a middleware solution will process data from multiple wireless locations and applications and then transmit it to a centralized software system that has a dashboard view of enterprise-wide events and exceptions. Also, the software should take full advantage of the realtime nature of wireless data by providing automated alerts when corrective actions need to be made as they happen.

5. Comprehensive applications. Advances in wireless technologies, sensors and associated software mean that new functions and applications are being developed all the time. Are you looking for a single, one-off wireless project, or do you want to take into account a network-wide system that can encompass multiple applications? You should consider and ask about new wireless applications such as the following:

- Video surveillance for safety, security
- Asset tracking and management
- Condition monitoring (temperature, humidity, vibration, voltage, tank levels and status, pressure and flow and so on)
- Communications: Two-way radios, cell phones, PA (public address) systems and PBX (business telephone) systems and alarms
- Access control and workforce mobility

6. Device neutral. There is no single wireless device or even protocol that's monolithic — in other words, one size does not fit all. Applications, physical environments and objectives all vary with each customer, and all these factors influence what type of device and protocol is best suited for the job. Should an installation be based on WiFi (802.11), WIMAX, 2.4 GHz, 900 MHz, active or passive RFID (radio frequency identification) or are there even some legacy, proprietary technology concerns to consider? Do transmissions need to be long-range or shorter-range? For these and many other complex reasons, it's important to choose a vendor that isn't tied to just one type of technology or protocol. The vendor must have an open platform that is "tag agnostic" and can leverage multiple types of devices to suit the specific needs of each application.

7. Professional services (scalability and extensibility). Does the vendor have the capability and experience to elegantly scale a wireless system beyond the initial project scope and develop a solution that's extensible to accommodate a widening array of applications and functions? Without a scalable and extensible wireless strategy, most industrial enterprises will find it difficult, or even impossible, to deploy, manage and maintain more than one or two wireless applications. There is a wide range of challenges that arise in developing a comprehensive wireless strategy. Various technologies are physically overlapping as well as sharing an infrastructure that supports multiple applications. The sheer magnitude and complexity of industrial plants and the density of devices to be deployed create wireless protocol coexistence and radio interference problems. In addition, application bandwidth, data, and security demands require active design and management while ensuring there is residual available bandwidth for future needs. A suitable vendor can respond to these types of questions:

- Does the solution call for data transmissions to be short-range, line-of-site or do they need to be long-range and omnidirectional?
- Will large objects and metal surroundings propagate or bend radio waves in the wrong direction or will there be interference from multiple wireless systems?
- Can bandwidth and data processing capabilities accommodate future network-wide growth?
- What is the system architecture for adding future expansions or extending future enhancements.

All these considerations — and many more — must be taken into account when mapping out and implementing a wireless network and applications. Professional services should be able to address how best to take care of the immediate project as well as have the vision to see how it can be leveraged for future growth and value.

8. Device management and provisioning. In addition to providing a "bird's eye view" of operations, wireless applications should have a comprehensive way to detect, manage and "heal" wireless devices within a project, plant or network. There should be an automated solution that enables administrators to set and enforce policies across all devices and systems within the entire network. Capabilities should be able to meter and route diverse communications based on criticality and realtime network availability. System alerts should notify the administrator and vendor of any areas of potential device- or bandwidth-latency problems, before they occur. These are core features that make it possible to promise security, performance, and reliability in a multi-vendor, multi-frequency industrial wireless network. An ideal system gathers and centralizes wireless network performance data and presents the data in table or graph format, such as producing wireless reports on "rogue" devices, spectrum signal and noise ratio strengths. In the end, this capability should allow administrators to use reports that help them to make informed decisions about whether the network needs to be tuned or expanded to meet operational goals.

9. Management and maintenance support and metrics. If something goes wrong, or needs fixing, what type of support can you expect from your vendor? Do they have around the clock support to meet your business needs for system reliability, especially during turnarounds when immediate responses are necessary to meet tight deadlines? Other support services that should be evaluated include wireless application management, diagnosis, troubleshooting, management of systems, policies, performance and security, auditing, remote monitoring and regular roadmap reviews. What types of measurements does your vendor provide to track stability and performance? Can the vendor help you establish a baseline of performance to determine the before-and-after impact of whether a wireless system is helping to achieve the desired results?

10. Process improvement. The vendor should be mindful of your business rules and processes and ensure that the system will not disrupt standard operating procedures. With that in mind, be aware that a wireless system often uncovers better ways to perform, whether in critical asset utilization, worker productivity or data availability. ■

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Solubility of Water in Benzenes As a Function of Temperature

The solubility of water in hydrocarbons is important for several reasons, including product quality. A new correlation is compared to experimental data

Carl L. Yaws, Preetam Rane and Vishal Nigam
Lamar University

The solubility of water in hydrocarbons contained in crude oil is very important. This importance will increase in the future in view of processing, safety, hazard and environmental considerations focusing on product quality and equipment sustainability. The following brief discussion illustrates the importance.

Any processing involving the lowering of temperature to values in the range of the freezing point of water may result in formation of solids (freezing of water or hydrate formation). Such solid formation will affect both fluid flow in piping and operational characteristics of equipment. For catalytic reactions, any water in the hydrocarbon may be a poison to the catalyst that promotes the hydrocarbon reaction. For reactions in general, any water in the reaction species may result in the formation of undesirable byproducts issuing from the hydrocarbon reaction. The presence of water in the product may be detrimental to quality. If sufficient water is in the product, it may prove to be unuseable.

Results are presented here for solubility of water in benzenes as a function of temperature. A new correlation for water solubility is also presented that provides reliable solubility values down to very low concentrations (parts per million range). The correlation is based on the boiling point temperature of the benzenes. Correlation values and experimental data are in favorable agreement. The results are useable in engineering applications involving processing, safety, hazard, environmental and "green" issues.

Correlation for water solubility

The correlation for water solubility as a function of temperature is based on the following equation:

$$\log_{10} S = A + \frac{B}{T} + C \cdot \log_{10} T \quad (1)$$

Where:
S = solubility in water, parts per million by weight, ppm (wt.)
T = temperature, K
A, B, and C = regression coefficients

The correlation applies to a temperature range of about 298 to 478K. The coefficients (A, B, and C) for the correlation were determined from regression of the available data. In preparing the correlation, a literature search was conducted to identify data source publications [*1–25*]. The publications were screened and copies of appropriate data were made. These data were

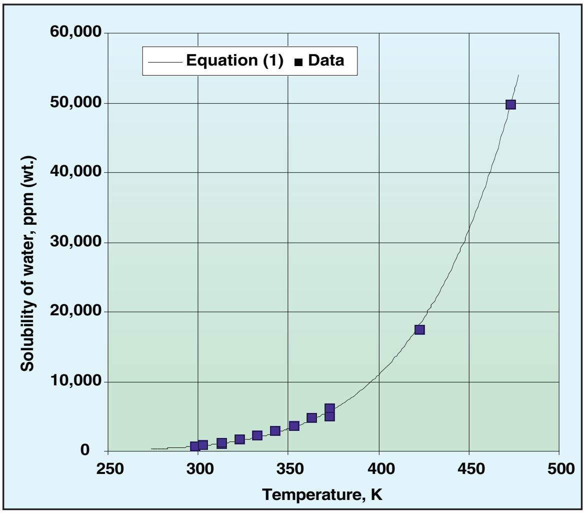

FIGURE 1. The solubility of water in benzene plotted as a function of temperature. The curve — generated from Equation (1) — agrees well with experimental data

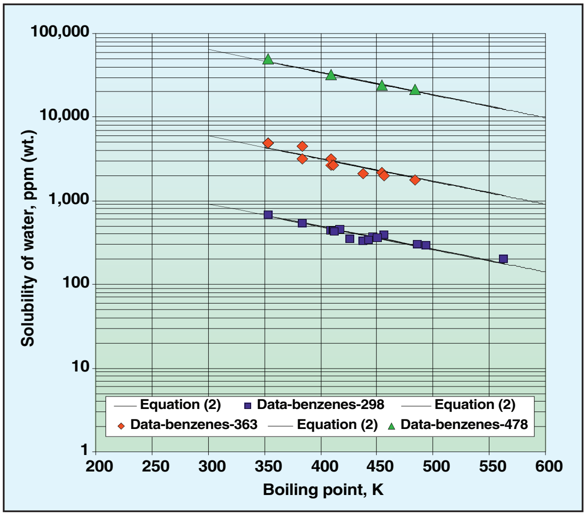

FIGURE 2. The solubility of water in benzenes as a function of the compounds' boiling points is plotted here. The curves — generated from the estimation equation at three different temperatures — agree with experimental data

$\log_{10} S = A + B/T + C \log_{10} T$ (S = solubility, parts per million by weight, ppm (wt.), T = temperature, K)

No	ID	Formula	Name	CAS No.	A	B	C	T_{min}	T_{max}	Code	S @ T_{min}	S @ 373K	S @ T_{max}
1	7339	C_6H_6	benzene	71-43-2	–14.7094	–287.1471	7.4815	298	473	1,2	691.88	5789.82	49,746.33
2	11216	C_7H_8	toluene	108-88-3	–13.3758	–335.0407	6.9646	298	478	1,2	541.78	4,348.78	38,116.97
3	14332	C_8H_{10}	ethylbenzene	100-41-4	–18.1438	–81.9761	8.5123	298	480	1,2	441.01	3,382.40	31,987.92
4	14333	C_8H_{10}	*o*-xylene	95-47-6	–11.9036	–407.8600	6.4376	298	478	1,2	454.93	3,632.69	30,844.83
5	14334	C_8H_{10}	*m*-xylene	108-38-3	–6.7832	–709.0506	4.7671	298	478	1,2	431.17	3,777.38	31,887.88
6	14335	C_8H_{10}	*p*-xylene	106-42-3	–17.6254	–121.7700	8.3560	298	478	1,2	438.97	3,457.85	32,040.02
7	17591	C_9H_{12}	cumene	98-82-8	0.9286	–1166.0841	2.2323	298	478	1,2	347.73	3,506.42	29,341.13
8	17592	C_9H_{12}	*m*-ethyltoluene	620-14-4	–10.0880	–517.6676	5.8286	298	478	2	396.47	3,274.75	27,746.90
9	17593	C_9H_{12}	*o*-ethyltoluene	611-14-3	–10.0985	–517.6676	5.8286	298	478	2	387.03	3,196.73	27,085.85
10	17594	C_9H_{12}	*p*-ethyltoluene	622-96-8	–10.0899	–517.6676	5.8286	298	478	2	394.79	3,260.83	27,628.98
11	17595	C_9H_{12}	1,2,3-trimethylbenzene	526-73-8	–10.1282	–517.6676	5.8286	298	478	2	361.40	2,985.04	25,292.14
12	17596	C_9H_{12}	1,2,4-trimethylbenzene	95-63-6	–10.1099	–517.6676	5.8286	298	478	2	376.98	3,113.74	26,382.65
13	17597	C_9H_{12}	trimethyl benzene	25551-13-7	–10.1166	–517.6676	5.8286	298	478	2	371.19	3,065.94	25,977.66
14	17598	C_9H_{12}	mesitylene	108-67-8	–15.4793	–275.2685	7.6481	298	478	1,2	332.74	2,837.68	27,160.59
15	17599	C_9H_{12}	propylbenzene	103-65-1	–10.0823	–517.6676	5.8286	298	478	2	401.70	3,317.90	28,112.48
16	20487	$C_{10}H_{14}$	butylbenzene	104-51-8	–28.3745	498.0378	11.8382	298	478	1,2	387.89	2,550.25	24,178.47
17	20488	$C_{10}H_{14}$	isobutylbenzene	538-93-2	–10.1192	–517.6676	5.8286	298	478	2	369.01	3,047.94	25,825.17
18	20489	$C_{10}H_{14}$	*sec*-butylbenzene	135-98-8	–10.5679	-491.2860	5.9749	298	478	1,2	370.58	3,036.11	25,737.98
19	20490	$C_{10}H_{14}$	*tert*-butylbenzene	98-06-6	-3.9069	–883.5354	3.7994	298	478	1,2	339.71	3,140.28	26,420.68
20	20491	$C_{10}H_{14}$	cymene	25155-15-1	–10.1289	–517.6676	5.8286	298	478	2	360.88	2,980.74	25,255.73
21	20492	$C_{10}H_{14}$	*m*-cymene	535-77-3	–10.1254	–517.6676	5.8286	298	478	2	363.76	3,004.54	25,457.42
22	20493	$C_{10}H_{14}$	*o*-cymene	527-84-4	–10.1338	–517.6676	5.8286	298	478	2	356.77	2,946.77	24,967.92
23	20494	$C_{10}H_{14}$	*p*-cymene	99-87-6	–10.1392	–517.1808	5.8313	298	478	1,2	359.17	2,966.19	25,132.66
24	20495	$C_{10}H_{14}$	1-methyl-2-propylbenzene	1074-17-5	–10.1519	–517.6676	5.8286	298	478	2	342.28	2,827.09	23,953.89
25	20496	$C_{10}H_{14}$	1-methyl-3-propylbenzene	1074-43-7	–10.1437	–517.6676	5.8286	298	478	2	348.77	2,880.71	24,408.21
26	20497	$C_{10}H_{14}$	1-methyl-4-propylbenzene	1074-55-1	–10.1478	–517.6676	5.8286	298	478	2	345.51	2,853.78	24,179.98
27	20498	$C_{10}H_{14}$	(S)-(1-methylpropyl) benzene	5787-28-0	–10.1495	–517.6676	5.8286	298	478	2	344.11	2,842.20	24,081.92
28	20499	$C_{10}H_{14}$	diethylbenzene	25340-17-4	–10.1440	–517.6676	5.8286	298	478	2	348.55	2,878.91	24,392.93
29	20500	$C_{10}H_{14}$	*o*-diethylbenzene	135-01-3	–10.1482	–517.6676	5.8286	298	478	2	345.16	2,850.92	24,155.77
30	20501	$C_{10}H_{14}$	*m*-diethylbenzene	141-93-5	–21.7542	108.2933	9.6730	298	478	1,2	350.21	2,593.89	24,387.25
31	20502	$C_{10}H_{14}$	*p*-diethylbenzene	105-05-5	–10.1491	–517.6676	5.8286	298	478	2	344.45	2,845.03	24,105.89
32	20503	$C_{10}H_{14}$	3-ethyl-*o*-xylene	933-98-2	–10.1768	–517.6676	5.8286	298	478	2	323.19	2,669.47	22,618.34
33	20504	$C_{10}H_{14}$	4-ethyl-*o*-xylene	934-80-5	–10.1654	–517.6676	5.8286	298	478	2	331.76	2,740.28	23,218.30
34	20505	$C_{10}H_{14}$	2-ethyl-*m*-xylene	2870-04-4	–10.1661	–517.6676	5.8286	298	478	2	331.23	2,735.82	23,180.52
35	20506	$C_{10}H_{14}$	4-ethyl-*m*-xylene	874-41-9	–10.1618	–517.6676	5.8286	298	478	2	334.56	2,763.37	23,413.98
36	20507	$C_{10}H_{14}$	5-ethyl-*m*-xylene	934-74-7	–10.1491	–517.6676	5.8286	298	478	2	344.47	2,845.21	24,107.40
37	20508	$C_{10}H_{14}$	2-ethyl-*p*-xylene	1758-88-9	–10.1574	–517.6676	5.8286	298	478	2	337.95	2,791.38	23,651.27
38	20509	$C_{10}H_{14}$	1,2,3,4-tetramethylbenzene	488-23-3	–10.2069	–517.6676	5.8286	298	478	2	301.52	2,490.50	21,101.98
39	20510	$C_{10}H_{14}$	1,2,3,5-tetramethylbenzene	527-53-7	–10.1878	–517.6676	5.8286	298	478	2	315.12	2,602.77	22,053.22
40	20511	$C_{10}H_{14}$	1,2,4,5-tetramethylbenzene	95-93-2	–10.1846	–517.6676	5.8286	298	478	2	317.41	2,621.75	22,214.02
41	22958	$C_{11}H_{16}$	pentylbenzene	538-68-1	–10.2080	–517.6676	5.8286	298	478	2	300.73	2,483.96	21,046.54
42	22959	$C_{11}H_{16}$	2-phenylpentane	2719-52-0	–10.1660	–517.6676	5.8286	298	478	2	331.31	2,736.50	23,186.33
43	22960	$C_{11}H_{16}$	3-phenylpentane	1196-58-3	–10.1687	–517.6676	5.8286	298	478	2	329.24	2,719.42	23,041.57
44	22961	$C_{11}H_{16}$	1-phenyl-2-methylbutane	3968-85-2	–10.1850	–517.6676	5.8286	298	478	2	317.10	2,619.12	22,191.77
45	22962	$C_{11}H_{16}$	1-phenyl-3-methylbutane	2049-94-7	–10.1902	–517.6676	5.8286	298	478	2	313.35	2,588.14	21,929.26

(Table continues on next page)

(Table continued from previous page) $\log_{10} S = A + B/T + C \log_{10} T$ (S = solubility, parts per million by weight, ppm (wt.), T, K)

No.	ID	Formula	Name	CAS No.	A	B	C	T_{min}	T_{max}	Code	S @ T_{min}	S @ 373K	S @ T_{max}
46	22963	$C_{11}H_{16}$	2-phenyl-2-methylbutane	2049-95-8	–10.1725	–517.6676	5.8286	298	478	2	326.41	2,696.02	22,843.28
47	22964	$C_{11}H_{16}$	2-phenyl-3-methylbutane	4481-30-5	–10.1606	–517.6676	5.8286	298	478	2	335.48	2,771.00	23,478.59
48	22965	$C_{11}H_{16}$	1-phenyl-2,2-dimethylpropane	1007-26-7	–10.1551	–517.6676	5.8286	298	478	2	339.71	2,805.92	23,774.53
49	23006	$C_{11}H_{16}$	1,2,4-trimethyl-6-ethylbenzene	—	–10.2286	–517.6676	5.8286	298	478	2	286.86	2,369.39	20,075.76
50	23007	$C_{11}H_{16}$	1,3,5-trimethyl-2-ethylbenzene	3982-67-0	–13.3771	–331.8442	6.8592	298	478	1,2	303.80	2,369.81	20,151.34
51	23008	$C_{11}H_{16}$	pentamethylbenzene	700-12-9	–10.2786	–517.6676	5.8286	298	478	2	255.64	2,111.48	17,890.56
52	25025	$C_{12}H_{18}$	hexylbenzene	1077-16-3	–10.2642	–517.6676	5.8286	298	478	2	264.25	2,182.61	18,493.23
53	25026	$C_{12}H_{18}$	1,4-dipropylbenzene	4815-57-0	–10.2166	–517.6676	5.8286	298	478	2	294.85	2,435.35	20,634.70
54	25027	$C_{12}H_{18}$	diisopropylbenzene	25321-09-9	–10.1944	–517.6676	5.8286	298	478	2	310.32	2,563.14	21,717.41
55	25032	$C_{12}H_{18}$	1,2,3-triethylbenzene	42205-08-3	–10.2408	–517.6676	5.8286	298	478	2	278.87	2,303.40	19,516.63
56	25033	$C_{12}H_{18}$	1,2,4-triethylbenzene	877-44-1	–10.2422	–517.6676	5.8286	298	478	2	278.02	2,296.34	19,456.83
57	25034	$C_{12}H_{18}$	1,3,5-triethylbenzene	102-25-0	–10.2364	–517.6676	5.8286	298	478	2	281.70	2,326.74	19,714.42
58	25043	$C_{12}H_{18}$	1,2,4-trimethyl-5-isopropylbenzene	10222-95-4	–10.2503	–517.6676	5.8286	298	478	2	272.84	2,253.60	19,094.66
59	25044	$C_{12}H_{18}$	4-*tert*-butyl-*o*-xylene	7397-06-0	–10.2068	–517.6676	5.8286	298	478	2	301.60	2,491.13	21,107.27
60	25046	$C_{12}H_{18}$	hexamethylbenzene	87-85-4	–10.3658	–517.6676	5.8286	298	478	2	209.15	1,727.48	14,636.86
61	25049.1	$C_{12}H_{18}$	2,4,6-trimethyl-1-propylbenzene	—	–15.4811	–209.1151	7.5399	298	478	1,2	298.24	2,240.24	19,094.66
62	26983	$C_{13}H_{20}$	heptylbenzene	1078-71-3	–10.3186	–517.6676	5.8286	298	478	2	233.15	1,925.77	16,316.99
63	26984	$C_{13}H_{20}$	1-methyl-2,4-diisopropylbenzene	1460-98-6	–10.2585	–517.6676	5.8286	298	478	2	267.76	2,211.65	18,739.24
64	28365	$C_{14}H_{22}$	octylbenzene	2189-60-8	–10.3684	–517.6676	5.8286	298	478	2	207.90	1,717.23	14,550.03
65	28366	$C_{14}H_{22}$	1,2,3,4-tetraethylbenzene	642-32-0	–10.3319	–517.6676	5.8286	298	478	2	226.09	1,867.45	15,822.85
66	28367	$C_{14}H_{22}$	1,2,3,5-tetraethylbenzene	38842-05-6	–10.3261	–517.6676	5.8286	298	478	2	229.17	1,892.88	16,038.36
67	28368	$C_{14}H_{22}$	1,2,4,5-tetraethylbenzene	635-81-4	–10.3292	–517.6676	5.8286	298	478	2	227.51	1,879.18	15,922.26
68	28369	$C_{14}H_{22}$	1,4-di-*tert*-butylbenzene	1012-72-2	–10.2946	–517.6676	5.8286	298	478	2	246.39	2,035.14	17,243.70
69	29455	$C_{15}H_{24}$	nonylbenzene	1081-77-2	–10.4164	–517.6676	5.8286	298	478	2	186.15	1,537.52	13,027.35
70	29456	$C_{15}H_{24}$	1,2,4-triisopropylbenzene	948-32-3	–10.3129	–517.6676	5.8286	298	478	2	236.24	1,951.26	16,533.01
71	29457	$C_{15}H_{24}$	1,3,5-triisopropylbenzene	717-74-8	–10.2966	–517.6676	5.8286	298	478	2	245.29	2,025.98	17,166.11
72	29458	$C_{15}H_{24}$	3,5-di-*tert*-butyltoluene	15181-11-0	–10.3129	–517.6676	5.8286	298	478	2	236.24	1,951.26	16,533.01
73	30357	$C_{16}H_{26}$	decylbenzene	104-72-3	–10.4595	–517.6676	5.8286	298	478	2	168.57	1,392.31	11,796.99
74	30358	$C_{16}H_{26}$	pentaethylbenzene	605-01-6	–10.4027	–517.6676	5.8286	298	478	2	192.12	1,586.82	13,445.12
75	30361	$C_{16}H_{26}$	(1-methylnonyl)benzene	4537-13-7	–10.4366	–517.6676	5.8286	298	478	2	177.66	1,467.43	12,433.46
76	30361.1	$C_{16}H_{26}$	(2,4,6-trimethylheptane)benzene	—	–18.1325	–63.7026	8.3464	298	478	1,2	202.52	1,454.65	12,433.46
77	31034	$C_{17}H_{28}$	undecylbenzene	6742-54-7	–10.5012	–517.6676	5.8286	298	478	2	153.11	1,264.61	10,715.00
78	31730	$C_{18}H_{30}$	dodecylbenzene	123-01-3	–10.5403	–517.6676	5.8286	298	478	2	139.94	1,155.84	9,793.38
79	31731	$C_{18}H_{30}$	hexaethylbenzene	604-88-6	–10.4598	–517.6676	5.8286	298	478	2	168.44	1,391.26	11,788.13
80	31732	$C_{18}H_{30}$	1,2,4,5-tetraisopropylbenzene	635-11-0	–10.3537	–517.6676	5.8286	298	478	2	215.06	1,776.30	15,050.54

code: 1 - data, 2 - estimate

then keyed-in to the computer to provide a database for which experimental data are available. The database also served as a basis to check the accuracy of the correlation.

The solubility of water as a function of temperature is shown in Figure 1 for a representative compound (benzene). The data of Chen and Wagner [*1*], Pollak and Lu [*9*], and Tsonopoulos and Wilson [*18*] were selected for the graph. The graph discloses favorable agreement between the data and Equation (1).

Tabulation of results

The results for solubility of water in benzenes as a function of temperature are given in Table 1. The tabulation is arranged by carbon number (C_5, C_6, C_7 and so on) to provide ease of use in quickly locating data using the chemical formula.

The tabulated values are based on both experimental data and estimates. In the absence of data, the estimates for isomers and large size compounds (compounds with more than ten carbons, that is compounds larger than C_{10}) should be considered rough values useful for initial analysis. If initial analysis is favorable, follow-up experimental determination is recommended.

Estimation equation

The following equation was used to ascertain values for the estimates:

$$\log_{10} S = A + B \cdot T_B \qquad (2)$$

Where:

S = solubility of the compound in water at T = 298.15, 363.15 and 477.59K, ppm (wt.)

T_B = boiling point temperature of compound, K

A = 3.780 for T = 298.15K,
 = 4.590 for T = 363.15K and
 = 5.625 for T = 477.59K

$B = -2.720 \times 10^{-03}$

Solubility values obtained from Equation (2) and experimental data are shown in Figure 2 for the three temperatures (298.15, 363.15, and 477.59K). The data in the figure are based on the compilations of Englin (and others) [*4*], Polak and Lu [*9*], and Solubility Data Series [*10–15*] at ambient temperature, and Chen and Wagner [*1–3*] and Tsonopoulos (and others) [*18–20*] at higher temperatures. Boiling point temperatures are from the compilations of Yaws [*22–25*]. General agreement of the equation and data are displayed for the curves at the three different temperatures.

An example calculation

In hydrocarbon processing, benzene (C_6H_6) comes into contact with water at 363.15K (90°C). The organic and aqueous phases are subsequently separated. Estimate the concentration of water in benzene at this temperature.

Substitution of the coefficients from Table 1 and the temperature into the correlation equation yields:

$\log(S) = -14.7094 - 287.1471/363.15 + 7.4815 \times \log(363.15)$
 $= 3.6532$

$S = 10^{3.6532}$
 = 4,500.00 ppm (wt.) ■

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Preventing Tank Corrosion

Why a tank's coating-application process makes all the difference

FIGURE 2. In the typical porcelain-enamel coating process, a liquid slurry of glass frit and proprietary chemicals are applied in multiple coats to cover the sheets and exposed edges. A chemical bond is created in the furnace where the steel and glass coating meet

David Wheat
CST Storage

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The interior surfaces of your storage tanks are constantly at risk. You undoubtedly walk past a tank and do not give thought to what is happening on the inside, but that is because you trust the interior coating to protect not only the storage vessel, but also the product being stored from corrosion that might occur on the tank.

Without a doubt, corrosion is the principal enemy of a storage vessel. It shortens a tank's lifespan incrementally and increases the possibility of contamination. Dry bulk chemicals are often abrasive to the tank walls, requiring a strong coating to resist scratches and gouges, which expose the steel to corrosion. All liquid products — even water — are corrosive. Unprotected steel can begin to corrode in a matter of hours.

So coating the interior of a tank is essential when it comes to protecting a tank. Dry bulk materials require hard, abrasion-resistant coatings that are slick, ensuring that all material passes out of the tank leaving minimal residue. Liquids require strong, consistent coatings that provide complete coverage without thin or missed spots. Choosing a tank with a high-quality coating that has been tested and proven to withstand these materials means less maintenance over time and less concern for you.

Variety in coatings

The quality of a coating and its resistance to corrosion determines the lifespan and quality of the tank. Many different coatings are found on the market today, including the common epoxy, glass-fused-to-steel, high heat coatings, cold weather coatings and coatings designed to withstand high levels of acidity or alkalinity.

FIGURE 1. Shown here is a glass-fused-to-steel storage tank including a containment tank

The choice of one coating over another should be made depending on the product to be stored. Each product has its own requirements and specifications. Epoxy coatings are commonly found in the tank industry. They are generally tough and chemical resistant, with excellent corrosion resistance. Epoxy coatings can be applied electrostatically, either as a powder or a liquid. On the exterior, epoxy coatings are typically combined with polyurethane topcoats to provide protection against environmental elements.

Glass-fused-to-steel coatings (Figure 1), which are commonly referred to as porcelain enamel, are applied in liquid slurry form to specialty steel and fired in a furnace (Figure 2) at 1,500°F to create an inert coatings that are very resistant to dry and liquid chemicals and materials. They are an excellent choice for certain applications where an organic coating may not be compatible with the material being stored, and where a long service life is desired.

Paint-based coatings are very common in the industry. They are factory applied for factory-welded storage tanks and field applied in the case of site-welded tanks. Though generally inexpensive, they do not have the service life that factory applied coatings provide, and extreme care must be taken to ensure the right environmental conditions when site-applying these materials to ensure uniformity and integrity of the final coating.

Regardless of the type of coating used, it is critical that the coating be suited for its intended storage application.

The coating process is critical

While the market offers a variety of coatings, the one true difference in coatings lies in the application process. Coatings themselves may have great selling points and use advanced technology, but if the coating is not applied correctly, the tank wall will be left exposed and vulnerable to corrosion.

The most consistent coating applications are achieved at the factory under electronically regulated and environmentally controlled circumstances. Taken one step further, the most durable tank coatings also are thermally cured at the factory. Some tank manufacturers apply coatings in the factory by hand and then allow them to air-dry and cure with ambient heat, which exposes the cure to environmental factors such as dust and humidity. Other manufacturers outsource the coating process altogether. An optimal coating solution is one that is both applied and thermally cured in controlled factory conditions, such as glass-fused-to-steel processes, before the tank is shipped and erected in the field. Factory welded and bolted tanks often offer this feature.

Field-welded and concrete tanks receive their coatings onsite after the tank has been erected. These tanks may need to undergo a chemical process to protect the coating while the tank is being erected. Once a tank has been erected in the field, there may be areas of the tank that are extremely difficult to sand blast or fully prepare for field coating. Field applied coatings are sprayed on using scaffolding to reach the walls and roof. Even "missing the smallest spots" leaves exposed areas open to corrosion. The thickness of coatings applied in the field cannot be controlled as closely as is possible under ideal factory conditions. Weather and other environmental factors — dust, humidity, temperature and wind — also affect the quality and timeliness of the curing process in the field. Because of the variables in this type of application, you should ensure there are adequate quality control measures listed in the specification by the tank manufacturer, and consider third party inspections.

The application process

Surface preparation is the first step in the application process. It involves both cleaning the surface and achieving a profile on the steel. Regardless of how good the coating is, it must have a clean surface with an adequate blast profile to perform properly, in the same way that the most advanced skyscraper must have a solid foundation to rest upon.

The most common method of surface preparation is abrasive blasting. Different abrasives can be used, including steel grit or shot, garnet, coal slag, and even items such as walnut shells. The type and size of grit should be chosen in accordance with the coating manufacturer's recommendations. Abrasive blasting may either be done automatically (typically by a centrifugal blast machine) or manually (air blasting). In the case of air blasting, it is critical that the air used for blasting is dry and free of contaminants. The surface should be inspected prior to the coating application to ensure that the proper cleanliness and profile have been achieved.

Powder coatings are applied using powder spray guns that apply an electrostatic charge to the powder particles when they are atomized (Figure 3). This charge draws it to the grounded part. The advantage of electrostatic application is that the charged particles are drawn preferentially to the thinnest areas, which results in a more uniform coating. They are also drawn to edges, which are typically difficult to coat.

FIGURE 3. Epoxy powder coatings are applied using powder spray guns, which apply a charge to the powder particles when they are atomized. The charge draws particles to the grounded part. The charged particles are preferentially drawn to the thinnest areas and edges, resulting in a uniform coating

In the typical porcelain enamel processes such as glass-fused-to-steel, a liquid-slurry of glass frit and proprietary chemicals is applied in multiple coats covering the sheets and exposed edges. A chemical bond is created during firing in the furnace where the steel and the glass coating meet.

It is important that the coating thickness be measured throughout the application process to ensure that the manufacturer's recommended thickness is achieved. If the coating is too thin, the steel may not be adequately covered and pinpoint rusting can soon occur. If the coating is excessively thick, it may crack from internal stresses or a loss of flexibility.

Testing the coating

Because the coating is such an important consideration, it is equally important that the quality-control tests used are up to standard. A wet sponge detector is commonly used by tank manufacturers. A wet sponge with an electrical charge is moved across the surface of the cured coating. The metal behind the coating also receives a charge. Wherever the wet sponge touches a "missed spot" or bare metal, a current is completed and the "holiday" is made known by either an audible or visual indicator. However, this test is accurate only for bare spots. It does not test for thinly applied coatings.

FIGURE 4. An accurate epoxy-coating test includes the use of a high-voltage spark detector, which shows not only the smallest missed spots in the coating, but also spots where the coating does not meet minimum thickness requirements

A more accurate test — the high voltage spark detector — also shows where coating does not meet minimum thickness requirements (Figure 4). Both a wand and the tank wall receive a charge and where the coating is bare or less than minimal thickness required, a spark appears showing the exact location of the holiday. Determining thin spots in the coating is vital because a thinly applied coating may allow for premature corrosion of the tank wall.

The safety factor

Coatings play a role in safety. It is unsafe to use an old storage tank to hold a product that it was not designed and tested for. If you are considering recycling a used tank for storing a new product, be sure to first have the tank professionally evaluated for safety and corrosion resistance. Also keep in mind that the coating for tanks used for storage of food should meet U.S. Food and Drug Administration (FDA) guidelines, or equivalent local standards.

Moving and expansion

If you would ever consider moving or relocating a tank, think about the coating. Tanks featuring factory-applied coatings usually are moveable without a follow-up recoat, as panels are individually coated in the factory and easily taken apart and reassembled. Coatings that are field applied will tear or break when the tank is dis-assembled and pieces are moved, creating seams where corrosion can start. It is important to consider whether you plan to expand your tank before it is built if at all possible. A bolted tank with factory applied coating to individual panels,

FIGURE 5. Steel bolted tanks with epoxy coatings are commonly used as holding tanks for process water at chemical processing facilities

when properly designed, will allow for adding rings (think upward) without affecting the coating on the original tank. A tank with a field-applied coating would require complete recoating after the expansion is completed.

'Green' tank coatings

The process of applying coatings after construction to field-welded and concrete tanks may also present challenges to the environment. Tanks constructed in the field must undergo sandblasting to prepare the surface. The field application of coatings includes the possibility of overspray and the release of volatile organic compounds (VOCs) into the environment. Safety measures must be taken to capture the VOCs. Bolted panel (Figure 5) and factory welded tanks that receive their coatings at the factory present less challenge to the environment because sandblasting particles and coating overspray are captured in highly efficient particle filtration systems.

Bolted tanks generally require less space in the field to construct. Onsite welding and concrete construction require a significant footprint in order to stage materials and construct the tank. This will require destruction of trees and local habitat that cannot be easily replaced after completion. Bolted steel tanks have been constructed in certain sites with as little as 5 ft of buffer between the tank and the environment around them.

Inspection and maintenance

Once a year, tanks should be inspected both inside and out to make sure they are in good shape. Any corroded areas should be properly prepared and touched up with a suitable maintenance coating. All sealants should be reviewed and reapplied wherever needed. One common rule of thumb is that a tank should be considered for repainting when it shows rust on 1% of its surface. A tank that is neglected will be susceptible to product contamination, extensive maintenance and recoating, safety hazards and significant downtime. Contact the tank manufacturer for recommendations, and make sure that the chosen maintenance coating is compatible with the stored product and environment.

Corrosion significantly shortens the life of a tank, so a good quality coating and application process during the manufacturing process often means less maintenance and less chance of the need to recoat the tank.

Locating an experienced vendor

To ensure the best quality coating on your tank, ask tank vendors to provide testing data and case histories about durability and how the coating performed against corrosion and abrasion with a product like the one to be stored. Ask how long the company has been fabricating tanks, what type of coating it uses, whether its coatings are factory applied and thermally cured (or field applied and cured by ambient air), what are the quality control measures, what is the volume sold, in what countries, and into which markets. Also consider tank manufacturers with third party accreditation, such as the ISO Quality Certification. ■

Edited by Gerald Ondrey

Author

David Wheat is director of inside sales at CST Storage, a division of CST Industries (2101 South 21st Street, Parsons, Kan. 67357; Email: dwheat@cst-storage.com), a company that specializes in the design, fabrication, factory coating and construction of tanks and covers for dry bulk and liquid storage applications. He holds a B.S.E.E. from Yale University (New Haven, Conn.) and has more than 18 years of experience in liquid and dry bulk storage.

Tony Thill is vice president of CST Industries, Inc. (9701 Renner Blvd., Lenexa, Kan. 66219; Email: tthill@tanks.com), a global leader in providing complete storage and cover solutions for all types of applications. Thill has more than 25 years of experience in growing businesses and product lines for many different industries and applications. He leads efforts in new market and product development, distribution development, international expansion, acquisitions and joint ventures and go-to market strategies for all CST divisions. Prior to CST, Thill spent the bulk of his career with GE Energy's Environmental services division eventually leading the Dry Filtration business segment formerly known as BHA Group, Inc. Thill holds a B.S. from The University of Kansas.

WHO'S WHO


Buscher


Weidman


Rodrigues


Egbert


Sudler

Pump Solutions Group (PSG; Houston), a subsidiary of Dover Corp., names *Karl Buscher* senior vice president–PSG Commercial.

David Weidman, CEO of chemical company **Celanese Corp.** (Dallas, Tex.), will retire in April. He will be succeeded by *Mark Rohr,* current executive chairman and former CEO of chemical company Albermarle.

AIChE (New York) appoints *Michael P. Harold,* the M.D. Anderson professor of chemical and biomolecular engineering at the University of Houston, as the new editor of the *AIChE Journal*. He succeeds *Stanley Sandler*, who is retiring.

Koch Membrane Systems (Wilmington, Mass.) promotes *Carlos Rodrigues* to business development manager, industrial and life sciences for South America.

Blacoh Fluid Control (Riverside, Calif.), a manufacturer of fluid-control products, names *Brandon Dalrymple* business development manager for the U.S. Northeast region and worldwide OEM business, and *Cristian Rohde* as business development manager for Latin America.

Dan Egbert joins **Stedman** (Aurora, Ind.), a manufacturer of crushers, cage mills and other size-reduction equipment, as parts sales associate.

Intelligrated (Cincinnati, Ohio), a provider of materials-handling solutions, promotes *Bruce Sudler* to senior sales engineer, Midwest region. ■

Suzanne Shelley

Emerson Rosemount

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Temperature Measurement & Control

Wahl Instruments

Thermal imaging cameras help spot problem areas

Heat Spy thermal imaging cameras (photo) are available in two series with 16 different configurations to suit a variety of applications. The z30 Seriew "Detector" is designed for on-the-spot maintenance inspections and repair. The z50 Series "Inspector" includes additional features for documenting and preparing reports with ease, including thermal and digital images. The base z30 Detector model features 11 languages, four color palettes, °C, °F or K measurement scales, hot-cold seeking and two fixed-spot measurements, as well as freeze-frame for viewing the current image. Units can be upgraded in the field to expand the functionality as needed, for instance to extend the temperature range or to include wide-angle and telescopic lenses. — *Wahl Instruments, Inc., Asheville, N.C.*
www.palmerwahl.com

Service installs thermowells per new ASME standard

This company's thermowell calculation service is now based on the new standard created by the American Society of Mechanical Engineers (ASME) that establishes the practical design considerations for thermowell installations and helps improve overall reliability of temperature measurement (photo). ASME updated its standard on thermowells from the previous standard, created in 1974, to create the ASME PTC 19.3TW – 2010. Using this new standard, this vendor's specially trained team provides recommendations on thermowell design and installation best practices. Calculations that follow the ASME PTC 19.3TW – 2010, provide the most up-to-date, accurate and complete thermowell recommendations. By using outdated standards to calculate thermowell size, there is an increased risk of failures due to increasing line sizes and pipe velocities. — *Emerson Rosemount, Chanhassen, Minn.*
www.rosemount.com/thermowellcalculations

Wireless multi-input temperature transmitter accepts eight inputs

The YTMX580 (photo) is a new wireless multi-input temperature transmitter built on the ISA100.11a industrial-automation wireless-communication standard. The YTMX580 is battery powered and features eight analog input channels, each configurable for thermocouple, RTD, DCV and 4–20-mA measurement. The YTMX580 is a cost-effective way to measure multiple temperature points in distant plant locations where there is no signal cabling or power available for traditional wired instrumentation. With eight input channels, the YTMX580 increases operating efficiency and reduces installation time and maintenance costs by combining multiple inputs into a single transmitter. — *Yokogawa Corp. of America, Newnan, Ga.*
www.yokogawa.com/us

TandD Corp

Yokogawa

Log temperatures without the need for wires

The RTR-505Pt wireless temperature logger (photo) features a large LCD display, holds 16,000 readings and is IP64 water resistant. The possible temperature range of the RTR-500Pt can be from –199 to 650°C depending on the sensor selected. The unit is com-

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

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patible with industry-standard, three-wire, Pt-100 sensors and accepts three-wire screw terminal attachments. Battery life is up to 10 months, or up to 4 years with the L Version. Communication range is up to 500 ft and can be extended with the use of repeaters. — *TandD Corp., Saratoga Springs, N.Y.* **www.tandd.com**

Mercury-free alternative for calibration is also more rugged

On March 1, 2011, the National Institute of Standards and Technology (NIST) stopped providing calibration services for mercury-filled thermometers, which have been a fixture for calibrating temperature sensors in the chemical process industries. The 1551A Stik thermometer (photo) provides a robust alternative, featuring a thin-film RTD sensor that provides repeatable accuracy of ±0.05°C (0.09 °F) over its full range from –50 to 160 °C (–58 to 320 °F). A stainless-steel sheath protects the sensor, making it much more rugged than the glass stems of mercury thermometers, so it is much better suited for challenging industrial environments. In addition, Stik thermometers are intrinsically safe (ATEX- and IECEx-certified), so they can be used in environments where potentially explosive gases are present. — *Fluke Corp., Everett, Wash.* **www.fluke.com/stik**

Fluke Corp.

Turck

Temperature transmitter incorporates advanced diagnostics

The STT250 temperature transmitter now includes advanced diagnostics for proactively managing the health of the device, thereby preventing failures before they occur and reducing plant downtime due to unscheduled repairs. Maintenance teams can also use the advanced diagnostic information stored on the transmitter to al-

Yokogawa

locate maintenance resources more effectively, while plant engineers can use onboard transmitter and sensor information for more accurate process analysis, leading to greater plant efficiency. All HART variants of the STT250 are also compatible with the HART 6 open standard, allowing for an even greater level of device health monitoring. The new transmitters support other open standards, such as the Electronic Device Description Language (EDDL) or certified Device Type Manager files, for fast startup and commissioning. The STT250 also features TUV SIL2 safety certification, allowing use with safety applications that require hot backups. — *Honeywell Process Solutions, Fort Washington, Pa.*
www.honeywellprocess.com

Check and calibrate thermocouples of 14 varieties

CL540ZA Series of thermocouple simulators (photo) checks and calibrates all thermocouple instruments. Units can be connected directly to the thermocouple inputs of smart transmitters, programmable logic controllers (PLCs), controllers and multichannel recorders and to verify their outputs or displays. Thanks to an easy-to-read backlit display, readings are possible even in the darkest areas of the plant. The CL540ZA Series works with 14 thermocouple types: J, K, T, E, R, S, B, N, G, C, D, L (J-DIN), U (T-DIN) and P (Platinel II). — *Omega Engineering, Inc., Stamford, Conn.*
www.omega.com

Rugged optical temperature sensing built for control

The DTSX200 distributed temperature sensor (photo, opposite page) takes the optical measurement technologies this vendor has acquired over the years in the measurement field and applies them to control applications, such as pipeline and tank leak detection, refinery vessel-reactor monitoring, and fire detection. With the ability to have stable operation in temperatures ranging from –40 to 65°C, the DTSX200 is ideal for use in harsh environments. Moreover, with its low power consumption of 16 watts or less, it can be easily powered by a solar panel and battery if no other power source is available. Meanwhile, it is compact in size. — *Yokogawa Corp. of America, Newnan, Ga.*
www.yokogawa.com/us

Omega Engineering

Temperature transmitters do not need specialized RTD cards

TTM Series temperature transmitters feature an analog output that eliminates the need for specialized RTD PLC input cards, saving the user the expense associated with these cards. Particularly suitable for use with sanitary requirements, such as food and beverage applications, the transmitters have stainless steel connections. The TTM Series provides a 4–20-mA output using an integrated PT100 resistance temperature detector. The sensors are plug-and-play, and come pre-scaled at 0 to 100°C, 0 to 150°C, –50 to 50°C, or –50 to 150°C. — *Turck, Minneapolis, Minn.*
www.turck.us

Infrared measurement extended to hotter temperatures

The MI3 Series infrared temperature-measurement system has been enhanced with MI3 1M and MI3 2M high-temperature-sensing heads, extending performance for non-contact temperature measurement in high temperature processes. The 1M and 2M heads provide a 1- and 1.6-µm spectral response respectively, and offer a wide measurement range of 500°C to 1,800°C (1 µm) and 250°C to 1,400°C (1.6 µm). Designed to deliver high performance and flexibility at the lowest installed cost per measurement point, the MI3 Series is said to reduce energy costs by allowing tighter process control and more efficient process heating. The sensing heads have a 120°C head ambient rating with 100:1 optical resolution and are available with standard laser sighting. Potential applications include silicon crystal growth, polysilicon reactors, secondary metal processing and metal heat treating. — *Raytek, Santa Cruz, Calif.*
www.raytek.com ■

Rebekkah Marshall

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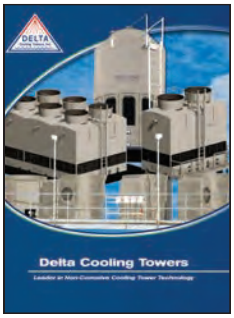

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Swagelok now carries RHPS series high-flow, pressure-reducing and back-pressure regulators, available in spring-loaded, dome-loaded, and air-loaded models. Constructed of 316L stainless steel and available in a variety of body sizes, RHPS series regulators can be used in many applications. ***www.swagelokbv.com***
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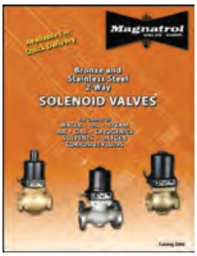

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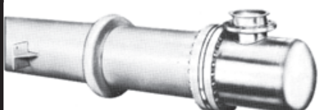

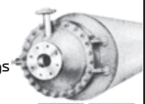

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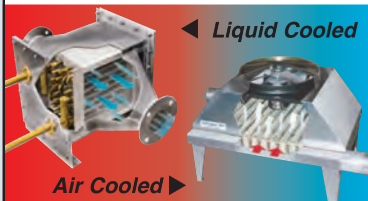

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6	21	36	51	66	81	96	111	126	141	156	171	186	201	216	231	246	261	276	291	306	321	336	351	366	381	396	411	426	441	456	471	486	501	516	531	546	561	576	591
7	22	37	52	67	82	97	112	127	142	157	172	187	202	217	232	247	262	277	292	307	322	337	352	367	382	397	412	427	442	457	472	487	502	517	532	547	562	577	592
8	23	38	53	68	83	98	113	128	143	158	173	188	203	218	233	248	263	278	293	308	323	338	353	368	383	398	413	428	443	458	473	488	503	518	533	548	563	578	593
9	24	39	54	69	84	99	114	129	144	159	174	189	204	219	234	249	264	279	294	309	324	339	354	369	384	399	414	429	444	459	474	489	504	519	534	549	564	579	594
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14	29	44	59	74	89	104	119	134	149	164	179	194	209	224	239	254	269	284	299	314	329	344	359	374	389	404	419	434	449	464	479	494	509	524	539	554	569	584	599
15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390	405	420	435	450	465	480	495	510	525	540	555	570	585	600

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BUSINESS NEWS

PLANT WATCH

Oxea to build its first production plant in China

October 29, 2011 — Oxea GmbH (Oberhausen, Germany; www.oxea-chemicals.com) will build a plant for the production of oxo derivatives in Nanjing, China. Oxo derivatives include alcohols, polyols, carboxylic acids, specialty esters and amines. The plant is scheduled to go onstream in 2013.

Lanxess and BioAmber partner to produce phthalate-free plasticizers

October 20, 2011 — Lanxess AG (Leverkusen, Germany; www.lanxess.com) plans to produce phthalate-free plasticizers from bio-based succinic acid from 2012 onward. Its strategic partner, BioAmber, Inc. (Minneapolis, Minn., www.bio-amber.com), produces bio-based succinic acid in a 3,000-metric ton per year (m.t./yr) plant in France, and expects to add an additional 17,000 m.t. of succinic acid capacity in 2013 at a new facility in Sarnia, Canada — located on a site within Lanxess' Bio-industrial Park. Under the terms of their joint-development agreement, Lanxess and BioAmber are developing a portfolio of renewable succinic-based plasticizers that can exceed the performance of phthalates at competitive prices.

Air Liquide to build two large ASUs for Korean steelmaker

October 17, 2011 — Air Liquide (Paris, France; www.airliquide.com) has signed a contract with Posco E&C, the Engineering and Construction div. of Posco, to design and build two air separation units (ASUs), each of which will have an oxygen production capacity of 3,750 m.t./d. These two new units will be installed at Posco's Gwangyang and Pohang sites in South Korea.

Evonik to build isophorone plants in Shanghai

October 13, 2011 — Evonik Industries AG (Essen, Germany; www.evonik.com) plans to build plants for producing isophorone and isophorone diamine in Shanghai, China. The Group is investing more than €100 million in the plants, which are scheduled to go onstream in the 1stQ of 2014. Evonik currently manufactures isophorone-chemistry products in Mobile, Ala., as well as in Marl and Herne, Germany. The plants in Shanghai will be Evonik's first for isophorone and isophorone diamine in Asia.

The Schweighofer Group chooses Aquantis to supply anaerobic plant

October 12, 2011 — The Schweighofer Group (Vienna, Austria; www.schweighofer.at/en/the-company/schweighofer-group.html), a family-owned enterprise with forest-based industry as its core business, has selected Aquantis (Ratingen, Germany; www.vws-aquantis.de), a subsidiary of Veolia Water Solutions & Technologies, to design and build a wastewater-treatment and energy-generation plant for its Schweighofer Fiber GmbH site in Hallein, Austria. The new plant will treat approximately 5,700 m³/d wastewater. The treatment process will also generate biogas with a combustion capacity of approximately 4 MWh.

Evonik to build hydrogen peroxide plant in China

October 6, 2011 — Evonik Industries AG plans to invest more than €100 million in a project to build a new production plant for hydrogen peroxide in Jilin Province in China. The plant will have a production capacity of 230,000 m.t./yr, thus increasing Evonik's current overall capacity of around 600,000 m.t./yr for H_2O_2 production by nearly 40%. Scheduled to be completed by the end of 2013, the plant will supply its H_2O_2 directly to the adjacent propylene oxide plant run by Jishen Chemical Industry Co., via a pipeline that will link the two facilities.

MERGERS AND ACQUISITIONS

Fluor acquires sulfur technology company

November 8, 2011 — Fluor Corp. (Irving, Tex.; www.fluor.com) has acquired Goar, Allison & Associates, a unit of Air Products. The Texas-based company provides sulfur technologies for upstream gas plants, downstream petroleum refineries and gasification.

Cobalt Technologies and Rhodia to develop bio-butanol in Latin America

October 19, 2011 — Cobalt Technologies (Mountain View, Calif.; www.cobalttech.com) and Rhodia (Paris, France; www.rhodia.com) have executed a memorandum of understanding that sets the basis for a strategic alliance to develop bio-based *n*-butanol refineries throughout Latin America. Under the terms of the alliance, Cobalt and Rhodia will work together to deploy Cobalt's technology for the conversion of sugar-cane bagasse into *n*-butanol for the chemicals and fuels market. The parties will initially develop options for deploying Cobalt's technology at a sugar mill.

M&G Group partners with TPG to form Beta Renewables

October 13, 2011 — Gruppo Mossi and Ghisolfi (M&G; Milan, Italy; www.gruppomg.com), through its wholly owned subsidiary Chemtex (Wilmington, N.C.; www.chemtex.com), has founded Beta Renewables, a joint venture (JV) with TPG Capital and TPG Biotech (collectively TPG; San Francisco, Calif.; www.tpgbiotech.com), established to exclusively license Chemtex's Proesa Technology into the global marketplace. Prosesa is said to be a breakthrough technology enabling production of fermentable sugars from cellulosic biomass. TPG and M&G are investing total capital of €250 million into Beta Renewables, in which M&G will hold a majority stake. Under the terms of the agreement, M&G will transfer the pilot plant in Tortona, Italy and the 40,000-m.t./yr industrial-scale cellulosic-ethanol plant currently being constructed in Crescentino, Italy to Beta Renewables. The plant is scheduled for startup in 2012 and will be the first industrial facility in the world producing second-generation bioethanol.

Lanxess strengthens its phthalate-free plasticizer portfolio

October 12, 2011 —Lanxess AG (Leverkusen, Germany; www.lanxess.com) has agreed to acquire Unitex Chemical Corp. (Greensboro, N.C.), a privately owned company with a capacity of more than 50,000 m.t./yr dedicated mainly to producing phthalate-free plasticizers and other specialty products. Financial details were not disclosed. The transaction was expected to close with immediate effect and Lanxess will finance the acquisition from existing liquidity. The Unitex business will be integrated into the Lanxess business unit Functional Chemicals.

Resinall Rütgers Resins acquires Neville Chemical Europe

October 4, 2011 — Resinall Rütgers Resins GmbH (RRR; Duisburg, Germany) — a JV between Rütgers Novares GmbH (Duisburg, Germany; www.novares.de) and Resinall Europe bvba (Brugge, Belgium; www.resinall.com) — has acquired the chemicals company Neville Chemical Europe BV (NCE; Uithoorn, Netherlands). The acquisition of NCE is part of the RRR expansion strategy and is designed to sustainably strengthen the JV partners' leading position within the European producers of industrial resins. The acquired company has extensive competencies in the development, production and marketing of high-quality hydrocarbon resins for the printing inks, coatings, asphalt and rubber industries. ■

Dorothy Lozowski

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

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Economic Indicators

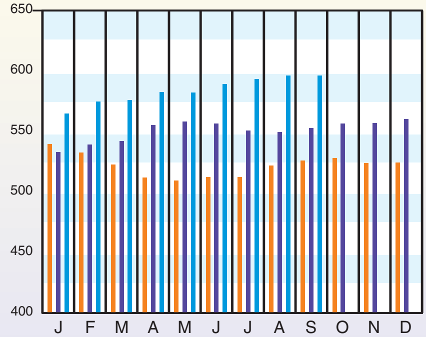
2009 ▬ 2010 ▬ 2011 ▬

DOWNLOAD THE *CEPCI* TWO WEEKS SOONER AT *WWW.CHE.COM/PCI*

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Sept.'11 Prelim.	Aug.'11 Final	Sept.'10 Final
***CE* Index**	596.0	596.1	552.5
Equipment	727.6	727.5	662.4
Heat exchangers & tanks	692.4	691.9	611.8
Process machinery	677.4	674.5	625.3
Pipe, valves & fittings	912.6	909.6	834.1
Process instruments	439.7	441.9	422.0
Pumps & compressors	909.9	909.9	902.9
Electrical equipment	510.1	512.6	482.5
Structural supports & misc	772.5	775.7	680.9
Construction labor	330.4	330.7	329.0
Buildings	520.2	521.1	502.5
Engineering & supervision	330.9	331.9	337.3

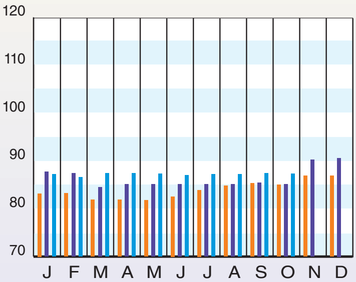
Annual Index:
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8



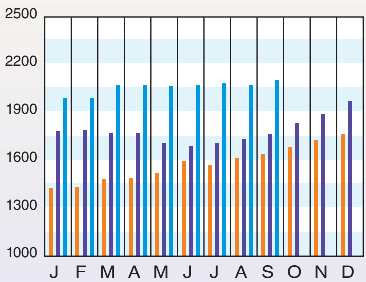
CURRENT BUSINESS INDICATORS

	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2007 = 100)	Oct.'11	=	87.3	Sep.'11	=	87.4	Aug.'11	=	87.2	Oct.'10	=	85.1
CPI value of output, $ billions	Sep.'11	=	2,106.9	Aug.'11	=	2,075.1	Jul.'11	=	2,083.1	Sep.'10	=	1,764.9
CPI operating rate, %	Oct.'11	=	75.4	Sep.'11	=	75.4	Aug.'11	=	75.2	Oct.'10	=	73.1
Producer prices, industrial chemicals (1982 = 100)	Oct.'11	=	331.0	Sep.'11	=	338.7	Aug.'11	=	336.5	Oct.'10	=	268.6
Industrial Production in Manufacturing (2007=100)	Oct.'11	=	91.3	Sep.'11	=	90.9	Aug.'11	=	90.6	Oct.'10	=	87.7
Hourly earnings index, chemical & allied products (1992 = 100)	Oct.'11	=	156.5	Sep.'11	=	157.2	Aug.'11	=	156.9	Oct.'10	=	157.2
Productivity index, chemicals & allied products (1992 = 100)	Oct.'11	=	108.7	Sep.'11	=	109.1	Aug.'11	=	109.7	Oct.'10	=	111.2

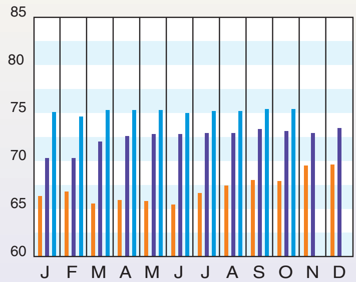
CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



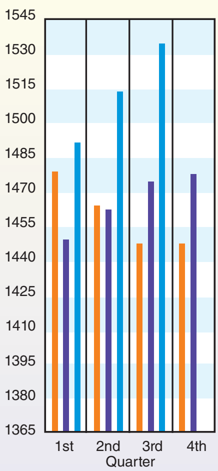
Current Business Indicators provided by Global Insight, Inc., Lexington, Mass.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	3rd Q 2011	2nd Q 2011	1st Q 2011	4th Q 2010	3rd Q 2010
M & S INDEX	1,533.3	1,512.5	1,490.2	1,476.7	1,473.3
Process industries, average	1,592.5	1,569.0	1,549.8	1,537.0	1,534.4
Cement	1,589.3	1,568.0	1,546.6	1,532.5	1,530.0
Chemicals	1,559.8	1,537.4	1,519.8	1,507.3	1,505.2
Clay products	1,579.2	1,557.5	1,534.9	1,521.4	1,518.3
Glass	1,491.1	1,469.2	1,447.2	1,432.7	1,428.5
Paint	1,608.7	1,584.1	1,560.7	1,545.8	1,542.1
Paper	1,502.4	1,480.7	1,459.4	1,447.6	1,444.5
Petroleum products	1,698.7	1,672.0	1,652.5	1,640.4	1,637.0
Rubber	1,641.4	1,617.4	1,596.2	1,581.5	1,579.3
Related industries					
Electrical power	1,517.6	1,494.9	1,461.2	1,434.9	1,419.2
Mining, milling	1,648.6	1,623.5	1,599.7	1,579.4	1,576.7
Refrigeration	1,884.4	1,856.4	1,827.8	1,809.3	1,804.8
Steam power	1,572.2	1,546.5	1,523.0	1,506.4	1,502.3

Annual Index:

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



CURRENT TRENDS

Capital equipment prices, as reflected in the *CE* Plant Cost Index (CEPCI), decreased slightly from August to September, the first decrease since May of this year and only the second decrease in a year. Typically, the CEPCI increases over the first half of a year, peaking in mid-late summer, and then decreases through year end. The atypical performance is a continuation of the economic recovery from the 2008–2009 recession.

Visit www.che.com/pci for more information and other tips on capital cost trends and methodology. ■