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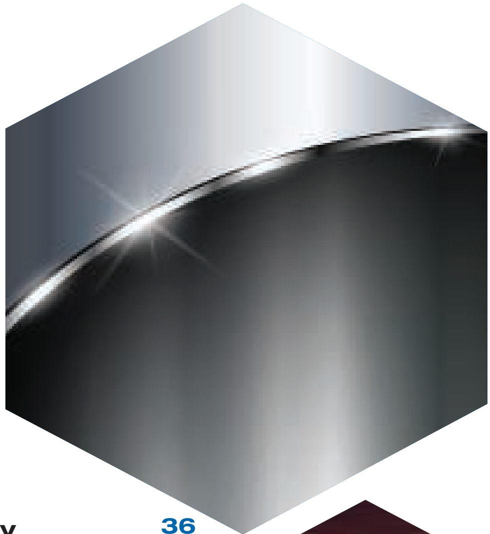

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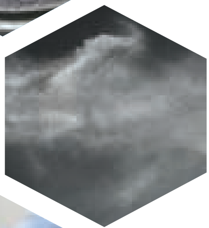

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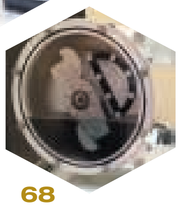

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BPA

Editor's Page

The changing workplace

On my way home from the office I have heard, on numerous occasions, fellow commuter-train riders lament about how their jobs are requiring them to do more and more with fewer people. It seems that this trend exists across the board, regardless of what profession you work in. Engineers are no exception.

Doing more

A recent research report by IHS (www.ihs.com) states that 52% of engineers who responded to a survey said that the pace of engineering is constantly increasing and 57% said that they are required to do more with less. The report, called "2015 Pulse of Engineering: The Changing Work Environment for Engineers Today," was based on a survey of 2,162 engineers and technical professionals in the industrial sector.

Engineers are also being called upon to multitask more. Forty-six percent of the respondents said that they are working on more projects now than two years ago. Sixty-nine percent of engineers are working on at least three projects concurrently, with 46% handling three to five projects at the same time. Perhaps some of the suggestions offered in our article on "Tips for the Multitasking Engineer" on pp. 65–67 are needed now more than ever.

Working faster

In addition to doing more, engineers are under increasing time pressure to get their work done. In the IHS report, 70% of respondents agreed that there are more time-to-market pressures for design projects. When asked what single performance target engineers were most pressed to meet, the top three answers chosen were: launch date (24% of respondents), product quality (21%) and customer satisfaction (20%). Perhaps some of the increased time pressure stems from the perception that competition is heavier, since it is now on a global basis and is ever-present (24 hours a day, 7 days a week).

Losing knowledge

A concern that I have heard for a number of years now, is that the workforce is losing valuable knowledge through the loss of highly experienced employees. The IHS report reiterates this concern. It says that an increasing loss of employees to turnovers (including severance, quitting and dismissals) as well as to retirement, were strong factors in workforce changes in companies. And, 47% of engineers said that the loss of knowledge and information as employees left the company was very important or extremely important. Seventy-one percent of respondents agreed that a shortage of talent and specialized knowledge hurt their companies' productivity or product quality.

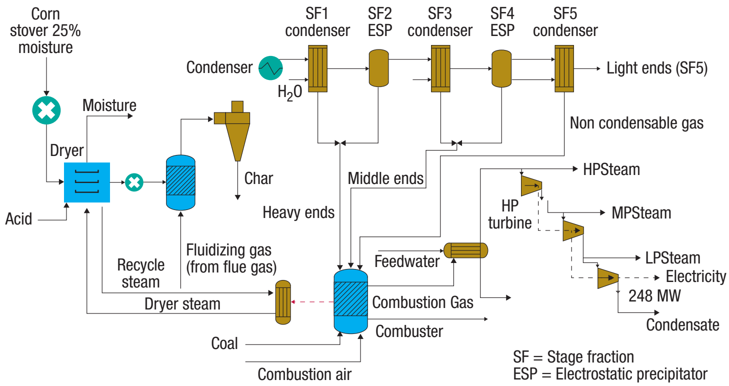
This topic of the changing workforce was also addressed at the recent AIChE Spring Meeting and Global Congress on Process Safety (Austin, Tex., April 28). At a presentation titled "Changing Demographics: Preserving Safety and Increasing Performance," Denise Brooks of Risktec Solutions Inc. (www.risktec.com) offered a solution to bringing knowledge and experience back into the workplace: to recruit and retain older workers. This was a refreshingly straightforward idea to hear, particularly since I learned from the presentation that the "older" employee is considered to be anyone above the age of 36, and so was likely relevant to most of the audience in the room. ■

Dorothy Lozowski, Editor in Chief

Circle 14 on p. 78 or go to adlinks.chemengonline.com/56198-14

Pilot plant slated for a fast-pyrolysis process that converts biomass into fuels

Edited by:
Gerald Ondrey



Plans are underway to build a pilot plant for a fast-pyrolysis process that will convert 10 ton/d of biomass into bio-oil and bio-char. The bio-oil can be used as renewable fuel oil or catalytically upgraded to transportation fuels, while the bio-char can be introduced into soils to improve nutrient and water retention in agriculture.

"We are developing a process for drawing down CO_2 in the atmosphere while simultaneously deriving economic benefit," comments Robert Brown, director of the Bioeconomy Institute at Iowa State University (ISU; Ames, Iowa; www.iastate.edu).

The process (flowsheet) takes place in a pyrolysis reactor that thermally breaks down biomass at 500°C in the absence of oxygen. Particles of biomass, such as wood waste, corn stalks and others, are processed in a fluidized bed containing sand, through which inert gas is flowing. The cellulose and hemicellulose in the biomass break down into dehydrated sugars, which can be used in fermentation processes or catalytically upgraded to fuels. The lignin breaks down into to phenolic oils, which can be refined into transportation fuels or blended with coal to be co-fired in power plants.

The residue of the pyrolysis process, at 10–15 wt.% of the products, is a carbonaceous material similar to charcoal that is stable in soils for long periods, where it aids retention of water and fertilizers and promotes crop growth. "Bio-char is a great carbon sequestration agent," Brown explains, "because the carbon is a stable solid, rather than a volatile gas [CO_2]."

Brown also envisions blending biomass-derived heavy ends with coal in a 30/70% mixture to bring coal-fired power plants in line with proposed limits on CO_2 emissions.

A step forward for the bio-production of L-arginine

The amino acid L-arginine plays a crucial role in our neurological and cardiovascular systems. It is sometimes consumed as a dietary supplement and its efficient industrial-level production is essential for its commercialization. L-arginine is a product of microbial fermentation and great effort has been devoted for many years to develop microbial strains to improve its production. The traditional method to achieve this is random mutagenesis, but that can be very labor-intensive and can lead to unwanted mutations in the microorganisms employed.

Now, a research team, led by professor Sang Yup Lee at the Korea Advanced Institute of Science and Technology (KAIST; Daejeon, South Korea; www.kaist.ac.kr), has employed a combination of random mutagenesis and systems metabolic engineering for overproducing L-arginine, paving the way for its industrial production.

In the biorefinery process, scale up of the bioreactor is a critical step toward the industrial-level production of the target chemicals, but often results in poorer performance of the microbial strain because of the differing cultivation environments caused by the scaled-up bioreactor. The team examined the performance of the engineered strain in the laboratory and at industrial scale bioreactors (5 L and 1,500 L, respectively), with good results and good reproducibility.

The team says the same approach can be used to produce other important biochemicals that share L-arginine biosynthetic pathways, such as L-ornithine, putrescine and cyanophycin.

HYDROCRACKING

Later this year, Albemarle Corp. (Baton Rouge, La.; www.albemarle.com) says it will add a new catalyst to its STARS (super type II active reactive sites) catalysts portfolio. Together with its Hydroprocessing Alliance partner, UOP LLC (Des Plaines, Ill.; www.uop.com), Albemarle is in the final stages of pilot-plant testing, and the global launch is planned for the second half of 2015. The new catalyst is targeting medium- to high-pressure hydrocracking pre-treat (HC-PT) operations. Pilot trials have shown that the new catalyst demonstrates reduced nitrogen content in HC-PT feeds to boost overall hydrocracking conversion and performance, says the company. The technology was developed by Albemarle and Nippon Ketjen Co. (Tokyo, Japan; www.nippon-ketjen.co.jp), and will be available through Albemarle, Nippon Ketjen and the UOP-Albemarle Hydroprocessing Alliance.

BIOMASS TO BTX

VTT Technical Research Center of Finland Ltd. (VTT; Espoo; www.vtt.fi) has developed a process to produce benzene, toluene and xylenes (BTX) from biomass. In the process, lignocellulosic biomass is gasified, and the product synthesis gas is converted to BTX via Fischer-Tropsch synthesis and aromatization. Over 85% of the recovered benzene exceeds 90% purity, and around 50% of the separated toluene has a purity of over 70%, says VTT. The value for the purified BTX fractions is estimated to be €1.40/L, which is higher than BTX derived from petroleum, but "significantly more competitive" than the price of other bio-based routes.

(Continues on p. 14)

Note: For more information, circle the 56-digit number on p. 78, or use the website designation.

Economically generating H_2 with SOECs

Toshiba Corp. (Tokyo, Japan; www.toshiba.co.jp) has started up a highly efficient electrolyzer for the production of hydrogen. The system is based on ceramic, solid-oxide electrolysis cells (SOECs), and is said to consume less power than alternative technologies, such as alkaline electrolysis (which suffer from corrosion) or polymer electrolyte membrane (PEM) electrolysis (which needs expensive rare-earth metals). Also, no platinum catalyst is required.

Over the past eight years, Toshiba has been developing SOEC systems based on scandia-stabilized zirconia (ScSZ) as a solid electrolyte, and a hydrogen electrode made of nickel-oxide–gadolinium-doped ceria (NiO-GDC). Since 2014, the 1-kWh system has undergone testing, with support from the New Energy and Industrial Technology Development Organization (NEDO; Kawasaki, Japan; www.nedo.go.jp) under the authority of Japan's Ministry of Economy, Trade and Industry.

This year, the company plans to demonstrate a 10-kWh-class system, and has the goal of producing 100-kWh-class systems capable of generating 30 m^3/h of H_2. Ultimately, Toshiba aims to create practical SOEC systems that can produce (using electricity from solar or wind generators) and store large volumes of H_2, and then utilize the H_2 to generate electricity (using solid-oxide fuel cells) during nighttime or windless days. The goal is for a charge-discharge efficiency of 80%.

Catalytic hot-gas filters reduce dust and pollutants

In late April, Unifrax I LLC (Tonawanda, N.Y. ; www.unifrax.com) and Haldor Topsøe A/S (Lyngby, Denmark; www.topsoe.com) signed a partnership agreement to begin a joint global effort to commercialize an innovative new line of catalytic filter candles. This new product family — developed for industrial hot-gas filtration — will be marketed as TopFrax filters.

The TopFrax catalytic filter candle is designed to remove oxides of nitrogen (NOx) and particulate matter, and will also be launched in a version capable of removing volatile organic compounds (VOCs), CO and dioxin that are generated in many industrial processes, including glass, cement and metals production, waste incineration and biomass processing.

Key features of these filters include: high-efficiency filtration of particulate matter (>99%), NOx removal efficiency (>95%), low ammonia slip, and filter porosity above 80%, says Topsøe. TopFrax filters can operate at temperatures up to 400°C (750°F), are compatible with sorbents, and are non-combustible, and corrosion resistant. Like the catalytic bag filters launched earlier this year (*CE*, March 2015, p. 7), these candle filters combine the removal of NOx, VOC, CO, dioxin and particulate matter into one integrated process, thus reducing capital and operating costs, as well as the footprint for pollution-control equipment.

Making H_2 directly from Si nanoparticles

A safe, low-cost technology for supplying H_2 to fuel-cell powered vehicles is being developed by researchers at Nisshin Kasei Co. (Osaka, Japan; www.nisshinkasei.co.jp). Unlike alternative methods that store H_2 by adsorption on solid materials at high pressure, Nisshin is utilizing silicon nanoparticles that generate H_2 at the point of use simply by reacting them with water.

The silicon nanoparticles, which have a diameter of less than 5 nm, were originally developed by professor Hikara Kobayashi at Osaka University (www.sanken.osaka-u.ac.jp). Kobayashi has shown that 1 g of the Si nanoparticles can generate up to 1,600 mL of H_2, at high rates of up to 400 mL/min. The particles can be reused after removing the oxide layer, which forms after the reaction with water. These nanoparticles can be made from waste silicon generated in the manufacture of semiconductors and solar cells.

Nisshin plans to develop cartridge-type H_2 generators, targeting first applications for emergency power generation, and then for fuel-cell vehicles.

Conductive plastic for high-conductivity applications

Electrically conductive plastics have been available for several years, but the use of carbon black as the conductive agent in the plastic resins limits their use to low-conductivity applications. Now, newly commercialized plastic pellets impregnated with metal-coated carbon nanofibers allow the resins to be used in applications requiring much higher conductivity.

These conductive plastic pellets, developed by Electriplast Corp. (Canton, Mich.; www.electriplast.com), are available in a range of different resin types and can contain several different types of metal-coated carbon fibers.

The conductive agents can be either long-fiber (6 µm) carbon nanofibers coated with metals (such as nickel or copper), or stainless-steel fibers. The fibers are compounded into one of several common plastic resins, including nylon, polypropylene, polycarbonate, acrylonitrile butadiene styrene and others.

Plastic components molded from the pellets can be used in place of cast aluminum to shield computer and electrical components from electromagnetic interference (EMI) in transportation applications, where the plastics can reduce weight by up to 60%.

Electriplast is on the verge of launching products for a host of other applications as well, including battery components and wiring, where the conductive plastics can replace metal braiding in coaxial cable.

"The company is focused on applications engineering, and we can tune the electrical properties to meet the specifications of an application," says Doug Bathauer, CEO of Electriplast, which is establishing partnerships to manufacture and market the technology and products in particular markets.

Smart polymers enhance coatings to reduce fouling

Scientists from Singapore, including Vivek Vasantha from A*STAR – The Agency for Science, Technology and Research (www.a-star.edu.sg) – developed a new block copolymer that can change its structure when placed in an electrolyte solution, such as salt water. The monomers are poly(ethylene glycol), or PEG, which is hydrophilic, and polysulfabetaine (PSB), which is halophilic (that is, it has a preference for salt solution).

Under the Innovative Marine Antifouling Solutions (IMAS) program, the scientists created block copolymers that can self-assemble to form either "conventional" or "inverse" micelles. The conventional micelles form in deionized water, and have a core of halophilic PSB with a hydrophilic PEG shell. When immersed in salt solution, the micelles reassemble themselves to create an inverse micelle, where PEG forms the core and PSB forms the shell.

According to the scientists, the material is easily controlled by salt alone, in contrast with some other smart materials that require a combination of stimuli such as pH, temperature or light. "The material appears to be highly tolerant of fluctuations in pH and temperature, which means it is potentially useful for dynamic marine environments," says Vasantha.

Current coatings to prevent fouling by marine organisms include toxic substances, and are short-lived because they are rapidly broken down by seawater. To replace traditional antifouling paint, the scientists mixed the block copolymers with primer to create a nontoxic coating. The scientists tested the material in seawater and reported that the self-assembling micelles kept the coated surfaces intact and the coating prevented settling by organisms such as barnacles.

The scientists believe their smart materials will also find application in enhanced oil recovery and biomedical science.

A smart app for pump monitoring

At Achema 2015 (June 15–19; Frankfurt, Germany), KSB AG (Frankenthal, Germany; www.ksb.com) will launch a new smartphone application (app) that enables non-specialists to quickly determine the power consumption of a pump during operation. Within seconds, the user can know if energy can be saved by optimizing the hydraulics of a pump that is running below the optimum.

With the Sonolyzer app installed on his or her explosion-protected smartphone or tablet, the user simply enters the motor rating, the rated motor speed, the head and flowrate of the pump, then holds the device next to an operating pump and starts a measurement. The app then “listens” to the sound coming from the pump’s motor, using the device’s built-in microphone, and records the sound for 20 seconds. From this, a rotational frequency spectrum is generated and the torque calculated and analyzed over the Cloud, using algorithms that have already been demonstrated over five years in the company’s PumpMeter system, says Christoph Emde, vice president, Application and Basic Research at KSB. With this information, partial loads can be instantly observed, indicating that the pump is not operating optimally, says Emde.

In addition to displaying the pump’s power versus flowrate curve, the app offers the user the opportunity to contact — via telephone or email — the nearest KSB specialist, who can then provide additional advice or recommendations.

The app, which will be available in June through the App Store (for Apple products) or Google Play (for Android devices), can be used with any pump running with an asynchronous motor.

Micronized rubber powder improves polymer loadings

A new process for partially devulcanizing and functionalizing micronized rubber powders (MRP) may allow the use of higher levels of the material than originally allowed in vehicle tires and other applications. Currently, MRP from end-of-life rubber is being used in loadings of 3–5% in new passenger car tires. The process, recently developed by Lehigh Technologies (Tucker, Ga.; www.lehightechnologies.com), yields a functionalized MRP that could double the allowable loading in new tires up to 10%.

Lehigh first developed MRP several years ago as a way to seize residual value from end-of-life tires. MRP is manufactured by cryogenically freezing recycled rubber material and processing it through a patented turbo mill to form rubber particles in the range of <50 to 400 µm (*Chem. Eng.*, October 2012, p. 11). In this form, MRP is used to displace virgin rubber feedstock in tires, oil-based raw materials in polyurethane and other materials, and thereby lower costs while maintaining the required performance properties.

The new process involves a patented, chemically assisted milling process that partially “unzips” the polymer structure of the rubber and adds chemical functionality, so that it can reform sulfur crosslinks when added to virgin rubber in the manufacture of new tires.

Lehigh’s advanced MRP from this process, called EkoDyne, improves “processibility” compared to non-functionalized MRP, and delivers the required physical and dynamic properties of tires in which it is used, says Lehigh CEO Alan Barton. The process, still in the R&D stage, was recently introduced at a tire tradeshow in Europe.

Use of Lehigh’s MRP has expanded in the tire market, as well as in the plastics-injection-molding market and as a component in rubber-modified asphalt for road building.

An efficiency boost for solar H_2

The New Energy and Industrial Technology Development Organization (NEDO, Kawasaki, Japan; www.nedo.go.jp) and the Japan Research Association of Artificial Photosynthetic Chemical Process (ARPChem) achieved a world-leading solar-energy conversion efficiency of 2% in the photocatalytic splitting of water to make H_2 in a system that used a kind of artificial photosynthesis reaction.

The researchers achieved this high efficiency — an order of magnitude higher than the 0.2% achieved to date — using a sheet-type photocatalyst having tandem-arranged parallel cells with the optimized combination of the H_2-evolution photocatalyst, $Cu(In, Ga)Se_2$, and the O_2-evolution photocatalyst, $BiVO_4$, both active under irradiation by visible light. A 3% efficiency by 2016 is the short-term goal, but the researchers are developing a new photocatalyst capable of converting longer-wavelength radiation and thus increasing the efficiency to 7% by 2019. They are targeting 10% solar-energy conversion efficiency by the end of 2021.

This ten-year, $150-million Artificial Photosynthesis Project, supported by the Ministry of Economy, Trade and Industry (METI), started in 2012 with the formation of ARPChem as the main organization to conduct the project to promote R&D to commercialize the technology by advancing joint studies. Partners in the project include nine universities, two research institutions and six companies, including Sumitomo Chemical Co., Fujifilm Corp., Mitsui Chemicals Inc., Mitsubishi Chemical Corp. and TOTO Ltd.

Dispersing sulfur into urea

A new technology demonstrated by Shell Sulphur Solutions (London; www.shell.com/sulphur) aims to incorporate micronized elemental sulfur (which provides nutrients to fertilized plants) into urea. The technology, UreaPluS, employs a patented emulsification technique that evenly distributes sulfur throughout the urea matrix, rather than simply coating the outside of the particle. Dispersion of elemental sulfur in urea — said to be an industry first — is beneficial compared to conventional external sulfur coatings in that stability and oxidation capabilities are increased.

The key to even distribution is to overcome the immiscibility of elemental sulfur and urea, which is achieved in this micronization process via the use of a high-shear dispersion unit, where molten sulfur and molten urea are combined in the presence of a multifunctional ionic surfactant to form an emulsion. Here, the elemental sulfur particles are coated with a layer of the surfactant and dispersed into the fertilizer or fertilizer precursor. Precise temperature regulation maintains the sulfur in a liquid form within the mixing device, allowing for control of the sulfur particle size and distribution. Once emulsified, the sulfur can remain stable throughout the down-

VTT is continuing larger-scale development work in its Bioruukki piloting center in Espoo. The aim is to demonstrate the industrial viability of the entire process – from biomass to aromatics to end products.

BIO-BASED HARDENER

Bayer MaterialScience GmbH (Leverkusen, Germany; www.materialscience.bayer.com) has developed a bio-based hardener for polyurethane (PU) coatings and adhesives. The product is based on pentamethylene diisocyanate (PDI), and has the same or better performance as conventional petroleum-derived isocyanates, says BMS. The new Desmodur eco N 7300 hardener is made from a starch from forage corn. Commercial production of Desmodur eco N 7300 is due to begin following mandatory REACH registration. A total capacity of up to 20,000 m.t./yr is to be provided at existing plants.

stream granulation process, even in particles smaller than 40 µm. The smaller the particles, the more quickly the elemental sulfur can be oxidized into a form that is usable by plants.

The UreaPluS technology can be integrated downstream of industrial urea-synthesis processes. The technology has been demonstrated at pilot-plant scale, and has not been shown to adversely affect the granulation process. In addition to sulfur, the group is testing incorporation of other micronutrients into urea, including boron, zinc and copper. Additional micronutrients provide flexibility to produce custom formulations.

Separating rare earth metals with UV light

Researchers from the Dept. of Chemical Engineering of KU Leuven (Belgium; www.cit.kuleuven.be), in collaboration with KU Leuven chemists, have discovered a method to separate two rare-earth elements — europium and yttrium — with ultraviolet (UV) light. The study, published earlier this year in *Green Chemistry*, promised to be a simpler and "greener" alternative to liquid-liquid extraction, which requires a solvent and multiple steps to achieve adequate separation, due to its low efficiency.

In early 2015, KU Leuven chemists developed ionic liquid technology to recycle europium and yttrium from collected fluorescent lamps and low-energy light bulbs. Their method recycles the red lamp phosphor as a whole to reuse the powder in lamps. For other applications, however, it is necessary to separate europium and yttrium from the rare-earth mixture.

In the new method, the aqueous solution of Eu^{+3} and Y^{+3} ions is irradiated with UV light. The Eu^{+3} ions are selectively reduced to Eu^{+2}, which then precipitates as $EuSO_4$, leaving the Y^{+3} ions in solution. The $EuSO_4$ is then filtered. More than 95% of the Eu is recovered as $EuSO_4$, which has a purity of 98.5%. A similar purity was obtained with industrial mixtures. The researchers are now working to improve the purity and optimize the process.

The research is part of the KU Leuven activities in the knowledge platform RARE3 (www.kuleuven.rare3.eu), a collaboration involving chemists, chemical technologists and material engineers, among others, to investigate the recycling of rare earth and other critical metals. ■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Plant Watch

Nippon Shokubai Europe to construct new production plants for SAP and AA

May 11, 2015 — Nippon Shokubai Co. (Osaka, Japan; www.shokubai.co.jp) plans to construct new facilities for the production of superabsorbent polymers (SAP) and acrylic acid (AA) in Europe, under its Belgium-based subsidiary, Nippon Shokubai Europe N.V. The new SAP and AA plants will each have a production capacity of 100,000 metric tons per year (m.t./yr).

Evonik opens expanded oil-additives plant in Singapore

May 7, 2015 — Evonik Industries AG (Essen, Germany; www.evonik.com) inaugurated its significantly expanded oil-additives plant on Jurong Island, Singapore after two years of engineering, planning and construction. The capacity of the plant has nearly doubled, making it Evonik's largest oil-additives production site.

BASF inaugurates polyamide polymerization plant in Shanghai

May 6, 2015 — BASF SE (Ludwigshafen, Germany; www.basf.com) inaugurated its new polymerization plant for polyamide 6 and 6/6.6 in Shanghai. The new plant has a production capacity of 100,000 m.t./yr.

Jacobs awarded contract by Huntsman for Singapore polyetheramine expansion

May 5, 2015 — Jacobs Engineering Group Inc. (Pasadena, Calif.; www.jacobs.com) has been awarded an engineering, procurement and construction management (EPCM) contract for an expansion program at Huntsman Corp.'s (The Woodlands, Tex.; www.huntsman.com) polyetheramine facility in Singapore. Construction is expected to be completed in the second half of 2016.

Victrex commissions U.K. polyaryletherketone plant

April 30, 2015 — Victrex plc (Thornton Cleveleys, U.K.; www.victrex.com) commissioned the first production stream of its new $138-million polyaryletherketone (PAEK) manufacturing plant. Recent investments increased Victrex´s production capacity by 70% to more than 7,000 m.t./yr.

Celanese to construct VAE emulsions plant in Singapore

April 29, 2015 — Celanese Corp. (Irving, Tex.; www.celanese.com) has begun construction of a vinyl acetate ethylene (VAE) emulsions production unit at the company's acetyls facility on Jurong Island, Singapore. The unit is expected to begin production by mid-2016. This Singapore unit will be the third VAE investment by Celanese in Asia.

Honeywell opens propylene-production catalyst plant in China

April 29, 2015 — Honeywell's (Morristown, N.J.; www.honeywell.com) Performance Materials and Technologies division has opened a new manufacturing facility in Zhangjiagang City, China to produce dehydrogenation catalysts used to convert propane to propylene.

Solvay launches construction for new silica plant in South Korea

April 27, 2015 — Solvay S.A. (Brussels, Belgium; www.solvay.com) has begun the construction of a production plant for highly dispersible silica (HDS) in Gunsan, South Korea. The plant has a production capacity of more than 80,000 m.t./yr, and is expected to be operational in the next two years.

Showa Denko to build hydrogen fluoride production facility in China

April 21, 2015 — Showa Denko K.K. (SDK; Tokyo, Japan; www.sdk.co.jp) plans to build a new high-purity hydrogen fluoride (HF) production facility in China. SDK aims to start operations at the new HF plant by the end of 2015.

Total converts existing La Mède petroleum refinery to biorefinery

April 21, 2015 — An investment of €200 million by Total S.A. (Paris, France; www.total.com) will transform the company's petroleum refinery in La Mède, France into a biorefinery to meet growing demand for biofuels. Crude oil processing will be halted at the end of 2016.

Henkel to double detergents production capacity in Mexico

April 21, 2015 — Henkel AG & Co. (Düsseldorf, Germany; www.henkel.com) has announced a €27-million expansion project at its Toluca production site in Mexico. The production capacity for detergents will be doubled.

Air Liquide starts up a large hydrogen production unit in Germany

April 17, 2015 — Air Liquide (Paris, France; www.airliquide.com) started up a new steam-methane reformer (SMR) unit located near Cologne, Germany. Air Liquide invested around €100 million in this unit, which will supply Bayer MaterialScience's new toluene diisocyanate plant. The new SMR will produce 22,000 m.t./yr of hydrogen and 120,000 m.t./yr of carbon monoxide.

Mergers and Acquisitions

IMCD to acquire U.S.-based specialty-chemicals distributor MF Cachet

May 11, 2015 — IMCD Group B.V. (Rotterdam, the Netherlands; www.imcdgroup.com) announced that it will acquire 80% of The

M.F. Cachat Co. (Cleveland, Ohio), a specialty chemicals distributor with a focus on coatings, construction, plastics, advanced materials and food. The acquisition has a value of approximately €85 million.

BASF to acquire Lanxess IP for polyisobutene production process

May 11, 2015 — BASF SE will purchase intellectual property (IP) for a new technology to produce high-molecular-weight polyisobutene (HM PIB) from Lanxess AG (Cologne, Germany; www.lanxess.com). On behalf of BASF, Lanxess will exclusively manufacture the new HM PIB for BASF under a longterm toll-manufacturing agreement.

Dow finalizes acquisition of Univation Technologies

May 7, 2015 — The Dow Chemical Company (Midland, Mich.; www.dow.com) announced that it has closed on the acquisition of ExxonMobil Chemical Co.'s ownership share of Univation Technologies, LLC, previously a 50/50 joint venture with Dow. This transaction was a collaborative decision between Dow and ExxonMobil.

Cargill acquires OPX fermentation technology

May 1, 2015 — Cargill (Minneapolis, Minn.; www.cargill.com) has acquired OPX Biotechnologies Inc.'s (www.opxbio.com; Boulder, Colo.) proprietary fermentation-based processes and systems. These technologies are used to produce bio-based chemicals from sugars for use in non-food applications such as lubricants, detergents, plastics, agrichemicals and personal-care products.

Showa Denko to divest phenolic resins business

April 29, 2015 — Showa Denko K.K. will transfer its phenolic resins business to Aica Kogyo Co. Ltd. Annual sales of the business were ¥4 billion in 2014. The business provides phenolic resins in various states, such as liquid, lumps, powder and grains

Endress+Hauser acquires process-automation business in Colombia

April 24, 2015 — Endress+Hauser (Reinach, Switzerland; www.endress.com) is acquiring the process automation business of Colsein Ltda., its longtime sales and service partner. Colsein will maintain its headquarters in Bogotà, Colombia once its process automation business is transferred to a new Endress+Hauser sales subsidiary in January 2016.

Jacobs acquires controlling interest in SHCE in China

April 22, 2015 — Jacobs Engineering Group Inc. has acquired a controlling interest in Suzhou Han's Chemical Engineering Co. (SHCE) in China. The company is now Jacobs Engineering (Suzhou) Co. The acquisition adds an engineering office in Suzhou, Jiangsu Province.

Henkel acquires hotmelt adhesives specialist Novamelt

April 17, 2015 — Henkel AG & Co. signed an agreement to acquire Novamelt GmbH (Wehr, Germany), a specialist in hotmelt adhesives. In fiscal 2014, Novamelt generated sales of around €50 million. ■

Mary Page Bailey

Flame Retardants: Safety is the Key

Producers continue to improve the performance of their flame retardants while ensuring safe handling and environmental responsibility

ICL-IP

No matter where you are reading this article — in your home, on the train, in an airplane, at the library or office — you are surrounded by synthetic materials (plastics and textiles), all of which are normally highly flammable. Fortunately, these synthetic materials contain flame retardants (FRs), which are incorporated into the polymers during processing so that the final product — be it the upholstery or foam padding you are sitting on, the insulation in the walls surrounding you, the housing of your computer or the circuit boards and other electrical components within — will not burst into flames with billowing black smoke when exposed to a candle, a lit match or an over-heated electrical circuit.

FRs serve two purposes, explains Philippe Salémis, director of the European Flame Retardants Association (EFRA; Brussels, Belgium; www.cefic-efra.com): to prevent the start of a fire, and to retard the progression of a fire. This gives people the extra time needed to escape from a small fire and more time for the firefighters to intervene, says Salémis.

As the number of synthetic materials — and products made from them — continues to grow, producers of FRs are working to develop new products for emerging applications. That's because when it comes to FRs, "there is no one-size-fits-all," explains Salémis. Each material has different properties, and the FR used has to be developed to perform its function while not altering the performance properties of the polymer in which it is used. As a result, there are over 140 different FRs on the market — about half of which are brominated, and half non-brominated (Table 1) — and more are continuing to be developed.

The market

According to the April 2015 report "Flame Retardant Chemicals: Technologies and Global Markets," which was compiled by Marcanne Green, an analyst for BCC Research (Wellesley, Mass.; www.bccresearch.com), the global consumption of FR chemicals for 2012 was estimated at 3.8 billion lb, and the FR chemicals market is expected to grow to 5.7 billion lb by 2019. The compound annual growth rate from 2014 through 2019 is projected to be 6.7% for the industry overall, according to the report.

Aluminum trihydrate (ATH) has the largest market share by volume, estimated to be 45% by 2019. Bromine-based FR chemicals should continue to be the largest sector by value, growing to 41% market share by 2019, says BCC Research.

The value of the flame-retardant industry is also expected to grow overall. The market is expected to reach $10.4 billion by 2019. The applications with the largest growth will be plastics and textiles. This is based on growth rates in electronics applications, housing and construction. Although all market applications for FR chemicals have ties to housing and construction, the plastics sector has been traditionally the largest consumer of flame retardants by volume, with textiles close behind.

Progress for safer, 'greener' FRs

Today, many organizations and governments are reassessing the benefits of FRs against the negative side effects that cause harm to human health or the environment, which became apparent over the last 40 years as FRs became more widely used, according to the BCC Research report. Therefore, the FR

IN BRIEF

- THE MARKET
- PROGRESS FOR SAFER, 'GREENER' FRS
- GREATER TRANSPARENCY
- CONTROLLING POTENTIAL EMISSIONS
- NEW DEVELOPMENTS

FIGURE 1 ABOVE. ICL-IP's Neot-Hovav plant — located in the Negev region of southern Israel — produces brominated flame retardants and other Br-based products

TABLE 1. CLASSES OF FLAME RETARDANTS

Class	Mode of action	Applications
Brominated	Bromine interacts with the fire cycle in the gas phase to stop the chemical chain reaction that leads to flame formation and a self-sustaining fire. In essence, brominated flame retardants either prevent a fire from starting in the first place, or significantly slow a fire down.	Highly effective, brominated flame retardants are used in a variety of materials, including textiles, electronics, building materials, plastics and foams. They are often used in combination with an antimony trioxide synergist.
Phosphorus	Flame retardants containing phosphorus interrupt the combustion process by promoting "charring." In the presence of a heat source, phosphorus flame retardants release phosphoric acid, which causes the material to char and form a thick glassy layer of carbon. This carbonated char stops the decomposition process (pyrolysis) and prevents the release of flammable gases, essentially cutting off fuel to the flame. It also provides a barrier between the material and the heat source.	Phosphorus flame retardants are used in some upholstered furniture, foam mattresses, textiles, television casings, rubber and plastics.
Nitrogen	Nitrogen flame retardants work in several key ways to provide fire protection. At high temperatures, they enable the formation of stable molecular compounds that stop the decomposition process (pyrolysis) and prevent the release of flammable gases. They also release inert nitrogen gases that inhibit the chain reaction leading to combustion, and can act as a synergist when combined with phosphorus to reinforce their flame-retardant functions.	Nitrogen flame retardants are used in insulation, furniture foams and electronics.
Chlorinated	Like bromine-based flame retardants, chlorinated flame retardants interact with the fire cycle to stop flame formation.	They are used in some polyurethane foam, rubber and flexible plastics.
Inorganic	A variety of inorganic compounds, most notably hydrated aluminum and magnesium oxides, are used as flame retardants, or, as is the case with antimony trioxide, as part of a flame retardant system in conjunction with bromine, phosphorus or nitrogen flame retardants. These flame retardants slow down the decomposition process and the release of flammable gases that fuel the combustion process, release inert gases that interrupt the chemical chain reaction that produces flames and produce a non-flammable and resistant layer on a material's surface, reducing the release of flammable gases.	Inorganic flame retardants are used in some plastics, paints, adhesives, rubber, textile back coatings, wire and cable.

Source: North American Flame Retardant Alliance

chemicals industry is in a state of transition, as some widely used FRs are being phased out.

For example, in May, ICL-Industrial Products, Inc. (ICL-IP; Tel Aviv, Israel; www.icl-group.com) announced that it was closing a production line in Israel that produces FR-1210 (Deca-BDE; decabromodiphenyl ether) FR product. This particular brominated FR (BFR) had been under scrutiny for many years due to concerns about health and environmental issues associated with it. Already back in 2009, the main producers, ICL-IP, Albemarle (Baton Rouge, La.; www.albermarle.com) and Chemtura (Philadelphia, Pa.; www.chemtura.com) committed to voluntarily phase out Deca-BDE in the U.S.

Last August, ICL-IP and Albemarle announced that the two companies entered into a manufacturing joint venture (JV) for the production of ICL's FR-122P polymeric FR and Abemarle's GreenCrest polymeric FR. Both FRs are designed to replace hexabromocyclododecane (HBCD), which had been the leading FR for expandable polystyrene (EPS) and extruded polystyrene (XPS) foam applications. HBCD is being phased out in the E.U., Japan and other countries.

The JV and partners will own and operate a 2,400-m.t./yr plant in the Netherlands, which is now operating, and a plant with a capacity of 10,000 m.t./yr in Israel (Figure 1), which had been running for several months until being disrupted by a strike (last month). After several years of evaluation and testing, ICL-IP began to commercially produce and market its FR-122P in 2013. Albemarle launched its GreenCrest product in 2013, and began commercial supply in April 2014 from the Netherlands plant.

Already in 2012, Great Lakes Solutions, a Chemtura business, commissioned its world-scale production facility for manufacturing Emerald Innovation 3000 FR, and commenced commercial production in April 2013 at its El Dorado, Ark. Plant, which has a nameplate capacity of at least 10,000 m.t./yr.

The technology behind Chemtura's Emerald Innovation 3000 FR, ICL's FR-122P polymeric FR and Albemarle's GreenCrest polymeric FR was first developed by Dow Global Technologies LLC (DGTL), a subsidiary of The Dow Chemical Company (Midland, Mich.; www.dow.com). In March 2011, DGTL announced the invention and development of the Polymetic Flame Retardant (PolyFR) — a stable, high-molecular-weight, non-PBT (persistent, bioaccumulative, toxic) substance. The additive is suitable for fire-safety applications for XPS and EPS foams, used for thermal insulation materials. The PolyFR technology is licensed by Albemarle, ICL-IP and Chemtura.

Last November, BASF SE (Ludwigshafen, Germany; www.basf.com) became one of the first European manufacturers to have switched its entire portfolio of PS-based insulation products for the European market to a new FR, nine months ahead of the deadline laid down in the E.U. REACH Regulation on chemicals. Both EPS and XPS products will be manufactured in Europe using PolyFR, which has a much better environmental profile than the HBCD used in the past, says BASF.

Because it is classed as a POP (persistent organic pollutant) under the UN Environment Program and as a svhc (substance of very high concern) under the REACH regulation, the use of HBCD as an FR in the E.U. will be prohibited as of August 21, 2015 and PolyFR, which is harmless, will be used instead, says BASF.

Although handling of the FR HBCD as such is prohibited, insulation containing HBCD is harmless to humans and the environment, both during use and during removal and energy recovery. That is because the FR is embedded in the polymer matrix, says BASF.

Greater transparency

Last month at Chinaplas 2015 (May 20–23; Guangzhou), ICL-IP launched Systematic Assessment for Flame Retardants (SAFR), what the company claims is a groundbreaking assessment tool for FRs. The tool expands upon existing hazard-based approaches to incorporate potential exposure into assessment outcomes, explains Ilan Elkan, ICL-IP's vice president of Sustainability and Advocacy. SAFR assesses the sustainability profile of individual FRs according to their application.

SAFR marks a new level of transparency, Elkan continues. "Not only will our direct customers benefit, but those up the user chain will be able to measure not only the hazard, but the exposure of any given flame retardant. This will allow them to make the most sustainable choice of flame retardant against a given application."

ICL-IP is in the process of reviewing its portfolio of FRs using SAFR, having already assessed over 70%.

The SAFR tool provides one of four outcomes for each product assessed: recommended, acceptable, not recommended and unacceptable. FRs that have a rating of "recommended" through to "not recommended" are all usable; however users of FRs that achieve a "not recommended" rating will be provided the option of an alternative product with a recommended or acceptable rating. ICL-IP products that have an "unacceptable" hazard rating — including those that are still in the development phase — will be, and in many cases have already been phased out in coordination with the value chain, says Elkan.

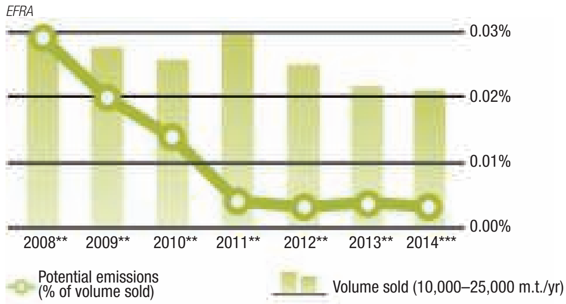


FIGURE 2. This graph shows the decline in potential emissions (as percentage of volume sold) of brominated FRs in Europe

Controlling potential emissions

Last month, the EFRA released the 2014 VECAP European Progress Report, marking the 10-year anniversary of the Voluntary Emissions Control Action Program (VECAP; www.vecap.info). The program was established 10 years ago by three of the main producers of FRs, together with the U.K. Textile Finishers association, and is run by EFRA. Today, the program has been operating in Europe, the U.S. and Canada, as well as being promoted in Mexico, China, Japan, South Korea and Taiwan.

Since 2008, VECAP has achieved major reductions (see Figure 2) of potential emissions of the three reported brominated flame retardants — TBBPA (tetrabromobisphenol A), Deca-DBE and HBCD — and emissions to land remain zero for all three. Also, a significant decrease in the potential emissions to land for 1,1'-(ethane-1,2-diyl) bis [pentabromobenzene] (EBP) dropped by about 35% in 2014 — the second year of reporting on EBP. This drop in potential EBP emissions despite a significant increase in sales of EBP (0–2,500 m.t./yr in 2013 and 2,500–5,000 m.t./yr in 2014) illustrates how well the VECAP program has worked for controlling emissions, according to the report.

Among the recommended best practices developed and being implemented by VECAP are those related to the transport, handling and disposal of the packaging in which the BFRs are sold. Central to the success of the program is its process of continuous improvement in the development of new best-practice recommendations, based on experience. For example, the 2014 survey identified the cleaning of worker's personal-protection clothing as a potential source of emissions to the environment. So a recommended practice is for contaminated clothing to be washed at industrial facilities where the wastewater is treated and the sludge is incinerated as hazardous waste.

New developments

Last December, Teijin Ltd. (Tokyo, Japan; www.teijin.co.jp) started production of a new phosphorus FR, FCX-210. The 1,000 ton/yr plant is being operated by chemical manufacturer Chitec Technology (Taipei, Taiwan: www.chitec.com).

Developed in 2013, FCX-210 incorporates the company's proprietary molecular-design technology. It is said to enhance the flame retardancy in a broad range of resins, including ABS, PS and nylon — materials in which conventional phosphorus FRs are less effective, says the company. The company plans to develop applications in the electronics and automotive markets, and expects revenues from its FR business to reach ¥4-billion by fiscal year 2018.

Meanwhile, in March, Archroma (Reinach, Switzerland; www.archroma.com) launched Pekoflam HFC, a halogen-free FR powder coating additive. Said to be the first powder additive to be listed for coating applications, Pekoflam HFC will support textile producers' and protective clothing manufacturers' efforts to achieve both Oeko-Tex 100 compliance and effective fire protection for their finished goods, says the company.

Perkoflam HFC is an organic phosphorus/nitrogen compound for synthetic materials such as polyamide fibers and blends.

Last October, Clariant (Charlotte, N.C.; www.clariant.com) announced that its Exolit OP 560 FR had been designated by the U.S. Environmental Protection Agency (EPA; Washington, D.C.) as a safer, more environmental friendly FR for polyurethane (PUR) foam used in furniture upholstery and other consumer products, compared to the traditional pentabromo diphenylether (pentaBDE). The FR product also meets internationally accepted flammability standards for flexible PUR, says Adrian Beard, head of Marketing and Advocacy for the FR Business line of the Business Unit Additives.

Exolit OP 560 — an oligomeric phosphonate polyol —is a reactive FR that eliminates unwanted emissions since it becomes chemically bonded with the polymeric PUR foam structure, says Clariant. ■

Gerald Ondrey

High-Performance Internals Boost Tower Capacities

New materials and designs help processors improve efficiency and reliability

Raschig USA

FIGURE 1. The Raschig Super-Ring offers a grid-like structure that provides a lower resistance to gas flow, reduces pressure drop and results in improved capacity compared to earlier packings

IN BRIEF

INCREASING CAPACITY

FOAMING AND FOULING

RELIABILITY

As in other areas of chemical manufacturing, processors want more efficiency from their distillation and mass-transfer operations. Increasing capacity, finding solutions to issues such as foaming and fouling that slow the process down, and lengthening lifetimes are high on their list of priorities. As a result, vendors of trays and packings are rethinking and redesigning their products to provide column internals that make the process more effective.

"In essence, it's about the hydraulics of contacting and separating vapors and liquids," explains Juan Portillo, manager, Chemicals/Gas Applications Engineering, with Sulzer Chemtech, USA, Inc. (Tulsa, Okla.; www.sulzer.com). "By striving to make the process more efficient, improvements are brought to the market to benefit the customers. A lot of what we're doing has to do with the shape and streamlining designs of the column internals."

For example, he says, one of his company's newest packings has a smooth S-shaped transition that allows more vapor flow and less liquid hold up, and their random packings have an open and uniform structure that minimizes both vapor and liquid stagnation within the packed bed. "When you step back and look at the designs, you can see why they should work from a hydraulic standpoint. And, when you look at the results and the operating data, you know the newer designs do work," notes Portillo.

Strategies to increase capacity, reduce foaming and fouling and increase reliability top the wish lists of chemical processors running distillation and mass-transfer operations. Fortunately, for each issue there is a solution.

Increasing capacity

"American processors are still somewhat recovering from the economic crisis of 2008, and, as a result, they are putting more emphasis on doing more with what they have," says Brad Fleming, general manager with the Process Equipment Technology division of GTC Technology US LLC (Houston; www.gtctech.com). "While there are fewer large, capital-intensive greenfield projects taking place in the states, we see a lot of revamps aimed at increasing capacity with minimal capital investment. There's a big push to squeeze the most out of existing infrastructures."

As a result, providers of internals are busily retrofitting existing columns with products designed to boost column efficiency. "Often, they want more capacity from an existing shell, so we replace traditional trays and packings with high-performance internals that allow processors to increase throughput, feed and product flowrates of the tower."

In many cases, swapping traditional internals for high-performance versions is a simple, low-cost way for processors to improve performance, resulting in increased efficiency or higher product quality or purity.

What is it about high-performance internals that makes the difference? In some cases it involves merely enhancing the physical features of traditional or existing-style equipment. An example of this would be replacing a traditional valve tray that features a round floating valve with a valve tray that offers smaller valves, which are more aerodynamically efficient. In other cases, the higher performance comes from completely new concepts, as high-performance struc-

Sulzer Chemtech

FIGURE 2. The open structure of the NeXRing 4th generation structured packing has inherently low pressure drop and high capacity to allow greater resistance to foaming applications

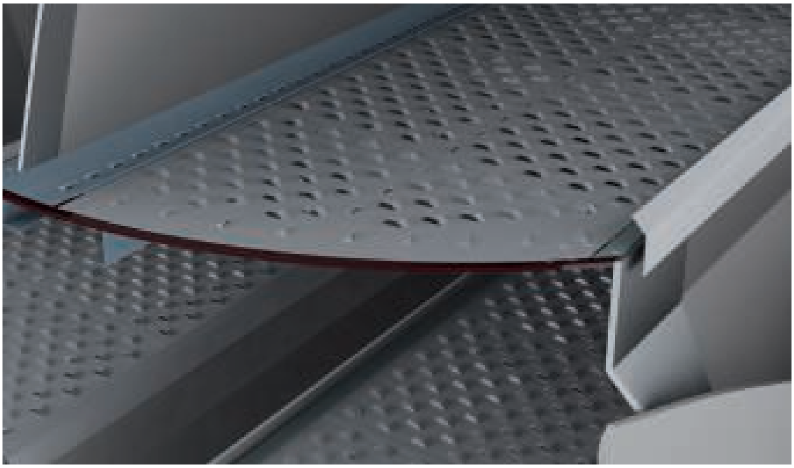
tured packings offer a completely different structural design than traditional packings.

In this vein, GTC offers its GT-Optim line of high-performance trays and packings. "The Optim line addresses various objectives, such as increasing capacity and efficiency, mitigating fouling, improving mechanical reliability and increasing efficiency of installation," says Fleming.

GT-Optim high-performance trays can be constructed of standard or exotic materials with various downcomer designs, such as straight, sloped, stepped, swept and truncated, and deliver performance improvements through higher turndown, less weepage and lower entrainment.

And, the company's GT-Optim Pak high-performance structured packing is designed to deliver greater column throughput at the same efficiency as traditional structured packing. It can be used in a range of application settings and is designed to optimize film flow vapor-liquid mixing, reduce pressure drop, increase capacity and provide higher separation efficiencies. The GT-Optim-e Pak is a high-performance, large-crimp structured packing that combines the advantages of increased charge rates, lower pressure drops and reduced energy requirements to create a packing with higher capacity and efficiency when compared to conventional trays. It features enhanced surface treatment and has been commercially proven to increase vacuum gas oil (VGO) lift from the vacuum residue.

Like structured packings, random packings have also gone through changes to provide higher performance characteristics, says Bill Kennard, sales director, with Raschig USA (Arlington, Texas; www.raschig-usa.com). The company's Raschig Super-Ring (Figure 1) is a fourth-generation random packing. "The geometry of this packing is entirely different," notes Kennard. "The first generation was the Raschig-Ring, second was the Pall-Ring, which was a modified version of the first Raschig Ring. The third-generation random packing featured a dif-



Sulzer Chemtech

FIGURE 3. VG AF anti-fouling trays are often used to provide high capacity and efficiency while proving resistant to fouling applications

ferent design with a metal, saddle-shaped packing, as opposed to a ring shape. The Raschig Super-Ring is more of a grid-like structure that provides lower resistance to gas flow, reduces pressure drop and results in improved capacity compared to earlier packings."

Kennard says that when compared to a second-generation packing like a Pall Ring, there may be a 25% increase in capacity at the same efficiency. Compared to a third-generation packing, users will likely see a 10% capacity increase.

These significant increases in capacity are due to the structure of the Super-Ring, which pursues the objective of producing turbulent film-type flows and prevents formation of drops. The large number of alternating wave swings also achieves a high degree of turbulence in the gas and liquid flows while, at the same time, it has an extremely open geometry. Due to the fluidically optimized shape of the Super-Ring, the randomly dumped packed bed automatically obtains a structure otherwise only found in the case of structured packings, says Kennard.

Likewise, AMACS (Houston; www.amacs.com) offers improved efficiency thanks to its approach to high-performance random packing. The SuperBlend 2-PAC technology is a blend of high-performance packing sizes placed in a single bed. AMACS blends two sizes of metal random geometry, so that, when combined, the patented blend achieves the efficiency benefits of the smaller packing size while retaining the capacity and pressure drop of the larger packing size. "Replacing your random packing with SuperBlend 2-PAC could increase the tower's efficiency by 20% or capacity by 15%, according to third-party verification by the Separation Research Program at the University of Texas," says J. Antonio Garcia, technology manager, Mass Transfer, with AMACS.

And, the company's Montz-Pak Type M and MN are further developments of the company's previous generation Montz structured packings. Type MN-series provides 30 % more separation efficiency and higher throughput capacity when compared to standard packing crimps. Higher purities, small column heights and simple tower de-bottlenecking are possible. Type M allows throughput increases of 30% compared to columns equipped with standard packing types due to the reduced pressure drop.

> *"Foaming- and fouling-resistant designs are continually requested."*
>
> Juan Portillo, Sulzer Chemtech

Foaming and fouling

"Foaming- and fouling-resistant designs are continually requested," says Sulzer Chemtech's Portillo. And as a result, the company offers several internals to help meet a myriad of needs. "For foaming conditions, UFM Trays offer high deck capacity so that larger downcomers can be used to handle foaming conditions. Also, for foaming systems, Sulzer's MellpakPlus structured packing has a unique design to mitigate liquid and foam build up within the packing itself. Finally, the open structure of our new NeXRing fourth generation structured packing (Figure 2) has inherently low pressure drop and high capacity to allow greater resistance to foaming applications."

For fouling services, he says the company's VG AF anti-fouling trays (Figure 3) are often used to provide high capacity and efficiency while proving resistant to fouling applications. "More recently," he notes, "Sulzer's XVG valve tray has been used successfully in some of the worst fouling applications."

Reliability

"Part of increasing capacity and maintaining high efficiency includes keeping the process running as long as is possible between changeouts," says Danny Mock, vice president and North American business unit manager for RVT Process Equipment (Knoxville, Tenn.; www.rvt-pe.com). "That said, our customers are always looking for products that can not only increase capacity and efficiency, but also provide higher levels of durability and reliability, so we really focus on the ability to design internals, packings and trays that will run for longer periods of time and operate at the capacity that our customers require."

To provide more-reliable and

longer-lasting internals, Mock says the focus is on effective fabrication of product and, often, the use of exotic materials. "The availability of exotic materials provides us with the ability to create a high-performance liquid distributor that can perform well in service, yet be made out of materials that will survive the harsh chemical environment in which it is used."

He says that it was very common for chemical plants to use ceramic liquid distributors, but often the densities were not high enough for the service. "But today's use of high-end metals and plastics for fabricating high-performance internals is changing the market."

As a result, RVT focuses not on a specific product line, but on the ability to provide its internals with innovative designs, as well as a variety of different materials of construction. For example, RVT supplies mass valve, sieve and dual-flow trays, bubble cap trays, tunnel trays (Figure 4) and also special tray constructions (such as cascade or chimney trays, shower decks and trays for foaming systems) in metal, and also in thermoplastic materials, such as polypropylene homopolymer (PPH), polyethylene (PE), polyvynal chloride (PVC), chlorinated PVC (PVC-C), polyvinylidene fluoride (PVDF), polytetrafluoroethylene (PTFE) and TFM/PTFE.

And, highly corrosive and high-temperature operations often require higher-grade materials. If chemical-resistant plastic material cannot be used due to decreasing stability at high temperatures, high-grade special materials like zirconium or tantalum can be used. "However, in some cases we can offer chemically resistant and competitive constructions that combine several materials in one part, such as a CFC load-bearing frame and distribution device made of tantalum drip tubes with all other components made of TFM/PTFE," explains RVT's Mock. "The ability to provide high-performance internals in combination with other lower-cost materials helps increase capacity and reliability at a fraction of the cost of using all high-end materials."

RVT Process Equipment

FIGURE 4. RVT supplies mass valve, sieve and dual-flow trays, bubble cap trays, tunnel trays (shown here) and also special tray constructions, such as cascade or chimney trays, shower decks and trays for foaming systems

Thanks to the variety of internal materials and designs available to today's processors, increasing throughput, efficiency and capacity while decreasing shutdowns and costs associated with maintaining columns and towers has never been easier. ■

Joy LePree

Software

Manage chemical inventories using this software tool

Biovia CISPro is a comprehensive chemical-inventory-management system that provides cross-referenced information about a broad array of chemicals, with details about physical characteristics, hazards, structure and more (photo). The information can easily be accessed from computers and mobile devices. The system can be used to track chemical containers from receipt to disposal, throughout a multi-facility operation. The framework can be customized to meet the organization's specific processes and workflows, and it can be configured by the site or by the business unit, while maintaining a central global database for all locations. Biovia CISPro is installed on the corporate server within the firewall, and it offers highly configurable security parameters that allow the facility to add or delete roles and permission levels and implement new security requirements at any time. This ensures end-to-end internal data security and control, says the company. — *Biovia Corporate Americas (formerly Accelrys), San Diego, Calif.*
www.accelrys.com

Track plant energy use and pinpoint opportunities

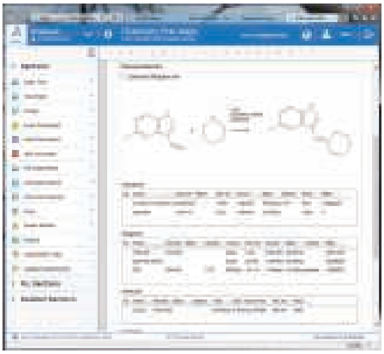
To improve plant energy performance, operators must first grasp how energy is being used by each process unit. By visualizing and tracking the energy consumption in each unit, inefficiencies can be identified and located (photo). This company's Energy Performance Analytics software uses energy performance indicators to track how energy is being consumed in a plant, and identifies gaps between targets and actual performance to help users identify countermeasures that can improve energy performance and reduce greenhouse-gas emissions. The software runs on a workstation that is connected via an inerface to the control systems, giving it access to pressure, temperature, flowrate and other plant data. It uses rigorous first-principle models to track energy flows and calcuate the energy performance for each process uint and individual piece of equipment, such as turbines, boilers and others. The software also compares actual performance against expected energy performance to pinpoint underperforming units and equipment. — *Yokogawa Electric Corp. Newnan, Ga.*
www.us.yokogawa.com.com

Software update extends this XRF analyzer's capabilities

This company's Phoenix II XRF analyzer (photo), a polarized energy dispersive X-ray fluorescence (ED-XRF) benchtop analyzer, now includes updated software. The analyzer is ideal for quantitative and qualitative elemental analysis in production, laboratory and quality-control applications. The new software features include enhanced data management, improved statistical calculation methodologies and a range of productivity enablers. These include archived data compatibility with laboratory information management systems (LIMS), Excel and others. New statistical-analysis options also allow a single sample to be run multiple times and to generate an analysis of the spectra along with metrics on noise levels and peak-shape position reproducibility. The system features an intuitive touchscreen display to simplify operation.— *Ametek Process Instruments, St. Cloud, Minn.*
www.ametekpi.com

Upgrade enhances electrical and instrumentation software

The Aveva Electrical and Aveva Instrumentation software provides support for electrical and instrumentation engineering and design in CPI plant applications and marine applications. New functionality includes best-in-class cable-routing capabili-



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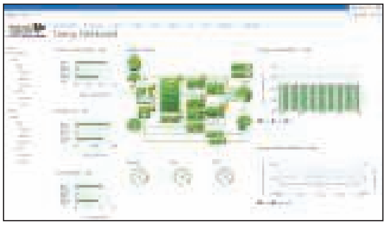


Yokogawa Electric

Ametek Process Instruments

Note: For more information, circle the 3-digit number on p. 78, or use the website designation.

ties (based on industry benchmarking) using Aveva Everything3D capabilities to ensure accurate cable length and sizing calculations for cable routing. These systems now offer greater flexibility in the way in which distributed engineering teams can configure and control projects, says the manufacturer. — *Aveva Group plc, Cambridge, U.K.*
www.aveva.com

Track-and-trace system supports production

Manufacturers of medical devices often use both discrete and batch manufacturing and assembly processes in their operations. The PharmaSuite V7.0 manufacturing execution system (MES) software provides a sole track-and-trace platform, enabling tracking capabilities down to the smallest saleable unit, says its maker, including medical devices that are combined or coated with a pharmaceutical ingredient during production. The ability to combine track-and-trace capabilities for both discrete and batch processes reduces the need for disparate systems and improves overall agility, says the company. Order-management, electronic device history record (eDHR) support, rework and repair capabilities and quality-assurance tools are built in. — *Rockwell Automation, Milwaukee, Wisc.*
www.rockwellautomation.com

Manage operations, from order entry through shipping

ProcessPro is an enterprise resource planning (ERP) solution that seamlessly integrates all aspects of plant operation in CPI facilities (in sectors ranging from specialty chemicals, food-and-beverage and pharmaceutical to nutritional supplements and cosmetics). The program provides support functions from beginning order entry through manufacturing, packaging, shipping, inventory management and accounting. The latest version of ProcessPro — Premier 10.5 — incorporates specific upgrades that were identified using customer feedback, industry trends and emerging technology. The package provides improved methods for managing production, usage information and sale orders, managing sales contracts and pricing data. Enhanced reporting and report-generation capabilities provide improved support for both quality control and customer service objectives. — *Process Pro, St. Cloud, Minn.*
www.processproerp.com

Automate and streamline instrument calibration


Endress + Hauser

Memobase Plus software manages the calibration of four different sensor types simultaneously: pH, dissolved oxygen, conductivity (both conductive and inductive), and chlorine. It creates an FDA-compliant audit trail for pH, oxygen conductivity and chlorine sensors (photo). The software provides guided, step-by-step instructions for the correct calibration procedure required for each sensor. It also provides complete traceability of test solutions, sensors, calibrations and measurement, says the company. Calibration reports are generated automatically as a PDF document or as a file that can be exported to Excel or similar software for further processing. Memobase Plus is FDA 21CFR Part 11-compliant, says the company. — *Endress + Hauser, Greenwood, Ind.*
www.us.endress.com

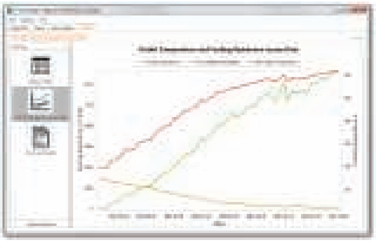
Logistics system streamlines materials movement


Emerson Process Management

This company's Syncade Suite manufacturing execution system (MES) now provides terminal managers with increased security tools and improved control of material movements and inventory. The Syncade Logistics module allows operators to manage the storage and distribution of materials transported by railcars, trucks, ships, barges and pipelines. The module

also facilitates tighter control of inline blending, tank swing changeovers and accounting at the line-segment level for accurate stock allocation. It generates all of the required documentation to meet customer and regulatory needs. In V4.9 of the software, security issues at the terminal are managed by controlling access to the physical facility and materials, and by capturing verification of railcars and trucks using security cards, biometric controls or RFID tags. All transactional information is archived and can be quickly retrieved for review or analysis. — *Emerson Process Management, Austin, Tex.*
www.emersonprocess.com

Fast, accurate analysis of heat-exchanger performance



HTRI

Heat-exchanger fouling is a top concern for heat transfer engineers. HTRI Edgeview software helps identify operating regimes that will reduce fouling, minimize downtime, lower utilities costs and increase production. Edgeview is compatible with this company's Xchanger Suite (photo), and provides evaluation and indicators of heat-exchanger performance. The software calculates fouling resistance for sensible and phase-change shell-and-tube equipment. With its multiple thermal performance models and expert analysis algorithms, Edgeview rapidly analyzes plant operating data, troubleshoots heat-exchanger performance issues, and diagnoses potential problems. Results are displayed using built-in graphing and reporting capabilities. — *HTRI, Navasota, Tex.*
www.htri.net

Improve 2-D and 3-D design and engineering efforts

Among the new capabilities and performance enhancements of the recently updated CADWorx 2015, this AutoCAD-based plant-design solution allows for the generation of .ifv files for viewing and sharing design models on the Apple iPad. The software offers piping and instrumentation diagram (P&ID) synchronization with the model, plus intelligent modeling and automatic production of design deliverables such as isometric drawings and bills of material, to improve productivity throughout the engineering and design process. Other capabilities include routing of mitered elbows, skewed pipe design and male/female needle valves; custom field default values for models; new tables in the specification editor; and improvements to the user interface. Even though CadWorx is an AutoCAD-based plant design solution, users still have access to industry standard solutions, such as IsoGen for isometric creation, and OrthoGen for the creation of automated plans, sections and elevations, says the company. — *Intergraph, Huntsville, Ala.*
www.intergraph.com

Software helps improve this company's networking devices

The latest version of WeConfig (V1.1), the company's network configuration-management software, is designed to enhance the usability of the company's WeOS family of industrial routers, switches and Ethernet line extenders by simplifying the initial configuration, backup and firmware upgrades to this company's devices. In addition to configuration support, the software now provides monitoring and diagnostic tools for network engineers. While WeOS devices are designed to automatically reconfigure themselves so the processes running the network are unaffected, the WeConfig software now graphically displays a failed link and a record of the time of the event to enhance problem diagnosis and troubleshooting. — *Westermo North America, Elgin, Ill.*
www.westermo.com

Simulation package includes extensive user support

ProMax is a versatile simulation software program that is used to optimize gas processing, petroleum refining and chemical facilities, with no necessary add-on modules. Pro-

Max provides highly accurate results for multiple systems from general hydrocarbon systems to specialty systems such as glycols, amines and sulfur units, says the manufacturer. Extensive engineering training and tutorials, and personal and online support, are provided with every ProMax license. — *Bryan Research & Engineering, Bryan, Tex.*
www.bre.com

Improve the display of process information

Precision Digital

ScanView EX Programming Software, for the VantageviewPD6730X and ProtEX PD6830X Modbus Scanners (photos), allow industrial plants to pair their existing Modbus systems with Precision Digital Modbus Scanners o provide the accurate display of, and quick access to, process information, both locally and remotely. ScanView EX gives operators full control of the Modbus scanner-configuration process, using an intuitive layout and user-friendly interface. Clearly labeled menus enable quick programming of all functionality. In addition, scanner configurations can easily be copied, saved, retrieved or printed in list form. ScanView EX features tabs that logically present functions and programming elements. Tabs include monitor, mode/PV setup, display, rate/totalizer, outputs, data logging and more. Within each tab, the features are organized by related item and include drop-down menus. — *Precision Digital, Holliston, Mass.*
www.predig.com

Here's help for building and using dynamic simulations

Mimic Simulation Software V3.6 is a dynamic-simulation software platform for managing plant-lifecycle business results at CPI facilities. It is used to develop realtime, dynamic simulations of process plant operations, and includes 14 new advanced modeling objects, integrated with solids property tracking, particle-size distribution and tunable comminution matrix in every object, says the company. Users in the oil-and-gas sector will benefit from several new dynamic modeling objects, including advanced turbine (gas and steam) capabilities, updated furnace object, and significant improvements to the program's pressure-flow solver. And users in the life sciences arena can now reap more benefits from lifecycle dynamic simulation with the introduction of the new bioreactor advanced modeling object, which provides opportunities to improve the operation of biotech facilities and the development of biotherapeutics. The component database now includes more than 1,500 compounds, for added modeling flexibility. — *Mynah Technologies LLC, Chesterfield, Mo.*
www.mynah.com

Modeling tool facilitates water-treatment design and operation

The Water Application Value Engine (WAVE) is a new digital modeling tool that is designed to simplify and accelerate the modeling of components, evaluate new and retrofit system designs, and plan construction of water-treatment systems. The innovative modeling software combines an integrated software program with the three components — ultrafiltration, reverse osmosis and ion exchange. By using the software's hydraulic-modeling calculation engine from pretreatment to final polishing, users reduce data-entry steps (and thus the risk of error during calculation and data re-entry from one calculation tool to another) and ultimately save time modeling water-treatment components being evaluated as part of the system design, says the manufacturer. — *Dow Water & Process Solutions, Houston*
www.dowwaterandprocess.com ■

Suzanne Shelley

Note: Additional software items can be found in the extended version of this department, at www.chemengonline.com.

Liquid-Liquid Extraction

Department Editor: Scott Jenkins

Liquid-liquid extraction is a common mass-transfer operation in which a target solute material is transferred from a feed phase into a solvent. The process is used in a number of applications, including: the removal of valuable products from fermentation broth; the removal of high-boiling-point organic materials from wastewater; recovery of hydrogen-bonded organic compounds (formic acid, acetic acid and others) from water; recovery of reaction products from a broth; washing of acids or bases from an organic stream; and others. This one-page reference provides information on how to asses the performance of a liquid-liquid extraction column.

Extraction operation

In liquid-liquid extraction, a feed solution is contacted with a liquid solvent that is immiscible with some of the components of the feed, but that dissolves another component of the feed solution. In the course of this contact, a desired material can be removed from the feed and transferred to the solvent phase. The solvent phase refers to the solvent with the dissolved solute, while the feed solution without the solute is called the raffinate phase.

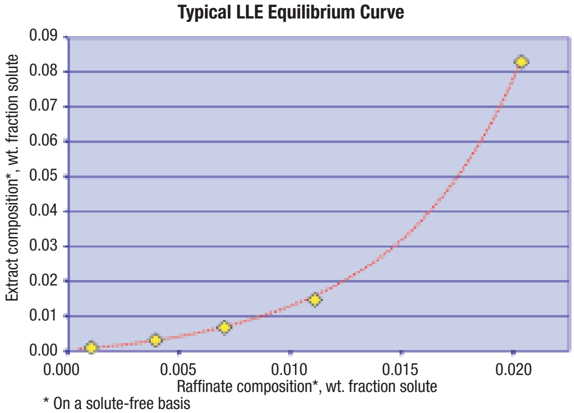
There are a number of extractor types for liquid-liquid extraction, including agitated columns, static columns, rotating disc contactors and others. In most cases, the two phases flow countercurrently, by exploiting the difference in density of the two fluids.

Column performance

Liquid-liquid equilibrium (LLE) data describe the steady-state partitioning behavior of the solute between the two phases. The concentration of the solute in the extract phase is plotted against the concentration of the solute in the raffinate phase (see figure). Each point along the curve defines a local distribution coefficient, *m*, according to the following equation:

$$m = y_a / x_a \quad (1)$$

where *a* is the solute, y_a is the weight fraction (concentration) of component *a* in the extract liquid and x_a is the weight fraction of component *a* in the raffinate liquid. If an LLE data set is available, and the column material balance is known, it is possible to determine the number of theoretical stages necessary to achieve a specific separation.



Column evaluation

To generate LLE data, a "shake test" can be used. These tests are conducted in reactor-type laboratory flasks with the capability to allow agitation and temperature control. Feed solutions containing varying solute concentrations are added to the flask along with varying amounts of solvent (corresponding to the solvent-to-feed ratio being used in the process). For each case, the two-phase mixture is heated to the desired temperature and the phases are mixed vigorously before being allowed to separate.

The two phases are then analyzed to determine the solute concentration in each. For the pair of samples in each test, the distribution coefficient is calculated. If the calculated distribution coefficients are relatively constant, the number of theoretical stages can be calculated using the Kremser equation.

$$n_s = \frac{\mathrm{Log}\left[\left(\dfrac{X_F - \frac{Y_s}{m}}{X_N - \frac{Y_s}{m}}\right)\left(1 - \dfrac{1}{E}\right) + \dfrac{1}{E}\right]}{\mathrm{Log}\, E} \quad (2)$$

Where:

n_S = number of theoretical stages

X_F = mass concentration of solute in the feed (solute-free basis)

X_N = mass concentration of solute in the raffinate (solute-free basis)

Y_S = mass concentration of solute in the solvent (solute-free basis)

m = distribution coefficient

S/F = mass ratio of solvent rate to feed rate

E = extraction factor [$m \times (S/F)$]

If the shake test results show a distribution coefficient that changes significantly with concentration, then a graphical method, such as the McCabe-Thiele method for determining column efficiency (number of theoretical stages), can be used.

The column performance and the Kremser equation can help to evaluate the effects of changes to key process variables. By changing individual input variables, engineers can quickly calculate the effect of the changes on column performance.

Glatz and Parker [*1*] outlined six steps to improving a liquid-liquid extraction process:

1. Generate LLE data for the current (existing) process
2. Obtain the material balance for the existing column, including flowrates, and solute concentrations for feed, extract and raffinate
3. Use the Kremser equation, graphical solution, or simulation to calculate the number of theoretical stages
4. Evaluate how changes in process variables affect column performance
5. Perform pilot testing based on results from step 4
6. Modify equipment and process based on steps 4 and 5 ■

Editor's note: This column is adapted from the following article: 1. Glatz, D. and Parker, W., "Enriching Liquid-Liquid Extraction," *Chem. Eng.*, November 2004, pp. 44–48.

Bio-based Methionine via Fermentation of Glucose

By Intratec Solutions

Methionine is an essential amino acid that is not produced by animals. Methionine must be obtained from dietary sources, and its major use is as an animal nutritional-feed additive. Methionine is mainly derived from petrochemical sources. However, biochemical routes to obtain it have been researched. For instance, a joint venture between CJ Bio (cjbio.net) and Arkema (arkema.com) initiated methionine production using both renewable and petrochemical raw materials; and Metabolic Explorer (metabolic-explorer.com), in partnership with Roquette (roquette.com), developed a process for 100% bio-based methionine.

The process

The production of L-methionine via a method similar to the one proposed in patents issued to Metabolic Explorer and Roquette is described below and presented in Figure 1. In this process, *L*-methionine is produced through a fed-batch aerobic fermentation, using glucose as the carbon source and ammonium thiosulfate as the nitrogen and sulfur source. Products obtained from this process are L-methionine powder (final product) and liquid L-methionine compound (byproduct).

Media preparation. Culture media used in the fermentation are prepared by mixing water, corn syrup (70 wt.% glucose) and aqueous ammonium thiosulfate solution in medium vessels.

Fermentation. A recombinant microorganism produces L-methionine through an aerobic fermentation process, which is divided into two phases: batch and fed-batch. Fermenters are filled with the batch medium, and fermentation occurs until glucose exhaustion, when the fed-batch phase is started by adding the fed-batch medium until the end of the fermentation.

Clarification and demineralization. Culture broth is clarified by the removal of insoluble and soluble organic impurities by centrifugation and ultrafiltration, respectively. Next, the broth is demineralized using ion-exchange resins to remove cations and anions.

Pre-concentration, crystallization and filtration. L-methionine is concentrated in an evaporator prior to crystallization under vacuum by water evaporation. Then, precipitated methionine is sent to a vacuum filter, where it is separated from the crystallization mother liquor, which still contains dissolved methionine.

Products recovery. Filtered L-methionine is directed to a dryer, where L-methionine powder with 99.5 wt.% of dry matter (90 wt.% of methionine) is obtained. Evaporated water is sent to a wash column before being used in methionine washing during filtration.

Also, the crystallization mother liquor is acidified with HCl, then concentrated, resulting in the liquid L-methionine byproduct, which contains 60 wt.% of dry matter (22 wt.% of methionine).

Economic performance

An economic evaluation of the process was conducted based on data from Q1 2014. The following assumptions were taken into consideration:

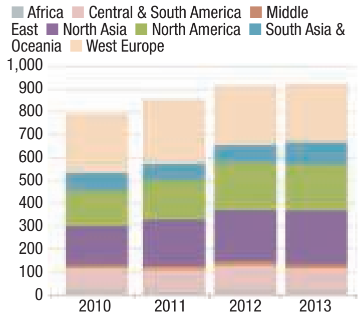


FIGURE 2. Methionine consumption by region

- A facility erected on the U.S. Gulf Coast with a nominal capacity of 87,600 ton/yr of L-methionine powder and 86,700 ton/yr of liquid
- Storage autonomy of 15 d for feedstock and 20 d for products

Estimated capital investment (total fixed investment, working capital and initial expenses) is about \$430 million, and operating expenses are about \$3,900/ton of L-methionine powder.

Global perspective

Historical methionine-consumption is presented in Figure 2. Globally, Western Europe, North America and North Asia are the major consumer regions. While most regions had similar growth in methionine consumption (average growth rates around 5%/yr), North Asia stands out at 11%/yr. ■

Edited by Scott Jenkins

Editor's Note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are prepared on the basis of publicly available and non-confidential information. The content represents the opinions of Intratec only. More information about the methodology for preparing analysis can be found, along with terms of use, at www.intratec.us/che.

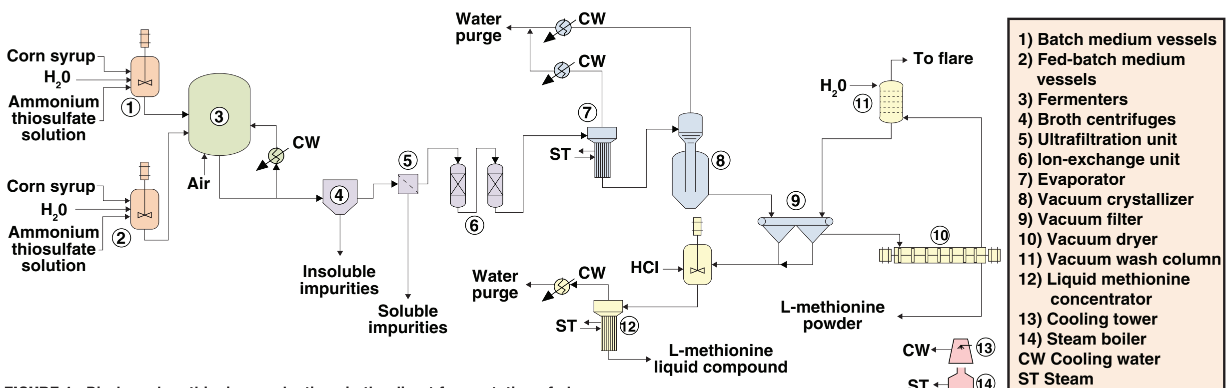


FIGURE 1. Bio-based methionine production via the direct fermentation of glucose

Materials Selection In The CPI

An overview of the many factors to be considered when selecting materials of construction

James J. Briem
Briem Engineering

IN BRIEF

Selecting a material of construction for process equipment in the chemical process industries (CPI) is normally not difficult. The material selection is often based on past industrial experience. With few exceptions, past experience is by far the best way to choose an acceptable material of construction. However, when past experience cannot be used as a guide, material selection can be complex and difficult. Unfortunately the complexity of the problem is often not fully recognized. The individual making the material choice may fail to consider all of the factors involved.

The objective of this article is to provide an overview of the many factors that should be considered when selecting a metallic or non-metallic material of construction. A checklist is provided in Table 1. Some of the many factors are obvious; others are not so obvious. Neglect of the not-so-obvious factors could result in costly equipment failures.

This article elaborates briefly on corrosion considerations, stress loading and a number of other factors that affect material selection. Initial and ongoing cost considerations are also reviewed.

Resources

Corrosion resistance is the first and most obvious factor to consider when selecting a material of construction for process equipment. The chemical environment provides the first clues to selecting an acceptable material. As mentioned, past industrial experience is the best way to address the corrosion issue. Other resources include laboratory corrosion tests, pilot-plant corrosion tests, published corrosion charts, data published by the National Assn. of Corrosion Engineers (NACE; Houston; www.nace.org), manufacturers data, textbooks, articles and materials consultants. Most of these sources are available on the Internet.

TABLE 1. MATERIAL SELECTION CHECKLIST
☐ Chemical environment
☐ Impurities
☐ Microbiologically influenced corrosion (MIC)
☐ Corrosion inhibitors
☐ Corrosion accelerators
☐ Chemical reaction inhibition
☐ Acidity
☐ Aeration
☐ Velocity [corrosion erosion and flow-accelerated corrosion (FAC)]
☐ Temperature
☐ Downtime corrosion
☐ Heat transfer
☐ Internal pressure
☐ Vacuum loading
☐ Residual stresses
☐ Thermal stresses
☐ Cyclic stresses
☐ Abnormal stresses
☐ Safety and health factors
☐ Codes and Specifications
☐ Product contamination
☐ Base material cost
☐ Ease of fabrication
☐ Finish appearance
☐ Desired life
☐ Reliability
☐ Availability
☐ Vendor
☐ Ease of repair
☐ Required maintenance
☐ Value of lost contents
☐ Value of downtime

Corrosive environment

In a corrosive environment, the primary constituents and their concentration ranges are usually known by the process or project engineer. Not so obvious, however, is the presence of impurities. The classic example of a harmful impurity is the chloride ion, which, under certain conditions, is known to cause stress-corrosion-cracking (SCC; Figure 1) and pitting of stainless steels. These insidious forms of corrosion can occur at concentrations as low as a few parts per million.

An impurity that is commonly found in water is bacteria. Bacteria cause a type of corrosion known as microbiologically influ-

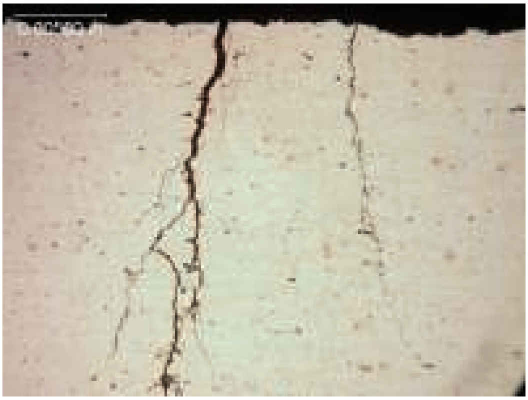


FIGURE 1. This is a polished and etched metallurgical cross-section of a stainless-steel pipe viewed at 200x magnification. The branching, transgranular cracks are characteristic of stress corrosion cracking

FIGURE 2. Microbiologically influenced corrosion (MIC) cannot be confirmed from visual inspection. Carbuncles near a weld seam are a strong indication of MIC. Fresh, wet carbuncles removed from a newly drained pipe can be cultured to confirm the presence of microbes and identify species present

enced corrosion, or MIC for short (Figure 2). This is a form of corrosion in which the bacteria can eat through stainless-steel tanks and piping in a few months. The bacteria primarily attack the retained, ferritic, metallic grains in stainless weldments, although MIC can occur in the base metal remote from weldments. The bacteria burrow caves (Figure 3). As observed with a scanning electron microscope, the cave surface has the appearance of a honeycomb structure (Figure 4). Unfortunately, most commonly used metals are subject to MIC attack to varying degrees.

The author's company is currently investigating MIC attack in a new processing plant at which the hydrostatic test water was left in the stainless-steel piping system for several months after the hydrostatic test. This stagnant water allowed bacteria to eat through several million dollars' worth of piping in a few months.

Some minor constituents of a chemical environment can actually inhibit corrosion. One not too obvious example of this is the inhibition of SCC of titanium in methanol. Titanium is subject to SCC in anhydrous methanol at room temperature, but if water is present in concentrations above 1%, the titanium will not stress-corrosion-crack. As another example, low concentrations of sulfites prevent oxygen pitting in boilers.

An infrequent, but potentially costly mistake is to select a material of construction that, if corroded, could inhibit a process chemical reaction. Nickel, copper and other metallic corrosion products have been known to kill a chemical reaction that was essential to the chemical processing operation.

The acidity of a chemical environment may have a significant effect on material selection. As a general statement, the lower the pH, the more aggressive the corrosion. A pH variation of a few points could make the difference between using a relatively inexpensive material and a costly material of construction. For example, a lower pH environment allows a lower chloride concentration to stress-corrosion-crack stainless steels.

The presence or absence of air (oxygen) may also affect the corrosion resistance of a material in a specific environment. The presence of O_2 or the occasional exposure to air may be necessary to maintain the protective oxide films on materials, such as stainless steel, which depend on a chrome-oxide film for corrosion resistance. On the other hand, the presence of air may destroy the corrosion resistance of a material that is normally not corroded in a reducing, O_2-free chemical environment. Boiler feedwater is a good example. A boiler can fail in six months if O_2 is present in the boiler feedwater. The same boiler could last six decades with deoxygenated feedwater.

Velocity

Velocity must be evaluated when selecting a material of construction, particularly when considering pumps, agitators, and other equipment subjected to relatively high fluid velocities. Velocity can manifest itself in a corrosive environment as "corrosion-erosion" or flow-accelerated corrosion (FAC). Of concern here is the fact that most published corrosion data are based on relatively stagnant corrosion conditions. Although there are a few exceptions, corrosion increases as velocity increases. An example is commercial-grade ambient-temperature sulfuric acid transport in carbon steel pipe.

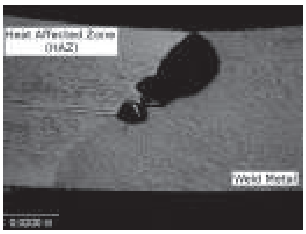


FIGURE 3. This magnified cross section of a weld in a stainless-steel pipe reveals a cave structure that confirms MIC. The cave structures typically occur at the boundary between a weld and the base metal

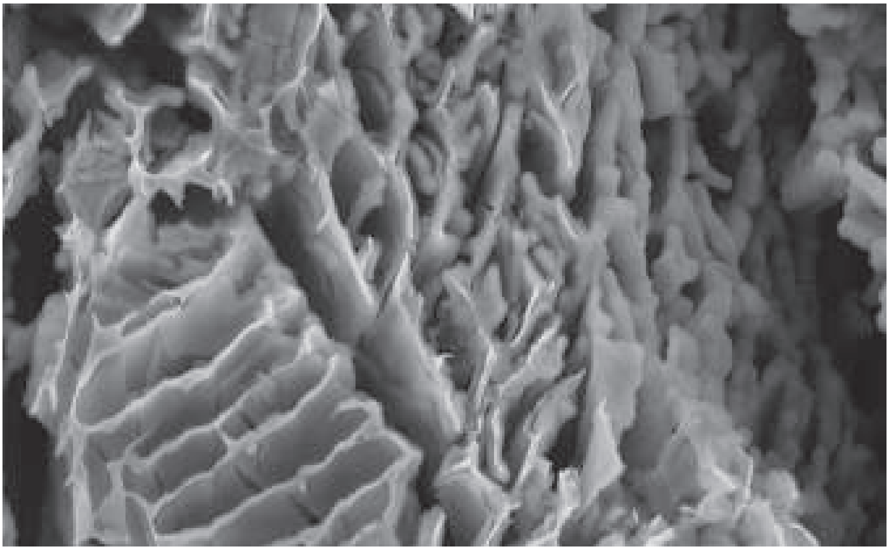


FIGURE 4. The honeycomb structure observed on the surfaces inside the cave confirms MIC. This is a scanning electron microscopic view at 1,800x magnification

At a velocity below 3 ft/s, the acid can be safely handled using carbon-steel pipe. At higher velocities, the protective iron-sulfate layer is stripped away from the pipe wall and corrosive failure occurs in a short time.

One notable exception to the above is microbiologically influenced corrosion. Bacteria like stagnant water. Flowing water inhibits MIC.

Temperature

The basic effect of temperature on the corrosiveness of an environment is well known by most process and project engineers. As a rough estimate, the corrosion rate doubles for every 10°C increase in temperature. This is essentially true up to the boiling point. If the operation is at a temperature above the dew point, in a gaseous state, the corrosion rate is essentially nil.

The above statements explain why condensing a corrosive gas results in corrosive attack that would not occur if the operation is kept above the dew-point temperature.

The effect of temperature must be carefully assessed for each environment. Many material failures occur because the temperature evaluated was the mass temperature of the corrosive material in a vessel, not the higher inside-surface temperature of a steam-jacketed vessel.

Cleaning/sanitizing operations

Consideration should be given to the procedure and frequency with which the process equipment will be cleaned and sanitized. It is not unusual for the cleaning operation to corrode processing equipment. Periodic cleaning with steam and cleaning agents can corrode processing equipment even though the basic production environment is non-corrosive. When designing for a specific operating environment, don't neglect the cleaning operation.

Surface finish/passivation

Surface finish is an important consideration particularly when dealing with stainless steels used in the pharmaceutical and food-processing industries. The surface finish must comply with U.S. Food and Drug Administration (FDA; Washington, D.C.; www.fda.gov) requirements to minimize the possibility of any bacterial growth on surfaces.

Another important finish consideration for stainless steel is the issue of surface passivation. Process engineers are familiar with the passivation of stainless steel with an oxidizing acid, such as nitric or citric acid. The passivation treatment produces a passive protection chrome-oxide film on stainless steels. This chrome-oxide film is responsible for the overall corrosion resistance of the commonly used austenitic stainless steels, such as 304 and 316. There is some controversy over the necessity for using a passivation treatment, either initially or at intervals while the equipment is operating. It is this author's opinion that the main reason for passivation is not necessarily to form the protective chrome-oxide film but rather to thoroughly clean the surface of any deposits on the surface that could initiate pitting corrosion of the stainless steel. Normally, stainless steel will self-passivate with intermittent exposure to the oxygen in the atmosphere. If there is no intermittent exposure of the stainless-steel sur-

FIGURE 5. This sprinkler system pipe sat too long without flushing or oxygen scavenger maintenance. Premature failure was caused by grooving corrosion of the longitudinal pipe welds

face to oxygen, then intermittent passivation treatments may be necessary to maintain the passive chrome oxide film on the stainless-steel surface. If this passive film is not maintained, the stainless steel becomes active and has a corrosion resistance approximating that of carbon steel.

Downtime corrosion

Corrosion that occurs when a piece of equipment is not operational can be more severe than corrosion that occurs when the equipment is online. Equipment that operates in a gaseous environment at moderate temperatures above the dew point will suffer more corrosion at lower temperatures than when online at an elevated temperature. An example of this is a boiler economizer operating in fluegas containing SO_2.

In a recent project, a boiler firing a biofuel gas with high-sulfur content failed in less than a year due to frequent shutdowns. A large fire-suppression sprinkler system sat stagnant and failed due to grooving corrosion (see Figures 5, 6 and 7).

Material properties

The next group of factors affecting materials selection includes mechanical and physical material considerations.

On occasion, the thermal conductivity of a material may determine its acceptability for process equipment, the most obvious example being heat exchangers. Low thermal conductivity may be desirable for certain equipment. For example, an un-insulated fiberglass-reinforced plastic tank may be more economical than an insulated carbon-steel tank.

Evaluation of internal pressure is addressed by standards, such as the ASME Boiler & Pressure Vessel Code and the ASME Piping Codes, and needs no elaboration here.

The intended or unintended presence of a vacuum should be considered. Be cautious of potential vacuum loading resulting from steam collapse in storage tanks. Vents frozen shut by ice or corrosion product have caused many tank failures when cold weather conditions caused steam to condense inside the vessel, creating a vacuum.

Both metallic and non-metallic equipment may contain residual stresses that are usually produced during equipment fabrication. Forming, welding and machining metals may result in significant residual-tensile stresses approaching the yield strength of the metal. These residual stresses are often the primary cause of SCC. Residual stresses may contribute to corrosion fatigue failures.

Thermal stresses are another consideration that should not be neglected for process equipment operating at non-ambient temperatures. Thermal stress occurs in a monolithic material that operates at different temperatures in different locations. Thermal stresses are also important when combining different materials with different coefficients of thermal expansion. Consider a plastic-lined vessel where the thermal expansion of the plastic can be an order of magnitude higher than the substrate steel.

Cyclic stress is often overlooked or underestimated. Cyclic stresses cause fatigue failure. Fatigue is the failure of a material under cyclic loading at a stress level well below the published tensile strength of the material. As a very rough estimate, fatigue strength is only about half the tensile strength of the material. In a corrosive environment, cyclic stresses can result in "corrosion fatigue," a stress-related material failure that can occur at a stress below the normal fatigue strength of the material.

Most published fatigue data are for fatigue strength in an air environment. When corrosives are present, the fatigue strength is even lower and if failure oc-

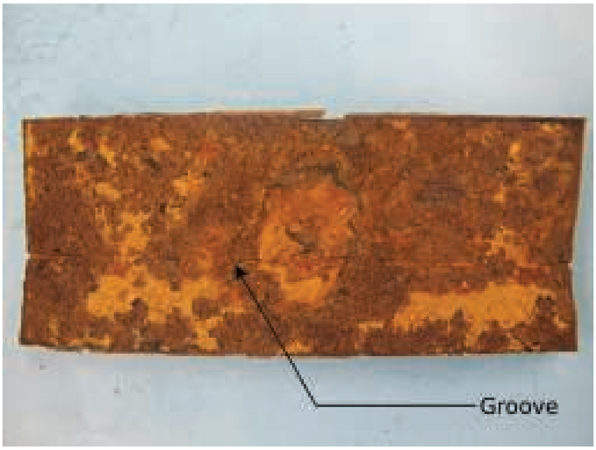


FIGURE 6. Stagnant water inside the sprinkler pipe caused grooving corrosion of the longitudinal weld seam

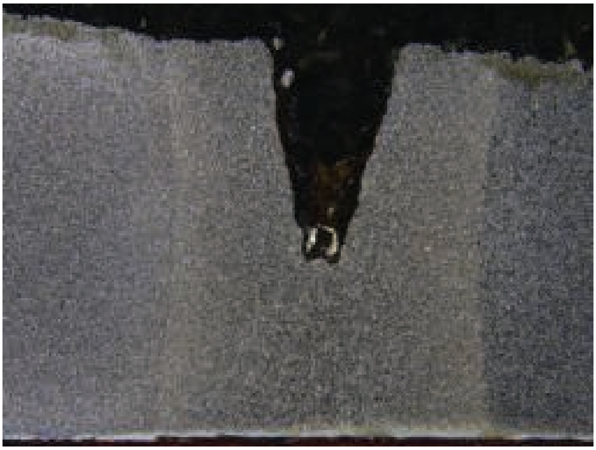


FIGURE 7. This metallurgical cross section of a sprinkler system pipe reveals grooving corrosion of the longitudinal weld seam. The grooving corrosion is caused by the weld seam being anodic (corroding) relative to the rest of the pipe wall, which is cathodic

curs, the failure mechanism is defined as corrosion fatigue.

Abnormal stress loads must be considered. Examples include pump vibration loads, loads resulting from agitator mountings, and, of course, the impact of an errant fork truck.

Safety

Today's increased concern for safety and health has had its impact on materials of construction. In the area of safety, it's easier to comply with an OSHA (Occupational Safety and Health Assn.; Washington D.C.; www.osha.gov) guard-rail requirement on a metal tank than on a plastic tank. Asbestos is no longer an acceptable material of construction. In the food and pharmaceutical industries, the material selection is often limited to a material that is virtually impervious to chemical attack.

Another factor to consider is the degree of hazard to humans and the environment that could result from the accidental release of hazardous materials contained in a vessel or pipe should failure occur.

The government, industry and individual companies have codes, standards and specifications that will often impact or even determine the selection of a construction material. These codes, standards and specifications must be considered when selecting materials of construction.

Cost

Naturally, in selecting a material of construction, the objective is to find a material that will result in a long safe service life at a reasonable cost. In assessing the economics of a material, both initial cost and lifecycle cost should be evaluated. A normal and reasonable first step in evaluating initial cost is an assessment of basic material cost. Consider the ease of fabrication. Are the materials easily formed, cut, bonded, drilled or welded? Is heat treatment required?

Finish and appearance will impact cost. Polished stainless steel may be necessary for equipment used in the food and pharmaceutical industries. Sprayed foam insulation is less expensive and less attractive than lagged, block insulation.

The life expectancy and desired reliability of the equipment may impact initial cost.

As an example of the result of the tradeoffs between initial cost and lifecycle cost, consider the bulk storage of commercial-grade sulfuric acid. The standard practice is to construct a new carbon-steel aboveground storage tank to API 650 standards using a 1/8 to 1/4 in. corrosion allowance. The steel may be specified as copperized to slow sulfuric acid attack. During the life of the tank, periodic thickness surveys are performed to monitor thinning of the shell. Toward the end of the tank's life, capacity may be reduced because of thinning of the lower plate courses. In this case, the best solution is a low initial cost with careful monitoring of vessel condition.

Material availability and the choice of a vendor will affect cost. Selecting a relatively exotic material that is fabricated by only a few vendors could significantly increase the cost and extend the delivery time of the equipment. This could impact overall project costs if the lack of availability delays startup because of extended delivery times. Consider also the qualifications of a vendor. A sound, basic material poorly fabricated seldom performs well.

Unfortunately it is not uncommon to neglect consideration of ongoing cost factors when selecting a material of construction. Ease of repair, required maintenance and availability of spare parts should be considered.

The value and potential danger of the material stored in a tank may impact material selection. Some consideration should be given to process downtime should a material fail. These three factors may affect the degree of conservatism used in selecting a material of construction.

Austenitic stainless steels

Austenitic stainless steels, such as 304 and 316 stainless steel, are the most commonly used metals in the CPI. As such, austenitic stainless steels deserve some special attention here, not only because of their extensive use, but also because austenitic stainless steels are subject to some unusual forms of corrosive attack.

Austenitic stainless steels are subject to general corrosion, pitting corrosion, SCC and MIC. Of these, general corrosion, where the surface corrodes relatively evenly, is perhaps the most understood. With general corrosion, the rate of corrosion normally slows with time since the corrosive agent must diffuse through the rust layer before it can attack the stainless steel surface. Pitting corrosion of stainless steel normally occurs in chloride environments. With pitting corrosion, the rate of attack actually increases with time because the pit acts to concentrate the corrosive agents and the pit forms a localized galvanic corrosion cell. Both factors increase the rate of pitting corrosive attack.

MIC has been discussed above. The rate of attack can be very aggressive. MIC is capable of causing stainless steels to fail in a matter of months. Although most bacteria are killed by sanitizing the equipment, at a temperature of about 180°F, the caves where the bacteria live still remain. Reintroducing the corrodant allows the bacteria to reoccupy homes (caves) and the MIC continues. MIC is a tough problem to deal with.

As noted previously, stainless steels are subject to SCC. The two prime factors that cause SCC are stress and, as the name implies, a corrosive environment. The stress that is normally responsible for SCC is residual stress, such as found in the heat-affected zone of a weld or resulting from a forming operation. These residual stresses are usually significantly more critical than operational stress.

The corrosive environment primarily responsible for SCC of stainless steels is chlorides. The primary variables that effect stress corrosion are stress, chloride concentration, acidity and temperature. Each of these factors has a limit below which SCC will not occur regardless of the other factors. For examples, if the stress level is low enough then SCC will not occur regardless of the chloride concentration, the alloy or the temperature. Although there are exceptions, SCC rarely occurs at a temperature below 160°F. If one of the listed variables is kept below a threshold limit, the equipment will never fail from stress corrosion cracking.

When assessing chloride concentrations it is important to note that what may be stated as being only a few parts per million chlorides is not necessarily representative of chloride concentration on the stainless surface. Often the processing equipment is operating in a situation where the chlorides are concentrated. For example, in a heat exchanger, the heat may actually drive off the water and leave the chlorides such that the chlorides will salt-out to a concentration of half a percent, which is above the threshold limit for SCC.

Concluding comments

The purpose of this article is to make process and project engineers more cognizant of the many factors involved in properly selecting a material of construction.

If all of the factors reviewed in this article are carefully evaluated, the process engineer is well on the way to selecting the optimum material of construction. I mention this not because you need to consider them all for every application but to show you that there is a lot more to selecting an acceptable material than looking at a published corrosion chart. ■

Edited by Gerald Ondrey

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Part 1

Advances in Process Temperature Measurement: Trends and Technologies

Process temperature measurement is a constantly evolving field, and new technologies have allowed for more reliable measurements to be realized in many applications

Michael Cushing
Siemens Industry

IN BRIEF

SHIFT TO THIN-FILM RTDS

TRANSMITTERS VERSUS DIRECT WIRING

TRANSMITTERS VERSUS SWITCHES

INTEGRATED ASSEMBLIES

THERMOWELL DESIGN STANDARDS

HIGH-ACCURACY RTDS

CLAMP-ON RTDS

Process temperature is the most widely used measurement in the chemical process industries (CPI), and is crucial to the efficiency and effectiveness of many processes. Examples of CPI units where process temperature measurement is critical include reactors, distillation columns, evaporators, heat exchangers, boilers, furnaces and more.

The market for process temperature measurement continues to evolve as user industries and technologies change. In recent years, several trends have been observed in the temperature-measurement market, based on newly available technologies, as well as the desire to reduce costs and improve operations. Several of these trends are covered in this article, including the following:

- A decreased reliance on thermocouples (T/Cs) as users shift to thin-film resistance temperature detectors (RTDs)
- A preference for the use of transmitters with RTDs (Figure 1) versus direct wiring
- A shift toward transmitters instead of switches in safety applications
- The increased availability of integrated temperature assemblies
- The widespread adoption of thermowell design according to the standards of the American Society of Mechanical Engineers (ASME; New York, N.Y.; www.asme.org) Performance Test Code (PTC) 19.3 TW-2010
- New products that are designed to solve old problems, such as high-accuracy RTDs used for energy flow or custody transfer, and clamp-on RTDs that are specially designed for use with small pipes and corrosive applications

FIGURE 1. An RTD assembly with a transmitter mounted in the connection head is becoming a popular option, as industry trends indicate a shift away from the use of direct wiring and switches

This article discusses these trends and the impact they have on process-temperature measurement.

Shift to thin-film RTDs

Temperature is the most commonly measured variable in process control, with over $400 million in RTDs and T/Cs sold annually in the U.S. alone, with about 30% of that total being used in the CPI, according to Global Automation Research (Minneapolis, Minn.; www.globalautomationresearch.com). Over the years, the industry has experienced a great deal of evolution in sensors and available physical-construction options. While the options are numerous, the optimum configuration for a particular application is not always clear. However, there continues to be a steady shift toward the use of RTDs in lieu of T/Cs across the board.

Concerns about maintenance, cost and accuracy are the primary drivers in the shift to the use of RTDs from T/Cs. Although, in many cases, T/Cs will have a lower initial cost when compared to RTDs, users may find that the value of the accuracy and stability offered by RTDs exceeds the initial cost savings of installing a T/C. The shift away from thermocouples is also reinforced by a trend toward the use of thin-film RTDs from wire-wound designs, since the cost difference is much less than with wire-wound devices. Additionally, with recent advances in technology, users may find that the benefits of an RTD can be obtained at a lower price premium than in the past.

Still, applications do exist where the use of a T/C makes sense, including those where the process temperature exceeds the limit of an RTD (1,200°F), or when a very fast response is needed. However, there are some fast-response RTD designs available that may also negate the use of T/Cs in the latter case.

Thin-film RTDs are typically limited to temperatures of 500°F, while wire-wound elements can withstand temperatures up to 1,200°F. Also, due to the construction of the sensing element, thin-film RTDs do not perform as well in environments where high levels of vibration or severe mechanical shock occur.

Transmitters versus direct wiring

The majority of process temperature measurements are still wired directly to the control system or to the recorder in use. This is usually done when the controller is relatively inexpensive and is located close to the measurement point. Transmitters can provide functionality without direct wiring, instead interacting with the RTD directly, and there are several benefits to their use with RTDs, detailed in the sections below.

Decreasing wiring costs. Standard 4–20-mA wiring is far less expensive than RTD or T/C wiring. This difference can be verified by calculating the distance of the wire runs and the cost of the T/C wire, and comparing this value with the cost of the standard signal wire plus the transmitter. The cost of three- or four-wire RTD cable makes the decision easier as well, although a four-wire design allows the use of a lighter grade of wire.

Protecting signals from noise and grounding problems. Operating with bad input data can cause off-specification product and increase material and energy usage. Transmitter circuits are designed to minimize the impact of noise that can affect input data. This is particularly useful when the temperature measurement is occurring near electrical equipment that may generate high radio-frequency interference (RFI) or electromotive-force (EMF) levels. The transmitter also provides electrical grounding.

Reducing hardware and stocking costs. Field sensors are connected to the distributed control system (DCS) and programmable logic controller (PLC) via input and output cards. Each input/output (I/O) card has a fixed footprint, so these cards will often limit the number of field-temperature devices that are connected, since they may require up to four wires versus two for standard 4–20-mA devices. The DCS or PLC direct-temperature input card is usually more expensive per point, and sometimes has a lower density (fewer points per card) that can increase the overall I/O cost. Using a universal input transmitter also reduces the variety of transmitters that must be stocked as spares.

Enhancing accuracy and stability. Transmitters can be ranged to only view a narrow span (say, 50 to 250°F), whereas a direct input must be able to process the full range of sensors used. The smaller range also provides better resolution and accuracy.

FIGURE 2. New integrated designs provide a thermowell, RTD, transmitter and local LCD display within a single device

Simplifying engineering and preventing miswiring. With only standard 4–20-mA input cards on the system, there is less need to group and segregate the temperature inputs. Maintenance of the I/O system is also made easier, and fewer I/O card spares will be needed.

Easing future upgrades. When a temperature instrument has been upgraded from a T/C to an RTD, it is much easier to make the change when only a short run of T/C wire needs to be replaced.

Transmitters versus switches

For safety applications, there is a growing recognition of the value of using a transmitter instead of a switch. This is because a transmitter has a "live zero" functionality, meaning that the 4–20-mA signal range indicates that the unit is working at a 0% output (4 mA). For a switch, the output possibilities are "zero" or "one," with the "one" value normally indicating that the switch's trip point has been exceeded. A "zero" output could result from a good measurement or a failed switch. This means that the information supplied by this measurement is less reliable than that provided by a transmitter.

The improved diagnostics available with smart devices make this position even more obvious. Engineers are increasingly using international standards, such as the International Electrical Commission's (IEC; Geneva, Switzerland; www.iec.ch) IEC 61508, IEC 61511, and the International Society for Automation's (ISA; Research Triangle Park, N.C.; www.isa.org) ISA S84 for designing their safety systems. Users even have the option to purchase temperature transmitters that have been tested and rated for safety-integrity levels (SIL) 2 or 3, as required for the process. This methodology is recommended.

THE CALLENDAR-VAN DUSEN EQUATION

The Callendar-Van Dusen (CVD) equation is used to define the relationship between resistance (*R*) and temperature (*T*) of platinum RTDs. It is also used in the international standard IEC 60751. For a more accurate relationship, the ITS-90 (International Temperature Scale) published by the International Committee for Weights and Measures is used. For the range from –200 to 0 °C, the CVD equation is as follows:

$$R(T) = R_0[1 + AT + BT^2 + C(T - 100)T^3]$$

For the range between 0°C and 661°C, the equation is shown below:

$$R(T) = R_0(1 + AT + BT^2)$$

Originally developed by British physicist Hugh Longbourne Callendar, and refined by M. S. Van Dusen, the CVD equations are used to determine the temperature-resistance behavior for platinum resistance temperature detectors. The CVD coefficients *A*, *B* and *C* are temperature-dependent, and can be determined for a specific RTD by using calibration techniques in a laboratory.

As an example, the coefficients for a Pt100 resistor (a platinum-constructed, 100-Ω RTD) according to the IEC751 and ITS-90 standards are given below:

- $R_0 = 100\ \Omega$
- $A = 3{,}908 \times 10^{-3}\ °C^{-1}$
- $B = -5{,}775 \times 10^{-7}\ °C^{-2}$
- $C = -4{,}183 \times 10^{-12}\ °C^{-4}$

Yet another coefficient, ⊠, is a linear parameter defined as the normalized slope between 0 and 100 °C, as shown below:

⊠ = $(R_{100}–R_0)/100 \times R_0$

For Pt100 RTDs — the most frequently used RTD type — ⊠ will be equal to 0.00385, per IEC 60751 calculation standards.

Integrated assemblies

Another trend in the industry is the growing use of integrated assemblies for process temperature measurement. An integrated assembly, as seen in Figure 2, provides a thermowell, RTD, transmitter and local LCD display with a single model number. This reduces costs for both suppliers and users by simplifying order processing and reducing installation costs. With an integrated assembly, the user gets a fully tested system, calibrated to match the sensor.

Thermowell design standards

In 2010, ASME updated its thermowell design standard (ASME PTC 19.3TW-2010) for the first time in many years, in response to numerous reports of failures. The consequences of poor thermowell design can be quite severe, including equipment damage, environmental incidents and loss of life. The new standard can be used for all common well styles — straight, tapered or reduced — and is intended to improve mechanical integrity and help to avoid issues created by excessive vibration, which causes sensor damage. Calculations to meet the new ASME standard should be available from suppliers.

High-accuracy RTDs

RTDs are rated for accuracy according to the IEC 60751 standard. For more details on IEC 60751 accuracy standards for temperature instruments, please see Part 2 of this Feature Report, "Transmitter-Sensor Matching Improves RTD Accuracy" on p. 46. Per IEC 60751, a Class B RTD has an accuracy of ±0.3°C, while a Class A RTD has an accuracy of ±0.15°C at 0°C. High-accuracy RTDs (what are called Class AA or A+) can have an accuracy as high as ±0.03°C, depending on the device and process conditions. Typically, per IEC 60751, Class AA RTDs are rated with an accuracy of 0.1°C at 0°C.

High-accuracy RTDs can be used for several applications where such precision is beneficial, including custody transfer and energy flow. Energy flow, measured in Btu/h, is used to determine the efficiency of heat exchangers and chillers, and is used for advanced control of distillation columns measuring the hot-oil flow in the reboiler and the internal reflux rate of the reflux drum (Figure 3).

When attempting to achieve the ultimate accuracy, the user has two options. First, Callendar-Van Dusen (CVD) data can be used for sensor matching from the RTD (usually a class B) and adjusted for the error in the transmitter (see the box above for more details on CVD calculations.) The second option is simply using a high-accuracy RTD. Several advantages of selecting a high-accuracy

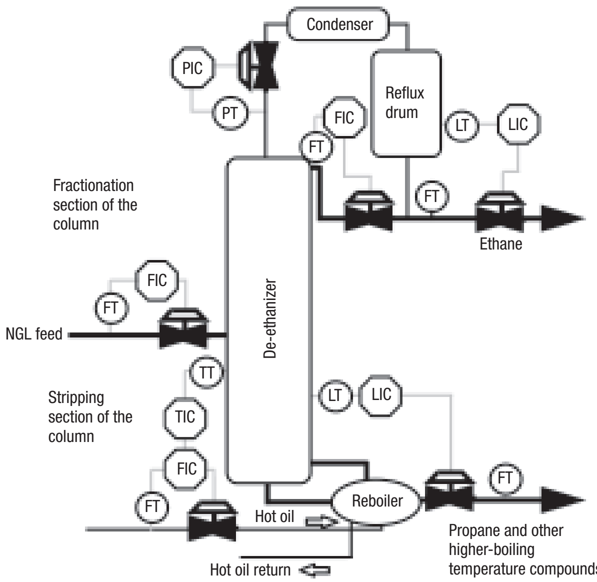
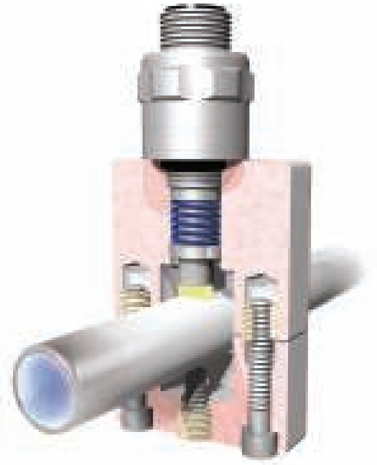


FIGURE 3. High-accuracy RTDs come in handy for energy-flow applications for the reboiler and reflux drum on a distillation column



RTD are as follows:

- Element selection results in a higher-purity platinum, which provides improved accuracy and stability
- Inherent ability to minimize the effects of self-heating
- The RTD is not married to a particular transmitter. This allows RTD, transmitter and sensor interchangeability
- Reduces downtime
- Eliminates any costs and fees associated with CVD calibration
- Satisfies the need for the best-possible accuracy at the point of measurement
- Improved linearity allows two-point calibration for purposes of recertifying, rather than five points as recommended by CVD
- Provides actual point-to-point accuracy rather than linearization (around three to five temperature points) with the CVD algorithm

Defining the required accuracies using a simple mathematical formula can help to determine whether a Class A or B device will provide the acceptable tolerance. Equations (1) and (2) below provide the definitions for Class B and A, respectively, where temperature (T) is measured in °C.

$$\text{Class B: } \Delta T = \pm(0.3 + 0.005T) \quad (1)$$

$$\text{Class A: } \Delta T = \pm(0.15 + 0.002T) \quad (2)$$

For example, using Equation (1) for Class B, the accuracy of the element at 100°C is ± 0.8°C. In the range of 0 to 100°C, high-accuracy RTDs improve upon the accuracy of a Class B RTD by an order of magnitude. Therefore, in this range, the Class B formula can be used, with the accuracy value increased by an order of magnitude. Using this method, the accuracy at 100°C would be ±0.08°C for a high-accuracy RTD.

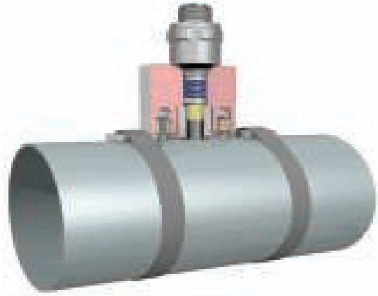


FIGURE 4. Clamp-on RTDs are useful in applications where very small pipes are required (left), but can also be used with large pipes (right). Clamp-on instruments are also beneficial in applications where the process conditions could be damaging to inserted instrumentation, such as with very corrosive materials

Clamp-on RTDs

In processes with small pipes, especially in laboratories or pilot plants, it can be very difficult to obtain an accurate temperature measurement. One solution is to use an external, clamp-on RTD (Figure 4) that is designed specifically to match the outside diameter of the pipe to maintain maximum accuracy. These RTDs can be calibrated to account for the thermal gradient across the pipe wall to attain this high accuracy. Clamp-on RTDs are an acceptable alternative to traditional, inserted RTDs, because they demonstrate very similar behavior with regard to response and accuracy (Figure 5).

The clamp-on approach is also useful when dealing with corrosive chemicals, since the sensing element does not come into contact with the process itself, only the outside of the piping.

Although temperature is among the simplest of the primary process measurements used today, an awareness of the latest options available for temperature measurement can yield significant savings and improvements to processes. ■

Edited by Mary Page Bailey

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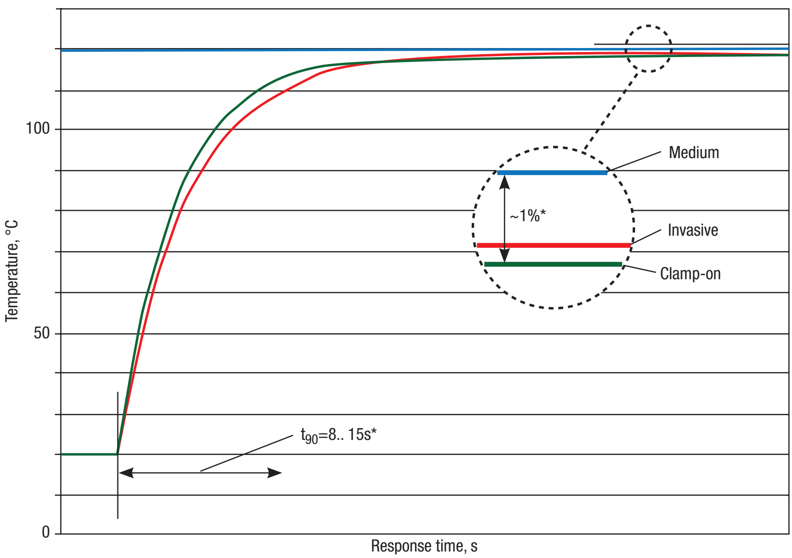

FIGURE 5. The accuracy and response of the clamp-on RTD compared to an inserted RTD show that they are very close throughout the response, meaning that the clamp-on is an acceptable alternative

Part 2

Transmitter-Sensor Matching Improves RTD Accuracy

RTD sensors will never exhibit behavior based on theoretical ideals, but understanding the fundamentals behind transmitter-sensor matching will enhance their accuracy

Keith Riley
Endress+Hauser

IN BRIEF

HOW ACCURATE IS AN RTD?

THE IDEAL CURVE IS NOT IDEAL

RTDS ARE NOT IDENTICAL

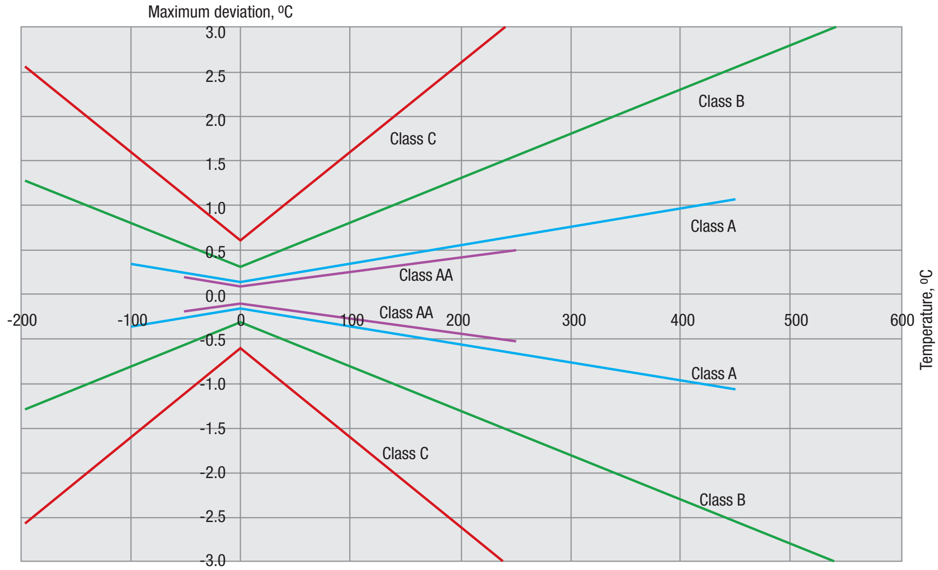

FIGURE 1. From IEC 60751 standards, RTDs can be categorized into four classes based on their accuracy

Temperature is the most common measurement in the chemical process industries (CPI). It is employed for a wide variety of purposes ranging from simple monitoring to the control of critical processes.

If monitoring and trending are the ultimate goals, a stable, highly repeatable measurement is all that is typically required. However, when temperature measurement is being used for process or quality control, the accuracy of the reading is much more crucial.

An example of a resistance temperature detector (RTD) in a monitoring application is on the inlet and outlet tube temperatures of a heat exchanger. Over time, the tubes of a heat exchanger will become fouled, and heat transfer will become less efficient. This efficiency drop is indicated by a reduced difference between the inlet and outlet temperatures, which can be monitored to ensure that proper heat exchange is occurring.

The operators who are responsible for controlling critical chemical processes — where reliable temperature information is required — must be certain that offsets in temperature measurements do not develop over time. The control system will act as it is programmed, based on the measurements it receives. Still, operators' skills are required to oversee what the control system is managing. Sometimes, even small shifts in reactor-temperature measurements can help guide an experienced operator or equipment-maintenance personnel to question the functionality of the process equipment or the process itself. Those responsible for process-optimization initiatives — where the objective is to fine-tune the efficiency or throughput of a process unit — depend on

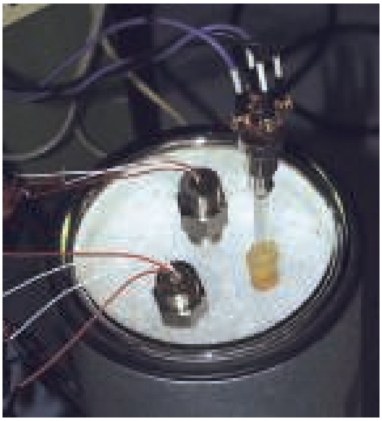

FIGURE 2. RTD probes are immersed in an ice bath at 0°C for testing and classification purposes

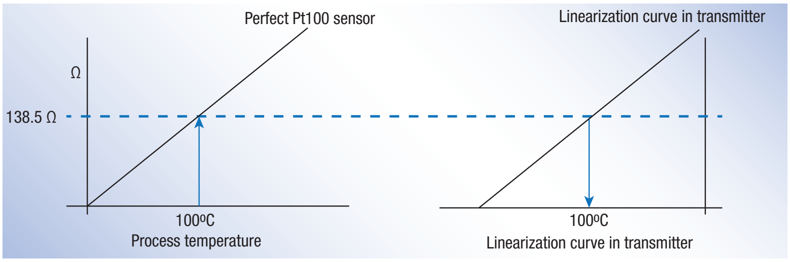

FIGURE 3. In a perfect world, the linearization curve will match the actual temperature, but this is not the case, due to a number of real-world factors

reliable trending data to make decisions on process adjustments. For example, it is extremely undesirable for the temperature information that is analyzed while troubleshooting or benchmarking the performance of a distillation column to be compromised by an RTD offset somewhere in the data trends or history. It goes without saying that an understanding of RTD accuracy and what data readings actually mean is important for personnel working in many different plant roles.

How accurate is an RTD?

When precise control is the goal, this leads to the inevitable question: "What company manufactures the most accurate RTD?" This is the wrong question. The question that should be asked instead is: "Does a particular company manufacture RTDs in compliance with International Standard IEC 60751?"

IEC 60751 specifies the ideal resistance-to-temperature relationship. It also qualifies the RTD classification concept, providing tolerances for each classification, as well as defining test procedures.

The ideal curve established by IEC 60751 for RTDs is the theoretical relationship between the resistance output, given in ohms (Ω), of the temperature probe and the temperature of the process. Unfortunately, no RTD ever follows this ideal curve. Component differences, such as wire diameter or manufacturing tolerances, prevent the temperature probe's performance from matching the ideal curve. Consequently, IEC 60751 has identified four classifications (Figure 1) to quantify the accuracy of individual RTDs. The four classes are as follows:

1. Class AA allows a tolerance of ±0.1°C at 0°C — this is the smallest tolerance, or minimal allowable deviation, from the ideal curve.
2. Class A allows a tolerance of ±0.15°C at 0°C.
3. Class B allows a tolerance of ±0.3°C at 0°C.
4. Class C allows a tolerance of ±0.6°C at 0°C — this is the largest tolerance for deviation from the ideal curve.

Testing to determine an RTD's classification is always performed at a controlled temperature of 0°C (Figure 2), the only valid test point, according to IEC 60751. This classification, and not the manufacturer of the RTD, is what determines RTD accuracy. From Figure 1, it is seen, per IEC 60751, that Class AA RTDs provide the highest levels of accuracy.

However, once RTD accuracy is understood, more questions may still remain. What avenues are available if an RTD is being used for process control, and the standard tolerance bandwidth according to IEC 60751 is not sufficient? A solution for improving temperature-measurement accuracy comes in the form of transmitter–sensor matching.

The ideal curve is not ideal

The default information that is programmed into a temperature transmitter is based upon the ideal curve. The ideal curve used in this article (Figure 3) is based on a Pt100 RTD.

The term Pt100 identifies the base resistance value for the RTD at 0°C. In this case, Pt100 means that this particular style of RTD will have a resistance of 100 Ω at 0°C. While Pt100 RTDs are the most commonly used devices in industry, there are other styles employed as well, such as Pt500 (500 Ω resistance at 0°C) and Pt1000 (1,000 Ω resistance at 0°C). These designations also identify the changes in resistance the unit will produce per 1°C change in process temperature, as follows:

- Pt100 = 0.385 Ω/°C
- Pt500 = 1.95 Ω/°C
- Pt1000 = 3.85 Ω/°C

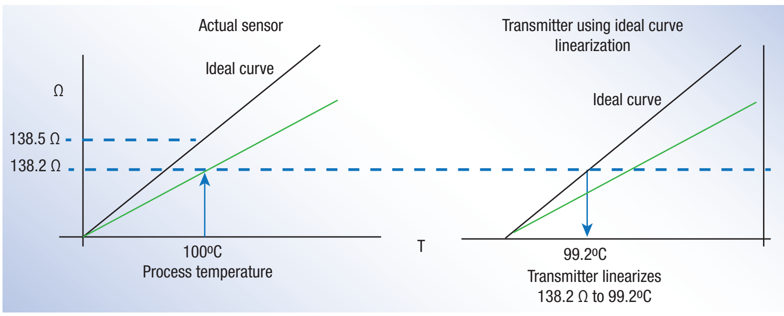

FIGURE 4. Standard linearization techniques in a temperature transmitter will produce errors. Here, the error is 0.8°C. The left side shows the comparison between the actual temperature sensor resistance value (green) and the ideal curve value at 100°C. The right side shows what the transmitter is going to actually generate as the value to the control system (black), which is 99.2°C

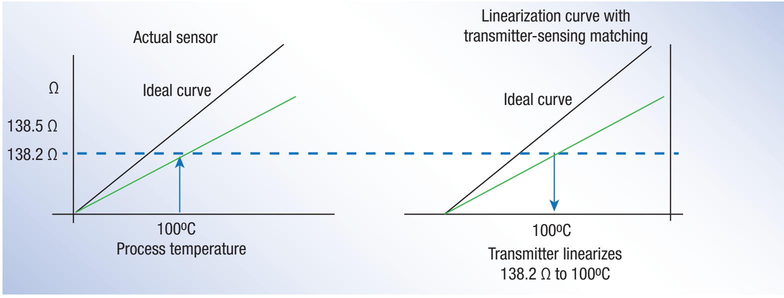

FIGURE 5. Transmitter–sensor matching produces a more accurate linearization curve than the ideal curve. The green line on the right shows the transmitter output that was linearized using transmitter–sensor matching

The vast majority of industrial RTDs are Pt100 devices. The primary reason for choosing a Pt500 or Pt1000 is for improved resolution due to the larger slope of their resistance change per degree Celsius.

For a Pt100 RTD at a given resistance value, the transmitter assumes that the corresponding process temperature matches the ideal curve for a Pt100 RTD, as shown in Figure 3. As previously explained, this will not be the case.

For example, using the ideal curve for a Pt100 RTD, the resistance at a process temperature of 100°C would be 138.5 Ω. This is also the information that the associated transmitter is expecting to see. However, this particular RTD actually provides a resistance value of 138.2 Ω when the process temperature is 100°C.

A transmitter using ideal-curve programming will provide the control system with a temperature value of 99.2°C based upon the 138.2 Ω resistance value it receives, versus a temperature value of 100°C for this resistance. This produces a 0.8°C measured error, as seen in Figure 4.

IEC 60751 identifies a process for platinum Pt100 RTDs where an equation developed by Hugh Longbourne Callendar and M.S. Van Dusen can be used to identify the unique performance curve for an individual RTD. This equation, called the CVD equation, is given in Equation (1). For a more detailed discussion of the CVD equation, please see the box in Part 1 of this Feature Report on p. 44.

$$R_T = R_0[1 + AT + BT^2 + C(T–100)T^3] \quad (1)$$

In the CVD equation, R_T is resistance at temperature T, R_0 is the resistance when T = 0°C, and A, B, and C are constants, commonly referred to as CVD coefficients. These values are specifically derived from each RTD sensor during calibration using laboratory-controlled baths at predetermined temperatures. The actual resistance at each of these points is recorded and used to develop the CVD constants, and to produce a performance curve unique to that specific RTD.

The CVD constants developed from the testing process are then programmed into the corresponding transmitter that is mated with the RTD temperature sensor. This produces a much more accurate linearization curve for that specific probe, and allows for optimal system accuracy.

If transmitter-sensor matching is performed on the RTD described in Figure 3, the 0.8°C error will be eliminated, producing a much more accurate measurement, as seen in Figure 5.

FIGURE 6. Many laboratories can calibrate sensors and transmitters, and determine CVD constants for an RTD and probe

RTDs are not identical

The expected improvement in accuracy with transmitter-sensor matching is difficult to quantify. Some manufacturers state that transmitter-sensor matching can improve accuracy by up to 75%. Depending upon the RTD in question, this may or may not be true. This degree of improvement may not be consistently realized for the two following reasons:

1. Accuracy will never be 100%, as there is a limited set of known test points when determining the real linearization curve for the RTD.

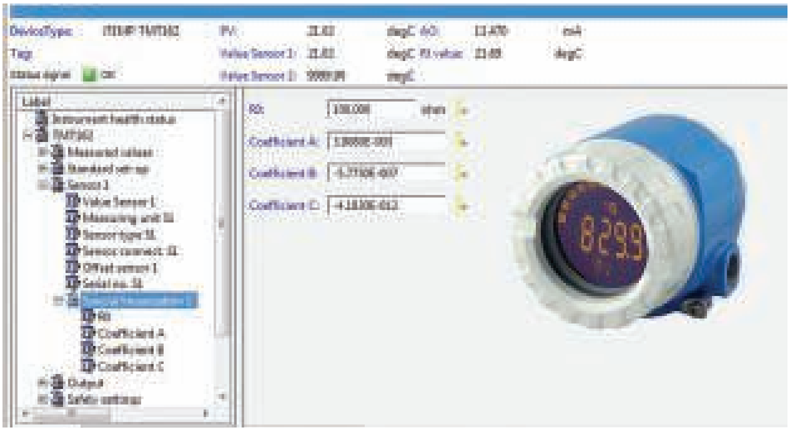

FIGURE 7. CVD data can be programmed into temperature transmitters using a number of commercial software programs. It is important to remember that new CVD constants must be specified when an RTD is replaced, even if the same transmitter is installed

Resistance-versus-temperature points that are not included in the testing of the RTD will not lie directly on the curve.

2. RTDs operate with varying deviations from the ideal curve, begging the question: "How close to the ideal curve was the RTD in question performing prior to identifying the real linearization curve?" Even if the RTD is a Class AA, the percentage of improvement will vary, depending upon if the unit was performing at the maximum allowable deviation, or at a point closer to the ideal curve.

A good analogy for the uniqueness of RTDs is monozygotic or identical twins. Even though identical twins are conceived at the same time from exactly the same "material," they are still unique individuals. On the surface, twins will look and even sometimes act alike, but they still maintain traits defining them as individuals. The same is true for RTDs, even those manufactured at exactly the same time using materials from the same production run.

It is important to remember that CVD constants are unique to a specific RTD. Consequently, if there is an assembly of a matched transmitter and sensor, and it becomes necessary to replace only the RTD temperature sensor, a new set of CVD constants for the RTD must be programmed into the transmitter. Should this step be overlooked or forgotten, the overall performance of the assembly will likely be worse than what would be realized by simply using the ideal curve values.

If a new RTD sensor is needed, there are two basic ways to reprogram the transmitter. The first is to send the RTD sensor and transmitter to a calibration facility, where the two will be matched in a laboratory (Figure 6). Many instrument manufacturers provide such a service.

It is important to remember that CVD constants are unique to a specific RTD.

The second method is to reprogram the transmitter using the CVD constants provided by the RTD manufacturer. With most "smart" transmitters, this is a relatively simple process. For example, a manufacturer may provide CVD data for input to an instrument-maintenance software program (Figure 7). An operator, maintenance technician or a service representative will then use the software and the CVD data to program a temperature transmitter with the correct information.

If the plant has an extensive instrument calibration laboratory, it can determine the CVD constants, and reprogram the transmitter accordingly.

The decision on how to proceed — that is, whether to use the normal IEC 60751 ideal curve or transmitter-sensor matching — is as unique as the RTD itself. Questions to ask when evaluating the best path forward include the following:

- What level of performance is required?
- What risks will be faced?
- Is there a cost-benefit concern?

For most monitoring applications, using the ideal curve and the standard Class AA, A, B or C performance expectations from IEC 60571 may be sufficient.

However, for control of critical applications or processes, transmitter–sensor matching might be needed. Overall system accuracy is not simply a matter of the RTD's measured error. It must also incorporate the performance of the transmitter as well, which is independent of the temperature sensor. Only calculating the combined effect of both components will yield realistic expectations for the accuracy of the temperature measurement. ■

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Filtration and Separation During Chemical Process Operations: Avoid Common Errors

The seven commonly made mistakes discussed here often lead to poor filtration and separation performance and many associated problems

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For almost any chemical process industries (CPI) plant, contamination is a reality that can cause numerous associated — and often chronic — problems. Some of the issues caused by contamination include: foaming, fouling, corrosion, solvent degradation and losses, deposition, undesired side reactions and impacts on downstream process operations. These problems invariably lead to capacity reductions, efficiency decay, inability to meet specifications, equipment failures and, high maintenance and operational costs. Problems with contamination can also lead to undesired environmental discharges and loss of profitability. Many of these detrimental effects can be mitigated by the use of proper contamination-control measures and appropriate separation technologies, such as chemical additives and mechanical separators and filters. This article focuses on proper mechanical separation.

Mechanical separation in chemical process operations, as related to contamination control, is generally undertaken in the following areas of the process:

- ***Feed stream*** — to remove contaminants from a process stream feeding a unit
- ***Effluent stream*** — to remove contaminants from the process stream leaving a unit
- ***Internal stream*** — To remove contaminants from a process stream that recirculates (such as amine solvents, glycol solvents and many other recirculating process solvents)

The predominant mechanisms for contaminant separation are as follows:

- ***Filtration*** — removes suspended solids in a liquid or gas stream
- ***Coalescence*** — removes free liquids and aerosols from a gas stream or emulsions from a liquid
- ***Adsorption*** — captures dissolved species, predominantly organic components, from a gas or liquid stream

Proper contamination control, prior to any chemical process operation, is essential to ensure plant stability, performance and low operational costs. This is often achieved when there is a thorough understanding of all inlet feed contaminants in a gas stream. Such an understanding will help to determine what separation process and system should be used.

Inlet contamination in chemical process units can vary drastically, and depends on a number of factors, including the following:

- Feed contaminant types, concentrations and variability
- Upstream processes for the feed and carried-over contamination
- Transmission methods and equipment used to take the feed material to the unit
- Chemical additives used upstream; along with a type and dosage amounts

Particle filters are most commonly used for removing suspended solids. These devices are most commonly in the form of disposable filters. These can provide a very cost-effective means of removing contaminants. They also have the advantage of physically removing the solids from the process — unlike backwash-filtration systems that typically recirculate the backwash stream (including contaminants) back to the front of the plant for reprocessing. With these systems, errors in design, errors in contamination variables, and errors in performance expectations can turn backwash systems into operational nightmares and lead to high operating costs.

Coalescers are used for the removal of free liquid contaminants

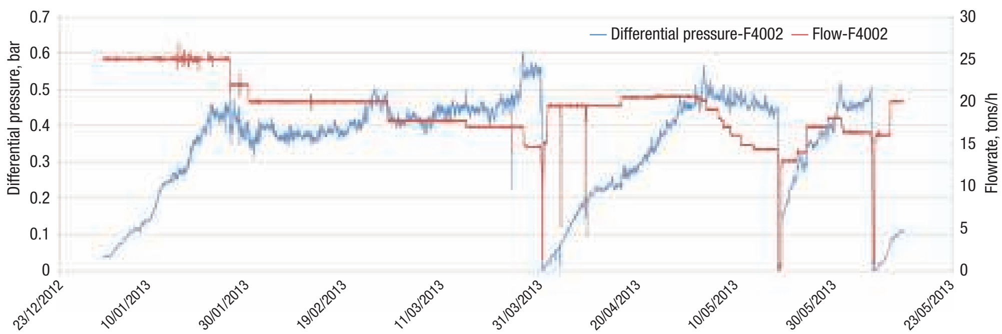


FIGURE 1. In this differential pressure trend for an automatic backwash system, note that the cycle times between backwashes decrease over time, indicating that the contaminants are not being fully back-flushed off the filtration media. The red line is the flow through the backwash filter, the blue line is differential pressure

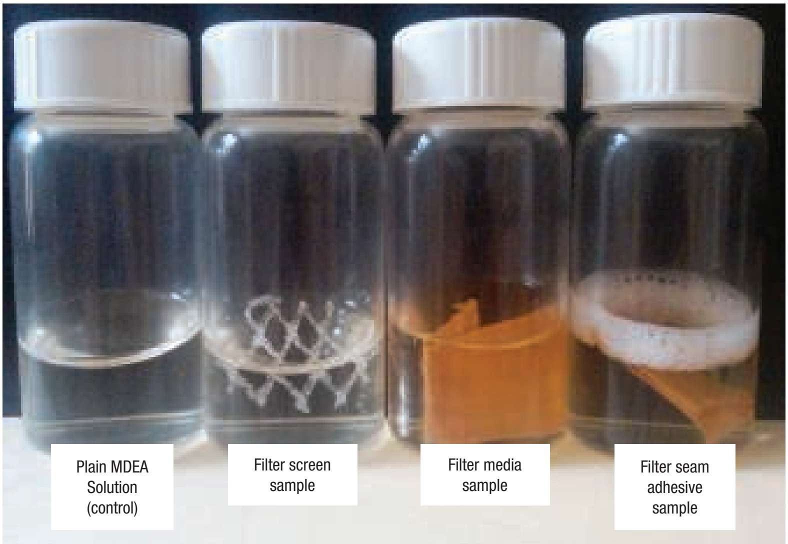


FIGURE 2. A "soak/foam test" was conducted to evaluate all of the materials of construction used in a particular filter element, to determine the cause of foaming in an amine solvent. This soak test was conducted at 77°F for 48 h, and following that, all vials were agitated for 1 minute (manually) and allowed to rest (to assess the development of foam). The photo was taken after the vials had rested for 10 minutes. In this case, the adhesive used in the filtration media was found to be the cause of the foam generation

from a gas stream or for separation of hydrocarbon and aqueous fluids, which can help a unit to maintain stable operation. But these devices make excellent particle filters, as well — although this is not their intended function. Coalescing elements are significantly more costly than a strict particle filter. If the process stream has a high solids loading, this leads to frequent plugging of the coalescing media, which can increase operational costs. Again, errors in application, design and expectation only drive costs up.

Adsorption devices such as activated carbon beds and molecular sieves, are not filters. But many plants operate in such a way that they act as a filter, and the buildup of unwanted materials can lead to premature replacement of the activated material. Again, errors in proper understanding of the feed contaminants often leads to poor performance.

Common errors

Certain CPI facilities may operate well with relatively high levels of contamination, while others can be severely disrupted at even minimal contamination levels. Each unit has to be carefully analyzed as a separate case in terms of characterizing the type and amount of contamination present and designing the most appropriate and cost-effective control measures. Too many operating facilities do not have appropriate contamination-control devices — their contamination-control techniques are either deficient or non-existent. During our work troubleshooting chemical process facilities, we have developed a set of general failure categories that cover the majority of the root causes. They are presented next as common errors of filtration and separation in CPI operations.

Error #1. Unsuitable technology for the application. This relates to the use of devices that are not able to properly function within the application or setting in which they are installed. Unsuitable technology selection often occurs in cases where poor understanding of the contaminants, or poor understanding of actual equipment performance leads to incorrect equipment selection.

In some cases, perceived capital cost savings also lead to incorrect equipment selection. One example of this is the use of automatic filters with metal-based filter media in high-fouling services. While this selection may seem like a good idea (to minimize maintenance), such devices do not perform adequately in all processes (and may actually be hindered by the presence of certain types of contaminants). Highly fouling liquid streams carry solids that may strongly adhere to the filtration surfaces. Sometimes these are semi-solids, whose buildup can cause many back-washable and other self-cleaning mechanical systems to perform well below expectations. The contaminants just cannot be removed to any significant extent because of the strong interaction with the filter media. This in turn requires frequent backwash cycling with large backwash volumes. The efficiency of the metal filter element seldom returns to initial performance levels.

For instance, Figure 1 shows the increase in differential pressure of an automatic filter in a process stream that contains fouling components. The blue line indicates the differential pressure. The red line is the flow. As shown, the mean time between backwash cycles becomes progressively shorter over time.

In addition, these suspended solids, in combination with hydrocarbon contaminants, are perhaps one of the most challenging mixtures to separate from a process stream. A secondary effect of using an automatic backwash system is that the backwash stream, with high entrained-solids content, must be treated elsewhere. When the effluent stream of the backwash system is used as the backwash fluid, this is typically recovered by reprocessing the backwash fluid. But reprocessing just ends up recycling the contaminants through the process if the solids and other contaminants are not physically removed.

Equipment such as pre-coat systems — which use diatomaceous earth as a filter aid — can provide effective separation, but they can create maintenance, waste and possible hazardous complications of their own. While these systems are important and have their applications in the CPI, the diatomaceous earth itself generates considerable waste quantities. This solid waste can also result in high product-fluid losses, as the waste is wet. And if H_2S is present in the fluid, the solid waste stream can also become toxic, and thus must be disposed as hazardous material or washed in some way. Diatomaceous earth also creates a fine dust when the filter is being replenished, and this can create a

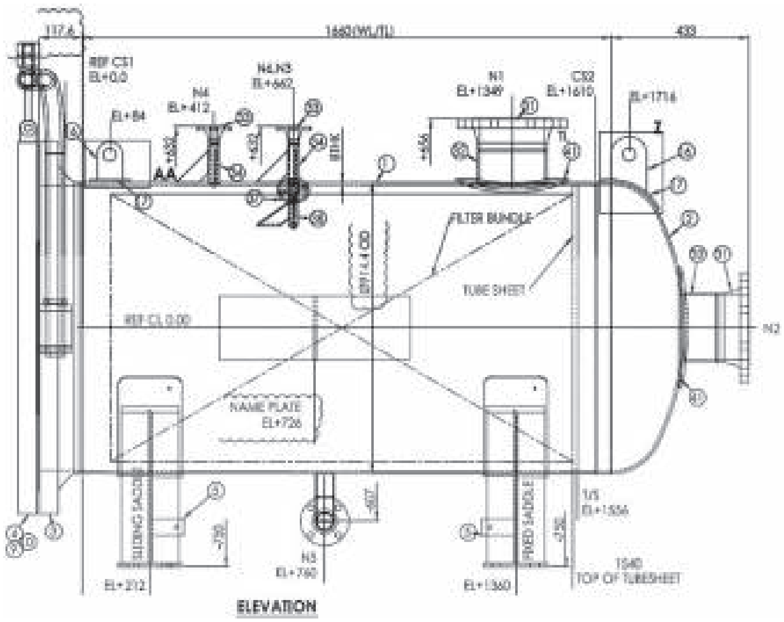


FIGURE 3. In this rich-amine particle-filter design, a vent and a drain were both missing. For this application, the missing vent led to the formation of a localized acid gas pocket and increased corrosion. With the missing drain, the process fluid was not allowed to be fully drained, since dirty filters that were plugged were holding the fluid back

breathing hazard and irritant, adding to the maintenance challenges.

The use of cyclonic separation devices can, to some extent, assist with solids separation, provided the contaminants have the right particle size and density. However, these units tend to be more appropriate for bulk separation. Application of cyclonic devices is quite specific and the operational windows are rather narrow. Hence, process variations (in terms of fluid stream, contaminant type or load) are not supported well by these devices without changes in their configuration. Nonetheless, the lack of moving parts and relatively high temperature-range capabilities make them attractive in many applications. Errors in contaminant characterization and unrealistic expectations of equipment performance can lead to poor separation efficiency. The industry is full of such technology misapplications. As a result, disposable filters are still one of the best alternatives for the removal of suspended solids in gas-processing operations.

Error #2. Incorrect compatibility (thermal, chemical, mechanical). When it comes to material compatibility, engineers should keep several things in mind. In general terms, the potential effects of contaminants or process fluid on the filter media and associated materials of construction (such as plastic parts, screens, epoxy adhesives and end caps), can be complex. These may include: chemical degradation of the media, media disassembly (such as media fiber release), media solubility (loss of media material), and media leaching (residues that are released from the media material).

Thermal compatibility is related to melting point (or softening point) of the material. High temperatures generally lead to deformation of the filtration media or plastic end caps, and this will likely increase chemical degradation.

Mechanical compatibility is directly related to the tensile strength of the material. In other words, how strong is the material under the actual process conditions? Chemical and thermal incompatibilities can lead to rapid mechanical degradation. An example of such a situation is the use of polyester filter media in any process that contains amines (either as a solvent or as a contaminant). Polyester undergoes chemical reaction with amine solutions, essentially causing the fibers to fail and the filter media to eventually rupture.

To illustrate chemical leaching effects, Figure 2 shows foam formation in an amine solvent caused by the epoxy adhesive in a filter. The epoxy is from the longitudinal seam that bonds the media together. Taken from an actual case study, this process unit experienced foaming in its absorber. After extensive investigation yielded no clear cause for the foam formation, the filter element was evaluated for its chemical compatibility with the process stream. A properly conducted soak test of all materials used in the filter element indicated that the adhesive used to bond the media was to blame for the foaming. As it turned out, incompatible filter elements were inadvertently used to reduce filtration costs. In the long run, this choice resulted in higher operational costs. A change to implement compatible filter elements eliminated the foaming problem.

Error #3. Deficient filter vessel design. As seen in many real instances of poor contamination control, a leading cause is often a defective vessel design. This can result from the following issues: undersized vessels; an unbalanced array of internals causing unbalanced flow distribution; incorrect internal flow geometries; incorrect placement of inlet or outlet nozzles; erroneous vent or drain locations; incorrect tubesheet thicknesses causing failure of vessel internals; lack of internal baffles resulting in damage to the internal elements (leading to media rupture); and others. In some cases, certain vessels can be modified, upgraded or improved. However, when vessels are undersized, there is little that can be done to affect the vessel's overall capacity. Undersized coalescer vessels will have considerable liquids carryover, and other separation systems will simply lack the necessary separation efficiency, leading to excessively high operational costs.

Figure 3 illustrates a vessel for a particle filter that was in a corrosive chemical service. As shown, there is a vapor vent (shown as N4 at the top of the figure) and a liquid drain (shown as N5 at the bottom of the figure) on the dirty (left) side of the tubesheet. However, there is neither a vapor vent nor a liquid drain on the clean (right) side of the tubesheet. There should be at least one vent

FIGURE 4. Shown here are coalescer elements with flat gaskets that have swelled and extruded out of place due to compatibility issues with the fluids they encountered during operation. Gasket swelling weakens the seal, creating leakage pathways

and drain on the clean side of the filter as well. In a process with H_2S or CO_2, the lack of this vent produces a pocket of gas. Without appropriate venting, this pocket cannot be eliminated, as there is no place for the gas to escape. The tubesheet separating the clean and dirty sides does not have holes high enough to allow the gas to escape and vent when filling. Meanwhile, the formation of a stagnant gas-liquid interface has a high potential for increased corrosion.

Draining the vessel will be a challenge as well. The vessel will be loaded with particle filters (not shown) which flow out-to-in, with the fluid flow moving through the tubesheet left to right. Once the filters are dirty and need to be changed out, the process fluid has to be drained through the drain valves. Because there is no clean side drain, the process fluid will have to try to backflow through the dirty filters, which will not flow easily because the pores in the media are plugged with particulates. The fluid will get stuck on the right side of the tubesheet. When someone goes to open the vessel and pulls a filter element off, process fluid could come gushing with it. This could be a potential safety issue.

Error #4. Inappropriate sealing surfaces. Often overlooked are the sealing surfaces, which have a direct impact on the performance of the filter elements. Sealing surfaces are present at the interface where the internal element — which is responsible for actual contamination separation — meets the vessel. These parts play a critical role in ensuring that the fluid is properly routed through the separation media without bypass. These seals are usually flexible gaskets or O-rings produced from elastomers. Each elastomer has its own compatibility issues with the fluids that it will encounter. Some filters use a knife edge that presses into the filter media and forgoes the use of an elastomer seal. The most common of these designs uses a "seat cup" that presses into the filter media. This type of seal has poor performance, and should only be used when chemical and thermal compatibility cannot be achieved with an elastomer. Flat gaskets are commonly used because they offer an inexpensive way to manufacture a seal on a filter. However, they must be aligned properly to work. If the compression on a flat gasket is uneven, it can enable leakage. This is especially critical for gas applications.

In Figure 4, the gaskets were not compatible with the process gas and they swelled. As a result of uneven compression and the presence of lube oil in the gas stream, the gasket extruded to one side, creating a by-pass channel for the lube oils. Elements that use O-rings as the seal should have been designed into the vessel. A piston-style O-ring seal generally provides even compression to the O-ring, as the compression is set by the end cap (this helps to eliminate the potential of overtightening by human error). The O-ring is also able to handle misalignment better without losing seal integrity. Even if the O-ring swells, the fact that it is encapsulated in its groove helps to keep it from extruding out while in service. Modification of the vessel to use elements with improved O-ring seals may be possible with custom internals.

Error #5. Wrong internals. This common problem relates to the use

FIGURE 5. Use of a filter element with incorrect media is a common problem. As seen in this example, contaminants accumulated at the surface of the filter element, but were blinding the media, preventing smaller contaminants from reaching the inner tapered-pore media, and resulting in reduced capture efficiency and shortened filter life

FIGURE 6. Due to the use of an incompatible lubricant grease, the lubricant solidified, cementing the elements into the vessel. The need to use force to remove the filter elements damaged the risers on which the elements sit

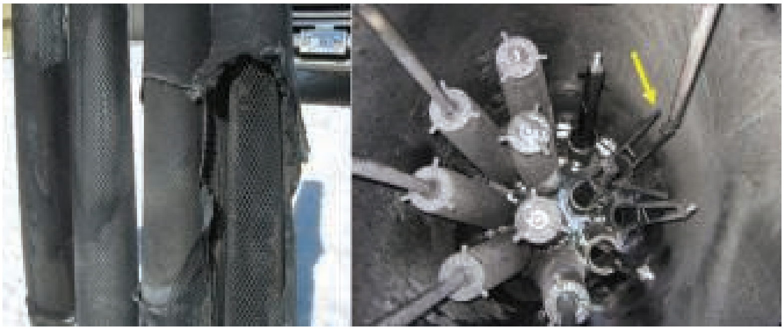


FIGURE 7. The ruptured coalescing elements and damaged riser support arm shown here were caused by excessive pressure drop across the vessel. Unfortunately, the pressure transmitter that should have provided an early warning of trouble malfunctioned due to below-freezing temperatures

of incorrect filter elements or coalescer-element designs and encompasses improper media selection. Filter elements with poor design and a non-optimal media surface area generally have reduced capacity for contamination capture and relatively low online life. This leads to increased maintenance requirements, and higher waste volumes and operational costs. However, when the design leads to excessive media surface area in a filter element, this will also lead to reduced contaminant-capture capacity, as a phenomenon called media blinding can take place. This occurs when parts of the media are collapsed together preventing even fluid flow.

Selection of the proper media efficiency is also an area where a number of failures can occur. Too often, operators have a poor understanding of the tradeoffs associated with the process separation, in terms of separation cost versus potential downstream effects of contaminants allowed to slip through. One must understand why a given contaminant must be removed (in terms of its potential impact on the process) and must understand the operational expectations of the filter at its location in the process. Sometimes extremely fine filtration is not needed. Other times, a filtration system that only captures relatively large solids is not sufficient to protect downstream systems.

To illustrate this, Figure 5 shows a filter that was designed with the expectation that it would operate as a depth filter. The expectation was that the filter would accumulate contaminants not only at the media surface, but also throughout the inner media layers, as the media was built with a tapered-pore structure. However, when the filter was cut open, one can see that only the outer media layer actually captured contaminants, leaving the inner sections relatively contaminant-free. An improved media array, using different materials with different capture efficiencies, produced a new filter element that was able to accumulate contaminants in all of its layers.

Error #6. Lack of or incorrect maintenance procedures. All separation systems need periodic human intervention for maintenance. Nonetheless, it is surprising how many filters and other separation systems go without proper maintenance. Many systems operate for years with no differential pressure increase, just to open the vessel and discover no filter internals. If a particle filter never builds differential pressure it is likely not working at all.

Proper maintenance of any separation system must start with a thorough internal inspection of the vessel, to detect any possible abnormality or damage. The sealing surfaces must be inspected to ensure that they are clear of solid deposits, minimizing the possibility of seal interference. And internals-replacement procedures must be reviewed periodically, to ensure the correct installation and operation of internals in the vessel.

To illustrate improper maintenance, Figure 6 shows the end cap of a coalescer element with missing O-rings used for sealing. Maintenance crews manually removed the O-ring, saying that this helped the element to fit better. Also, the photo shows a crusty white residue at the base of the end cap. This hardened material originated from the grease that was used to facilitate element installation on the vessel riser. The grease material reacted with the hydrocarbons in the gas stream and solidified, essentially cementing the elements into the vessel. Maintenance crews had to use a winch system to pull the elements out. However, unaware of the cause of the problem, they reused the same grease, creating a repeated pattern of problems. Meanwhile, the need to use force to remove the filter element caused damage to the internal support risers. Once the internal supports were repaired, the use of a proper (inert) O-ring lubricant led to a smooth element installation with both O-rings, and easy element removal with no material-compatibility issues.

Error #7. Instrumentation deficiencies. Another area that is often disregarded is the need for proper instrumentation. Some filtration systems have no instrumentation, while others have incorrect instrumentation. We often find that level-control instrumentation is specified exactly to expected liquid-contaminant density and has no tolerance designed in.

For example, level controls have to properly consider the density of the fluid that is to be detected (liquid-liquid or gas-liquid). If a liquid contaminant removed from a gas stream has a specific gravity of 0.80, the level indicator should be designed for 0.70–0.75, not exactly at 0.80 if using a float style device. This will allow variations in the liquid contaminant that may occur under process

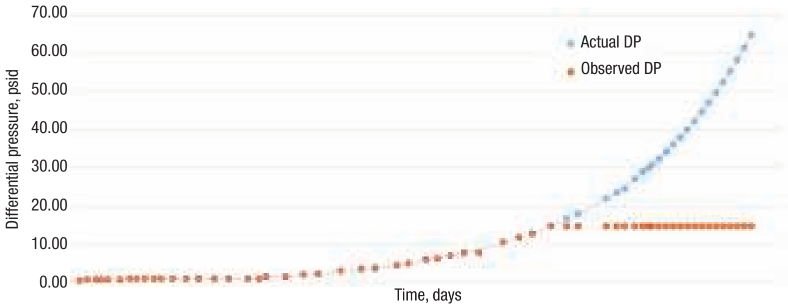


FIGURE 8. Shown here are differential pressure trends on coalescing elements that ruptured from high differential pressure. The red line is what was observed and the blue line is the actual differential pressure. The transmitter froze in cold weather, giving an incorrect signal

conditions.

The location of instrumentation is also important. Some instruments can be severely affected by the weather, such as extreme cold. Proper monitoring of differential pressure is particularly important, since it is often the main way some vessels communicate what is happening operationally with regard to contaminants. Figure 7 shows coalescing elements that experienced extremely high differential pressure that went beyond the recommended terminal endpoint and beyond their structural strength limit. What happened is that the differential pressure transmitter froze and the signal went flat.

Figure 8 shows what the operators saw in the control room. The red line is the observed differential pressure and the blue line is the actual. The differential pressure was slowly climbing but then, once the transmitter quit functioning properly, the differential pressure signal flat lined. Operators just assumed that it was normal. The reality is that any filter building differential pressure from contaminants, that suddenly flat lines, is a clear indication that something is wrong.

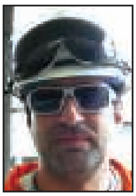
Particle filters often only have differential pressure devices, while coalescer vessels are much more complex. They use differential pressure gages, level controls and dump valves. Whatever the filter system, it is important that all of these components are properly working, especially when trying to troubleshoot. In addition, it's important to understand the trends and information gathered from the instrumentation. Otherwise situations can go overlooked that actually require immediate attention.

Concluding remarks

Invariably, the most important observation made during many years in the field is that poor contamination control is to blame for the vast majority of process upsets and has a direct impact on efficiency and operating costs. The seven common problems discussed in this article comprise the most common reasons why filtration systems do not operate as expected. Efforts to reconcile these common issues can improve contamination control and help to improve overall process control in the system. Also important to note is that efforts to reduce capital expenditures (by, for instance, opting for the lowest-cost separation and filtration options) will ultimately lead to higher processing costs, lower reliability, frequent unit upsets and a loss in profitability. This led us to develop the saying, "a cheap filter can be really expensive". Finally, each unit and process has its own equilibrium point where the cost of contamination control is acceptable and balanced with optimum efficiency levels. Engineering firms and suppliers have the responsibility to be involved in finding such balance with the objective of supplying the right separation and filtration solution for each individual plant. ■

Edited by Suzanne Shelley

Author



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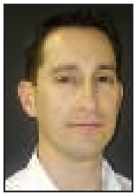

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Measuring Exposures to Aerosols and Dust

Accurate measurements of exposures to aerosols and dusts by plant personnel can be tricky. Here is some help for determining exposures and addressing uncertainties

Aaron Bird
CD-adapco

Uncontrolled aerosols (defined as suspensions of fine solid or liquid particles in gaseous media) in the chemical process industries (CPI) are of significant concern both as explosion hazards and as sources of adverse respiratory-health effects among exposed workers. Events such as the 2008 explosion of airborne and deposited sugar dust at the Imperial Sugar refinery in Port Wentworth, Ga., which killed 16 people and injured 42, are tragic, and conditions leading to this type of explosion are a legitimate cause for alarm. However, sometimes overlooked are the adverse health effects from long-term exposure to airborne contaminants. While the number of early deaths from chronic dust exposures has steadily decreased from a high of nearly 5,500 per year in the early 1970s, airborne dusts still contribute to the illness and early deaths of over 2,000 U.S. workers each year [*1*].

The combined risks of combustible-dust explosions, and of long-term exposure to airborne dusts make it clear that efforts to measure and control airborne aerosols, including dusts, must continue to ensure workplace safety.

Unfortunately, this is not a simple proposition. Barriers remain in determining accurate aerosol concentrations, controlling airborne and fugitive dusts, and knowing what regulations apply to the various sectors of the CPI. This article provides information on how sampling of airborne dust is conducted, how personnel exposures are calculated and how to deal with the uncertainty in those measurements, relative to compliance with governmental regulations.

Personal exposure

Exposure to airborne dust contaminants is determined in nearly every case by measuring the time-weighted average of exposure over the period of a single work shift in the breathing zone of the potentially affected worker. This is referred to as personal sampling for air contaminants. Compliance with legal limits is then determined by comparing the exposure value with the legal permissible exposure limit in a ratio called severity, *Y*, as follows:

$$Y = (\text{Personal exposure concentration}) \div (\text{Permissible exposure limit}) \quad \textbf{(1)}$$

Once *Y* is determined, the resulting ratio is adjusted by the sampling and analytical error [SAE; Equations (2) and (3)], and then compared with compliance criteria according to upper and lower 95% confidence limits. SAE is determined from statistical errors of the analytical method(s) used in the laboratory and is combined with the errors resulting from sampling and later handling. Combining errors in this way may result in large SAE values.

$$UCL_{95\%} = Y + SAE \quad \textbf{(2)}$$

$$LCL_{95\%} = Y - SAE \quad \textbf{(3)}$$

In Equation (2), UCL is the upper confidence limit and LCL in Equation (3) is the lower confidence limit. Compliance with Occupational Safety and Health Administration (OSHA; Washington, D.C.; www.osha.gov) legal limits is established when the $UCL_{95\%}$ is less than one. Non-compliance, along with a possible OSHA citation, is concluded when $LCL_{95\%}$ is greater than one. In the condition where LCL is less than one and UCL is greater than one, a possible overexposure is concluded.

For exposure concentrations close to the permissible exposure limit, the value of the SAE determines whether an overexposure (or possible overexposure) has occurred. As noted earlier, SAE values can be large, thus interpretation of how errors contribute to the SAE could mean a facility is in non-compliance with federal regulations even though the personal sample is less than the legal limit.

Interpretation is not just limited to personal dust exposures. It is the root of the issue for combustible dust safety, as well. LePree [*2*] outlines the U.S. Federal government's response to combustible-dust explosions by broadly applying the OSHA General Duty Clause in cases where standards, such as a combustible-dust standard, have yet to be written.

This can be confusing for business managers. The presence of clearly written standards — or the intentional absence of them — allows employers to confidently do business knowing they are in compliance with federal and state regulations. In situations where the law is ambiguous and where there is room for broad interpretation, it is arguably "safer" for processors to collect accurate measurements of workplace airborne concentrations using reliable tools and subsequently to control exposures to levels well below the regulatory limits than it is for them to risk being cited for noncompliance and allow unsafe, unhealthy conditions that could lead to explosion or illness.

Protecting workers' health and safety is of paramount importance, but can we go too far in creating overly protective workplaces? In the imaginary world of unlimited resources, the answer would be no. Unfortunately, we don't live in an imaginary world. Resources are indeed limited. Chemical processors feel constant pressure to deliver the highest-quality products, maximize throughput, keep inventories low, protect the health and safety of the entire community, and to have minimal impact on the environment. And these goals are sought within an environment of legal and statistical ambiguity. It is an unenviable position to be in. So what can be done?

There are two approaches that can be used to address this challenge. The first is statistical in nature and has immediate application, but it is also overly protective and likely very expensive. The other, engineering design of aerosol samplers, is a longer-term approach but would serve to allow for better characterization of variability so sampling and analytical error of dust exposures would be more tightly controlled. Both approaches are described in the following sections.

Aerosol sampling statistics

Correct and accurate measurement of aerosols in the workplace is dependent on the nature of the material being sampled. Currently, OSHA regulates approximately 500 air contaminants, of which around 10% are aerosols. Respiratory exposure to these materials, and many more that are not regulated, can result in severe adverse health effects or even death. In addition to the health hazard, many of these dusts are known combustion hazards. Table Z-1 of the Toxic and Hazardous Substances, (found in OSHA 29 CFR 1910.1000) is a complete list of federally regulated airborne contaminants and contains legal permissible exposure limits (PEL) for peak, short-term, and

TABLE 1. TWO WORKERS' FICTITIOUS EXPOSURES TO ALUMINUM TOTAL DUST (PEL 15 mg/m^3)

Worker ID	Location	Date	Exposure (mg/m^3)
094	Mixing	2014/09/06	4
0152	Intake	2014/09/06	1
094	Mixing	2014/09/07	6
094	Mixing	2014/09/08	6
0152	Intake	2014/09/07	3
094	Mixing	2014/09/09	5
0152	Intake	2014/09/08	5
094	Mixing	2014/09/08	4
0152	Intake	2014/09/07	13

1 Worker ID 094 GM = 4.919019 mg/m^3
2 Worker ID 094 GSD = 1.2249965
3 Worker ID 0152 GM = 3.73687570 mg/m^3
4 Worker ID 0152 GSD = 2.91100820
5 Worker ID 094 95th percentile statistic = 6.8684746 mg/m^3
6 Worker ID 0152 95th percentile statistic = 21.670059 mg/m^3

eight-hour work-shift exposures. The table lists exposure concentrations in parts per million (ppm) and mass per volume (mg/m^3). Generally, gas exposure levels have units in volume-based concentration as ppm, while dust exposures are mass-based concentrations in mg/m^3.

A number of recognizable materials are found in OSHA's Table Z-1 including aluminum, malathion, tin and many others. Malathion and tin have PELs for total dust. Aluminum has PELs for total dust and respirable dust. The distinctions between total and respirable dust are important to note because they reflect the location within the lung where disease would be present if exposure were to occur over long periods of time. Total dust refers to exposures that may affect the entire airway, from the nose and mouth down to the alveoli in the gas-exchange region of the lungs.

Total dust samplers collect all dust sizes that penetrate past the nose and mouth, which is about 100 micrometers (µm) and smaller. Respirable dust refers to the particulate matter that is of most concern when it penetrates past the upper and middle parts of the airway and then is transported into the gas-exchange region. These dusts are typically less than 10 µm in diameter and most are less than 5 µm. Conducting personal breathing zone (PBZ) sampling to generate a valid exposure measure requires that the correct sampling protocols be used. For malathion or tin, this would mean sampling for total dust. For aluminum, this could mean sampling for both total and respirable dust concentrations.

Instructions for conducting personal sampling are available in the OSHA Technical Manual [*3*]. Specific sampling protocols for hundreds of materials can be found in the NIOSH Manual of Analytical Methods [*4*]. Sampling undertaken "in-house" should receive oversight by an industrial hygienist who is certified by the American Board of Industrial Hygiene (ABIH; Lansing, Mich.; www.abih.org). Those who have earned this designation are referred to as Certified Industrial Hygienists (CIHs) and many processors have one or more employed as key members of their environment, safety and health departments.

TABLE 2. SIMPLIFIED VIEW OF AIHA EXPOSURE CATEGORIZATION SCHEME [*5*]

Exposure category	Rule-of-thumb description	Recommended interpretation
0	Trivial, non-existent exposures	$X_{0.95} \leq 0.01$ x OEL*
1	Highly controlled, limited exposure	0.01xOEL $\leq X_{0.95} \leq$ 0.1 x OEL
2	Well controlled, few exposures at low concentrations	0.1xOEL $\leq X_{0.95} \leq$ 0.5 x OEL
3	Controlled, frequent exposures at low concentrations	0.5 x OEL $\leq X_{0.95} <$ OEL
4	Poorly controlled, frequent exposures often at high concentrations	$X_{0.95} >$ OEL

*OEL is occupational exposure limit, which includes legal permissible exposure limits (PEL)

TABLE 3. RECOMMENDED STATISTICAL INTERPRETATIONS FOR EXPOSURE TO ALUMINUM TOTAL DUST

Recommended interpretation	Aluminum total dust PEL = 15 mg/m^3	Exposure cat.
$X_{0.95} \leq$ 0.01 x PEL	$X_{0.95} \leq 0.15$	0
0.01 x PEL $\leq X_{0.95} \leq$ 0.1 x PEL	$0.15 \leq X_{0.95} \leq 1.5$	1
0.1 x PEL $\leq X_{0.95} \leq$ 0.5 x PEL	$1.5 \leq X_{0.95} \leq 7.5$	2
0.5 x PEL $\leq X_{0.95} <$ PEL	$7.5 \leq X_{0.95} < 15$	3
$X_{0.95} >$ PEL	$X_{0.95} > 15$	4

Example exposure

Suppose the plant safety and health team, in concert with a CIH, has collected full-shift personal breathing-zone samples for two workers over the course of five work shifts. The safety and health (S&H) team thus has five total dust-aluminum measurements to use as indications of each worker's overall exposure. This is useful for understanding the extent of the exposure experienced by the worker, as well as for predicting what possible exposures may occur in the future. This strategy also allows for the development of a long-term exposure-control strategy and the mitigation of combustible-dust hazards, if present.

The example fictitious exposure data collected by the S&H team can be seen in Table 1 for workers with confidential identifiers 094 and 0152. These IDs would be known only to members of the S&H team and possibly to members of company management or human resources dept. In real air-sampling campaigns, the use of identifiers is common and identities are kept in confidence. Note that a large amount of data is collected when conducting air sampling campaigns, some of which is personal, and thus must be protected. Table 1 would represent a small subset of the entire data record.

In this case, we treat the personal samples as being lognormally distributed [*5–6*] and then calculate the geometric mean (GM), geometric standard deviation (GSD) and percentile decision statistics according to Equations (4), (5) and (6), as follows:

$$Geometric\ mean\ (GM) = \sqrt[n]{x_1 \times x_2 \times x_3 \ldots \times x_n} \quad (4)$$

$$GSD = exp\sqrt{\frac{\sum_{i=1}^{n}[\ln(x_i) - \ln(GM)]^2}{(n-1)}} \quad (5)$$

The GM and GSD can be easily calculated by hand. However, IHDataAnalyst software (EASi; www.oesh.com/software.php) can also be used to quickly calculate these values. For the data in Table 1, worker ID 094 has a GM of 4.9 mg/m^3 and a GSD of 1.2. Worker ID 0152 has a GM of 3.7 mg/m^3 and aGSD of 2.9 [*Editor's note: for exact values, see footnotes below Table 1*]. Because the collected air samples are part of the lognormal distribution, with GMs of 4.9 and 3.7, respectively, they accurately represent the data from within those distributions. Note the difference in GSDs between these two groups; one is relatively small, at 1.2, and the other is rather large, at 2.9. A quick look at the raw values for each worker reveals that one is tight (4, 6, 6, 5, 4), while the other has a broader range (1, 6, 5, 13). The tight grouping allows for confident prediction that the next sample taken for worker 094 will likely be close to these values. However, the broader range of the exposure groupings for the second worker opens the door to the possibility that the next value could be very high. This is problematic, as we will soon see.

Interpreting exposure data

Now that both the GM and GSD for the two workers are known, we can find any value from within the respective distribution by calculating a percentile statistic according to the following:

$$\hat{X}_{0.95} = GM \times GSD^{1.645} \quad (6)$$

The product of the geometric mean and geometric standard deviation raised to the power of the z-score for the desired percentile will result in a comparison statistic that can be used to assess risk [5]. We look in the standard normal z-table and see that the 95th percentile corresponds to a z-score of 1.645. Plugging in the GM, GSD and z-score for the grouping of samples for worker 094 gives a value for the 95th percentile statistic of 6.9 mg/m^3. We do the same for worker 0152 and get a 95th-percentile statistic of 21.7 mg/m^3 [*Editor's note: for exact values, see footnotes for Table 1*]. These two values are compared to the Exposure Categorization Scheme proposed by the American Industrial Hygiene Association (AIHA) [7] and further developed by Hewett [5] (Table 2).

For the current example, we are interested in the PEL for aluminum total dust, which is 15 mg/m^3. Applying this value to the recommended statistical interpretation column gives us Table 3.

Exposures seen by worker 094 are relatively low and close together, resulting in the 95th percentile decision statistic of 6.9 and thus the exposure category of 2, "well controlled, few exposures at low concentrations," provides adequate qualification. Those of worker 0152 are low and close together, with one significant exception (at 13). This single high value causes a much higher 95th percentile decision statistic of 21.7 for these lognormally distributed data. This value is well above the PEL of 15, and thus we could say the exposure is "poorly controlled."

It is notable that the lower mean exposure seen by worker 0152 (GM = 3.7) has the higher GSD (2.9), and thus has a much higher 95th percentile statistic. This is because it is associated with the broader range of values. The highest of these, 13 mg/m^3, may look like an outlier in comparison with the others in this exposure group. Instead, this value is a true measure of the worker's exposure to aluminum dust on the day it was collected and serves as an indicator that concentrations of this magnitude do exist. The wide variability of the exposure group sampling measurements for worker 0152 indicate that dust for the associated process is not being controlled. Further, this variability reveals that if this process continues uncontrolled, even higher exposure concentrations could occur. That is, the next sample taken could indicate that the worker is exposed to a concentration of aluminum dust well above 13 mg/m^3. We've already seen that an SAE of 20% would push this particular sampling result into a legal noncompliance category, indicating that overexposure has occurred. Moving toward the upper end of the distribution of measurements, we would see higher and higher concentrations, all of which would be above the legal limit. The worker could be at risk for adverse health effects and the plant operators would be held responsible for putting the worker in that position.

From here, additional exposure categorization work would be valuable, and is recommended. For example, this could include a recalculation of 95% upper and lower confidence limits, evaluation of the possible use of respiratory protection, adjustments to the ventilation (or other dust-control) systems, collection of additional sampling measurements, and subsequent reassessment of the exposures using a Bayesian approach. As before, such steps should be taken under the watchful guidance of a CIH.

Returning to the discussion of the samples in the second worker's exposure group, the wider variability reveals the presence of uncertainty in the system. The findings do provide enough information to begin taking steps to reduce the exposure concentrations to lower and more consistent values. Most likely this will begin by checking the performance of the ventilation and dust-control systems and then be followed by further investigations, if necessary. In addition to these, there could be other sources of variability and each must be characterized in order to make the system more reliable and predictable. One important source is the fundamental design and performance of aerosol samplers used to collect exposure samples. This aspect of uncertainty determination is taken up in the next section.

Aerosol sampler performance

Multiple samples within an exposure group will each contain multiple sources of variability, which is compounded when we look at the samples over time and space, and from sampler to sampler. Sources of variability buried within the exposure measurement include work rate, work behavior, process being sampled, environmental conditions, pump performance and sampler performance, among others.

Aerosol samplers used for sampling the size fraction listed in OSHA Table Z-1, known as total dust, include the 37-mm closed-face sampling cassette, the Institute for Occupational Medicine (IOM) Inhalable Sampler, and the SKC Button sampler. Of these, the first was not designed specifically as an aerosol sampler; rather, it was adapted from the field of water sampling. The latter two were designed in wind tunnels to meet the performance of the inhalability criterion that was established to mimic the concentration by particle size inhaled

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HOT PRODUCTS

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Hayward Flow Control www.haywardflowcontrol.com by a human [8–11]. Subsequent studies have shown that the 37-mm cassette performs like a designed inhalable sampler (like the IOM and SKC button) when wall losses are incorporated into the sample analysis [12–14]. The inhalable fraction expression is given as the following:

$$SI(d) = 0.5(1 + e^{-0.06d}) \qquad \textbf{(7)}$$

where $SI(d)$ is the sampling efficiency for the inhalable fraction and d is the particle diameter. This expression is intended to describe the percentage of particles in the air at specified diameters between 1 and 100 µm that will penetrate into the human airway.

Adoption of the inhalability criterion has now gone international after early calls to do so [15]. This also includes sampling efficiency prediction for thoracic (50% sampling efficiency cut-set at 10 µm) and respirable size fractions (50% cut-set at 4 µm), although this article is limited to discussion of the inhalable fraction. These performance metrics for aerosol samplers are now referred to as the CEN/ISO/ACGIH Inhalable Criteria. The criteria were developed in moving air conditions. However, there have been recent calls and studies regarding a calm-air sampling criteria. This makes sense considering that much of the air inhaled by workers really is calm, rather than constantly moving [16, 17].

The CEN/ISO/ACGIH sampling criteria are ideal and protective. These criteria essentially represent the expected average inhalability for humans over the range of particle sizes from 1 to 100 µm. The criteria are applicable only to inhalation. That is, when a worker inhales particles and then exhales, the fraction considered for potential illness comes from only the inhalation portion of total respiration. Physiologically, we know that many inhaled particles will be exhaled, however, the current convention is used because aerosol samplers are intended to be operated for continuous inflow, which in turn is a protective approach for assessment of potential illness due to occupational exposure. After all, every human has a different response to exposures and it would be nearly impossible, and certainly financially prohibitive, to continuously monitor every worker, all the time, for any signs or symptoms of illness. Instead, we control exposures to levels well below the PELs and consider any particles that penetrate into the human airway as potential risk candidates for onset of illness.

Aerosol samplers, therefore, should collect the size fractions that penetrate into the human airway. Designs of new samplers and redesigns of existing samplers should be based on optimization of performance according to the CEN/ISO/ACGIH Inhalable Criteria for moving air, as well as optimized for a calm-air performance standard. Aerosol samplers have been studied in numerous wind-tunnel and calm-air chamber experiments, but few have been intentionally optimized for agreement with human inhalability. Samplers designed in this way would allow for better characterization of sampling variability and thus reduction in uncertainty when assessing occupational exposures. ■

Edited by Scott Jenkins

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Tips for the Multitasking Engineer

These tips, based on experience, can help engineers keep on top of their many tasks

Elindoro S. Rodriguez
INVISTA

IN BRIEF

- ORGANIZE FILES AND EMAILS
- DOCUMENT EVERY PROJECT
- SHARE PROJECT CHANGE DOCUMENTS
- PRIORITIZE PROJECTS
- MANAGE THE SMALL TASKS
- SUMMARIZE ALL PROJECTS
- EXAMPLES

It is not uncommon for engineers to be working on multiple projects at the same time. Have you been in a situation where project priorities have changed and you are now expected to pursue one of your old, low-priority projects as a high priority? Although you last worked on it a year ago, your supervisor is expecting you to quickly pick up the pace as if you last worked on it yesterday. How about while working on various projects, you received a request for assistance from your sister company overseas. They are in urgent need of technical details for another project you were involved in more than a year ago. Fortunately, there is a way to become an effective multitasking engineer. This article shares a few tips that I have found useful over the years.

These tips will assist in managing not only the multiple high-priority projects, but also the many small tasks that constantly come up in one's day-to-day work activities. These will help engineers become highly organized, a definite requirement in today's fast-moving engineering technology and business innovation environment.

1. Organize files and emails

Prepare an electronic project-tree structure to organize and keep electronic records for every project you undertake. For example, the very top Level-1 folder could be labeled "Projects". Under this are Level-2 subfolders such as, "Process Area1," "Process Area2," Process Area3" and so on. Then for each area subfolder, create Level-3 folders, for example "1_projectx", "2_projecty", and "3_projectz". I have found it helpful to further create Level-4 subfolders under each Level-3 project, such as "Quotations", "Approval forms," and so forth. All electronic files related to each project are therefore stored in the appropriate folders. Then, similarly for your email application platform, create an identical project-tree structure using the same folder names. Consistency of the structure between the project electronic files and email files will facilitate the quick retrieval of key project information.

2. Document every project

Record everything related to each project in an electronic document. The top header section of this document should include

TABLE 1. PROJECTS SUMMARY

Area Equipment Name	MOC# Date	WO# Date	PSSR Date	Project Type Coordinator	P&IDs update Status	SAP Project Title / *Project Description* / -Status / CAD Drawings	Project Co-owners Display
Area1 Reactor	MOC# 2912 3.22.12	WO# 93674 4.16.12	PSSR 10.12.12	Non-Project E. S. Rodriguez II	W123624 W125734 12.5.13 DONE	Add DCS logic to automate control loop *Area1 – Install automation logic to Reactor Temp Loop* -Download 10.10.12, project completed and filed 1260254A, 1260255A	Proj w/ E Cruz CAKD-G00

vital information, such as project title, starting date, work order number, project manager, type of project, project team members, process-and-instrumentation diagrams (P&IDs), date completed, and so on. Then the body of the document should contain technical details of the project as numbered entries on a per-day basis. For emails, first store them in the appropriate email folder or subfolder. Then copy and paste the contents of the email into the document. On numerous occasions, a project requires generating and sharing spreadsheets, databases, or diagramming and vector-graphics electronic files. All of these files are created and then retained in the respective project folder.

One advantage to using electronic files over handwritten logbooks is that the electronic version is searchable by words or parts of a word. In some projects, such as in research and development, a handwritten logbook is the preferred method of keeping detailed notes. In those cases, maintaining an electronic file is still suggested. I would not recommend duplicating logbook notes into the electronic document. Daily journal entries to the electronic file could simply be keywords used in the logbook. Thus, one can benefit from the search capabilities of an electronic file, and still be able to use the logbook for logging details of the project.

3. Share change documents

Prepare a project change document, which is typically one page for small to mid-size projects. It is recommended to be no more than two pages. It summarizes the goals and objectives and may contain some level of design detail. If the project is a replacement or modification, discuss the existing setup and follow it up with a review of the new setup.

To assist in the write-up and to help visualize the project, I have found it very helpful to include a simple schematic. The purpose of the change document is to serve as a guide during the detailed design stage. More importantly, it can be used as an overview and functional scope-of-work description of the project. As such, before proceeding with the design, ensure that it is approved by your customer.

Frequently, the design requirement is altered as the project proceeds. Keep track of the modifications by issuing updated versions of the document and highlighting the sections that were revised. Add a revision table at the bottom of the write-up and update it accordingly. The revised change document should be distributed to the project team to make sure everybody is on the same page, and each version should be approved by the customer. The final design to be implemented is as described in the latest revision.

4. Prioritize projects

After working on your first few projects, it will become evident that project prioritization is a dynamic task. A top priority when first assigned could be demoted to a medium- or low-priority project. Vice-versa, a low-priority project could be elevated as high-priority. The business environment drives this change. Seek advice from your superiors regarding re-prioritization of your projects to ensure that the project impact is maximized. This process can typically be done on a semi-annual basis.

Prioritization should be used as a guide in your multitasking efforts. It is possible to execute low- and medium-priority projects concurrently with a high-priority project. This happens when there is a momentary pause on a high-priority project, such as waiting for information from a supplier or customer, or while a project is on temporary hold. In these instances, one begins or continues on another project. Thus, the multitasking scenario can be seen here at play.

It is easy to remember the major tasks required to keep the project moving. However, one is continuously challenged by the small stuff.

5. Manage the small tasks

It is easy to remember the major tasks required to keep the project moving. However, one is continuously challenged by the small stuff. For example, in a meeting, let's say you were assigned to follow-up on an important subject. In addition, in a project where you were assisting a colleague, you were supposed to follow-up on a technical issue. To be an effective multitasking engineer, one would need to manage these small tasks. It is possible to cope with the small stuff while toiling away on the major ones.

One solution is to keep a running list of "things to do." In an electronic document, compile a list of all the small tasks that need your attention. As time permits or as required, work on each entry. After each one is completed, mark it as "done" so it would be easy to check which tasks need attention. If this list is continuously updated, there is no excuse why small tasks should be left undone. You may want to keep the compiled list for future reference and start over a new list on an annual basis. These files may be kept at the Level-1 "Projects" folder for easy access.

6. Summarize all projects

Prepare one, tabular electronic document that would be saved in the "Projects" Level-1 folder. This will serve to summarize all the projects that you have worked on. It would show projects that are currently active, cancelled, on hold or in progress. Summarize, in tabular format, important information for each project. It would contain selected information from the top header section of each project. This document will prove useful, for example if one is searching what project belongs to a specific work order number, or vice versa without having to access and search each project document.

One may argue that for the table header, there is so much information to display that not all column information will fit in one row, even if the landscape-page-document format or a smaller-text font size is used. However, it is possible to populate related columns vertically in the table header. Table 1 shows the Projects Summary table header and an example project entry. To quickly assess if the project is completed, on hold, in progress or is cancelled, one may use different text background colors. Text formatting as shown in the last column can further highlight the SAP Project Title (underlined) and Project Description (italics).

Examples

Documenting tests. Several years ago, while working for a major distributed control system (DCS) company, one of my projects involved an international paint manufacturer that implemented batch software to handle its operations. The customer had also just purchased the recipe management software from our sister company overseas. I was assigned to transition to the support role, since the original project engineer decided to leave the company.

Part of my learning curve was to visit our sister company and make sure we could deliver the product. At our sister company's office, I witnessed the simple tests to show that recipe information was downloaded and correctly received by the batch software running in the DCS. Details of the software test setup were documented and stored in an electronic file.

More than a year later, the customer visited our sister company and wanted to see first-hand that the batch-recipe download function would work. However, our colleagues overseas had trouble duplicating the test runs done the last time I visited them. I received an email from the lead engineer that asked if I could remember the details. I responded by attaching the electronic file, which contained details of the successful test setup. My colleagues were very grateful and were successful in demonstrating the software functionality.

It is always difficult to start anything new. However, once it becomes a habit, documenting projects becomes second nature.

Restarting a cancelled project. I also worked on a project that went through several phases; from being active, to being put on hold and then eventually it was cancelled. This happened within a time period of about a year. However, the project was restarted and questions came about regarding technical details that were previously discussed. Since some of my team members discarded information about this project when it was cancelled, most could only offer scant information. On my part, I was able to refer back to the saved electronic files and emails on this project. This allowed the team to smoothly proceed as the required critical information was made available.

Final thoughts

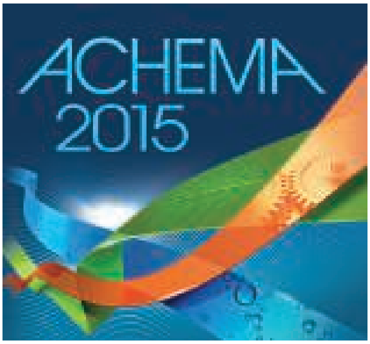
The keywords to remember are: organize, document, share, prioritize, manage and summarize (ODSPMS as the acronym). These are six action words that will not only help one to focus on high-priority projects, but also make one mindful of the smaller tasks that are always thrown into the mix of major tasks of several projects.

It is always difficult to start anything new. However, once it becomes a habit, documenting projects becomes second nature. It would save time and effort and transform you to a truly effective multitasking engineer. Note that Tip Number 2 could also be applied to your personal life. At one time, for insurance purposes, I wanted to find out when I purchased my home theater system and the serial numbers of the system components. It was so much easier to search an electronic file than a filing cabinet where the folder of interest could have been missing, or misplaced, since I had recently moved. ■

Edited by Dorothy Lozowski

Author

Elindoro S. Rodriguez II is currently senior process control engineer for INVISTA (P.O. Box 2626, Victoria, TX 77902; Email: elindoro.s.rodriguez@invista.com; Phone: 361-572-2091). He has more than 30 years of experience in the DCS automation and process control applications field and has been with INVISTA for more than seven years. He previously worked for Xerox Research Centre of Canada, Foxboro Canada, and Bailey Canada/ABB. He has published articles and presented papers on production quality systems, pilot plant automation, controller tuning and heating systems. He received his B.S.Ch.E. from De La Salle University (Manila, Philippines), and an M.S.Ch.E. from the University of Notre Dame (Indiana). He is a member of the International Society of Automation (ISA), American Institute of Chemical Engineers (AIChE) and Professional Engineers Ontario (PEO).




Wieland-Werke


Atlantic Zeiser


Milestone

Professionals from all sectors of the chemical process industries (CPI) will convene June 15–19 in Frankfurt am Main, Germany, for Achema 2015. This year's event will host over 3,600 exhibitors, who will showcase some of the world's newest equipment, services and technologies for the CPI. The following Show Preview highlights a small selection of Achema's 2015 exhibitors.

In addition to the extensive exhibition portion of Achema, a concurrent technical conference will take place, where experts from around the world will gather to discuss and learn about numerous CPI-related topics. This year's conference puts special focus on the following three areas: advances in bio-based chemicals; innovative process analytical technology; and industrial water management, which is the topic of a plenary lecture on Monday, June 15. A second plenary lecture, on Thursday, June 18, is titled "Chemical production for tomorrow's challenges."

Panel discussions on shale gas and Germany's energy outlook will take place on Tuesday, June 16 and Wednesday, June 17, respectively. A special event platform, entitled "Biobased World" will present a large range of production processes in industrial biotechnology.

The numerous technical-conference sessions cover a diverse array of topics, including: reaction engineering, electro-biotechnology, modular plant concepts, corrosion management, solids processing, catalysis, laboratory techniques, heat-transfer innovations, thermal and electrical-power engineering, microprocess engineering and more. For the full program of technical lectures, please see www.achema.de.

Attendees at the show can keep up with the events of Achema by reading the *Achema Daily*, a bilingual, daily newspaper published by *Chemical Engineering*, in collaboration with Vogel Media (Würzburg, Germany; www.vogel.de). The *Achema Daily* will be distributed to the event's attendees, and also will be available digitally at www.chemengonline.com, for those unable to attend the event.

Reliably isolate fluids with these double-wall safety tubes

GEWA-safe double-wall safety tubes (photo) feature defined leakage paths between the inner and outer tubes for the reliable separation of reactive, hazardous or explosive fluids without the need for additional circulation. The thermal contact of the two tubes results in outstanding heat transfer without the need for additional heat-transfer fluid. Depending on the desired application, the tubes are available with either smooth or profiled surfaces in copper, cupronickel and stainless steel. The safety tubes are used in the pre-heating of fuel gas for gas turbines, for the protection against environmentally harmful and toxic substances and for the isolation of heat-transfer oil. Hall 5.1, Stand D54 — *Wieland-Werke AG, Ulm, Germany*

www.wieland.de

Print labels up to four times faster with this system

The Digiline label-printing system (photo) is based on contact-free inkjet technology with inks that cure within a fraction of a second when exposed to ultraviolet (UV) light. The print is resistant to wear and abrasion that may occur during the packaging process. Compared to other thermal-transfer printers, Digiline systems can achieve four times higher speeds of up to 60 m/min, says the company. The system also includes an integrated label buffer that automatically adapts to the changing cycle speeds of the connected label applicator. Hall 3.1, Stand J50 — *Atlantic Zeiser GmbH, Emmingen, Germany*

www.atlanticzeiser.com

A microwave-digestion system with remote control capabilities

The Ethos UP (photo) is an advanced microwave-digestion system that can accommodate up to 44 samples in its 70-L microwave cavity. Easy-to-use reaction sensors enable complete quality control of the digestion conditions. In combination with a vent-and-reseal functionality, the sensors ensure complete digestions without any loss of volatile compounds. The Ethos UP also includes a new

Web-based application that provides extended instrument control from outside the laboratory, allowing for remote monitoring of every sample. Hall 4.2, Stand J80 — *Milestone S.r.l., Sorisole, Italy*
www.milestonesrl.com

Use this dosing system with aggressive fluids

The Chemskid system (photo) is designed for the accurate dosing of chemical products, and is especially suitable for aggressive fluids. The system can handle flowrates ranging from 0 to 700 L/h. The standardized, compact unit is equipped with operating and standby pumps, as well as their accessories. The pump access is secured in a shock- and corrosion-resistant cabinet that can be either fixed to a wall or skid-mounted. Applications where the Chemskid system is suitable include heavy-metal precipitation, pH and odor control, environmental control and injection of additives. Hall 8.0, Stand D58 — *PCM Europe S.A.S., Champtocé sur Loire, France*
www.pcm.eu

Comprehensive seminars and training on centrifugal pumps

This company's Academy for Pumps and Systems offers comprehensive courses to help engineers, operators and maintenance personnel better understand centrifugal pumps and associated auxiliary equipment. Depending on the subject matter, sessions may be structured as an open seminar or as practical training. Students will gain an understanding of the theoretical principles of centrifugal pumps while also learning about the latest pump technologies on the market. Hall 8.0, Stand A71 — *Sulzer Pumpen (Deutschland) GmbH, Bruchsal, Germany*
www.sulzer.com

These interface devices offer high signal density

The IMX12 Series of isolator interface devices (photo) provides maximum signal density within a slim 12.5-mm housing, while also offering speed, accuracy and flexibility. The devices of the IMX12 series can be used seamlessly in a range from 10 to 30 V d.c. The devices are fully developed and certified for use in safety integrity level (SIL) 2 functional safety loops. Hall 11.1 C26 — *Hans Turck GmbH & Co. KG, Mülheim an der Ruhr, Germany*
www.turck.com

New options for pump cleaning and sterilization

This company's ALH range of pumps is now available with a new option that provides simplified cleaning and sterilization. The optional clean-in-place (CIP) wheel (photo), now available on several pump models, allows users to retract the pump shoes automatically, simply by reversing the direction of rotation of the pump. The CIP wheel is available for pumps in the flowrate range of 0.5 to 10 m^3/h, and where the maximum discharge pressure can reach 15 bars. Hall 8.0, Stand E1 — *Albin Pump S.A.S., Montelimar, France*
www.albinpump.com

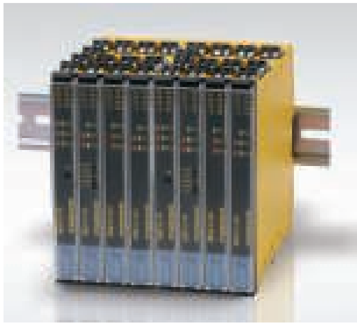
Control nitrogen purge gas with this monitoring system

This company's 9500 nitrogen-purge control system (photo) monitors and adjusts atmospheres in soldering machines and heat-treatment furnaces, reducing nitrogen use and waste. The system monitors the residual oxygen. This oxygen measurement is then used to automatically control the opening of a valve, which regulates the flow of nitrogen. The 9500 system is available in three different configurations: panel-mounted or bench-mounted oxygen- and nitrogen-control systems; NEMA 4X/IP66 waterproof and weatherproof control units for O_2 and N_2; or 19-in. rack mount. Hall 11.1, Stand A1 — *Systech Illinois, Oxfordshire, U.K.*
www.systechillinois.com

Explosion-proof certified tank-cleaning equipment

The TWK Series of tank-cleaning heads (photo) has been certified for use in explosion-proof areas. These tank heads provide online high-pressure cleaning of vessels, without the use of chemical additives, mechanical tools or bolting. With only water used for cleaning, the cycles are shorter and more effective than previous methods,


PCM Europe

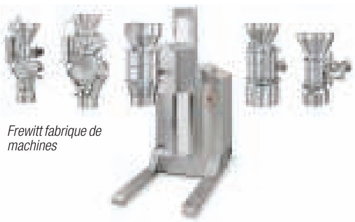

Hans Turck


Albin Pump

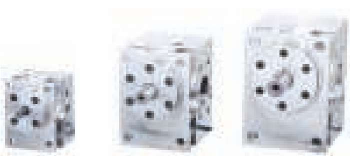

Systech Illinois


Uraca

Lenzing Technik



Frewitt fabrique de machines



Maag Pump Systems

Rotork Controls

says the company. An optimized displacement diameter allows for the tank cleaning heads to be used with very small access openings. Hall 8.0, Stand E38 — *Uraca GmbH + Co. KG, Bad Urach, Germany*
www.uraca.de

A bag-filter system with advanced regeneration

The OptiFil 100 bag-filter system (photo) is designed for fine filtration of particulate impurities in the size range of 1 to 25 µm. The OptiFil 100 features a patented regeneration system with a high backwash efficiency and low fluid losses. The OptiFil 100 system can replace an already installed bag-filter system without any additional welding work. Applications for the OptiFil 100 include water filtration and cooling-lubricant purification. Hall 5.0, Stand E17 — *Lenzing Technik GmbH, Lenzing, Austria*
www.lenzing-technik.com

Attach up to five heads to this universal milling platform

The FreDrive multifunctional milling platform (photo) can accommodate up to five different grinding heads, providing primary crushing, de-agglomeration, granulation, fine grinding or control screening. Intended for use in the chemical, pharmaceutical and food industries, the FreDrive can process sticky, hard or crystalline powders with varying product characteristics. The FreDrive can be mounted on a mobile lifter, and users have the option to dock the mill anywhere in the production area to bring the device to a desired height. Hall 3.1, Stand F3 — *Frewitt fabrique de machines SA, Granges-Paccot, Switzerland*
www.frewitt.com

Use these gear pumps with abrasive or corrosive media

Cinox/Therminox gear pumps (photo) are designed specifically for use in the CPI. The pump range can operate in environments with high viscosity, pressure and temperature, as well as with abrasive solids and corrosive fluids. A wide selection of material construction and the availability of various heating technologies across the entire pump range provide solutions tailored to a number of demanding applications. Application-specific clearances provided added efficiency. Hall 8.0, Stand C38 — *Maag Pump Systems AG, Oberglatt, Switzerland*
www.maag.com

New cone-valve technology eradicates segregation in IBCs

This company has incorporated new cone-valve technology into its intermediate bulk container (IBC) systems, enabling the feeding of blended powders and granules directly to roller compactors and tablet compression without the risk of segregation. By eliminating segregation, the company can now offer large-scale IBCs up to 3,500 L in volume, with the reassurance that the product will be fully discharged from the IBC. Larger IBC systems allow for larger batch sizes, reduced labor and costs, and simplified connections and disconnections for maintenance and cleaning. Hall 5.0, Stand C8 — *Matcon Ltd., Worcestershire, U.K.*
www.matconibc.com

New features added to this family of electric actuators

This company has added several new features to its line of CMA electric actuators (photo), including increased functionality for manual local control at the valve, enhanced LCD positional display and programmable fail-to-position performance. CMA actuators are available for quarter-turn, rotary or linear operation and are used in many applications, including for the operation of process-control valves and other continuous modulation applications, such as for metering pumps and damper drives. The actuators are powered by single-phase or direct-current supplies, and include a permanently lubricated and maintenance-free drive train. Hall 8.0, Stand A76 — *Rotork Controls GmbH, Hilden, Germany*
www.rotork.com

Achieve higher torque with these elastic couplings

Flender N-Bipex elastic-claw couplings (photo, p. 71) are designed predominantly for use with hydraulic systems and geared motors, and

are available in ten sizes. Constructed of nodular cast iron, the couplings' combination of optimized cam geometry and newly developed elastomers lead to a longer service life when compared to standard couplings. Depending on the size, torque has been increased by 10–20% over previous models. The couplings can be used across a temperature range of –50 to 100 °C without compromising nominal torque. Hall 11.0, Stand C3 — *Siemens Process Industries and Drives, Nürnberg, Germany*
www.siemens.com/couplings

Ultrasonic clamp-on flowmeters operate at extreme temperatures

The Fluxus F/G70X and F/G80X Series (photo), said to be the world's first ultrasonic clamp-on flowmeters, provide permanent, non-invasive flow measurement for liquids and gases, and are certified for SIL 2 operations. The available flow transducers cover a nominal size range from 6 mm to 6.5 m, and the flowmeters can provide flow measurement, even at extreme pipe-wall temperatures ranging from –170 up to 600°C. In addition, due to internal temperature compensation and internal signal processing, Fluxus meters are highly zero-point stable and drift-free, ensuring precise measurement data. Hall 11.1, Stand A16 — *Flexim GmbH, Berlin, Germany*
www.flexim.com

Rotor-stator geometry makes these pumps versatile

The Visco.pump (photo) is a progressive-cavity pump that is specially designed for dosing and dispensing fluids and pastes. The pump's technology is based on the volumetric principle of an infinite piston where the rotor and stator form a sealed metering chamber. The eccentric movement of the pump's rotor allows for a low-shear motion of the medium from one chamber to the next chamber without compounding the media. With optimized rotor and stator geometry, the pumps are capable of handling smaller capacities, making them suitable for a number of sealing and lubrication applications. Hall 8.0, Stand D2 — *Beinlich Pumpen GmbH, Gevelsberg, Germany*
www.beinlich-pumps.com

A direct-mountable LCD display for flowmeters

The Count-On Mini electronic LCD display device (photo) can be mounted directly onto a flowmeter. With simple operation driven by only two buttons, the Count-On Mini displays two lines of information, providing users with data on the measured flowrate. The first line shows the numerical value and the second line provides the units of measure. The measured values are automatically saved. Upon loss of power, meter values and specific settings (such as the meter's K-factor or the selected unit of measure) remain stored within the unit. Hall 8.0, Stand F85 — *KRAL AG, Lustenau, Austria*
www.kral.at

Monitor bursting-disk performance with this system

This company's Non-invasive Monitoring Unit (NIMU; photo) monitors the performance of bursting disks, providing information about the way a bursting disk responds to positive and negative pressure. A NIMU can be attached within a blind hole in the bursting-disk holder, thus isolating it from the process medium. The unit can be easily serviced and replaced without opening the pipeline. This signalling method is particularly suited for critical processes and applications that require the entire system to be completely impermeable. Hall 9.1, Stand C26 — *Rembe GmbH, Brilon, Germany*
www.rembe.de

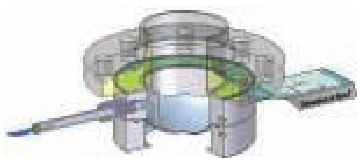
Achieve constant inflow to vacuum-conveying systems

This company's new pneumatic pickup device (photo) enables constant inflow of powders, particles and granules in vacuum-conveying systems. The pickup device operates completely automatically on the basis of the set-transport pressure, rendering mechanical dosage devices, such as sluice valves or screws, unnecessary. The pickup device plays a crucial role in this company's Slow Flow Conveying systems, which are used to pneumatically transport fragile, sticky and soft products. Hall 5.0 D17 — *Dinnissen B.V., Sevenum, the Netherlands*
www.dinnissen.nl

Siemens Process Industries and Drives

Flexim

KRAL

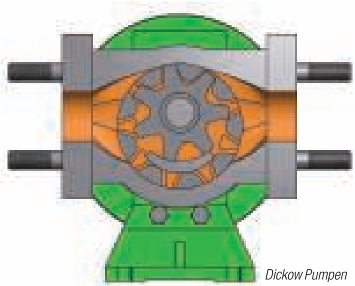


Rembe

Beinlich Pumpen

Dinnissen

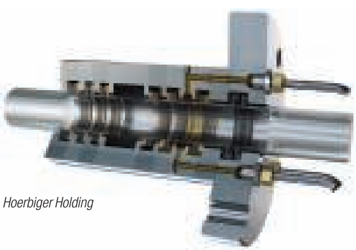
Aucotec



Dickow Pumpen

Fritsch

Gneuß Kunststofftechnik



Hoerbiger Holding

LEWA

This software automatically specifies piping classes

The new "smart piping" feature of this company's Engineering Base (EB) software platform (photo) allows for consistent structuring and segmentation of pipes, and also provides a workflow for specifying pipe classes based on current national and international standards. Once the correct pipe class has been selected, EB will present the user with the appropriate compatible materials for equipment, bolts and so on, as well as the pressure and temperature constraints. Ensuring rapid, accurate materials selection decreases errors, recalculation and downtime. Hall 9.2, Stand B12 — *Aucotec AG, Hanover, Germany*

www.aucotec.com

These magnetically driven pumps can handle high-viscosity fluids

Magnetically driven GML/GMB pumps (photo) are designed to handle toxic, explosive or other dangerous liquids that react upon contact with the atmosphere. For these services, the pumps' containment shell replaces the single- or double-acting mechanical seals with external fluid reservoirs and the necessary control equipment. The rotor and idler gears are made of tough materials, which can handle the stresses of high-viscosity operation. Additionally, a patented lubrication method extends overall life by reducing friction. Hall 8.0, Stand D54 — *Dickow Pumpen AG, Waldkraiburg, Germany*

www.dickow.de

Prevent compressor leaks with this rod-sealing system

The XperSEAL rod-sealing system (photo) for compressors uses pressurized oil to keep the gas in place, ensuring leak-free sealing for the lifetime of the compressor, according to the company. This system can be retrofitted easily to existing compressors, and uses no more oil than conventional lubricated packing. A conventional compressor-packing case contains a stack of sealing elements surrounding the piston rod. With XperSEAL, a volume of pressurized oil replaces some of these elements. Because the oil conforms exactly to the surface of the rod, gas cannot leak out as long as the oil is at a higher pressure than the gas. Hall 8.0, Stand D28 — *Hoerbiger Holding AG, Zug, Switzerland*

www.hoerbiger.com

Laser particle-size analysis in the nano-scale range

The Analysette 22 range of laser particle-size analyzers feature a wide range of measurement capabilities. The MicroTec model has a measuring range of 0.08–2,000 µm. The NanoTec Plus model (photo) provides measurements down to the nano-scale range. Both models feature a modular design and utilize static light-scattering technology. A variety of dispersion modules, which allow for fast, thorough wet and dry dispersion, are available. Hall 4.1, Stand J49 — *Fritsch GmbH, Idar-Oberstein, Germany*

www.fritsch.de

More types of materials can now be handled by these extruders

The MRS extruder (photo) was originally specified for processing polyethylene terephthalate (PET), but has recently been used in applications with nylon and other polyolefins. Materials testing for use in many expanded applications is underway. With a patented combination of a single-screw extruder with a multiple-screw section, this extruder is very sturdy and particularly well-suited for recycling applications. The MRS product line includes many sizes of extruders, ranging in capacity from 35 to 200 kg/h. Hall 5.0, Stand B33 — *Gneuß Kunststofftechnik GmbH, Bad Oeynhausen, Germany*

www.gneuss.com

This micro-metering pump system is hermetically sealed

The Intellilab (photo) represents a new evolution in micro-metering pumps, and is primarily used for metering in high-pressure synthesis and hydration processes. Because the fluid is hermetically blocked against the atmosphere and the hydraulic system of the pump, the Intellilab is also suitable in mini-plant applications. The risks of spillage and fluid contact with the outside environment are eliminated. At a

discharge pressure of up to 500 bars, flowrates between 10 and 500 mL/h at an accuracy of ±1% are possible. In automatic mode, the pump can be controlled from a distributed control system (DCS) via an analog signal. Hall 8.0, Stand C62 — *LEWA GmbH, Leonberg, Germany*
www.lewa.de

Environmental technologies that are adaptable to users' needs

This company's environmental technologies for exhaust-emissions treatment and industrial-waste incineration, including regenerative thermal oxidizers (RTO; photo), regenerative catalytic oxidizers (RCO) and zeolitic rotor-concentrators, are designed to eliminate up to 99.8% of polluting emissions from volatile organic compounds (VOCs). These technologies are adaptable to each customer's technical requirements, and can be used with a large range of solvents and processes. Hall 9.1, Stand B39 — *Tecam Group, Barcelona, Spain*
www.tecamgroup.com

Advanced heat-exchanger tubes enable more compact designs

The patent-pending CW Tube is an elliptical finned tube for heat exchangers (photo) that enables up to 25% less heat-exchange tubing, but with comparable ratings for heat and power output. Designed using advanced computational fluid dynamics (CFD) methods, the CW Tube's extremely efficient design offers many benefits, says the company, including lower investment costs, more compact equipment dimensions, decreased energy consumption and quieter fan operation. Hall 4.0, Stand F46 — *HX Holding GmbH, Bochum, Germany*
www.gea-hx.com

These hygienic pumps are food-contact compliant

The FP70 range of hygienic pumps (photo) are available for flowrates up to 55 m^3/h and with motor power up to 5.5 kW. FP70 pumps are constructed from cold-rolled 316L stainless steel, and models with stainless-steel motors (photo) are available as well. This pump range complies with food-contact regulations, and is designed to pump clean or slightly contaminated liquids in filtration units, distilleries, filling machines, injectors and cleaning systems. Hall 8.0, Stand F78 — *Packo Inox N.V., Diksmuide, Belgium*
www.packopumps.com

Prevent dust leakage in bag filters with this sealing-tape technology

This company's process to automatically bond a polytetrafluoroethylene (PTFE) sealing tape (photo) onto either flat- or double-felled seams in bag-filter fabrication is effective in preventing dust-particle leakage through the pinhole of the sewing stitches and, in the case of thermo-welded seams, to avoid possible contamination due to fibers coming loose from the edges. The PTFE-based sealing tape can be applied on a wide range of polymeric fibers, and is offered in two versions. The High Temperature (HT) variety is capable of withstanding very aggressive working conditions such as in coal-fired boilers and cement plants. The Low Temperature (LT) variety mainly applies to polyester and acrylic. Hall 5.0, Stand C45 — *Testori S.p.A., Novate Milanese, Italy*
www.testori.it

This compact safety system integrates cybersecurity protection

The Tricon CX compact safety system (photo) protects against inherent risk and hazards, as well as external threats, such as cyberattacks. The compact design has led to a 67% reduction in weight when compared to previous models, as well as overall lower power consumption. Other features of the Tricon CX include new automated tests and verification for safety logic, fast analog inputs, choice of direct-termination panel and a 300% increase in controller-tag capacity. Hall 11.0, Stand C41a — *Schneider Electric SE, Rueil Malmaison, France*
www.schneider-electric.com

A plate-and-frame heat exchanger that is very compact

The new DuroShell plate-and-frame heat exchanger (photo, p. 74) is designed to provide more uptime and a longer overall lifetime in tough operating conditions. Its compact dimensions make the DuroShell easy to retrofit into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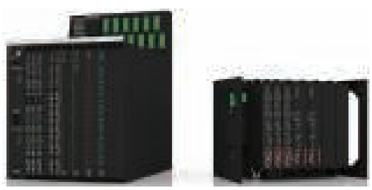
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tight spaces for capacity expansions. The DuroShell's fatigue resistance and efficient thermal performance make it suitable for demanding applications, including those with high pressures, high temperatures and corrosive substances. Hall 4.0, Stand D4 — *Alfa Laval AB, Lund, Sweden*
www.alfalaval.com

Use these tank-cleaning heads in inaccessible areas

The TankMaster range of tank-cleaning heads (photo) features a gear unit that disperses water jets very densely, reaching every part of the container's interior, which ensures thorough cleaning. Containers and tanks are quickly reusable, which aids efficient capacity utilization. The TankMaster can also be used to clean areas that are difficult to access or inaccessible. The system can either be attached to a hose or installed in a fixed position on a device inside the tank. To control the water jet, the user can regulate the rotors' speed of rotation. Hall 9.0, Stand C11 — *WOMA GmbH, Duisburg, Germany*
www.woma.de

These rotary-lobe pumps can handle diverse materials

The VX Series of rotary-lobe pumps (photo) features five ranges — a total of 26 models — with different drives and materials, making the series suitable for a number of diverse media, including emulsions, glues, latex, varnishes, paints and more. Capacities in the VX Series range from 3 to 1,400 m^3/h. The pumps are compact, and are self-priming and resistant to dry running. Many materials of construction are available, including a nickel-based alloy that is suitable for especially aggressive media. Hall 8.0, Stand F64 — *Hugo Vogelsang Maschinenbau GmbH, Essen, Germany*
www.vogelsang-gmbh.com

Automatically adjustable compressor-air delivery

The Sigma Air Manager 2 (SAM 2) master controller is designed to provide comprehensive compressed-air station management to ensure minimal energy consumption. The SAM 2 system also optimizes pressure values, automatically adjusts compressor-system air delivery to accommodate for fluctuating air demand and optimizes system efficiency through constant analysis of the relationship between control losses, switching losses and pressure flexibility. Hall 8.0, Stand A4 — *Kaeser Kompressoren SE, Coburg, Germany*
www.kaeser.com

This filling machine isolates products from interference

The Stery Capsy aseptic filler and stoppering machine for injectable pharmaceuticals (photo) features a unique balcony design that keeps the area in which the product is exposed separate from where the mechanical components are installed. This ensures a perfectly sterile process, in addition to decreasing washing, drying and decontamination times by 50% compared with conventional machines, according to the company. The Stery Capsy also provides accessibility to all critical zones, and simplified management of spare parts and maintenance. Hall 3.1, Stand G3 — *Marchesini Group S.p.A., Pianoro, Italy*
www.marchesini.com

These surge protectors warn before plant protection is lost

Plugtrab PT-IQ surge protection devices (photo) warn plant operators before protection of the plant is lost. To achieve this, each voltage-limiting component in the protective plugs is continuously monitored. If the performance limit has been reached as a result of frequent surge voltages, this is indicated by a yellow signal on the protective device and via remote signaling. This surge-voltage protection is available with traditional screw connection technology, as well as with push-in connection technology. Hall 11.1, Stand A27 — *Phoenix Contact GmbH & Co. KG, Blomberg, Germany*
www.phoenixcontact.com

Use this software to reduce heat-exchanger fouling potential

Edgeview software (photo, p. 75) is designed to address heat-exchanger fouling issues, helping to identify operating regimes that will reduce foul-

ing, leading to minimized downtime and lower utility costs. The software provides evaluation and indicators of heat-exchanger performance, and calculates fouling resistance. With its multiple thermal-performance models and analysis algorithms, Edgeview rapidly analyzes plant operating data, troubleshoots heat-exchanger performance issues and diagnoses potential problems. Hall 4.0, Stand A62 — *Heat Transfer Research, Inc. (HTRI), College Station, Tex.*
www.htri.net

Pre-shaped diaphragms make these triplex pumps robust

The HMT pump range (photo) features slow-running, triplex piston-diaphragm pumps that operate safely, even when dry, and can be installed in conditions where pressures reach 250 bars. HMT pumps are also equipped with pre-shaped diaphragms that are not subjected to any stretching during the entire stroke. These pumps are suitable for use with aggressive, toxic, flammable, shear-sensitive or abrasive materials. Hall 8.0, Stand H47 — *ABEL GmbH & Co. KG, Büchen, Germany*
www.abel.de

Achieve high-efficiency mixing with less power input

This company's patented High Efficiency Shovel (HES; photo) is designed for mixing solids in horizontal ploughshare mixers, while requiring less drive power than standard shovels. An opening in the shovel results in a 40% reduction in the starting torque and also reduces the idle power, says the company. The HES is suitable for industries that process heavy products or where the individual particles of solid materials tend to clump. Hall 6.0, Stand C2 — *Gebr. Lödige Maschinenbau GmbH, Paderborn, Germany*
www.loedige.de

This double-sided tablet press continuously measures weight

The Kilian KTP 720X (photo) is a new double-sided rotary press that can compress up to 1,020,000 tablets per hour. KTP 720X presses are suitable for processing temperature-sensitive products. Two manufacturing modes — for mono- and bi-layer formats — are integrated into the machine. During operation, the press continuously measures the weight of the tablets while they are being produced. Hall 3.0, Stand B49 — *Romaco Pharmatechnik GmbH*
www.romaco.com

These explosion-proof luminaires' light output generates no heat

The Lumistar ASL 57 Ex explosion-proof luminaire uses high-efficiency LED-technology, making it possible to obtain brightnesses that could previously only be achieved by discharge lamps, according to the company. This leads to a reduction in power input. Additionally, due to highly effective heat isolation, no heat will be developed at light output, says the company. Hall 8.0, Stand E84 — *F.H. Papenmeier GmbH & Co. KG, Schwerte, Germany*
www.papenmeier.de

These agitators continue to run, even as the vessel is emptied

BMRT agitators' advanced magnetic design allows for vessels to be emptied while the agitator remains running. Some of the magnetic force is used to lift the impeller, reducing friction on the impeller's ceramic bearing. This helps to avoid abrasion and wear. Nearly vertical blades ensure shorter mixing times and less energy input. Hall 9.1, Stand E51 — *ZETA Biopharma GmbH, Graz, Austria*
www.zeta.com

Stainless-steel bellows ensure containment in these pumps

The SLC Series of eccentric-disc pumps (photo) feature a unique sealless design with a double stainless-steel bellows that ensures durability and full containment of products. The pumps deliver very high suction and discharge pressures that allow them to self-prime and eliminate any costly product leakage. SLC pumps can run dry for up to 5 min, and the self-compensating eccentric-disc principle provides consistent flowrates over long periods of time. The flowrate is accurate, even at low speeds. Hall 8.0, Stand D37 — *Mouvex, Auxerre, France*
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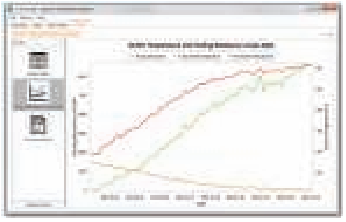
Mary Page Bailey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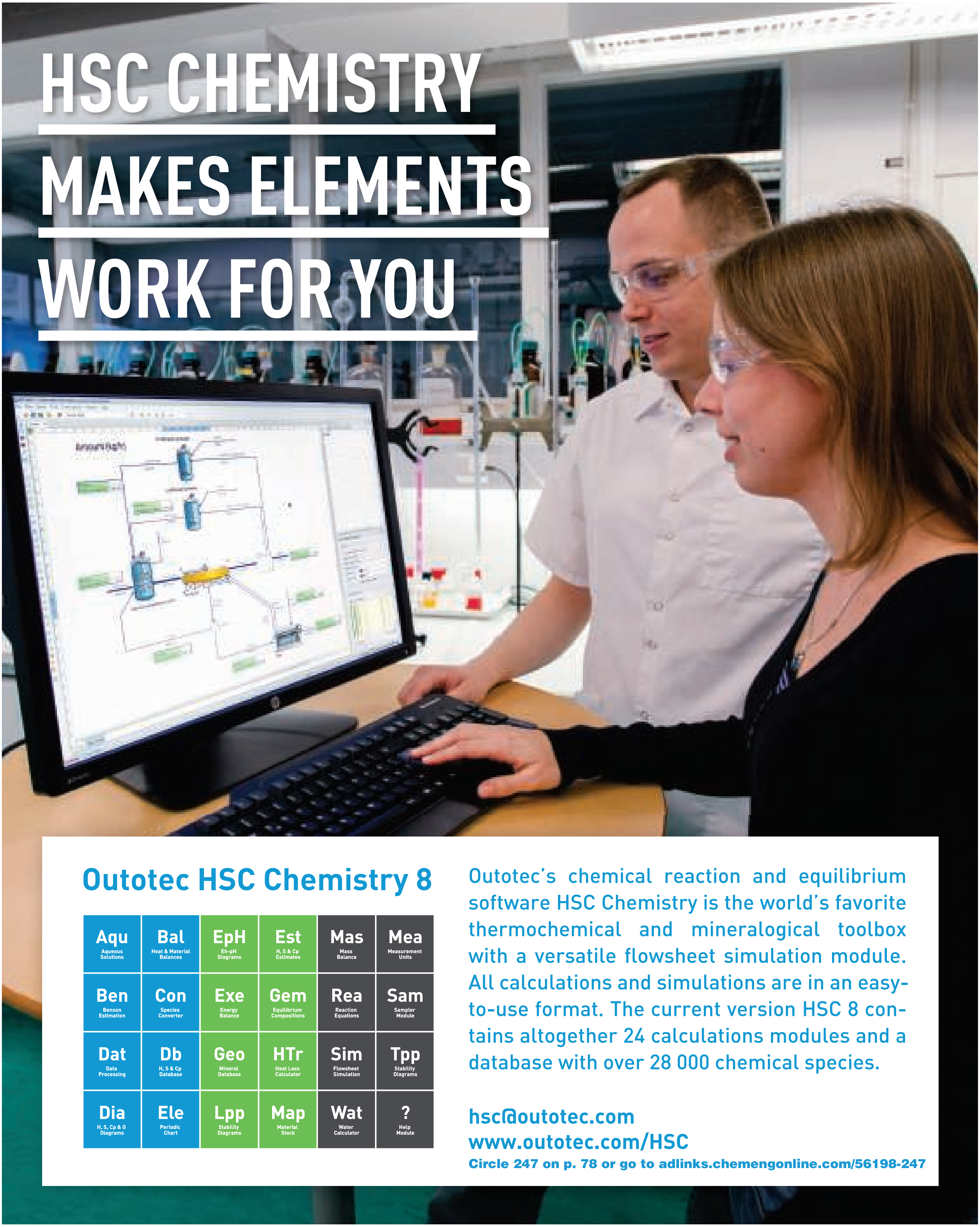
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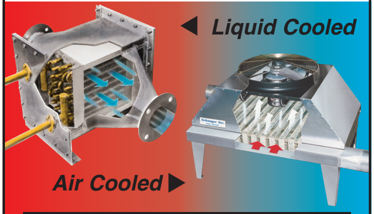

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CE Index	568.7	570.5	571.5
Equipment	688.1	691.8	692.9
Heat exchangers & tanks	624.6	631.4	627.9
Process machinery	672.2	674.0	662.9
Pipe, valves & fittings	858.5	863.2	876.1
Process instruments	404.1	403.9	410.4
Pumps & compressors	953.5	950.9	932.9
Electrical equipment	513.5	513.8	514.6
Structural supports & misc	745.9	748.0	760.5
Construction labor	321.7	318.4	319.6
Buildings	545.3	545.3	542.3
Engineering & supervision	319.5	319.6	322.5

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

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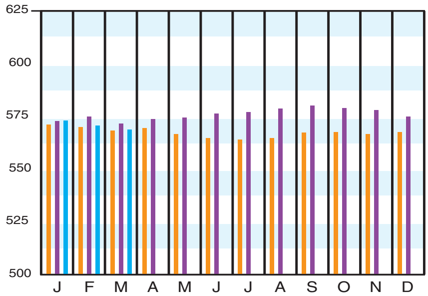
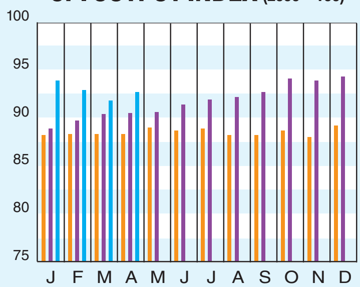


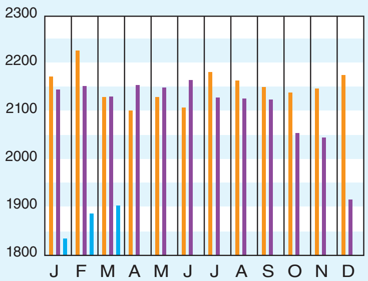
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS		YEAR AGO
CPI output index (2000 = 100)	Apr.'15 = 92.7	Mar.'15 = 92.5	Feb.'15 = 92.7		Apr.'14 = 90.6
CPI value of output, $ billions	Mar.'15 = 1,904.0	Feb.'15 = 1,911.4	Jan.'15 = 1,864.0		Mar.'14 = 2,179.5
CPI operating rate, %	Apr.'15 = 77.4	Mar.'15 = 77.3	Feb.'15 = 77.5		Apr.'14 = 76.4
Producer prices, industrial chemicals (1982 = 100)	Apr.'15 = 238.5	Mar.'15 = 245.4	Feb.'15 = 241.8		Apr.'14 = 294.8
Industrial Production in Manufacturing (2002=100)*	Apr.'15 = 101.5	Mar.'15 = 101.5	Feb.'15 = 101.1		Apr.'14 = 99.1
Hourly earnings index, chemical & allied products (1992 = 100)	Apr.'15 = 158.5	Mar.'15 = 157.9	Feb.'15 = 157.3		Apr.'14 = 157.1
Productivity index, chemicals & allied products (1992 = 100)	Apr.'15 = 108.3	Mar.'15 = 107.9	Feb.'15 = 108.1		Apr.'14 = 108.0

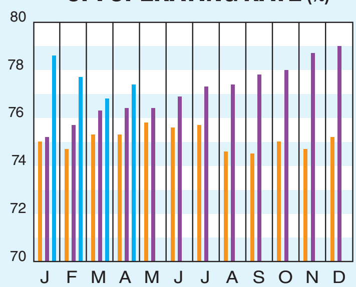
CPI OUTPUT INDEX (2000 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



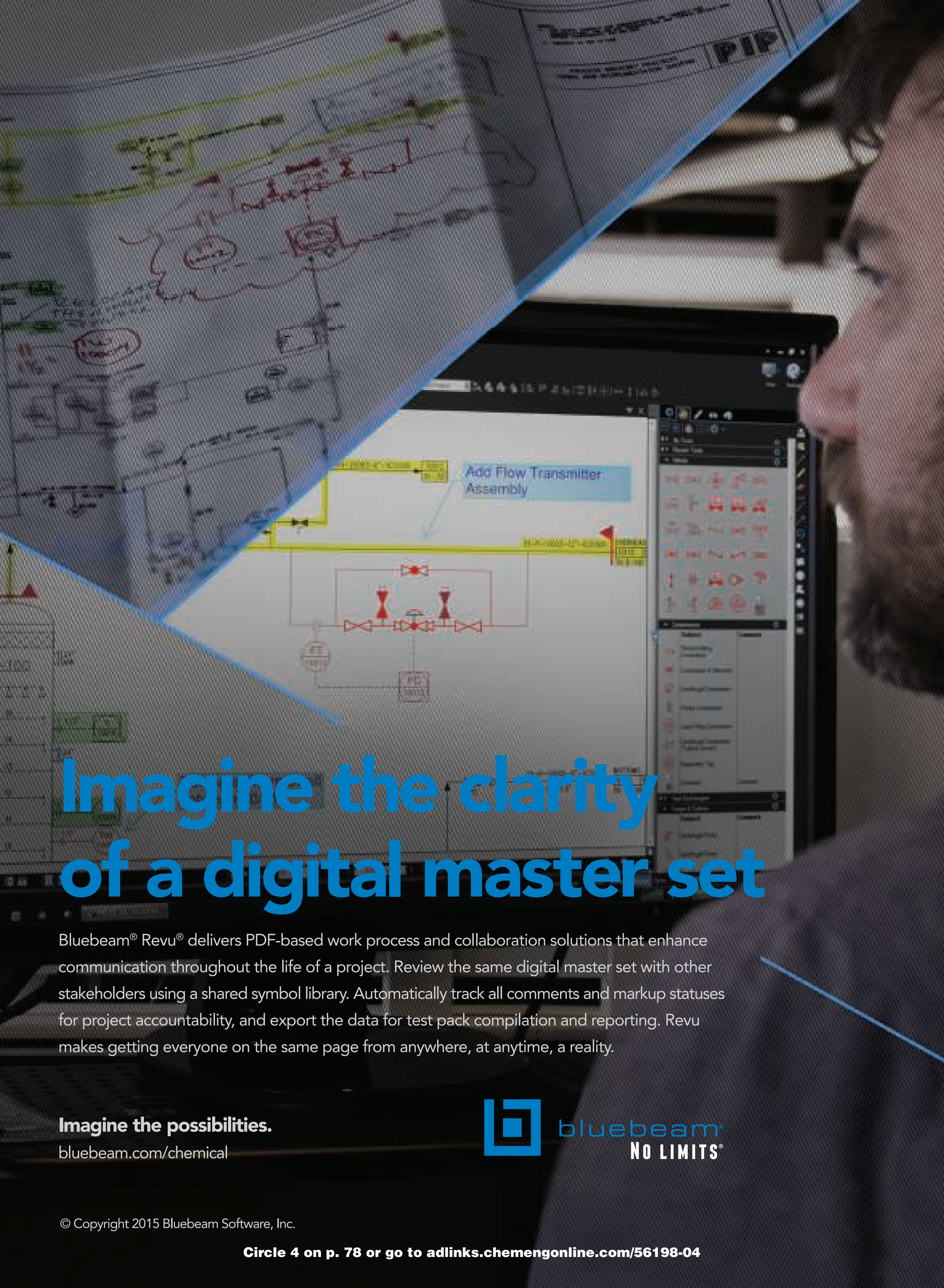
*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the March 2015 *CE* Plant Cost Index (CEPCI; top; the most recent available) once again declined from the previous month's value, and remains 0.5% lower than the corresponding value from a year ago at the same time. The preliminary value for the Equipment subindex in March was down from the previous month, while the Construction Labor subindex was higher. The Buildings and Engineering & Supervision subindexes were relatively constant from the previous month.

Meanwhile, the latest Current Business Indicators (middle) numbers showed a slight increase in CPI output index for April 2015, but also a small decrease in CPI value of output for March. Compared to the values from last year at this time, the current CPI output index is higher, but the CPI value of output is lower.

Correction: The graphs associated with the *CE* PCI have been adjusted in this edition of *Chemical Engineering* to address a mistake in the graphs for the April and May issues of the magazine. The editors would like to thank Stephen Vullo, an astute reader from Japan External Trade Organization, who pointed out the error. The 2015 PCI values were reported correctly in the April and May issues of the magazine, but the bars on the PCI graph that represent the monthly PCI index values from the two previous years were printed incorrectly. They were offset by one year, with the noted year being one year behind the actual number to which it corresponds. The bars for 2015 were correct, and the actual numbers in the table were correct and were not affected. The bar graphs have now been corrected.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