CHEMICAL ENGINEERING

August 2012

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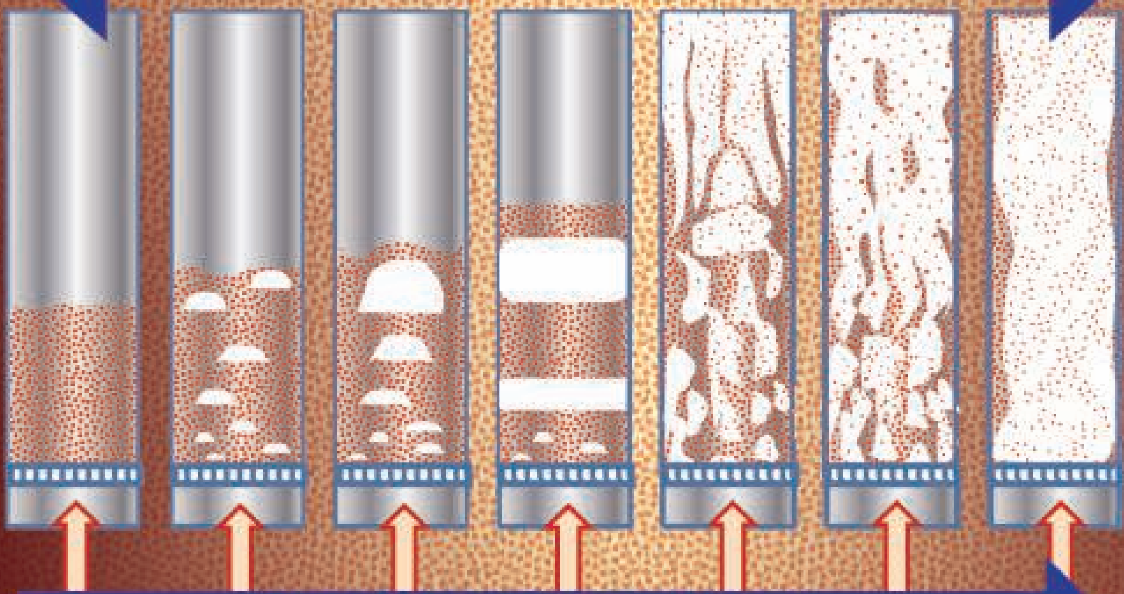
Gas-Solids Fluidization



A PRACTICAL PRIMER

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Process Lead Responsibilities In Design Projects

Waterhammer In Condensate Return Lines

Facts at Your Fingertips: Heat-transfer Expansion Tank Design

Achema 2012 Takes a Forward View

Focus on Pipes and Fittings

Focus on Temperature Measurement & Control

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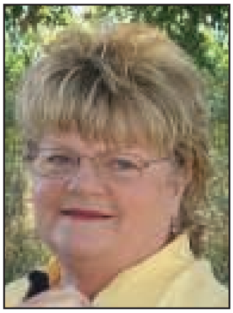
A tribute to an inspiration



This past June, I lost possibly the most-influential person on my career as it stands today. My aunt and colleague, Sandra L. Baccinelli, former human resource manager at Worley Parsons, passed away on June 15th due to the effects of bone cancer. I cannot imagine how I would have become *Chemical Engineering's* first female Editor in Chief without her impact. Meanwhile, there is also a very good chance that many of you would not be in your current positions either. Over her lengthy career, "Sandy" staffed multitudes of the world's greenfield, brownfield and turnaround projects with project managers, engineers, crafts and tradespeople.

For me, the example of Sandy's own, odds-defying career was always an inspiration. Working her way up in this industry was much more of a challenge when she entered the business than it is for young women today. I recall an era when she was actually required to wear a skirt and high-heeled shoes to work. On top of that, she was one of a relatively small number of people in the engineering, construction and procurement business who survived the process of three corporate buyouts. She started with a company called Erbauer Construction, which was bought by SIP, then absorbed by Parsons Corp. Ultimately that part of Parsons — the entire energy and chemicals group — was sold to the company that would be renamed WorleyParsons.

Surviving through so many ups and downs was quite an accomplishment, and yet Sandy did more than just inspire. She pointed to and opened many doors for me. The first one came in the form of a yellow ornamental hard hat that she gave to me when I was about eight years old. Sandy's company had sponsored the thin-plastic give-away at an industry event. Old timers in the chemical process industries probably remember those hats that *Chemical Engineering* handed out at tradeshows in the 1970s and 1980s. In fact, it was one veteran's nostalgic recollection that triggered my own memory of the hat that had decorated the top of my childhood closet for over 20 years. Although I had already worked for the magazine for awhile at that point, I had long ago forgotten that the words Chemical Engineering were on the front, and I had never before made the connection between the font and the magazine's former logo.

Later on, near the end of my university years, Sandy opened the door for my first internship at Parsons in Houston. Once I was finished with my chemical engineering degree, she lined up interviews at the company's corporate headquarters, in Pasadena, Calif., where my chemical engineering career really took root. During that time, her advice was definitely practical. Before my first plant visit, for instance, she made sure that I did not look like too much of a rookie by encouraging me to go out the night before and "rough up" my brand new hard hat and steel toed boots on the street. I am not sure how much effect that had on other peoples' impressions of me, but at the very least it made me a little less nervous.

These days, when I talk with readers about what keeps them up at night, the challenge of finding and cultivating chemical-engineering talent almost always gets a mention. And, in that context, one of the biggest hurdles is attracting young people to the profession and keeping them there. Sandy served that mission for over three decades, and she blazed trails for many of us along the way. ■

Rebekkah Marshall

Letters

Education needs a reality check

Three years after receiving my B.S.Ch.E. degree from Columbia University, and working in industry for a power company and at a refinery, I was asked to give a talk to the New York City chapter of the American Institute of Chemical Engineers (AIChE) students' night on my early experience in the field. One of my observations for the audience was that when I arrived at my first job, a summer program with the Tennessee Valley Authority (TVA), I did not know which way to turn a valve, or, for that matter, anything else about an actual process plant. I was, however, taught rigorous tensor analysis in a course called Transport Phenomena. I was envious of the students from the local and state universities who seemed to know their way around far better than I did. I wondered out loud to the audience, what had I borrowed all that money for?

In my remarks, I proposed that engineering schools should offer two tracks — one for students likely to continue through graduate school and one for students like me who would be seeking jobs in industry. My big regret at that time was that, other than a lab class (where much of the equipment did not work), I was not taught much of anything that I would consider practical. I remember this old, crusty guy in the back row — at the time I thought he was ancient but now I am probably close to his age — raised his hand when I concluded and mumbled something like, "I've been waiting thirty years for someone to say these things."

Many of the engineers I have talked to over the years had similar experiences, especially if they attended so called "elite" or top tier engineering schools. To read in the June article, Chemical Engineering Education Evolution, that "there is a rising awareness, however, that university departments must be connected more to industry…" and that "It's actually quite remarkable that so little has changed in the chemical engineering curriculum…" caused me to gasp out loud. "Really? Another thirty years later, engineers are still molded to turn tensors but not valves?" Then I realized these quotes were from the chair of the department at my Alma Mater!

Fortunately, I was able to make a career out of another gap in the engineering curriculum — communication skills — and became an editor for an technical trade journal and then a consultant. It sounds as if this gap has been addressed, at least at my old school. Still, it seems there's plenty of room for academia and engineering schools to stake out some competitive advantages and help their students in the jobs they need to pay back their student loans.

Jason Makansi
President, Pearl Street Inc., St. Louis, MO

Postscripts, corrections*

July, Development Speeds Up In Catalysis, pp. 18–20: The name of Dow's Cherie Wrenn was misspelled. Our apologies.

June, Draining Process Vessels, pp. 34–40, had two errors:
1. Equation (15) was not labeled
2. In Equation (32), the sign for the third term should be (–) not (+). ■

* The online versions of these article have been ammended and can be found at http://www.che.com/archives/extras/ps_and_corrections/

Calendar

NORTH AMERICA

World Class Process Safety Management for Chemicals, Petrochemicals & Refining. T.A. Cook Consultants (Houston). Phone: 919-510-8142; Web: tacook.com/psmusa
Houston, Tex. **September 18–20**

Plastics in Photovoltaics 2012. Applied Market Information LLC (Wyomissing, Pa.). Phone: 610-478-0800; Web: amiplastics.com/events
Phoenix, Ariz. **September 19–20**

Polyurethanes Technical Conference. American Chemistry Council (Washington, D.C.). Phone: 202-249-7000; Web: polyurethane.americanchemistry.com
Atlanta, Ga. **September 24–26**

SOCMA's 2012 Leadership Conference and 9th Annual Chemical Industry Golf Tournament. SOCMA (Washington, D.C.). Phone: 202-721-4100; Web: socma.com/leadership
Cambridge, Md. **September 25–27**

International Pittsburgh Coal Conference. University of Pittsburgh (Pittsburgh, Pa.). Phone: 412-624-7440; Web: engr.pitt.edu/pcc
Pittsburgh, Pa. **October 15–18**

Gasification Technologies Conference 2012. Gasification Technologies Council (Arlington, Va.). Phone: 703-276-0110; Web: gasification.org
Washington, D.C. **October 28–31**

3rd Annual ChemInnovations Conference & Exhibition, co-located with Clean Gulf/Industrial Fire, Safety and Securty, and Shale EnviroSafe Conference & Exhibitions. TradeFair Group (Houston). Phone: 713-343-1891; Web: cpievent.com
New Orleans, La. **November 14–15**

EUROPE

40th International Conference on Coordination Chemistry. University of Valencia (Valencia, Spain). Phone: +34-93-238-87-77; Web: iccc40.com
Valencia, Spain **September 9–13**

Global Chemical Industry Sustainability Summit. Chemical Industry Roundtables LLC (Houston). Phone: 212-486-6166; Web: chemroundtables.com
Brussels, Belgium **September 10–11**

Calendar

9th IUPAC International Conference on Polymer-Solvent Complexes & Intercalates. International Union of Pure and Applied Chemistry (IUPAC; Research Triangle Park, N.C.). Phone: 919-485-8706; Web: iupac.org
Kiev, Ukraine **September 11–14**

International Conference on Catalysis in Organic Synthesis. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences (Moscow, Russia). Phone: +7-499-1355-328; Web: ioc.ac.ru/iccos-2012
Moscow, Russia **September 15–20**

Post-Conference Symposium on Frontiers of Organometallic Chemistry. Saint-Petersburg State University, Dept. of Chemistry (St. Petersburg, Russia). Phone: +7-499-1355-328; Web: ioc.ac.ru/iccos-2012
St. Petersburg, Russia **September 21–22**

8th World Adhesive & Sealant Conf. The Assn. of European Adhesive and Sealant Industry (FEICA; Brussels, Belgium). Phone: +32-267-673-20; Web: wac2012.org
Paris, France **September 18–21**

Green Solvents for Synthesis 2012. Dechema e.V. (Frankfurt am Main, Germany). Phone: +49-69-7564-0; Web: dechema.de/gsfs2012
Boppard, Germany **October 7–10**

Gastech 2012 London. BG Group plc (Reading, U.K.). Phone: +44-118-935-3222; Web: gastech2012.co.uk
London, U.K. **October 8–11**

ASIA & ELSEWHERE

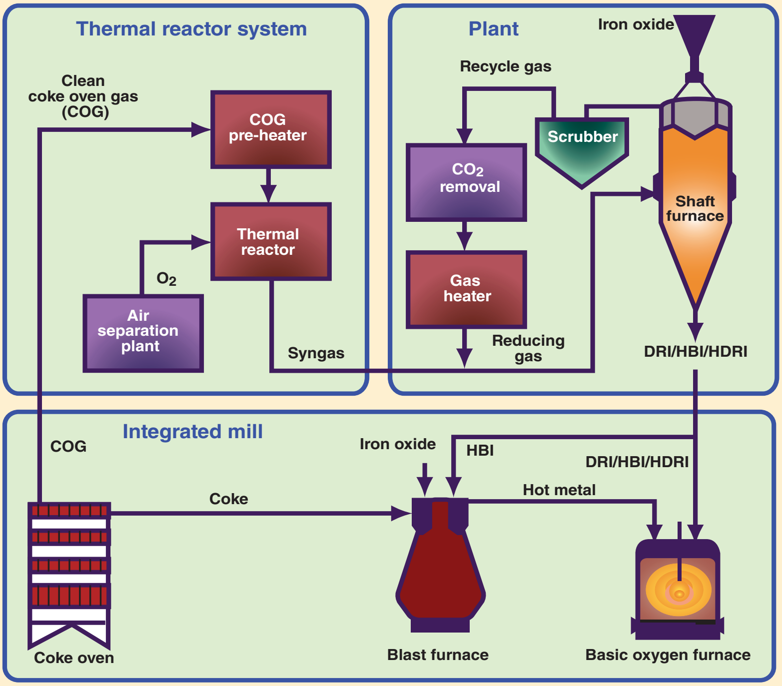
4th International Symposium on Pesticide & Environmental Safety. China Agricultural University (Beijing, China). Phone: +86-10-62732830; Web: 2012iupac.com
Beijing, China **September 15–20**

15th International Biotechnology Symposium and Exhibition. The Korean Society for Biotechnology & Bioengineering (Seoul, South Korea). Phone: +82-2-556-2164; Web: ibs2012.org
Daegu, South Korea **September 16–21**

8th IWA World Water Congress & Exhibition 2012. International Water Assn. (IWA; London, U.K.). Phone: +44-207-654-5500; Web: iwa2012busan.org
Busan, South Korea **September 16–21** ■

Suzanne Shelley

Coke oven offgases may help to increase steel production



Two dissimilar iron-making methods — a conventional blast furnace using coke from coal, and gas-based direct reduction of iron ore — are combined in a process being developed by Midrex Technologies, Inc. (Charlotte, N.C.; www.midrex.com) and Praxair Inc. (Danbury, Conn.; www.praxair.com). Designed to use offgases from the coke-making operation in integrated steel mills, the process offers three advantages: it uses the unwanted offgases from the coke ovens to produce direct reduced iron (DRI); it provides an alternate process gas for DRI, and it can increase the efficiency of blast furnaces by adding DRI to the conventional iron-ore feed.

Midrex, the world's leading supplier of DRI plants, is providing the direct reduction technology. In the standard Midrex process, natural gas (methane) is reformed to produce hydrogen and carbon monoxide (typically about 2:1 H_2:CO), then these gases are reacted with the Fe_2O_3 in iron pellets at 800–1,000°C, leaving metallic sponge iron.

In the new arrangement, offgases from coke ovens will be reformed to obtain H_2 and CO, which will be fed into a Midrex shaft furnace to react with iron ore pellets. Unlike methane, coke oven gases are a complex mixture comprised of approximately 50% H_2 and 30% methane, plus small amounts of CO, CO_2, O_2 and volatile hydrocarbons, says Robert Hunter, a Midrex marketing manager. In contrast with conventional steam reforming, which takes place at around 2,000°F over a catalyst, the Midrex-Praxair process uses a thermal reformer, which operates at a "higher" temperature, but without a catalyst, says Hunter. The thermal reactor is heated by part of the coke oven gases. Praxair is providing the O_2 for the process and has designed special burners to handle the gases.

Part of the resultant DRI can be fed to a blast furnace and/or to a steel furnace. Adding 10 wt.% metallic iron to a blast furnace increases the production rate by 8% and achieves fuel savings of 7%, says Hunter. Midrex is pilot-testing the thermal reactor.

This valve tolerates up to 80% differential pressure

Differential pressure can be a tough problem for butterfly valves, in that it can cause damaging cavitation. As a rule of thumb, for instance, a typical butterfly valve can only handle a maximum of 30% differential pressure (DP), explains René van der Gaag, global product manager lined-valves process for Tyco Flow Control (Breda, The Netherlands; www.tyco.com/flowcontrol). Tyco's new Monovar control valve, however, can take up to 80% DP. This is a benefit for many applications, such as water-treatment systems where high DP is common in both effluent streams and streams into treatment steps.

Monovar's operating principle is very simple, van der Gaag says. "There are two plates, each with the same number of holes," he explains. One plate is fixed, while the other can move. As the plate moves, the individual hole openings can be decreased, thereby reducing the flow of fluid and the DP. Cavitation might occur with the Monovar, van der Gaag says, but with effects that are far-less severe. Unlike what happens in other butterfly valves, cavitation does not occur near the pipe walls, and therefore is not of a damaging type.

Turbulence downstream of the valve is very short, so elbows and other fittings can be installed at closer lengths downstream. Meanwhile, there are limited moving parts, so the maintenance burden is low and reduces total cost of ownership, van der Gaag says.

A new electrolysis cell

At Achema 2012, ThyssenKrupp Uhde GmbH (Dortmund, Germany; www.uhde.eu) introduced a new generation of its single-element electrolysis cell, Generation 6, which offers improved energy consumption and increased active-membrane area. These improvements are due to an elastic element that enables the entire active area of the membrane to be positioned between the electrodes without any gaps. This development ensures that a uniform pressure is transferred across the entire area of the membrane. Zero gap is achieved across every square inch, without compromising the advantages of the single-element design, says Uhde.

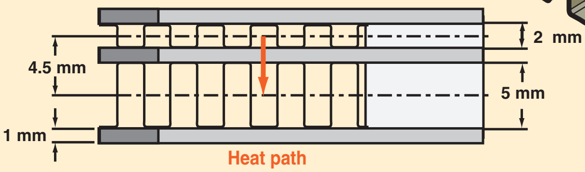
Fine-tuning biomass

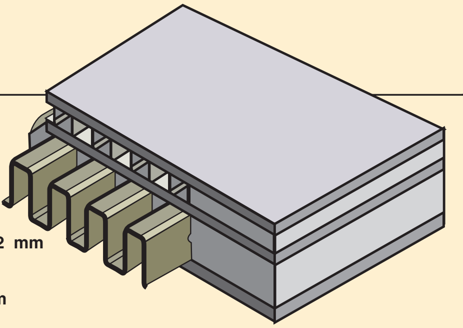
A team of researchers at the Joint BioEnergy Institute (JBEI; Emeryville, Calif; www.jbei.org; part of

(Continues on p. 10)

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

A more-efficient Fischer-Tropsch reactor





The production rate (per amount of catalyst) for generating liquid hydrocarbons from syngas by the Fischer-Tropsch (F-T) process, using a slurry reactor or tubular reactor, is generally limited to about 30% of the maximum rate. The restraining factor is heat removal from the highly exothermic reaction, says Steven Vallee, chemical applications engineer for Chart Energy & Chemicals Inc. (La Crosse, Wisc.; (www.chartindustries.com). Chart is developing a new reactor, called a compact heat exchange reactor (CHER), that is said to solve this problem and could theoretically achieve close to 100% conversion.

A conventional fixed-bed F-T reactor is typically a shell-and-tube vessel in which the gas flows through the catalyst-laden tubes, while coolant flows outside. When a cobalt catalyst is used, the temperature must be limited to about 200–240°C (higher for an iron-based catalyst), explains Vallee. This is achieved by diluting the syngas with nitrogen or diluting the catalyst, in addition to cooling.

In contrast, CHER is a plate-and-fin structure (diagram) comprised of process layers of narrow channels (under 10 mm), sandwiched between coolant layers. Syngas flows over a cobalt catalyst in the channels and a conventional hot-oil-based coolant passes through the coolant layers. In this arrangement "heat exchange is intensified, so we don't have to dilute the gas or the catalyst," says Vallee. Consequently, he adds, a commercial unit would be about one-tenth the size of a commercial F-T reactor.

Chart has done pilot tests and is working up to a 100-bbl/d unit. Because of the smaller size, the company expects the capital and operating costs would be roughly 50% below those of conventional plants.

(*Continued from p. 9*)

Lawrence Berkeley National Laboratory; Berkeley, Calif.; www.lbl.gov) has demonstrated a technology that allows temporal and spatial control of gene expression in biomass plants. The scientists, led by Dominique Loqué and Henrik Scheller, introduced gene transcription promoters to various biomass plants that induce increased gene expression of the same gene in a positive feedback loop. The team was able to improve desirable properties of bio-

(*Continues on p. 13*)

Making synthetic rubber from biomass

Ajinomoto Co., Inc. (www.ajinomoto.com) and Bridgestone Corp. (Both Tokyo, Japan; www.bridgestone.com) have jointly developed a bio-based, high-*cis*-polyisoprene synthetic rubber. The two companies began an R&D cooperation in June 2011 to combine their know-how — Ajinomoto's state-of-the-art fermentation technologies for producing amino acids and Bridgestone's polymerization-catalyst technology — to develop synthetic rubber from biomass, thereby ensuring the stable, sustainable supply of synthetic rubber.

Ajinomoto has developed microorganism strains that can produce isoprene monomer, and has successfully manufactured bio-isoprene at the laboratory scale using a fermentation process. Bridgestone has successfully polymerized this monomer into synthetic rubber, polyisoprene.

Ajinomoto plans to study scaling up the process and to secure non-edible biomass resources. By 2013, the two companies plan to establish a combined process and judge its business feasibility, with a goal of commercial production of bio-based isoprene rubber by around 2020.

Scaleup of a CTL process with carbon capture

The Yankuang Group (Zoucheng City, Shandong Province; www.ykjt.cn), one of China's largest coal companies, and Accelergy Corp. (Houston; www.accelergy.com), are jointly developing a large-scale, low-carbon, coal-to-liquids (CTL) plant incorporating both direct and indirect liquefaction, in Erdos in China's Inner Mongolia Province. The plant, which will produce 68,000 bbl/d of fuel per day, will use a hybrid configuration of Accelergy's direct micro-catalytic coal liquefaction system — licensed from ExxonMobil Research and Engineering Co. — and Yankuang's proprietary Fischer-Tropsch indirect liquefaction.

In indirect liquefaction, coal is first gasified to form synthesis gas, which is converted to liquids by means of a catalyst and Fischer-Tropsch chemistry. Direct liquefaction, on the other hand, is a "sledge hammer approach". It uses pressure, heat and a catalyst to crack the coal to produce liquids.

Direct liquefaction may be more efficient than indirect liquefaction, and may also have a better carbon footprint.

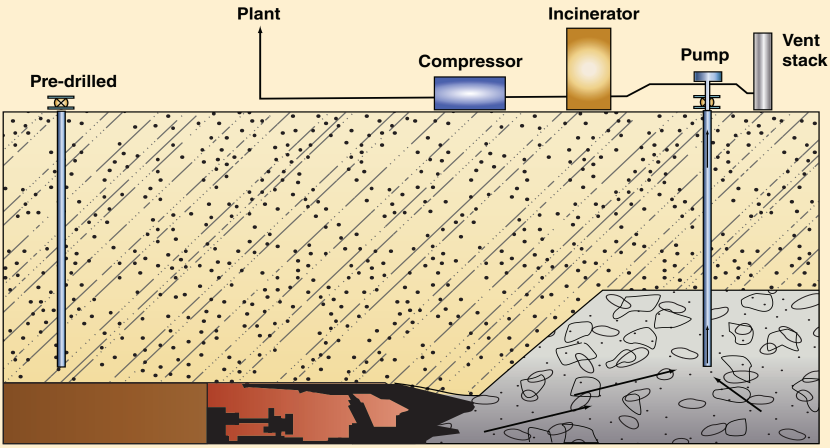
The project will incorporate Accelergy's TerraSync carbon capture and recycle system. In this system, produced CO_2 passes through a photobioreactor that grows cyanobacteria harvested from soils adjacent to the plant.

By incorporating the TerraSync system, the project is expected to achieve a thermal efficiency of better than 60%, and a 100% reduction in CO_2 emissions, according to Accelergy.

The facility will produce a mixture of distillate fuels including gasoline, diesel and jet fuel.

Accelergy recently began fuel production at its pilot plant at the Beijing Research Institute for Coal Chemistry. The company says its direct liquefaction process offers China a solution that produces less CO_2 than traditional petroleum refining and has a significantly higher overall efficiency than conventional CTL technologies.

Methane recovery from a trona mine



Last month, Solvay Group (Brussels, Belgium; www.solvay.com) unveiled a methane recovery system (the MaRS Project) that captures methane liberated by mining trona ore (trisodium hydrogendicarbonate dihydrate), and pipes the gas to nearby processing facilities as a fuel for process heating. Sodium carbonate, a key ingredient in making glass, soap, paper and other products, is the major component recovered from trona.

The first-of-its-kind system in the U.S. complies with U.S. Environmental Protection Agency (EPA; Washington, D.C.) air-quality and safety regulations on mine ventilation, while simultaneously reducing the operation's greenhouse-gas footprint by combusting waste mine methane. The methane recovery system is now fully operational at Solvay's trona mining and refining operations near Green River, Wyo.

Methane liberated from rock strata during mining is pumped to the surface by creating negative pressure in a small drillhole that allows the gas to exit underground mining areas. The liberated gas is then compressed and piped to a Solvay facility about four miles from the borehole field. There, the waste methane's thermal energy is put to use in a large dryer used to remove moisture from the final product, soda ash.

To date, the patent-pending, closed-loop system has prevented about 150,000 metric tons (m.t.) of carbon-dioxide-equivalent (CO_2e) from entering the earth's atmosphere and is currently registered with the Climate Action Reserve, a voluntary carbon registry. The methane recovery system has the capacity of harvesting enough liberated methane to equal about 300,000 m.t./yr CO_2e, says Solvay senior vice president and site manager Ron Hughes. He believes MaRS can double that total over time.

The mass production of organic-modified metal oxide nanoparticles

A system that continuously produces 10 ton/yr of nanoparticles has been developed by Tadafumi Adschiri, principal investigator at the Advanced Institute for Materials Research (AIMR) and professor at the Institute of Multidisciplinary Research for Advanced Materials and New Industry Hatchery Center, Tohoku University (Sendai; Japan; www.wpi-aimr.tohoku.ac.jp/en). The process, which uses a supercritical hydro-thermal device, was developed in a project of the New Energy and Industrial Technology Development Organization (NEDO), in collaboration with Japan Chemical Innovation and Inspection Institute (JCII; Tokyo; www.jcii.or.jp).

With this system, a slurry of high concentration (30 wt.%) of organic and inorganic compounds in water is mixed at supercritical conditions (374°C and more than 220 atm), and product is continuously recovered after the reaction. A heat-recovery system makes the process very energy efficient, says Adschiri.

JCII and its company members have demonstrated the effectiveness of the organic-modified nanoparticles produced by this method for applications in semiconductor sealing materials and power devices. For example, organic-modified boron nitride particles synthesized by the supercritical hydro-thermal device exhibit low viscosity and suppressed void formation even under highly filled conditions, which enabled the continuous fabrication of film-type electrical insulator capable of withstanding high voltages (40–50 kV), and having a thermal conductivity of 20–40 W/m·K — an order of magnitude higher than existing materials. Also, organic-modified alumina particles synthesized by the device have a high thermal conductivity (10 W/m·K) and maintain a low fluidity as a sealing material, even at high concentrations (80 vol.%).

The researchers are now working to further scale up the technology, enhance the energy efficiency even more and develop a system for recycling wastewater. They are also synthesizing other organic-modified nanoparticles for applications in the automobile and electronics industries.

(*Continued from p. 10*)

mass crops compared to wild types. For example, the team was able to generate a genetic mutant of the crop *Arabidopsis* with a lignin content that is 33% lower than that in the wild variety of the plant. Other properties they were able to adjust included a lower hemicellulose-to-cellulose ratio and better drought tolerance.

A new UHP O_2 generator

Last month, Praxair Distribution, Inc. a subsidiary of Praxair, Inc. (Danbury, Conn.; www.praxair.com) introduced StarGen, its ultra-high-purity (UHP)

(*Continues on p. 14*)

Detecting sub-50-nm particles in ultrapure water

A new particle-size measurement technique has been developed and used to evaluate filter retention efficiency for particles with an average diameter of 12 nm by C.T. Associates Inc. (Eden Prairie, Minn.; www.ctassociates-inc.com) and W.L. Gore and Associates (Newark, Del.; www.gore.com). Scientists at C.T. Associates developed the liquid nanoparticle sizer (LNS) for evaluating filtration devices that remove fine particles from the ultrapure water used in semiconductor manufacturing. Particles on the order of 10 nm in size can reduce yield and harm device reliability in semiconductor manufacturing.

To make measurements with the LNS, a colloidal suspension undergoing analysis is injected into a nebulizer, which converts the suspension into ultrafine droplets with a median diameter of about 300 nm, explains Gore's Uwe Beuscher, coauthor of a white paper about the work. The water in the droplets evaporates, leaving the particles suspended in air that had been purged of foreign particles beforehand. The key to applying this approach to measuring sub-50-nm particles is the ability of the nebulizer to precisely produce small and uniform droplets, Beuscher writes. Also, the particle suspension needs to be dilute, so that no more than one particle is present in each droplet. Conventional aerosol-measurement techniques, such as a scanning mobility particle sizer, are then used to determine total concentrations of particles larger than a certain size.

The testing apparatus was used to measure the retention efficiency of an ultrafiltration (UF) module commonly used in semiconductor manufacturing, in combination with a high-retention microfiltration (MF) filter cartridge. The testing was accomplished by pumping ultrapure water through the system and challenging the filters with silica particles upstream of the test filters. The particles had an average diameter of 12 nm. The testing demonstrated that filtering the water in series, with the combination of the UF module, followed by the MF cartridge resulted in optimal particle removal (greater than 99% efficiency for 12-nm particles in all tests).

(Continued from p. 13)

oxygen generator, which is designed to produce 99.9999% O_2 from ambient air. This alternative to cylinders for supplying UHP O_2 saves users time for recalibrating laboratory equipment and other types of analyzers, says the company.

The system uses Praxair's proprietary solid-state oxygen separation and compression technology, which enables StarGen to operate for several years with no adjustments after initial setup, and provides a continuous supply of UHP oxygen without batch-to-batch variations.

The system is suitable for applications requiring UHP O_2, such as laboratories, combustion analyzers used in food, soil, petroleum, plastics and other areas, as well as for calorimeters, TGAs ASTM oxidation procedures and catalyst laboratory testing, says the company. ❑

Knowledge-based approach to catalyst development

Petroleum-derived ethylene normally contains traces of acetylene, which interferes with the conversion of ethylene into polyethylene (PE). Because it is difficult to separate it, the acetylene is selectively hydrogenated to ethylene — without subsequent hydrogenation to ethane — using a palladium-based catalyst. Scientists at the Max Planck Institute for Chemical Physics of Solids (Dresden; www.cpfs.mpg.de) and the Fritz Haber Institute of the Max Planck Society (Berlin, both Germany; www.fhi-berlin.mpg.de) have developed an iron-aluminum-based catalyst with the same performance as Pd-based catalysts, but costs much less.

A systematic, knowledge-based approach was used to identify the iron-aluminum alternative, rather than the experiment-intensive trial-and-error method often used in catalyst development. First, the reaction mechanism that takes place at Pd-sites was deduced. Then, the chemists looked for alternative intermetallic compounds with geometrical and electronic properties that were similar to that of the Pd active site of conventional catalysts. This search first yielded a gallium-palladium compound, and then a compound with the similar crystal structure but without palladium, namely $Al_{13}Fe_4$.

Although the new catalyst still needs to undergo testing to determine the feasibility in industrial processes, the scientists believe the approach can also be used to develop other catalysts to replace those using precious metals.

A self-healing dynamic membrane

French researchers from the Institut Européen des Membranes (CNRS/ENSCM, Université Montpiellier; www.iemm.univ-mont2.fr) and the Institut de Chimie Radicalaire (CNRS, Aix-Marseille Université) have developed what is claimed to be the first dynamic membrane for water filtration that not only can adjust its pore size — depending on the water pressure — but can also repair itself if it breaks. The research was published in the June issue of *Angewandte Chemie*.

The membrane is made of three polymers with different solubilities that form micelles. At low pressure (around 0.1 bar), the pore size is around 5 nm, which allows macromolecules and viruses to be filtered. Increasing the pressure, 1-nm sized pores form, for filtering salts, dyes and surfactants. At a pressure of 5 bars, pores of 100 nm are formed that can filter bacteria and suspended particulate matter. The 1.3-µm-thick membrane also repairs itself via a self-assembly process, even at a perforation of 85 times the membrane thickness. ■

Newsbriefs

ACC launches new macroeconomic indicator

In June, the American Chemistry Council (ACC; Washington, D.C.; www.americanchemistry.com) released the first monthly report of its Chemical Activity Barometer (CAB), a new leading macroeconomic indicator. The June CAB indicates that the U.S. economy will experience modest or decreased growth in economic activity for the remainder of the year.

The CAB is a composite index of chemical industry measures that produces a leading indicator of broader economy-wide activity. It comprises indicators drawn from a range of chemicals and sectors including indicators relating to the production of chlorine and other alkalies, pigments, plastic resins, and other selected basic industrial chemicals; chemical-company stock data; hours worked in chemicals; publicly sourced, chemical price information; end-use (or customer) industry sales-to-inventories; and several broader leading economic measures (such as building permits and new orders).

Enzyme-based carbon capture pilot test results

Results from a field pilot test of enzyme-based carbon-capture technology from Codexis, Inc. (Redwood City, Calif.; www.codexis.com) indicated that CO_2 capture at coal-fired power plants with enzyme-based technology is viable. The field test was conducted at the National Carbon Capture Center in Wilsonville, Ala. on fluegas emitted from a power plant. The Codexis technology is based on development of carbonic anhydrase, which catalyzes the transfer of CO_2 in nature. Preliminary analysis of the enzyme-based carbon-capture system suggests that it can substantially reduce parasitic energy loss compared to carbon capture with monoethanolamine.

CSB launches new safety video

The U.S. Chemical Safety Board (CSB; www.csb.gov) has released a new safety video that examines the concept of inherent safety and its application across industry. "Inherently Safer: The Future of Risk Reduction" stems from the August 28, 2008, explosion that killed two workers and injured eight others at the Bayer CropScience chemical plant in Institute, W. Va. As a result of ongoing concern over the safety of the facility, the U.S. Congress directed the CSB to commission the National Academy of Sciences (NAS) to study the feasibility of reducing or eliminating the inventory of methyl isocyanate (MIC) stored at the Bayer plant. The NAS study explored how the concept of "Inherent Safety" could be applied at the facility. The NAS panel noted that the goal of inherently safer design is not only to prevent an accident, but to reduce the consequences of an accident should one occur. The eleven-minute video features interviews with NAS panel members and staff, as well as commentary from the CSB chair and investigators. The video is available to stream or download on the CSB's website. ■

NEW WEB TOOL CHARTS RENEWABLE TECHNOLOGY COSTS

A new Web application collects cost and performance estimates for electric power generation, advanced vehicles, and renewable fuel technologies and makes them available for utilities, policy makers, consumers and academics. The Transparent Cost Database (TCDB; available at www.openEI.org) application provides technology cost and performance estimates that can be used to benchmark company costs, model energy scenarios, and inform research and development decisions.

Developed by the U.S. Dept. of Energy's (DOE) National Renewable Energy Laboratory (NREL; Golden, Colo.; www.nrel.gov), TCDB offers "a first-cut estimate of current and projected costs and performance characteristics for vehicles, biofuels and electricity generation," with a current focus on renewables, NREL analyst Austin Brown says. The TCDB provides access to published historical and projected cost estimates for electricity generation, biofuels, and vehicle technologies. The cost data are sourced from published studies and the DOE's internal planning documents. DOE works closely with private companies to accurately estimate technology costs.

Economic outlook for U.S. chemistry mixed at mid-year . . .

Following a strong fourth quarter in 2011, the U.S. economy started 2012 on firm ground with gains in consumer spending, manufacturing output and housing. However, those positive gains appear to be eroding, according to the ACC's *Mid-Year 2012 Situation and Outlook*, released in July.

The report finds that first and second quarter 2012 growth was weak and that underlying drivers will constrain growth for the remainder of the year. The financial crisis in Europe and slowdown in China and other emerging economies continue to take a toll on demand for U.S. exports. This outlook, coupled with weakness in U.S. manufacturing will likely produce muted demand for chemical products in the second half of 2012. Overall, American chemistry output is anticipated to rise by 0.5% in 2012, before accelerating to a 2.3% growth rate in 2013.

. . . while strong gains in capital spending are forecast

Strong gains in capital spending by U.S. chemical manufacturers are expected during the next several years, according to the *Mid-Year 2012 Situation and Outlook* report from ACC. Capital spending for U.S. chemistry will reach $35.5 billion in 2012, and will steadily rise to $51.5 billion by 2017, the report anticipates. The projected capital spending gains are the result of announced new investment in petrochemicals and derivatives arising from shale gas developments, the report says. "The need to add capacity and improve operating efficiencies will play a role as well," ACC adds.

ACHEMA 2012 TAKES A FORWARD VIEW

The major emphasis at Achema 2012 was on preparing for a future where sustainability and bioprocessing are likely to play larger roles in CPI business and operations

Achema 2012 — the 30th International Exhibition Congress on Chemical Engineering, Environmental Protection and Biotechnology that occurred in late June in Frankfurt am Main, Germany — took a decidedly forward-looking stance, focusing on a set of topics that the chemical process industries (CPI) will have to address in the future, including increased attention on sustainable processes and systems as well as the transition to an economy based on renewable energy and biomass.

By most accounts, Achema 2012 was considered a success, with 167,000 attendees visiting 3,773 exhibitors and listening to 900 lectures on various topics within chemical and biological processing. According to event organizer Dechema e.V. (Frankfurt, Germany; www.dechema.de), the proportion of exhibitors from outside Germany was almost half, with 56 different countries represented. Dechema also noted that 83% of Achema 2012 visitors rated the event's quality as either "good" or "very good" in a post-event survey.

Among the themes that emerged from Achema was the key role to be played by the CPI in promoting a sustainable society and in utilizing renewable chemical feedstocks and fuels. These themes were reflected in many of the presentations at the event, as well as in the many of the exhibits featuring products for environmentally sound processes and bioindustrial processing.

The bio-based economy

With over 300 exhibitors specifically related to biomass processing, and a unifying feature known as "Biobased World," Achema 2012 placed a heavy emphasis on examining the various implications of moving toward a world economy based on renewable biomass, rather than on fossil fuels.

Achema's Biobased World was intended to be a venue in which companies involved all along the value chain of bioprocessing could come together to learn from each other. The event included a specific exhibition area, technology transfer sessions, and a conference program that included talks about a wide range of bioprocessing topics, including new microbial, enzymatic and catalytic production systems, process scaleup, downstream processing, biorefineries and more.

Biobased World featured a two-day conference within the wider Achema event that focused on the European bioeconomy, specifically. A presentation given by Maive Rute, director of biotechnology, agriculture and food in the European Commission (EC) Directorate-General for Research and Innovation, suggested that growing and implementing the bio-based economy in Europe depends squarely on research investment, stakeholder engagement and market enhancements. Toward improving bioeconomy markets and enhancing competitiveness, Rute said the EC Joint Research Center has set up a bioeconomy observatory to collect data that will inform policy decisions related to the bio-based economy. Further, her organization intends to help biorefinery networks develop, support solutions involving bio-based technologies for existing industries, and promote adoption of bio-based products.

In the research and innovation category, Rute commented that the goal should be to make the best use of funding, while continuing to increase investment in research. Among the EC initiatives in this area are to develop bio-based industry clusters to support innovation and to support entrepreneurship training.

Picking up on the theme of research and innovation in the bioeconomy, Martin Scheele, of the EC Directorat-General for Agriculture and Rural Development, spoke about closing the gap between research and practice. Research in Europe is very good, he explained, but often the results of that work are not fully exploited, and not translated into actual practice.

Bioeconomy hurdles

In most cases, there remains a price differential between petroleum- and biomass-derived hydrocarbons, but the gap is narrowing, and eventually,

carbon atoms could have the same market value, whether they come from petroleum or biomass. The gap will likely be closed by overcoming the various technical hurdles to economic bioprocessing. These include developing processes with the ability to utilize multiple biomass feedstocks to produce the same product, a topic that came up often at Achema 2012. Other challenges mentioned in Achema presentations included the land constraints that must be considered in growing bioenergy crops.

Bio-based developments

In an example of how the bio-based economy is moving ahead in the real world, Beta Renewables (Rivalta Scrivia, Italy; www.betarenewables.com), a joint venture between the Chemtex div. of Gruppo Mossi & Ghisolfi and TPG, announced at Achema the planned startup in fall 2012 of the world's first commercial-scale second-generation cellulosic ethanol plant in Crescentino, Italy. The facility is a 20-million gal/yr biorefinery that will produce both bioethanol and "green" electricity. The facility uses Beta's Proesa technology, which converts energy crops, such as miscanthus and switchgrass, or agricultural waste, such as sugarcane bagasse, into fermentable C_5 and C_6 sugars, which are then processed into ethanol and other chemicals. Proesa's enzymatic pretreatment process runs significantly faster than other enzymatic hydrolysis technologies, the company says, and is free of acids and alkalis and produces minimal waste.

Beta Renewables recently signed an agreement with Gevo, Inc. (Englewood, Colo.; www.gevo.com) to develop an integrated process for cellulosic isobutanol. The project would integrate the Proesa enzymatic pretreatment technology with Gevo's integrated fermentation technology platform for producing bio-based isobutanol and derivatives.

Sustainability science

Movement toward an economy based on renewable energy and biomass is closely related to the burgeoning field of sustainability. Achema served as a focal point for several aspects of sustainability, including the need to establish a robust body of science in the field. And developments at the June event in Germany complement the work of other sustainability experts going on elsewhere.

An indicator of the growing interest in assessing sustainability in a more scientific way is the recent launch of a new peer-reviewed journal, titled *ACS Sustainable Chemistry & Engineering*, by the American Chemistry Society (ACS; Washington, D.C.; www.acs.org). The journal is intended to be a forum for research on reducing environmental harm and achieving sustainable processes. The journal's editor-in-chief will be David T. Allen, chemical engineering dept. chair at the University of Texas at Austin. The first articles in the journal will be published online in autumn 2012, and the first full issue will appear in January 2013.

Measuring sustainability

As attention on sustainability and green chemistry builds, one of the major challenges for CPI companies will be how to assess and quantify their sustainability efforts. Valid models and metrics are needed to accurately determine the degree of sustainability associated with a process or product in order to make sound decisions for R&D, manufacturing and marketing.

"Sustainability only makes sense when a system is considered as a whole, from raw materials to end of life, and its interactions with society and the environment are also accounted for," explains Alexei Lapkin, a chemical engineering professor at the University of Warwick (Coventry, U.K.; www2.warwick.ac.uk) who has made green chemistry and its measurement part of his research program. Gaining this level of understanding is not trivial — it is a time-consuming operation that requires a large volume of data that must be checked for accuracy and reliability, Lapkin adds.

Other scholars, including Michael Neuman and Stuart Churchill, collaborators from the University of New South Wales (Sydney, Australia; www.unsw.edu.au) and the University of Pennsylvania (Philadelphia, Pa.; www.upenn.edu), respectively have contributed to the discourse on sustainability metrics as well. "What has been missing in science, engineering and public policy is a rigorous definition of sustainability, and a theory to conceptualize and measure it quantitatively," the pair writes. They have developed a model for measuring the sustainability of processes that adapts and integrates the first and second laws of thermodynamics with the concept of rate processes. The combination is necessary, the researchers argue, because while thermodynamics yields the limits of what can be accomplished within a system, the rate process framework provides a way to incorporate the rates of regeneration and replenishment of resources compared to the rates of depletion, extraction and consumption. A model based on both thermodynamics and rate processes can be generalized for physical and social-economic phenomena, the researchers suggest.

Neuman and Churchill's work includes development of a set of equations that permit the calculation of the degree of sustainability of any process in a way that takes into account spatial and temporal factors. The equations permit empirical applications that correspond to complex, evolving conditions across space and time.

Existing approaches to quantifying sustainability have limitations. For example, cost-benefit analyses, have been shown to lack validity for decision-making in sustainability, Churchill says. And life-cycle assessment (LCA) approaches, can also be somewhat lacking, Lapkin says.

Achema sustainability session

At Achema, attendees heard about the launch of a new program designed to bring an aspect of third-party peer review to claims on the sustainability of a product, process or service. The International Certificate on Sustainable Standards for Engineering (ICOSSE) program was developed by the AIChE's Institute of Sustainability, along with Dechema. Darlene Schuster, executive director of AIChE's Institute for Sustainability, says the criteria for the certificate program are drawn from AIChE's Sustainability Index, a tool that helps companies benchmark their sustainability performance against a group of their peers. It combines technical and engineering components with financial and social metrics traditionally employed in other sustainability measures.

Applications to the ICOSSE program are reviewed by an advisory board, which determines which ap-

CHEMICAL ENGINEERING SCHOLARSHIP IS ACCELERATING

Toward the conclusion of Achema 2012, professor Jaap Schouten, dean of the Dept. of Chemical Engineering and Chemistry at Technische Universiteit-Eindhoven (The Netherlands; www.tue.nl), delivered a keynote address on the future of chemical engineering. Before looking forward toward the possible hotspots of the future of chemical engineering, Schouten first looked to the past. Specifically, he discussed a study he conducted involving the history of scholarship in chemical engineering. Schouten tracked all publications in seven key chemical engineering journals, including *Industrial Engineering Chemistry Research, Chemical Engineering Science, AIChE Journal, Chemical Engineering Journal* and others, over the past 60 years (1951–2011). Schouten found that almost 25% of all chemical engineering papers published in those seven journals have appeared in the last four years, and over half of all papers have appeared in the last ten years. "Our industry is exploding, in terms of the numbers of papers," he said. According to his analysis, China has recently taken over the number one spot in terms of the number of papers published, but the U.S. still ranks first in terms of scientific impact (as measured by the number of citations per paper).

Judging from the most highly cited papers, it seems from Schouten's analysis that there has been a shift in the types of papers with the highest citation rate from science-oriented papers being more cited overall in the past, and a focus on citing application-oriented papers in more recent years. ❑

plications will receive the recognition. There has been initial interest in the program, Schuster reports.

During the same session at Achema, Peter Saling, the head of sustainability evaluation at BASF SE (Ludwigshafen, Germany; www.basf.com) presented his company's activities toward quantifying sustainability. BASF has developed Eco-Efficiency Analysis as a method to systematically assess the sustainability of products and processes in a holistic way. The tool uses a life-cycle assessment approach to evaluate the environmental impact of a product or process from the point of raw material extraction to end-use and recycling and disposal options. In addition to the LCA, the Eco-Efficiency Analysis also includes an assessment of the carbon footprint of the product or process, as well as the total cost of ownership.

A product or process is scored in each of a set of six categories, including energy consumption, toxicity potential, emissions, resource consumption, land use and risk potential. The scores are weighted to arrive at a single Eco-Efficiency profile that can be compared to alternatives to determine the degree of sustainability of the product or process.

BASF has enhanced the Eco-Efficiency Analysis with its SocioEco-Efficiency Analysis (also known as SEEBalance), which incorporates the impact of products and processes on society, in addition to the costs and environmental impact. The aim is to quantify the sustainability performance of a product or process on an ecological, social and economic basis.

Saling said the method has been used by BASF to compare alternative process technologies, product packaging materials and help make strategic decisions on investments, facilities, research and development, marketing and stakeholder relations. BASF has also applied the method, which has been certified by TÜV, the German Association for Technical Inspection, and NSF International, to other processes outside the company.

Resource management

In keeping with the sustainability theme, Achema also featured a keynote address about the challenges and opportunities of recycling metals that are used for specific functionality and performance in electronic and other high-tech devices. Christian Hagelüken, director of European Union government relations at Umicore AG & Co. explained that concentrations of several critical metals are higher in "urban mines" of collected electronics parts than those generally found in primary ore deposits. The challenges associated with recycling these technology metals include thermodynamic constraints on processes, societal organization for recycling consumer products and the accessibility of materials within the devices. Ultimate success in this area will depend on innovation on the material side, as well as on the product design side, Hagelüken said, including improved collection systems, new processes for difficult material mixes and improved education about this issue. ■

Scott Jenkins

Equipment News Roundup

SMALL BUT MIGHTY

New materials and designs allow seals and gaskets to stand up to harsh CPI conditions

Eagle Burgmann

FIGURE 2. The use of microcrystalline diamond coatings makes the seal faces extremely hard and wear resistant and gives the seals excellent heat conductivity, maximum chemical resistance and low friction

The A.W. Chesterton Co.

FIGURE 3. This Low Emissions block valve packing is guaranteed to leak no more than 100 ppm for five years

Victrex

FIGURE 1. High performance thermoplastics such as PEEK are often specified for sealing applications due to their excellent physical properties: high temperature durability, creep resistance, stiffness and compatibility with a wide range of chemical environments

Sometimes the smallest parts — such as seals and gaskets — can have the greatest impact on plant performance. For this reason, seal and gasket manufacturers are developing innovative new materials and designs that will help these diminutive, but important, components stand up to the harsh operating conditions of the chemical process industries (CPI).

"With multiple seals and gaskets responsible for essentially 'making or breaking' the entire system, the ultimate driver is to eliminate or severely reduce the cost of maintenance and downtime whenever possible," says Marion Fisher, market development manager with Victrex (West Conshohocken, Pa.).

Marcus Pillion, president of Eagle Burgmann (Houston) agrees. "While this is not a new story, chemical processors need equipment to last longer and handle more upset conditions," he says. "The run-ability of a plant is vital these days, so equipment must last longer and be more efficient. For this reason there's a strong drive for new materials and better products in the seals and gasket industry."

Mighty materials

High-performance thermoplastics, such as polyether ether ketone (PEEK; Figure 1), are more often being specified for sealing applications due to its advantageous physical properties, such as high-temperature durability, creep resistance, stiffness and compatibility with a range of chemical environments, says Fisher. "PEEK polymer can be used as a rigid primary seal. However it needs to be manufactured to very tight tolerances to be used this way," she continues. Elastomeric materials are commonly used as primary seals, but their mechanical properties require changes to the seal design in high-pressure applications. Where many elastomeric materials may fail by extruding under pressure, a thermoplastic backup seal ring will increase the pressure limits of elastomeric O-rings and maintain their seal integrity in many demanding environments.

"Many applications are using injection molded PEEK and PEEK films to fulfill these needs in chemical processing operations," says Fisher. This is because PEEK polymer is a much tougher material option and has excellent creep resistance under high-pressure, high-temperature (HPHT) conditions, which helps reduce downtime and maintenance costs in that it needs to be replaced less frequently, she says. Back up rings prevent the extrusion of elastomeric seals in blowoff preventers, risers and valves and allow communication and power connectors to function in demanding and corrosive environments.

Another material innovation includes the use of microcrystalline diamond coatings. "The use of this new material allows operators to have more upset conditions and have a seal that lasts and survives without breaking down as quickly as other materials," says Pillion.

A diamond coating of 8 µm or more in thickness makes the seal faces extremely hard and wear resistant, he says. In addition, the diamond material gives the seals excellent heat conductivity, maximum chemical resistance and low friction.

"The faces can now handle more upset conditions like run dry, which the operators appreciate because now the process itself doesn't need to be perfect," says Pillion. "And, processes rarely are, so this innovation allows operators room for improvement."

A BREATH OF FRESH AIR

Another major concern for chemical manufacturers is the current need to reduce fugitive emissions of toxins like volatile organic compounds and hazardous air pollutants that come from valves, flanges and seals in vaporous forms, says Walt Moquin, business development manager with The A.W. Chesterton Company (Woburn, Mass.).

As part of the Clean Air Act of 1990, the U.S. Environmental Protection Ageny (EPA; Washington, D.C.) was focused on fugitive emissions in the refining industry. As that industry is currently under LDAR (leak detection and repair) programs, the agency is looking closely at the chemical industry, with several major plants having already been issued Consent Decrees. This means they've been found in violation of the Clean Air Act and must, on an ongoing basis, guarantee to the EPA that they will start measuring, monitoring and reducing emissions — usually down to the mid- to low-hundreds parts-per-million (ppm) range — according to the specific Clean Air Act Consent Decree they were issued.

"This is new to the chemical industry and some processors aren't aware that they're in violation, and they should be working to put a plan together that will help them with compliance," says Moquin.

Part of that plan should include packings for low emissions control, he says. The EPA defines "Low E Packings" as those that are guaranteed to leak no more than 100 ppm for five years. This is accomplished via improved technology. "The primary leak point in valves is at the stem and packing interface," says Moquin. "The advanced construction of Low E Packing (Figure 3) results in a non-hardening, flexible packing that will not shrink or absorb moisture. The strands that make up the packing slide easily over one another in response to gland pressure, creating a secure and reliable seal, even in harsh process conditions." ❑

Developing new designs

"When plants have a leakage problem with their gasketed joints, in many instances, they end up installing the same style gasket, using the same installation procedures and three months later they have the same old problem," says Ed Crowley, Northeast regional manager with Flexitallic (Deer Park, Tex.). "But the industry is constantly working on new designs to improve gasket performance, allowing them to compensate for harsh conditions or deficiencies in the equipment or process, and plants are updating their installation procedures to incorporate best practices," he says.

One example of a new gasket design includes Flexitallic's launch of the Change gasket, which testing has shown to provide superior compression and recovery compared to traditional gaskets. The Change gasket consists of a metallic core and can be supplied with a variety of facing and filler materials such as Thermiculite, polytetrafluoroethylene (PTFE) or flexible graphite, making it suitable for a range of applications.

Crowley says the new gasket is a hybrid of a spiral wound gasket and Kammprofile gasket to offer the best performance characteristics of both traditional designs. "This allows it to seal better than conventional gaskets in cyclic conditions, because the Change gasket acts like a spring and therefore maintains a tight joint during thermal cycles," he notes.

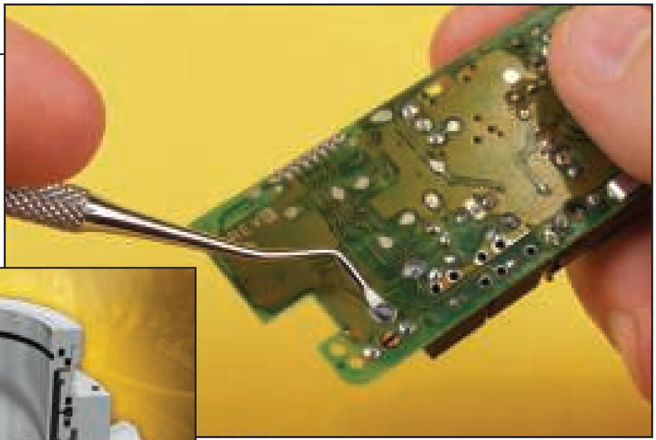
Circle 22 on p. 60 or go to adlinks.che.com/40270-22

SEAL AND GASKET PRODUCTS

Mechanical seals in one assembly for mixers
Featuring both single and double cartridge configurations and designed for easy installation and maintenance, ChemSeal cartridge seals (photo) can be removed from the agitator as a complete assembly and repaired on the workbench before re-installation. The "swing-out" agitator seal-change design contributes to the ease and speed of seal replacement. The seals are available in a variety of materials to meet critical temperature and pressure ratings, satisfying a range of mixing/agitation applications. — *Chemineer, Inc., Dayton, Ohio*
www.chemineer.com


Chemineer

A silver-filled sealant for bonding and sealing
Developed for bonding and sealing, the EP3HTSMED epoxy system (photo) features a rapid cure schedule and a tensile shear strength exceeding 1,000 psi. The silver-filled epoxy adhesive/sealant provides electrical conductivity with a volume resistivity less than 0.001 ohm cm. Serviceable over a temperature range of –60 to 400°F, the sealant is resistant to severe thermal cycling and many chemicals. The product is a thixotropic paste and requires no mixing. It needs only contact pressure during the heat cure of 20 to 40 minutes at 300°F. — *Master Bond Inc., Hackensack, N.J.*
www.masterbond.com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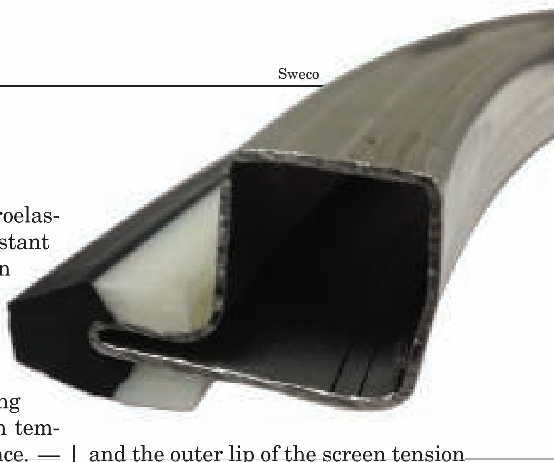
Sweco

Gaskets for high-temperature applications

Therma-Pur can be used to seal connectors in biomass gasification, marine and land-based exhaust systems, turbochargers and mineral and fertilizer processing. The gasket is made in a solvent-free process and combines a unique blend of raw materials with a fiber core. The material provides sealing effectiveness in temperatures to 1,800°F, including extreme thermal-cycling conditions. The low organic-fiber content and non-oxidizing formulation also exhibit low weight-loss ratio. The fiber core makes it safe to handle. The gasket is available in a range of configurations. — *Garlock, Palmyra, N.Y.*
www.garlock.com

A wear-resistant fluoropolymer for shaft seals

To address the compatibility requirement of synthetic lubricants used in industrial gears, a new fluoroelastomer material — a wear-resistant FKM — was developed for use in radial shaft seals that interact with aggressive oils in industrial-gearbox sealing applications. FKM material blends are used in applications containing synthetic oils, as they offer high temperature and chemical resistance. — *Simrit, Elgin, Ill.*
www.simrit.com

A conductive gasket suitable for food applications

The C2 gasket (photo; 24 to 72 in. round) is a co-extruded product of FDA white silicone and conductive black silicone, to produce a gasket that can be used in food and high-static processes. The FDA white silicone element is the only portion exposed to product contact, while the black conductive component of the gasket makes contact with the frames and the outer lip of the screen tension ring (for Sweco STP and spot-welded screens only). — *Sweco, Florence, Ky.*
www.sweco.com

Seal and bearing materials for sanitary applications

Turcon MF6 and Zurcon Z431 PEEK seal and bearing materials (photo, p. 27) conform to the latest version of the 3-A Sanitary Standard and are capable of withstanding high temperatures and the cleaning regimes used in food and beverage manufacturing. Suitable for a range of seal profiles, scrapers and wear rings, Turcon

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Trelleborg

AdvantaPure

MF6 is part of the company's range of PTFE-based sealing materials formulated for food contact, pharmaceutical and medical applications. Zurcon Z431 PEEK is suitable for valve and bearing applications. — *Trelleborg AB, Trelleborg, Sweden*
www.trelleborg.com

Seal and weld biotech-grade tubing

The AdvantaTube Sealer and Sterile Welder (photo) are programmed to seal and weld AdvantaFlex biopharmaceutical grade TPE tubing. TPE tubing works well in peristaltic pumps, may be molded to form sampling and batch filling assemblies and exhibits low levels of extractables. The welder produces tubing welds, where two open ends of tubing are heated and joined to form a leak-free, single length of tubing using an automated process. The welder maintains the sterility of wet, dry or fluid-filled tubing and works with gamma irradiated and autoclaved AdvantaFlex. The sealer offers simple operation. A 10-ft cord connects to a base and allows users to bring the remote sealing head to the tubing. The unit uses heat and compression to securely seal fluid-filled or unfilled tubing in two minutes. — *AdvantaPure, Southampton, Pa.*
www.advantapure.com

Piston rings for oil-free, compressed-gas applications

Carbon-graphite is available for use in piston rings needed to seal high-pressure gas in applications requiring compressed gases that do not contain oil or grease. The piston rings are used in conjunction with carbon-graphite guide rings or carrier rings, which hold the piston centered on a cylinder bore. The self-lubricating, carbon-graphite piston rings and guide rings are used in reciprocating compressors, where oil-free gases, such as air, steam, refrigerants, hydrogen, hydrocarbons, chlorine, nitrogen and oxygen can be compressed to pressures greater than 800 psi. — *Metallized Carbon Corp., Ossining, N.Y.*
www.metcar.com ■

Joy LaPree

Focus

FOCUS ON

Pipes & Fittings

Sartorius Stedim Biotech

A tube welder for sterile biopharmaceutical applications

The Biowelder Total Containment (TC) system (photo) features innovative technology that permits sterile connection of liquid-liquid thermoplastic tubing that has an outer diameter of up to 1 in. and that is used on disposable bag assemblies in all biopharmaceutical manufacturing processes. The sterile welding process is fully automated and can be performed in non-classified or classified environments while maintaining product sterility. The thermal weld produced by BioWelder TC ensures stability, thus guaranteeing an ultra-safe connection. The system has been qualified; biological, physical and extractables tests were conducted to obtain data representing a variety of process conditions, including critical ones. — *Sartorius Stedim Biotech, Aubagne, France*
fr.sartorius.com

ParkerHannifin

This hose is suited for food and pharma applications

This company offers USP Class VI certified RCTW (rubber covered fluoropolymer hose; photo) to transfer materials without contaminating the integrity of the product. USP Class VI certification includes stringent testing of the tube materials to determine biocompatibility, toxicity and extractables of a product. For end users, especially in the pharmaceutical and food industries, purity, taste, smell, color and extractables are critical characteristics. These RCTW hoses are extremely flexible, easy to clean and handle temperatures up to 300°F. The EPDM rubber covers the FEP tube with multi-layers of rubber and polyester reinforcement with an added helical wire for support. The rubber and polyester insulates the tube, and the wire helix supports full vacuum service. Sizes range from 1/2- to 4-in. inner diameter. — *ParkerHannifin / Parflex Div., Parker Page International Hose, Fort Worth, Tex.*
www.pageintl.com

Tube-Tec

Custom-made pipes in just about any geometry

This company is a specialist for manufacturing cylindrical, helical coil systems, flat coils, spirals, elbows and circular manifolds. The company has 20 mandrel and three-reel bending machines capable of bending pipes with an outer diameter of up to 168.3 mm. Elbows with thin walls, such as those used for pneumatic conveying, are manufactured in a special procedure, bending tubes with an outer diameter up to 355.6 mm, minimum radius 2.5 mm × O.D. The company is equipped to form any material such as carbon steel, high- and medium-alloyed steels, austenitic materials, high-strength, heat-resistant nickel alloys (incoloy, Hastelloy, a high nickel ferrous material) zirconium and titanium for aggressive acids. — *Tube-Tec Rohverformungstechnik GmbH, Nistertal, Germany*
www.tube-tec.com

A new double-containment system for hazardous liquids

Introduced in May, the Double-See was developed in response to market demand for an improved pressure-rated double containment system for transporting hazardous liquids. The new system offers a simplified installation method, a patented coupling closure design that allows conformance to the ASME B31.3 test inspection requirements, and a unique 3D thermal-expansion compensation feature. With the Double-See system, both primary and secondary pipes are cut to the same length and can be joined simultaneously. This saves significant time and prevents potential mistakes caused by staggered pipe-cut measurement errors, says the company. Double-See is available in PVC and CPVC; either material can be primary or secondary, with Clear PVC always being an option for the containment pipe. System sizes range from 1/2 in. × 2 in. to 6 in. × 10 in. The new piping systems are suitable for a wide range of applications, including water and wastewater treatment, chemical delivery, dosing and processing, microelectronics, life sciences, metal working/finishing, waste collection and more. — *Georg Fischer Piping Systems, Tustin, Calif.*

www.us.piping.georgfischer.com

Walther-Präzision

Leak-free couplings that also prevent contamination

Clean-break couplings of the new CP Series (photo) were developed for water hydraulic applications and for demanding media in the chemical and medical sectors, for process technology and engineering. Ergonomic and non-squirting operation — even under residual pressure — is made possible by means of a special clean-break valve technology. The function-related residual leakage is thus mini-

mized in such a way that very little media is lost when the fitting is disconnected. At the same time, very little foreign media enters into the pipe system when it is reconnected. Couplings are made in stainless steel (as standard), and are available in nominal sizes 6, 9, 12 and 16. — *Walther-Präzision, Carl Kurt Walther GmbH & Co. KG, Haan, Germany*
www.walther-praezision.de

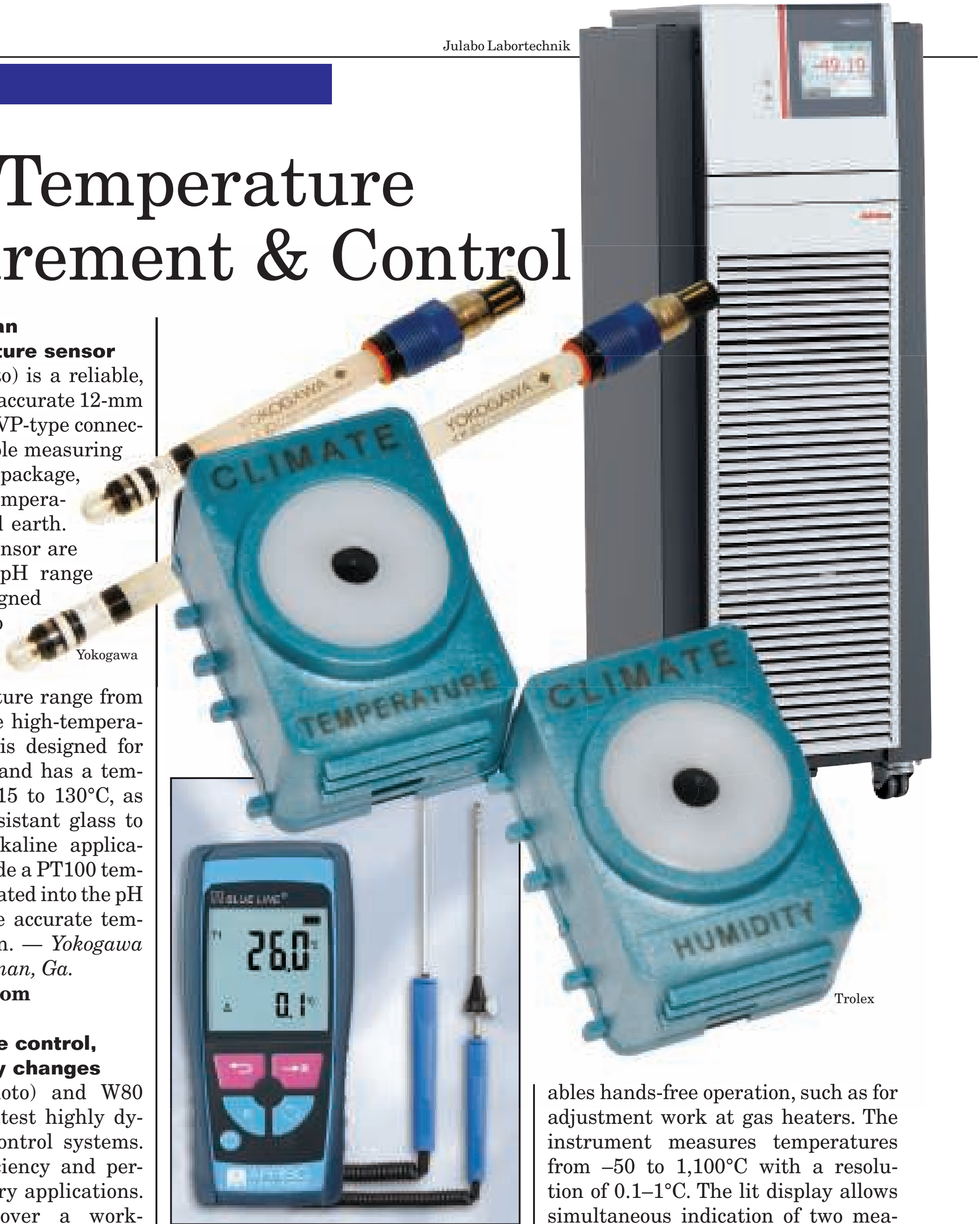
W.L. Gore

A new size for this range of pipe couplings
This leading manufacturer of mechanical pipe-joining systems has introduced a major update to its Style 77 coupling. The two-piece coupling, a mainstay in the mining industry, is now available in 14- to 24-in. sizes. The Style 77 coupling, designed for cut grooved systems, creates a flexible joint and is ideal for abrasive service piping, such as tailings and slurry lines. Maintaining the same design characteristics as the multi-segment coupling, the new two-piece design reduces handling and enables easier and quicker installation, says the manufacturer. The Style 77 is rated for 300-psi service from 14–22 in., and for 250-psi service in the 24-in. size. It is available with a grade "E" EPDM (ethylene propylene diene monomer) gasket for water service, or grade "T" nitrile gasket for air with oil vapors. — *Victaulic Co., Easton, Pa.*
www.victaulic.com

Gasket tape for very large flanges
This ePTFE tape (photo) can save time and money when joining large flanges Based on this company's patented expanded polytetrafluoroethylene (ePTFE), the new Series 500 Gasket Tape for large steel flanges enables industrial plants to save time, money and trouble compared to conventional large gaskets, says the manufacturer. The new gasket tape is said to deliver at least a 50% greater creep resistance than other ePTFE gasket tapes, which gives greater assurance of a secure seal, maximizing operational reliability and performance of flanged connections, says product specialist Peter Wagner. Because the user can create a gasket instantly in any shape, regardless of flange size or complexity, Series 500 Gasket Tape (photo) is a great time saver; it eliminates the time needed for large, custom gaskets to be fabricated off-site. — *W.L. Gore & Associates, Inc., Newark, Del.*
www.gore.com ■

Gerald Ondrey

FOCUS ON Temperature Measurement & Control



Julabo Labortechnik

Yokogawa

Trolex

Afriso-Euro-Index

This pH probe has an integrated temperature sensor

The new SC25V (photo) is a reliable, very stable and highly accurate 12-mm pH sensor that uses a VP-type connector to integrate multiple measuring elements in a single package, including a built-in temperature sensor and liquid earth. Two versions of the sensor are available, both with pH range from 0 to 14 and designed for pressures up to 10 bars. The general purpose version has an operating temperature range from –10 to 80°C, while the high-temperature/alkaline version is designed for harsher applications, and has a temperature range from 15 to 130°C, as well as a chemical-resistant glass to prolong its life in alkaline applications. Both types include a PT100 temperature sensor integrated into the pH compartment for more accurate temperature compensation. — *Yokogawa Corp. of America, Newnan, Ga.*
www.us.yokogawa.com

Precise temperature control, even when viscosity changes

The Presto A80 (photo) and W80 are this company's latest highly dynamic temperature control systems. They unite high efficiency and performance for laboratory applications. Both instruments cover a working temperature range from –80 to 250°C, provide 1.2 kW of cooling capacity and 1.8 kW of heating capacity. The powerful, maintenance-free pumps deliver 1.7 bars and pump up to 40 L/min, and the high flowrates at consistent pressure dynamically adjust to viscosity changes of the bath fluids. The required pump capacity can be adjusted in four stages or as a pre-programmed pressure value. Extensive interfaces permit flexible applications with remote control via an Ethernet network, wireless control with the company's Wireless TEMP solution or integration into a control system. — *Julabo Labortechnik GmbH, Seelbach, Germany*
www.julabo.de

This handheld device measures a wide temperature range

The TMD7 electronic thermometer (photo) is designed to measure the temperature of surfaces, liquids and soft plastic media as well as air and gases. The lightweight measuring device is protected against dirt and shocks by means of a plastic protective sleeve. A magnet at the back enables hands-free operation, such as for adjustment work at gas heaters. The instrument measures temperatures from –50 to 1,100°C with a resolution of 0.1–1°C. The lit display allows simultaneous indication of two measured values (current value, minimum or maximum values). — *Afriso-Euro-Index GmbH, Güglingen, Germany*
www.afriso.de

Monitor mine environments with these systems

The Sentro 8 and Sentro 1 systems now have humidity and temperature modules (photo) available for environmental monitoring in the mining industry. The temperature module can sense temperatures in the range from –10 to 40°C with an accuracy of ±2°C, whereas the humidity module ranges from 10 to 95% relative humidity with

WIKA Alexander Wiegand

Omega Engineering

Laude Dr. R. Wobser

±8% accuracy. The temperature (or humidity) module also gives a sub display of the current humidity (or temperature). *— Trolex Ltd., Stockport, U.K.*
www.trolex.com

Detect a flame from a distance within seconds
The Sierra Monitor 3600-I Triple IR (IR3) Flame Detector detects fuel and gas fires at long distances with a high immunity to false alarms. The device can detect a 1-ft^2 gasoline pan fire at 215 ft in less than 5 s. It features a heated window to eliminate condensation and icing; HART capabilities for digital communications; low power requirements; and a compact, lighter design. The unit can perform automatic and manual built-in-tests to assure continued reliable operation, with a mean-time-between failure (minimum) of 150,000 h. Multiple output options are available, including three relays for alarm, fault and auxiliary; 0–20 mA (stepped), HART Protocol for maintenance and asset management, and RS-486 (Modbus compatible). *— Sierra Monitor Corp., Milpitas, Calif.*
www.sierramonitor.com

Temperature regulation from –80 to 350°C and higher
The process-cooling system Kryoheater KH 150 (photo) is a refrigeration system with an extremely wide temperature range that covers the technical areas of application between laboratory thermostat and heating and cooling system for production. It can be used, for example, to control the temperature of reactors, for environmental simulation, automotive and solar technology, material testing, and for thermostating heat exchangers and evaporators. Depending on the module used, the Kryoheater can operate at temperatures down to –35°C (single-stage compressor), –50°C (two-stage compressor) or –80°C (two refrigeration systems in cascade). The electrical heater enables operation up to 200°C, with an optional system for up to 350°C. Explosion-protected versions are also available. *— Lauda Dr. R. Wobser GmbH & Co. KG, Lauda-Königshofen, Germany*
www.lauda.de

This thermal-imaging camera covers a wide temperature range
The OSXL-T60 series of thermal imaging cameras (photo) is CE compliant (FLIF T62), and is said to have the highest thermal imaging resolution in its class. It also features the industry's first Wi-Fi connectivity, which adds power to analysis, reporting and sharing. Other features include high thermal sensitivity (0.05°C at 30°C), a wide temperature range (–20 to 650°C) with ±2% accuracy, a focal plane array detector with 640 × 480 pixels infrared (IR) resolution, interchangeable lens with four times continuous zoom, MeterLink Wireless Communication and an SD card slot for image storage of more than 1,000 radiometric jpeg images. *— Omega Engineering, Inc., Stamford, Conn.*
www.omega.com

A sensor tailor made for monitoring flat-glass production
This company produces solutions tailored to specific conditions of use. For example, the recently introduced MMG7 sensor is the latest addition to its Marathon pyrometer series, and was specifically developed for use in the production of thin glass. The MMG7 measures IR radiation at a wavelength of 7.9 µm, which is precisely adjusted to the measurement spectrum of the reflecting medium and to the temperature range from 300 to 900°C. At shorter wavelengths, the background radiation could distort the results, while surface reflection is too strong in the longer wavelength region. This point sensor has a 100:1 resolution and achieves a precision of ±1% and a repeatability of ±0.5% or ±0.5°C. With a response time of just 120 ms, the device delivers reliable data even in very fast processes. *— Raytek GmbH, a Fluke Company, Berlin, Germany*
www.raytek.de

Reed contacts enable fast switching with this thermometer
This company now offers gas-actuated thermometers with reed contacts (photo). The recently developed Models 73 and 74 are suited for a wide range of applications, especially for use with programmable logic controllers (PLCs). The reed contacts can be operated in a temperature range of –200 to 600°C. Because of their low contact transition resistance, reed contacts feature a high switching accuracy and a long service life (switching cycle of up to 108). With changeover contacts as a standard switching function, they are also very flexible. The slender design of the reed contacts enables the case height to be reduced by 35% compared to a design with other contacts, says the manufacturer. *— WIKA Alexander Wiegand SE & Co. KG, Klingenberg, Germany*
www.wika.de

An amplifier for converting temperatures to voltages
The Type 5155A multi-channel temperature and pressure charge amplifier is designed to convert the charge signal from all types of piezoelectric sensors and Type K thermocouples into a proportional voltage output signal, for the effective monitor, control and optimization of injection molding processes. Offered in two measurement ranges, with a choice of single, two- or four-channel operation, the device's measurement range inputs can be switched over individually for each channel by remote control. Amplifiers equipped with temperature inputs are provided with one charge amplifier unit and one temperature amplifier, or two charge amplifiers and two temperature amplifiers, in an IP65-rated seal. *— Kistler North America, Novi, Mich.*
www.kistler.com ■

Gerald Ondrey

AUGUST
New Products

Gebr. Lödige Maschinenbau

Richter Chemie-Technik

Yokogawa

Pepperl+Fuchs

This butterfly valve has a PTFE lining

This leading manufacturer of plastic-lined valves and process pumps has expanded its product range of shut-off and control butterfly valves (photo). The company now offers valves with a PTFE disc/stem unit to DN 750 (30 in.) or with a metallic disc/stem unit up to DN 1000 (40 in.). The body lining is made of PTFE. The valves are soft-sealing and gas tight (both lined and metallic versions), and can be used for operating pressures of 0.1 mbar vacuum up to 10 bars and at operating temperatures of –40 to 200°C. The wetted materials are FDA-compliant (U.S. Food and Drug Admin.), and therefore also suitable for use in food processing, pharmaceutical and other sectors. The version with the metallic disc/stem unit is also suitable for free-flowing bulk materials. — *Richter Chemie-Technik GmbH, Kempen, Germany*
www.richter-ct.com

A rubber liner prevents wear in this mixer

Materials that tend to harden during mixing cause rapid wear of the machines. The new continuous-motion Druvaflex Ploughshare mixer (photo) was developed with such applications in mind. The Ploughshare mixer was equipped with a vessel made of multi-layered, reinforced rubber. Due to its elasticity, the flexible mixing vessel — secured in a steel corset — is better able to withstand the pressure of the mixing blades. These blades have the effect of loosening the hardened, brittle product layers from the walls and the material is returned to the mixing process. Rapid wear of the mixing blades and troublesome vibrations are thus effectively prevented. The Druvaflex mixer is available in several sizes for throughputs up to 200 ton/h. — *Gebr. Lödige Maschinenbau GmbH, Paderborn, Germany*
www.loedige.de

A flowmeter for large process lines

The AXW (photo) is a new, larger addition to the Admag series of magnetic flowmeters. The AXW series is suitable for industrial process lines, water and other basic applications. Sizes are available from 500 to 1,000 mm with a wide liner selection, including PTFE, hard rubber and polyurethane. The AWX series comes standard with ASME, AWWA, EN, JIS or AS flanges. A submersible version is also available. — *Yokogawa Corp. of America, Newnan, Ga.*
www.us.yokogawa.com

Space-saving I/O modules with fast maintenance functions

The new four-channel universal I/O module LB104A (photo) for Zone 2 can be placed in a 16-mm wide enclosure due to a new energy-saving electrical design. This is a space saving of 50% compared to the predecessor model. Thus, costs-per-channel can be reduced by using smaller control cabinets. Furthermore, all new modules have status LEDs that display the respective status of the module for each channel, for fast diagnostics. The universal I/O module is also able to operate as analog input or analog output (4–20 mA), or as digital input or digital output. The respective settings can be adjusted in the Device Type Manager for each channel. — *Pepperl+Fuchs GmbH, Mannheim, Germany*
www.pepperl-fuchs.com

This oxygen analyzer is compact and accurate

The XTP601 (photo, p. 32I-2) is a new, compact oxygen analyzer for applications in the process, power-generation and marine industries. The device uses

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

Michell Instruments

thermo-paramagnetic sensor technology to provide stable percentage measurements of oxygen in process gases, including hydrogen, nitrogen and air. It can be configured to measure 0–1% up to 0–50%, 80–100% and 90–100% ranges to meet the specific needs of users, and includes barometric pressure compensation. This helps to provide extremely accurate measurements — ±0.02% O_2 for a 0–1% range, for example. The XTP601 has two isolated 4–20-mA outputs, and is available with general-purpose housing for non-hazardous areas, or an EExd explosion-proof enclosure. — *Michell Instruments, Ely, U.K.*
www.michell.com

New RO membranes with high salt rejection
Five new types of Lewabrane membrane-separation elements for reverse osmosis (RO) are now available. As of July, high-rejection (HR) types with membrane surface areas of 370 and 440 ft^2, and high-flow (HF) types, with membrane surface areas of 370, 400 and 440 ft^2 are available. The HR type elements are designed to provide extremely low salt passage in normal operation, with more than 99.7% salt rejection. The Lewabrane RO products are spiral-wound polyamide composite membranes, with standard lengths of 40 in. and diameters of either 4 or 8 in. The B090 HF 404 membrane element with 4-in. dia. has a unique ATD (anti-telescope devices) design at the end of the element, which extends the surface area of the membranes by almost 6% over other commercially available elements. This leads to higher water productivity. The permeate flowrate is 9.4 m^3/d on average, with a salt rejection of 99.5%. — *Lanxess AG, Leverkusen, Germany*
www.lewabrane.com

A pressure calibrator you can hold in your hand
Extending its line of hand-held measurements, this company has added the model CPH6510 intrinsically safe pressure calibrator (photo). With an accuracy of 0.025% of span and various additional functions, the new device is suitable for a wide range of applications, including those in hazardous areas. It is available with either one or two built-in reference pressure sensors. This allows 24 different measuring ranges of up to 700 bars to be covered. The instrument also accepts transmitter output signals (0–24 mA) and the ambient and medium temperature (–40 to 150°C) is measured by a resistance thermometer. A pressure-switch test function completes the functionality. — *WIKA Alexander Wiegand SE & Co. KG, Klingenberg, Germany*
www.wika.com

WIKA Alexander Wiegand

This new process metering pump boasts many new features
The new Zentriplex process metering pump (photo) features a completely new construction offering the following key benefits and advantages: ultra-compact dimensions, low weight and energy efficiency — a process pump that produces high outputs and efficiency with minimal floor space requirements. The diaphragm dosing heads and hydraulic ends are arranged in a star shape around a drive mechanism, thereby minimizing stresses and loads. The pump is capable of achieving higher pressures and capacities with significantly less material and lower drive outputs. Multi-layer safety diaphragms ensure safe, leakage-free metering and the Zentriplex also has many versatile uses due to its modular construc-

ProMinent

Hugo Vogelsang Machinenbau

Romaco

tion — gear motor, hydraulics/drive mechanics and liquid end. The liquid end and drive mechanism unit are assembled on top of each other to save space, ensuring that the Zentriplex can be used in confined applications or as a direct replacement for existing pumps. — *ProMinent Dosiertechnik GmbH, Heidelberg, Germany*
www.prominent.de

The service life of this pumps is long, and it's easy to service
For pumping demanding materials, this company has launched the IQ series (photo), a low-maintenance product that is easy to use and has low operating costs. The IQ series is designed for industrial applications, wastewater treatment plans and tanker trucks or mobile units in which a pump with a traditional design can't easily be installed just anywhere. The pump chamber consists of one central component. The integrated injection system guides coarse matter through the pump so that it causes much less serious damage. This considerably increases the service life of the pump — by up to 150% in field tests. The number of essential spare parts has been reduced by half, significantly cutting the time it takes to replace wear parts. When any of the wear parts are replaced, from the pump chamber to the seal, not one screw of the connection to the pipes needs to be undone. The pump remains fully attached to the pipework. — *Hugo Vogelsang Machinenbau GmbH, Essen, Oldenburg, Germany*
www.vogelsang-gmbh.com

Improve processing times with this homogenizer
Featuring a new homogenizer generation, the FrymaKoruma Dinex vacuum-processing unit (photo) provides optimal processing times, droplet distribution and product quality. The improved tool geometry enables the product processing time in the homogenizer to be extended and increases the overall efficiency of the system. The optimized energy input is a particular advantage for shear-sensitive products. The tiny droplet sizes achieved with this system enhance the quality of creams, ointments, lotions and dispersions being manufactured. — *Romaco Pharmatechnik GmbH, Karlsruhe, Germany*
www.romaco.com

Eliminate valve noise before it's born
Acoustical noise from control valves is not only potentially harmful to

workers, but the vibrations can also cause damage to pipelines and other equipment. The new Neles Q2-Trim reduces noise up to 30 dB compared to a typical control valve. The Neles Q2-Trim is a combination of various techniques resulting in multiple benefits for operators. By eliminating the damage that high noise can cause to process plants, employees and surroundings, the Q2-Trim ensures a safe working environment for personnel, stable process control and longer uninterrupted plant runtime. Neles Q2-Trim is an addition to the existing Q-Trim technology, and is available for pressure classes ASME 150–600, in sizes 2–16 in. and PN 10–100 in sizes DN 50–400 in standard ball valves. The standard trim material is stainless steel; Q-Trims made of special alloys and larger sizes are available upon request. — *Metso Automation, Helsinki, Finland*
www.metsoautomation.com

Bartec

Measure moisture in natural gas lines with this system
The Hygrophil F (photo) uses a patented Fabry-Perot interferometer principle to measure trace moisture in natural gas. The sensor element of the moisture sensor type L1661 is made of a multiple layers of optically high-reflective and low refractive materials. Pores with a diameter in the tenth of a nanometer range are generated by means of a special manufacturing process. Water molecules of the medium to be measured are absorbed into these pores and change the properties of the optical filter, so that the light passing into the measuring layer undergoes a wavelength shift that is proportional to the moisture content. This is evaluated with a polychrometer and allocated to a dew point. With this procedure, a dew point measurement range of between –80 and 20°C at a precision of ±1°C is realized. It can be used directly in the pipeline under a pressure of up to 200 bars. — *Bartec Benke GmbH, Reinbek, Germany*
www.bartec-benke.de ■

Gerald Ondrey

Waterhammer In Condensate Return Lines

Inserting high-pressure condensate into a low-pressure, pumped condensate-return line can cause waterhammer. Understand why and avoid it

Wayne Kirsner
Consultant

FIGURE 1. The rupture of this check valve from a steam trap assembly allowed the condensate system to drain over 600 ft^3 of condensate over a long weekend into a steam vault, completely flooding it

There is a temptation that steam design engineers find difficult to resist — to put condensate from high-pressure (HP) steam mains directly into the low-pressure (LP), pumped condensate-return (CR) mains. After all, the CR main is so convenient — it is generally laid right next to the outgoing steam main in the same tunnel, trench or racks as the CR main returning to the steam plant. And, the good practice alternatives to dumping the condensate directly into the pumped CR (such as running a dedicated separate HP condensate-return pipe back to the steam plant; or if a user's flash tank is not nearby, flashing the condensate in a small vented tank at each trap then pumping it back into the CR main), seem like swatting a fly with a sledge hammer. After all, we're only talking about flow from a few steam traps discharging maybe 50 lb/h, which is less than one cubic foot of water per hour for each one.

Admittedly, there are so-called work-arounds for this design problem that are less costly and complicated than the good practice alternatives, but I do not believe engineers have proof that they really work. The most popular of these alternatives, was the winner in a competition held years ago by a manufacturer's trap magazine to find the best work-around, but, I believe it failed to prevent the waterhammer that split the check valve pictured in Figure 1.

This article discusses what caused that failure, and gives engineers a criterion for determining if a pumped condensate-return line will hammer when high-pressure and high-temperature condensate is inserted into it. It only addresses what causes condensation-induced waterhammer, which occurs as a result of injecting HP condensate into a LP, pumped condensate return. It does not address column closure waterhammer, another common form of waterhammer in CR systems. Column closure waterhammer is addressed in Ref. 1.

Typical waterhammer scenario

Let us consider a typical scenario where HP condensate at the saturated steam temperature — say 338°F for 100 psi steam — exits the steam main through a steam trap whose pressurized discharge is piped directly into a CR main. The CR main is already flowing full of condensate that is being pumped from atmospheric condensate receivers in the basements of campus buildings or condensate collection points at steam consumers located upstream. The condensate pumps must provide enough pressure to hydraulically push and lift the condensate back to the steam plant — say 15 psig in this scenario. Because the condensate receivers are vented to the atmosphere, condensate received by them flashes to atmospheric pressure and 212°F (at sea level). After some tank and line losses, condensate temperature (in the pumped CR line heading back to the plant) is probably less than 200°F.

When the 338°F saturated condensate (from the 100-psi steam main) is discharged through the steam trap, it undergoes a pressure drop as it passes through the trap orifice to the pressure of the CR line — 15 psig in this scenario. At that pressure, 338°F water cannot exist. The hottest possible water temperature at 15 psig is the saturation temperature of water at that pressure (equivalent to 250°F). Therefore, 88 degrees (338 – 250°F) must be shed from the condensate. In the English system of units, one Btu corresponds to a 1.0°F change in temperature for 1 lb of water, so shedding 88°F pretty closely[1] corresponds to shedding 88 Btu/lb of condensate.

1. A video clip of watercannon can be viewed on the author's website at www.kirsner.org.

Now ask yourself, what happens to this energy?

The answer is that it goes into making steam. Consider that vaporizing an entire pound of 250°F condensate would require about 900 Btu (per the steam table). Since only 88 Btu of excess energy are available, about 10% of each pound of 338°F condensate leaving the 100-psi steam main for the 15-psi condensate system will vaporize to saturated steam, while the remaining 90% of condensate discharge remains in liquid form. So, by mass, there are nine parts water to one part steam entering the condensate return line.

But the masses of the two phases are not what we would notice if trap discharge were visible. We would notice the relative volume of the two phases. Volume wise, the specific volume of saturated steam at 15 psig is about 800 times that of an identical mass of liquid water. Thus, by volume, the ratio of steam to water looks like 800 parts steam to 9 parts water, or 89 to 1. Therefore, what you would see exiting the trap is predominantly steam with a fine water mist interspersed in the steam.

What we essentially have, then, when the HP condensate discharge enters the CR main is a large volumetric flow of saturated steam at 250°F entering a pumped CR line full of 200°F water at 15 psi. The water is subcooled roughly 50°F with respect to the entering steam. This is enough subcooling to support condensation-induced waterhammer. In other words, if the entering steam is able to blow a sizable bubble, which is subsequently surrounded by subcooled condensate, the bubble can abruptly collapse, thereby allowing the surrounding water to rush in to the void left behind by the disappearing steam and smack into itself. Depending on the size of the void, the overpressure from this waterhammer event can exceed 1,000 psi.

Is waterhammer guaranteed?

The answer, surprisingly, is no. And this explains why some steam systems are able to get away with injecting HP condensate into LP pumped condensate returns without severe waterhammer. What determines whether the two mixing flows will hammer as they mix

If $R_{c/s}$ can continuously be kept >1.0 — plus a margin for imperfect mixing — waterhammer due to insertion of flash steam into subcooled condensate can be avoided

is the ratio of the condensing capacity of the condensate flow to the heating capacity of the incoming steam flow. Researchers at Creare, Inc. first defined this ratio as $R_{c/s}$, although their notation and definition are modified slightly here for the scenario being discussed. $R_{c/s}$ is defined as follows:

$$R_{c/s} = \frac{\text{Condensing capacity of the condensate flow}}{\text{Heating capacity of the steam flow}} = \frac{m_c c_p \Delta T_{\text{below saturation temp}}}{m_s h_{fg}} \quad \textbf{(1)}$$

Where:

m_s = the mass flow of flash steam, lb/h

m_c = the mass flow of subcooled condensate, lb/h

c_p = the heat capacity of water (1 Btu/lb-°F)

$\Delta T_{below\ saturation\ temperature}$ = the degrees of subcooling below the saturation temperature, °F

h_{fg} = heat of vaporization, Btu/lb

- ***If $R_{c/s}$ is < 1.0:*** there is not enough flowing condensate-heat capacity to condense all incoming steam flow, so steam bubbles will remain in the mix. The resulting two-phase mixture will not collapse in a waterhammer because there is not enough condensing capacity to allow it to do so. But, the flow is susceptible to hammering downstream if another subcooled-condensate flow merges with the bubbly mixture so that $R_{c/s}$ then goes over 1.0.
- ***If $R_{c/s}$ is initially > 1.0 and there is perfect mixing of the two streams:*** All steam will be condensed as it enters the flowing condensate return main and no steam bubbles will remain to collapse. Thus, if flows remain steady, the mix will not hammer. Call this the "stable" mixing region with respect to $R_{c/s}$. (Note, however, if $R_{c/s}$ is just slightly above 1.0 with imperfect mixing or stratification of the flows, some steam bubbles may persist temporarily and waterhammer would be possible. This is explained below).

The complicating factor in any normal steam system is this: Flows do not remain steady. Condensate pumps cycle on and off to maintain their receiver's tank level; blast discharge traps fire, then dwell, then fire again; and downstream in the CR main other condensate streams may tee-in heading back to the steam plant. All these events change the $R_{c/s}$ of the overall mixture stream. In what the author considers to be a landmark paper written in the mid 1980s for the nuclear power industry, each of these shifting conditions was tested as a function of $R_{c/s}$ with varying liquid-flow velocities to see when waterhammer occurred [2]. In these tests, steam was injected coaxially and cocurrently through a 2-in. injector pipe that was mounted to discharge axially down the middle of an 8-in. pumped condensate line as shown in Figure 2. One hundred and fifty tests for waterhammer were performed, of which about one-half exhibited waterhammer. The tests showed the following:

Case A: Sudden increase in condensate flow. If $R_{c/s}$ was initially < 1.0 in a mixture of constant steam and condensate flows (so that steam bubbles persisted in the mix) and condensate flow was suddenly increased (as if an additional condensate pump were started) so that $R_{c/s}$ exceeded 1.0, a waterhammer always occurred. The situation was similar if the condensate flow was ramped up from a lower flow to a higher flow, although water hammer did not occur in every instance. One waterhammer did occur with initial $R_{c/s}$ as high as 1.3 into the stable region — presumably the result of incomplete initial mixing, which allowed some bubbles to persist.

Case B: Abrupt shutoff of steam flow. Likewise, if $R_{c/s}$ was initially still < 1.0 in the mixture but instead of condensate flow increasing, steam flow

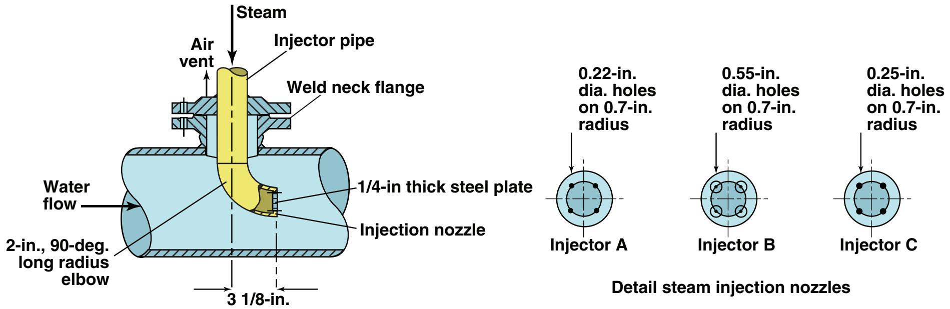


FIGURE 2. In tests, steam was injected coaxially and cocurrently through a 2-in. injector pipe that was mounted to discharge axially down the middle of an 8-in. pumped condensate line as shown here [2]

were abruptly shut off, then again waterhammer generally occurred, as in Case A above as the $R_{c/s}$ abruptly increased above 1.0. An everyday example of this circumstance occurring might be the cycling off of a large blast-discharge trap where its discharge had been sufficient to cause $R_{c/s}$ to locally be < 1.0 in the condensate return line. In some experimental runs — presumably due to incomplete initial mixing — waterhammer was recorded in these circumstances with initial $R_{c/s}$ as high as 1.1.

Case C: High point in pipe coupled with steam shutoff. When a high point was constructed in the condensate pipe during the experiments — specifically a 5% up-sloping pipe joined a 5% down-sloping pipe just downstream of the trap discharge — waterhammer occurred when steam was shut off, even if initial $R_{c/s}$ was as high as 1.4 in one instance and 1.2 in two other instances. This indicated that even though the initial $R_{c/s}$ exceeded 1.0, steam could collect at the high point in the line and persist there long enough to hammer when $R_{c/s}$ was suddenly increased by shutting off steam inflow.

Calculation of $R_{c/s}$ along with these tests provide a roadmap for the troubleshooter to determine what is causing waterhammer when high-pressure and high-temperature condensate is inserted into relatively low-pressure, subcooled pumped CR lines. I stipulate "pumped" because I'm speaking of lines that are completely full of water that are pressurized (or else they would be little motive force to accelerate the water into the void left by collapsing steam) and "subcooled" with respect to the pressure in the line (or else the flashed steam would not rapidly condense to form a void). Of course, the subcooled water need not be pumped but could be flowing under pressure for any other reason. An example would be a high-pressure, high-temperature bypass blowdown from a once-through steam generator (OTSG) coming off line and then mixing in a common line with the cooler bypass blowdown that is discharging from another OTSG being brought on line.

For the designer who wants to "get away with" injecting high-pressure and high-temperature condensate into a pumped condensate return main without waterhammer, the utility of the $R_{c/s}$ is straightforward: keep $R_{c/s}$ >1.4 (1.0 plus a margin for imperfect mixing of 0.4) so that all steam is being condensed by subcooled flow as it enters the condensate return line and, thus, never has a chance to create a steam bubble of any size that can collapse in a condensation-induced waterhammer. Keep in mind that even if $R_{c/s}$ goes below 1.0 at any point in the condensate return system, water hammer is not guaranteed. But, the system is susceptible to hammering if either of the following circumstances changes in the mix:

1. A large blast-discharge trap cycles off
2. Another subcooled condensate flow merges with the CR line downstream

Watercannon

The foregoing discussion has been about waterhammer occurring in the CR main. Watercannon, in contrast, occurs within the discharge piping from the steam trap, which is discharging flash steam and condensate into a pumped CR main. The term, watercannon, refers to water hammer in a vertical tube that is injecting steam vertically downward into a cold pool. [2]

When the flow of high-pressure and high-temperature condensate from the trap shuts off, flash steam is left in the discharge pipe and is entrapped between the closed steam trap and the subcooled water in the condensate return line. If the water is subcooled more than 40°F, the flash steam can rapidly condense, leaving a relative vacuum in the discharge line. The pressure in the condensate return line will then accelerate condensate back up the trap discharge line, causing it to slap into the steam trap or check valve if there is one protecting the trap. Watercannon experiments in the laboratory with water pushed by just atmospheric pressure have recorded more than 1,000 psi overpressure on the valve being struck, when the water is halted.

This is what I believe happened to the check valve pictured at the beginning of this article. It was installed as shown schematically in Figure 3. Listed below is the perfect storm of conditions that I believe enabled the waterhammer that split the check valve body and then a description of what I believe happened.

1. The trap assembly discharged condensate from a 60-psi steam main (saturation temperature = 308°F) to an adjacent, pumped condensate-return line returning sub-200°F condensate back to the steam plant from a single condensate receiver and set of duplex pumps in an upstream building.
2. The duplex pumps in the building cycled on and off to maintain the level in the condensate receiver.
3. The steam trap discharging 60-psi saturated condensate into the pumped condensate return line was a thermodynamic trap (equivalent to a blast-discharge type trap).
4. The engineer used the scheme depicted in Figure 3 to inject the HP condensate into the pumped CR

2. The exiting steam will blow steam bubbles in the pool, and the bubbles will rapidly condense and collapse. If the steam entry point at the top of the tube is choked or has been valved off completely (so that source steam cannot supply makeup steam to the tube as fast as the steam condenses), pool water can be accelerated up the tube into the collapsing steam void in the tube, slamming into the valve that is restricting steam flow at the top of the tube.

main. The idea of the sparger was to break up the flash steam into small bubbles as it enters the condensate return so that any bubble collapse would not involve a large movement of water.[3] This probably works to aid mixing if $R_{c/s} > 0$. I presume it does not help if $R_{c/s} < 1.0$. As far as I know, this idea first appeared in a steam-trap manufacturer's magazine as the winner of a competition to identify the best way to avoid waterhammer while injecting high pressure condensate into a low-pressure, pumped condensate return. The scheme has been repeated in other publications from other sources since then but I am not aware of it ever being rigorously tested.

5. The free area of the sparger holes exceeded the free area of the inside of the distributor pipe, so there was not much restriction to the backflow of condensate from the CR Main.

Under these conditions, the thermodynamic trap would have discharged flash steam into the CR main periodically when the condensate return pumps were off, so there was no condensate flow from upstream. Essentially, the $R_{c/s}$ would have been 0, allowing flash steam bubbles to persist in the CR Main. The 8-in. expanded pipe sleeve, shown in Figure 3, gave a convenient site for flash steam that did not move downstream to collect because of the high point created by the leaving eccentric reducer. The steam bubbles, which did not buoyantly move uphill in the CR system, would have coalesced into a large bubble in the 8-in. sleeve of the distribution sparger.

The calculation in the box (p. 37) shows that when the condensate return pumps in the upstream building cycled on, the Rc/s of the mix of flowing condensate and trap discharge would have gone to well above 1.0, even if the steam trap was still firing. Thus, the steam bubbles in the CR main that were exposed to the onslaught of subcooled condensate would have collapsed. Collapse of the large steam bubble lodged in the 8-in. sleeve would have been particularly violent. The inrushing water from the

3. Water moving into a void needs non-negligible void volume in order to accelerate to an appreciable velocity to cause water-hammer.

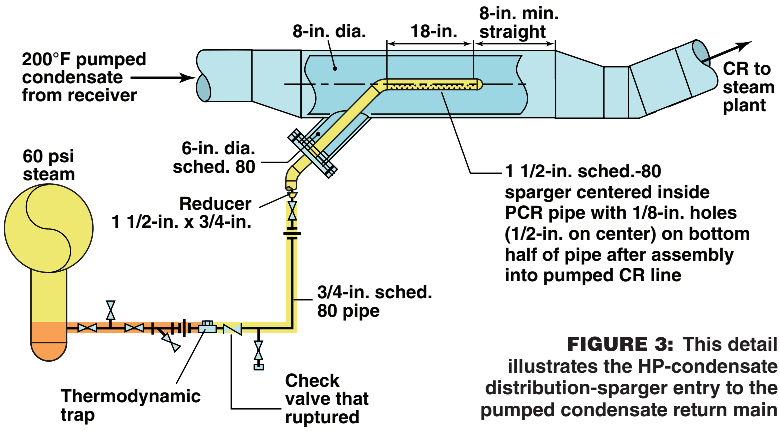


FIGURE 3: This detail illustrates the HP-condensate distribution-sparger entry to the pumped condensate return main

pumped condensate and the back flow of condensate in the CR line would have collided in the collapsing steam void. In addition, if we imagine that the trap had just cycled off so that the trap discharge pipe was still full of flash steam, the pressure of the incoming water columns would have forced water back through the holes of the 1 ½–in. sparger and accelerated it down the ¾-in. trap discharge piping toward the thermodynamic trap.[4] The water column would have been halted, however, by the check valve, which absorbed the impact of the waterhammer collision. Besides jerking the condensation return piping, the resulting waterhammer overpressure would have exerted a hoop stress in the check valve and the ¾-in. piping leaving the check valve. Examination of the check valve showed that the rupture occurred on the downstream side of the flapper where the water column would have struck. The sparger assembly was not available for inspection as it had been disposed of by the time of my investigation.

Could the watercannon have been prevented by a different nozzle design? The tests cited in Ref. 2, examined the effects of three different outlet-nozzle designs on the waterhammer in the condensate return main and steam discharge piping. The nozzles were flat, round plates affixed to the end of a 2-in.-long radius elbow, which entered the 8-in. pipe, turned 90 deg., and discharged steam along the axis of the pipe as shown in Figure 2. The injector plates had four holes

4. The dropping pressure could have, at most, fallen to as low as the vapor pressure of the onrushing condensate. At a temperature of about 200°F, the vapor pressure is about 12 psia.

drilled concentrically on a 0.7–in. radius from the center of the plate, with the only difference being the hole size as described below.

a. Nozzle A: Four 0.22-in. dia. holes; 4.5% net free area
b. Nozzle B: Four 0.55-in. dia. holes; 28% net free area
c. Nozzle C: Four 0.25-in. dia. holes; 5.8% net free area

In the experiments, watercannon was suppressed with Nozzles A and C. It only occurred within the discharge pipe terminated with Nozzle B — the injector with the greatest free-opening area. Apparently, the openings in Injectors A and C restricted the inflow of water so that a substantial velocity could not develop in the discharge pipe heading back toward the check valve and trap. Otherwise, the performance difference in the different injectors was not remarkable. All three vibrated and shook as steam ejected from them and collapsed when $R_{c/s} > 1.0$. The suppression of waterhammer by the restricted nozzles suggests a possible deterrent to watercannon in HP, high temperature trap-discharge lines into LP condensate-return lines.

Outcome of another popular workaround scheme. It is worth noting that there were three other vaults on the pipe run back to the steam plant in which HP traps discharged condensate from the 60-psi steam main into the CR main. There was no waterhammer damage at these vaults nor reports of waterhammer noises as far as I know, even though the $R_{c/s}$ would have greatly exceeded 1.0 in the CR main at these sites, too, when the upstream condensate return pump energized. These three vaults did not

CALCULATION OF $R_{C/S}$ ONCE THE CONDENSATE PUMP CYCLED ON

1. The trap capacity was about 500 lb/h. The saturation temperature of 60-psig condensate temperature is 308°F. The lift to the steam plant from the location of the vault was 40 ft, requiring 17 psi of pressure in the CR line. The saturation temperature of 17 psig is 254°F. That means that the 308°F condensate had to shed 54°F ($\Delta T_{above\ saturation\ temperature}$) to exist at 17 psig. Assuming a specific heat, c_p, of 1.0 Btu/lb °F, that is equivalent to 54 Btu/lb. So the amount of flash-steam heat that would have to be absorbed to condense all potential flash steam ($m_s h_{fg}$) was at most 500 lb/h × 54 Btu/lb = 27,000 Btu/h, or 450 Btu/min.
2. If condensate cooled to 200°F, while sitting in the condensate receiver tank waiting to be discharged, then relative to 17 psig, it has 254–200 = 54°F of subcooling ($\Delta T_{below\ saturation\ temperature}$). Again, assuming a c_p, of 1.0 Btu/lb °F, that is equivalent to 54 Btu of cooling capacity per pound of condensate. Thus, if each pound of condensate can neutralize 54 Btu of steam, the required condensate flow to neutralize 450 Btu/min of flash steam energy is: 450 Btu/min / 54 Btu = 8.33 lb/min. This rate of 8.33 lb/min is equivalent to a little more than 1 gpm of condensate flow (m_c).
3. So 1 gpm is the condensate flow needed to merely absorb all flash steam energy from the trap discharge while it is discharging. If condensate flow exceeds this amount, all flash steam will be condensed.
4. Each 5-hp duplex condensate pump that was part of the upstream condensate receiver assembly was selected to move 60 gpm at 60 psi pressure differential. Assuming the pump operated at this point on its pump curve, and the trap was firing, $R_{c/s}$ with the pump and trap on would have been 60 gpm / 1gpm = 60. ❏

utilize a distribution sparger to break up flash steam entering the CR main. Instead they contained finned heat-exchange tubing downstream of the traps through which the condensate flowed to reject heat into the vault before it was injected into the CR main. This arrangement would have at least limited the amount of flash steam injected into the condensate return. An advantage these vaults had is that they were downstream (in terms of the condensate return's flow direction) of Vault 4. Therefore, the condensate reaching these downstream vaults was somewhat prewarmed by steam injection upstream at Vault 4 before it reached them and thereby had less subcooling available to collapse flash steam.

Did the degree of subcooling of the pumped condensate matter? The $R_{c/s}$ factor incorporates both the flowrate and subcooling of the condensate flow, so it is not clear from Ref. 2 tests whether or not there was a minimum subcooling below which no waterhammer, including watercannon, could take place. The experiments were run with subcooling, which was purposely varied between 50 and 175°F to see if subcooling was an important parameter. With regard to the severity of the waterhammer collapses, the degree of subcooling did not seem to be, by itself, significant. The researchers did not, however, check to see if there was a minimum subcooling necessary to support waterhammer in the CR main.[5]

Summarizing advice

If high-pressure and high-temperature condensate is to be injected into a pumped condensate return line:

1. Maintain an $R_{c/s} > 1.0$ continuously, for the mix of the trap discharge with the pumped CR (plus a margin for poor mixing of about 25%; or, if you've got high points in the CR main where steam can collect, a margin of about 50%). To aid in maintaining this condition:
   - Provide variable flow CR pumping (as opposed to on/off control) in an effort to maintain flow as steady as possible
   - Avoid blast discharge traps like inverted bucket traps in favor of modulating discharge traps. Thermostatic traps with high subcooling settings seem like a good idea to me as long as drip legs are sized to handle the condensate backup
   - Avoid piping designs with local high points where flash steam may temporarily collect
2. Do not try to inject the discharge from HP traps directly into a pumped CR Main if there is only one set of CR pumps upstream and operating in an on/off mode

Keep in mind, the higher the pressure is in the CR main, the more forceful the condensation-induced waterhammer will be in the condensate return system. Pressure gauges, or at least ports for them, should be provided in the CR main to calculate the $R_{c/s}$ in order to troubleshoot problems.

Even with $R_{c/s}$ >>1.0, watercannon within trap discharge lines can still be a problem. In fact, I do not understand why it is not more of a problem when high-pressure cycling traps discharge into low-pressure, pumped condensate-return lines. Most steam-main trap assemblies, after drawing condensate off drip legs near ground level, lift the condensate in a ¾-in. pipe run to above the CR main, then turn down to drop the trap discharge into the top of the pipe. This configuration seems perfect to me for watercannon when the traps cycle off. Most trap assemblies, as far as I have noticed, do not seem to suffer from watercannon when the traps cycle closed. Thus, I hesitate to recommend that restrictive nozzles like Nozzle A and C (shown to suppress waterhammer in Ref. 2 tests) be provided at all high-pressure and high-temperature trap-discharge outlets into low pressure CR lines.

Where there is a problem, however, another simple solution appeared to work in one case on which I consulted. Waterhammer was occurring in the discharge piping from HP inverted bucket traps into a pumped CR main running in a pipe rack about 9 ft above the traps. The owner, upon my suggestion, placed an additional check valve just upstream of the discharge into the CR line at the top of a piping rack. That stopped the hammering by preventing the condensate in the CR main from accelerating all the way down the vertical rise to slam the trap assembly 9 ft below when the trap cycled off. ■

Edited by Rebekkah Marshall

5. 20°C is generally considered to be the minimum subcooling to enable condensation induced waterhammer, but there is no minimum subcooling required where flow is motivated to move into a steam bubble by, say, a pump starting.

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Cover Story

A Primer on Gas-Solids Fluidization

To develop suitable fluidized-bed processes for gas-solids systems, the ability to predict behavior and calculate essential operating parameters is critical. Some of the key concepts and equations are presented

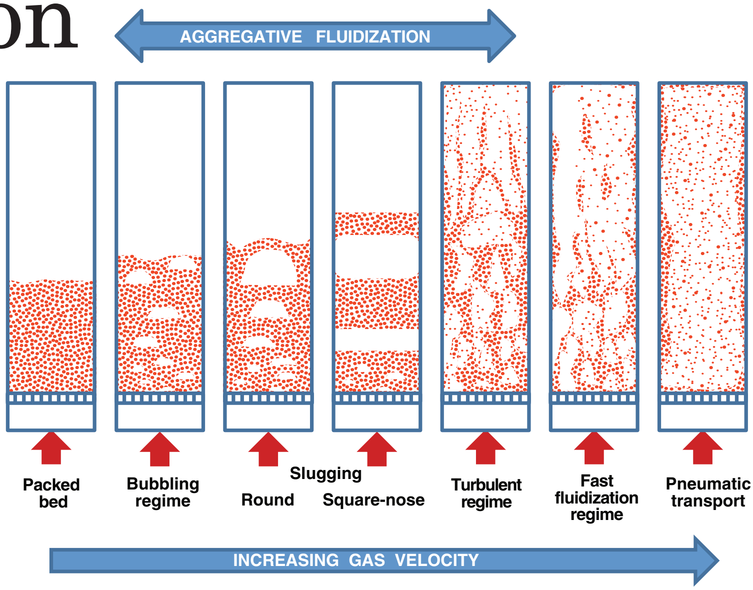

FIGURE 1. Different fluidization regimes in gas-solid systems are demonstrated here (Image adapted from [5] and [7]

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The earliest application of the fundamental concepts of fluidization dates back to 16th century when a German scientist (Georgius Agricola) described a process to upgrade ores. However, it was not until the 1930s, with the development of the Winkler coal-gasification process, that commercial use of fluidized beds on an industrial scale was recognized. The need for gasoline during the World War II accelerated the development and implementation of the fluid catalytic cracking (FCC) process by a consortium of U.S. petrochemical and engineering companies.

During the past five decades, fluidization technology has been extensively applied to various chemical processes. It provides better heat and mass transfer between the fluid and the solid compared to conventional packed- or moving-bed unit operations. Some common industrial processes using fluidization technology include drying, catalytic cracking, chemical synthesis, adsorption-desorption, gasification, pyrolysis, granulation, calcination, combustion, coating, bioreaction, polymerization, ore beneficiation and coking. This article summarizes the basic concepts of fluidized-bed technology and provides a useful collection of equations for gas-solids systems.

Background

When particulate matter or bulk solids are poured into a vessel, the particles arrange themselves into a random configuration to form a fixed (or packed) bed. The space between the particles becomes filled with ambient gas and forms a network of interconnected voids. The volume occupied by the packed bed is always greater than the volume of the particulate material itself. The ratio of void volume to the total volume of packed bed is called voidage. Sometimes "porosity" is used to describe voidage of packed beds, but this should not be confused with porosity within the particles.

When a fluid (gas or liquid) is introduced uniformly at the bottom of the packed or fixed bed, it percolates upwards through the interstitial voids. The drag of the gas on the particles is counteracted by the pressure drop across the bed or the weight of the bed divided by cross-sectional area. The packing configuration of the bed remains unaltered as the fluid finds the tortuous path through the packing in the upward direction.

If the upward velocity of the fluid is increased such that the weight of the bed per unit cross-sectional area is equal to the pressure drop across the bed, then the particles begin to suspend and particle-particle contact is no longer assured. This condition is called minimum fluidization. Further increase in fluid velocity, will cause the suspended bed to exhibit "fluidity" or fluid-like behavior, creating the so-called fluidized bed.

Much like fluids, the particles in a fluidized bed can be stirred and discharged from a lateral orifice in the vessel. Particles of higher density will

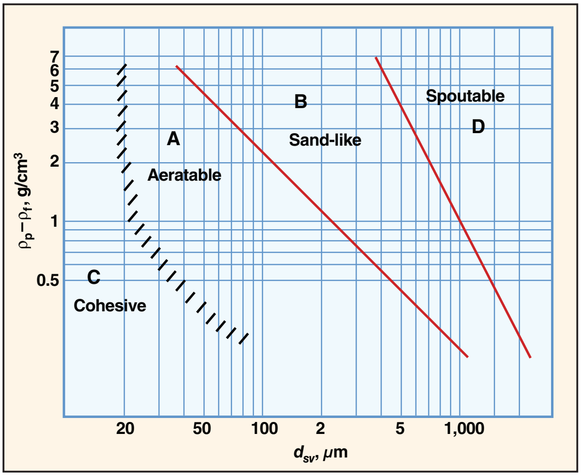

FIGURE 2. Geldart classification for fluidization characteristics in air at ambient conditions [3]

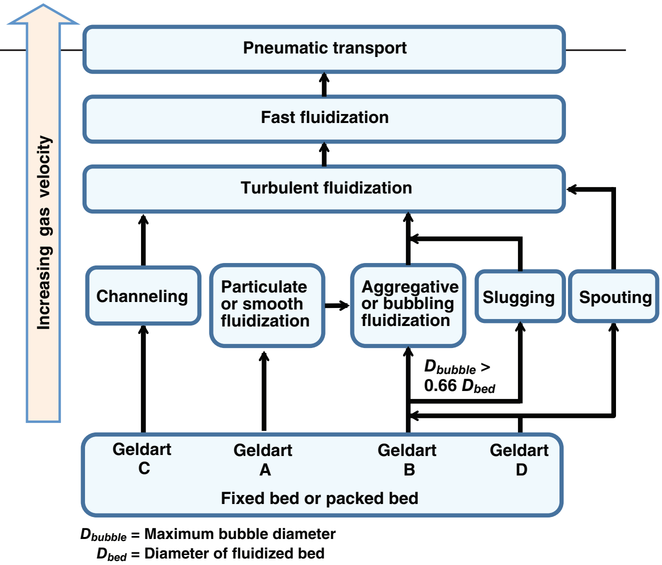

FIGURE 3. Shown here are the typical transitions between various fluidization regimes

tend to sink while the lighter ones will tend to float to the surface of the bed. The top surface of a fluidized bed will be relatively horizontal (with an angle of repose of zero) and the particles will flow from a higher elevation to a lower elevation. Bubbling beds also have similar behavior as sparged liquid columns.

The behavior of the bed after minimum fluidization depends on whether the fluid is a liquid or a gas. For liquids, as the upward flow of liquid is increased, the packed bed continues to expand uniformly and homogenously with increasing interstitial void space until the particles are eventually carried away (elutriated) [9]. This type of fluidization behavior is called particulate or homogenous fluidization.

However, when the fluid is a gas, the excess gas may manifest itself as bubbles. The bubbles will result in two distinct phases within the bed and give an appearance of non-homogeneity. Such a behavior is called aggregative fluidization (Figure 1). Transition from a packed bed to either particulate or aggregative fluidization for gas-solid systems depends on particle and gas properties. To develop fluidized-bed processes for gas-solid systems, the ability to predict flow behavior and calculate essential operating parameters (such as minimum fluidization velocity, flow regimes, bubbling characteristics and more) is critical.

As shown in Figure 1, as the gas flowrate is increased in a bubbling gas-solid fluidized bed, the bubbles coalesce and may grow larger as they migrate to the bed surface (with coarse or granular solids) or achieve a stable size (with fine powders). The passage of bubbles through the bed will result in mixing and churning of the bed material, which creates uniform conditions within the bed. If the bubbles get larger than two-thirds of the bed diameter, slugging may result. Slugging conditions can cause severe pressure fluctuations and bed vibrations along with significant reduction in heat and mass transfer. Commercially scaled units for fine powders tend not to exhibit slugging. However, slugging behavior may be observed with coarse materials.

Further increase in gas flowrate and the onset of a turbulent regime is marked by the disappearance of a distinct bed surface. At this point, the void spaces and the particles form co-continuous phases. At higher velocities, the contents of the bed are elutriated (carried out of the vessel), thereby resulting in partial depletion of the bed material. This fluidization regime — also known as fast fluidization — is characterized by an axial concentration gradient, a subtle core-annulus profile and recirculation at the walls.

At even higher gas velocities, complete removal of the bed material can occur. The "bed" becomes divided between a developing flow and fully developed axial flow with a distinct core-annulus radial profile. This flow regime is referred to as the transport flow regime.

Geldart classification

In 1973, Professor Derek Geldart proposed a simple and elegant approach for predicting the fluidization behavior of particulate materials in a classic paper [2]. He plotted the density difference between the solid phase and the fluid phase versus particle size on a log-log plot, and proposed four major classes (A, B, C and D) based on their fluidization behavior (Figure 2). These have come to be known as Geldart particle classifications.

Since the density of gas is typically three orders of magnitude smaller than the density of particles, the particle density dominates the *y*-axis. The particle diameter on the *x*-axis refers to the surface-volume diameter (d_{sv}) for uniform-sized particles and the surface-volume mean diameter (d_{svm}) when the particles are non-uniform in size.

Typical characteristics of each of the Geldart classes are summarized here:

Class A

- Fine powders
- Easy to fluidize; aeratable
- Exhibit homogenous or particulate fluidization until bubbling
- The bubbling velocity is greater than the minimum fluidization velocity
- Good mixing occurs during complete fluidization
- Slow deaeration rate or long de-fluidization time observed
- Examples include fluidized catalytic cracking catalysts, high-density polyethylene powders and TiO_2

Class B

- Granular appearance, sand-like
- Exhibit aggregative or bubbling fluidization from the onset
- Starts bubbling immediately after incipient fluidization
- Fast deaeration observed
- Examples include coarse sand, polymer granules, detergents, coal feeds and coke

Class C

- Fine (d_p<20 µm) and cohesive powders with high interparticle interaction
- Powders tend to channel during fluidization
- The bed may retain gas for extended periods (that is, may experience a long de-fluidization time)
- Usually requires flow aids for fluidization (such as vibration or additives)
- Examples include fine coal, carbon black, talc, flour, fumed silica and nanoparticles

Class D

- Large particles
- Solids tend to fluidize poorly or exhibit spouting
- Exhibits fast deaeration
- Examples include plastic pellets, rocks, pebbles, grains and seeds

Not all of the fluidization regimes shown in Figure 1 are observed in practice. This depends on the Geldart classification of the material and the bed geometry (in terms of diameter and the height/diameter ratio). The typical flow regime transitions have been summarized in Figure 3.

Minimum fluidization velocity

Minimum fluidization velocity is the transition velocity at which packed-bed behavior changes to fluidized-bed behavior. It corresponds to the condition where the weight of the bed per unit cross-sectional area is equal to the pressure drop across it. The pressure drop increases linearly with gas velocity in a packed bed until the total drag force on the bed starts to approach the weight of the bed (Figure 4).

In beds with small bed diameter (<6 in.), the effective bed weight is slightly less than the calculated bed weight because the bed is partly supported by retaining walls due to friction, and by the distributor plate. If the bed is pre-compacted or the diameter is small, the pressure drop exhibits a peak value before settling into a largely constant value. For beds with wide particle-size distribution, the pressure drop curve will be broader without a distinct point of inflection.

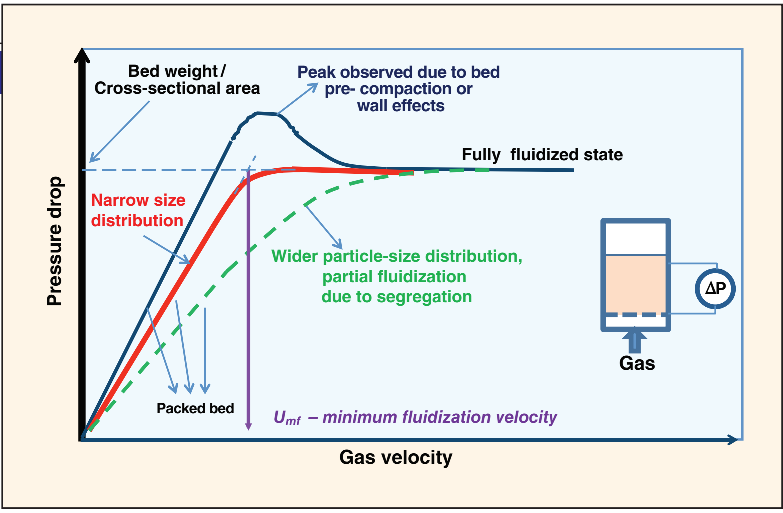

FIGURE 4. Shown here is a characteristic pressure drop response as the packed bed transforms to a fluidized state with increasing gas velocity

TABLE 1. CALCULATION OF SURFACE-VOLUME MEAN DIAMETER

Upper sieve size (Mesh)	Aperture size, micron	Lower sieve size (Mesh)	Aperture size, micron	Average particle size (d_{pi})	Weight fraction (x_i)	x_i / d_{pi}
20	833	28	589	711.0	0.10	0.00014
28	589	35	417	503.0	0.15	0.00030
35	417	48	295	356.0	0.27	0.00076
48	295	65	208	251.5	0.13	0.00052
65	208	100	147	177.5	0.10	0.00056
100	147	150	104	125.5	0.07	0.00056
150	104	200	74	89.0	0.09	0.00101
200	74	270	53	63.5	0.06	0.00094
270	53	Pan	0	26.5	0.03	0.00113
					Sum x_i / d_{pi} =	0.00592
					d_{svm}, micron =	168.8

The minimum fluidization velocity is estimated by linearly extrapolating the packed-bed characteristics and fluidization characteristics, and locating the point of intersection. This is shown in Figure 4 for an example with a narrow particle-size distribution.

The experiment to determine minimum fluidization velocity is best performed by first achieving a fully fluidized state, and then progressively decreasing the gas flowrate.

Pressure, temperature effects

High temperature and pressure conditions are common in commercial processes that use fluidized-bed technology. However, it is often difficult to conduct laboratory experiments at such elevated conditions. Knowlton (Chapter 2 in Yang [*12*]) provides an excellent review of the effect of temperature and pressure on the minimum fluidization velocity. Higher pressure increases the gas density with little change in viscosity, whereas higher temperature increases the viscosity but decreases the density. As a result, the combined effect of temperature and pressure changes often creates confounding effects on the actual state of fluidization.

- Effect of pressure (as shown in Figure 5):
  - The minimum fluidization velocity (U_{mf}) is insensitive to pressure for fine powders (Geldart class A materials)

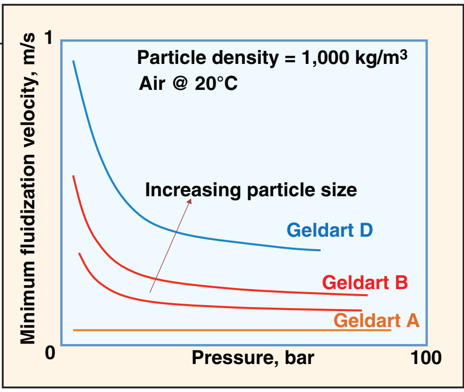

FIGURE 5. The effect of pressure on minimum fluidization velocity is shown here (adapted from Yang [*12*])

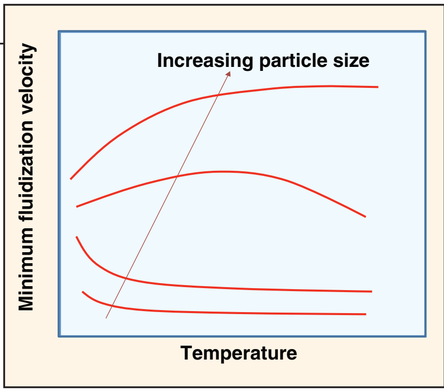

FIGURE 6. Shown here is the effect of temperature on minimum fluidization velocity (adapted from Yang [*12*])

TABLE 2. THE SPHERICITY OF COMMON PARTICLE SHAPES		
Shape	**Relative proportions**	**Sphericity (ϕ_s)**
Sphere	-	1
Spheroid	1:1:2	0.93
Spheroid	1:2:2	0.92
Spheroid	1:1:4	0.78
Spheroid	1:4:4	0.7
Ellipsoid	1:2:4	0.79
Cylinder	*H* = *D*	0.87
Cylinder	*H* = 2*D*	0.83
Cylinder	*H* = 4*D*	0.73
Cylinder	*H* = 0.5*D*	0.83
Cylinder	*H* = 0.25*D*	0.69

- Geldart class B and class D materials exhibit a decrease in U_{mf} with pressure

• Effect of temperature (as shown in Figure 6):
- U_{mf} decreases with increasing temperature for fine powders
- At intermediate particle size, the U_{mf} exhibits a maximum value where viscous forces dominate at higher temperatures
- For larger particles, U_{mf} increases with temperature due to a decrease in density

Particle characterization

Particle size. Size, shape, density and surface characteristics are key intrinsic parameters that dictate the response of a particle in a flow field. While one may use any average dimension of the particle to qualitatively reflect its size, a more precise and meaningful definition is required for calculation purposes.

The size of a spherical particle is uniquely determined by its diameter. Similarly, the size of regular isotropic particles (cylinders, cubes, spheroids) can be uniquely defined by two dimensions. In the real world, however, we deal with irregular three-dimensional particles whose "size" parameter must be uniquely determined. The most logical approach is to define an equivalent diameter that corresponds to a sphere and exhibits the same behavior as the irregular particle when subjected to a given physical process under consideration.

The most common equivalent diameters are briefly defined here. There are no definitive guidelines for the selection of the most appropriate diameter that applies for every situation.

Volume diameter (d_v). The diameter of a sphere having the same volume as the particle is defined by Equation (1):

$$d_v = \sqrt[3]{\frac{6V_p}{\pi}} \quad (1)$$

Surface diameter (d_s). The diameter of a sphere having the same surface area as the particle is defined by Equation (2):

$$d_s = \sqrt{\frac{S_p}{\pi}} \quad (2)$$

Surface-volume diameter (d_{sv}). The diameter of a sphere having the same ratio of volume to external surface area as the particle. This is also known at the Sauter diameter, and is defined by Equation (3):

$$d_{sv} = \frac{6\ V_p}{S_p} = \frac{d_v^3}{d_s^2} \quad (3)$$

A sphere is often used as the reference shape because of its theoretical and experimental convenience. Sieve diameter, Stokes' diameter, Feret diameter, Martin diameter, Perimeter diameter, Chord and Projected area diameter are other notable equivalent diameters that are defined and used in the literature.

Mean or average diameter. Granular materials or bulk solids are an assemblage of particles of varying sizes and shapes. If we were dealing with a collection of uniform sized spheres, the mean or average particle size would simply be a function of the diameter of the sphere. If the bulk solid consists of spheres of varying sizes, then the appropriate average equivalent diameter must be calculated. Similarly, for bulk solids consisting of irregular particles one must first define a property of interest (volume, surface area), estimate the average value for the mixture and then calculate the diameter of the equivalent sphere with the same property value.

The surface-volume mean diameter [d_{svm}; also called Sauter mean diameter, and defined in Equation (4)] is widely accepted and used as the equivalent average (mean) particle diameter for many fluidized bed applications, fluid-particle systems, bins, hoppers and chutes. It is mathematically equivalent to the harmonic mean diameter and can be approximated by the following equation:

$$d_{svm} \cong \frac{1}{\sum \frac{x_i}{d_{pi}}} \quad (4)$$

This definition can be applied to data gathered using sieve analysis or the laser-diffraction method.

A bed of spheres of d_{svm} equivalent diameter will have the same bed surface area per unit volume as the actual bed. This representation creates the necessary bias toward the finer fraction, which reflects the significance of fines in fluidized bed and bin and hopper operations.

A worked example. Calculate the surface-volume mean diameter (Sauter mean diameter) for a granular material using data from sieve analysis. The data and calculations are shown in Table 1.

Median diameter (d_{50}). Particle diameter corresponding to 50% on the cumulative weight percent curve of particle size distribution. Similarly, d_{95} corresponds to 95% on the cumulative weight curve of particle size distribution.

Particle density. Particle density (ρ_p) is defined as the mass per unit volume of the particle. The space occupied by solid, open and closed pores is included in the volume calculation. This is the most commonly used definition of density in correlations. When the volume calculation only includes the volume of solid and closed pores, the corresponding density is called the skeletal density.

Particle shape. The shape factors are based on some combination of surface area, volume, projected area and projected perimeter. The relevance of a shape factor to an application depends on method of measurement and the critical attributes for process performance. For fluid-particle flow systems, namely packed beds and fluidized beds, sphericity (ϕ_s) is most useful. It is defined via Equations (5) and (6):

$$\phi_s = \frac{\text{Surface area of equivalent volume sphere}}{\text{Surface area of particle}} = \left(\frac{\text{Surface of sphere}}{\text{Surface of particle}}\right)_{\text{same volume}} \quad (5)$$

$$\phi_s = \left(\frac{d_v}{d_s}\right)^2 = \frac{d_{sv}}{d_v} \quad (6)$$

The sphericity of a sphere is equal to 1. It is easy to calculate the sphericity of regular isometric particles (this is demonstrated in Table 2). It should be noted that various shapes can have the same sphericity value. Estimation of the sphericity of irregular particles requires measurement of the surface area of particles in the bed. In practice, effective sphericity is back-calculated from the system response (using, for example, the experimental pressure drop in a packed bed and Ergun's equation [see Equaton (24), below].

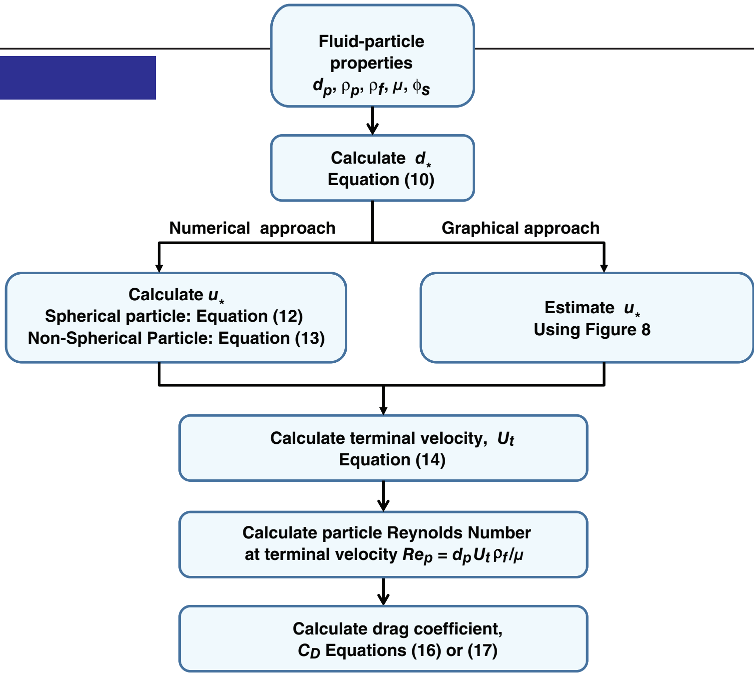

FIGURE 7. This generalized calculation scheme can be used to determine the terminal velocity and drag coefficient

Particle hydrodynamics

Terminal velocity and drag coefficient. When a single (isolated) particle is allowed to settle in a stationary infinite-fluid medium, it reaches a constant settling velocity where the gravitational force is balanced by the drag force and its buoyancy. This constant settling velocity is called the terminal velocity. The settling behavior of an ensemble of particles — the hindered settling behavior (discussed in greater detail below) — is affected by the concentration of the particles.

The forces acting on a particle moving relative to a fluid medium depend only on flow in the immediate vicinity. The drag coefficient for a single particle in an infinite medium is defined using Equation (7):

$$C_D = \frac{\text{Force Acting On Particle}}{\text{Dynamic Pressure} \times \text{Projected Area Of Particle}} = \frac{F}{\left[\frac{1}{2}\rho_f U_f^2\right] A_p} \quad (7)$$

A simple definition of drag coefficient for Stokes regime (Re_p<0.2) is found in Equation (8):

$$C_D = \frac{24}{\mathrm{Re}_p} = \frac{4}{3}\frac{d_p\left(\rho_p - \rho_f\right)g}{\rho_f U_f^2} \quad (8)$$

$$U_t = \frac{d_p^2\left(\rho_p - \rho_f\right)g}{18\mu} \quad (9)$$

While Equation (9) is commonly used for quick estimation of terminal velocity, it does not address the conditions at higher Reynolds number and non-spherical shapes that are often encountered in practice.

A generalized approach for spherical and non-spherical particles. A generalized approach to calculate terminal velocity and drag coefficient in fluid-particle systems was proposed by Haider and Levenspiel [6] (see Figure 7). Characteristic curves with dimensionless particle size (d_*) and velocity (u_*) as the x- and y-axes, respectively, are plotted in Figure 8.

x-axis:

$$d_* = d_p\left[\frac{\rho_f(\rho_p - \rho_f)g}{\mu^2}\right]^{1/3} = Ar^{1/3} = \left(\frac{3}{4}C_D \mathrm{Re}_p^2\right)^{1/3} \quad (10)$$

y-axis:

$$u_* = U_t\left[\frac{\rho_f^2}{\mu(\rho_p - \rho_f)g}\right]^{1/3} = \frac{\mathrm{Re}_p}{Ar^{1/3}} = \left(\frac{4}{3}\frac{\mathrm{Re}_p}{C_D}\right)^{1/3} \quad (11)$$

Where:

$$Ar = d_p^3\left[\frac{\rho_f(\rho_p - \rho_f)g}{\mu^2}\right]$$

$$\mathrm{Re}_p = \frac{d_p U_t \rho_f}{\mu}$$

d_p = Equivalent volume diameter (d_v) of the particle.

The dimensionless velocity (u_*) for

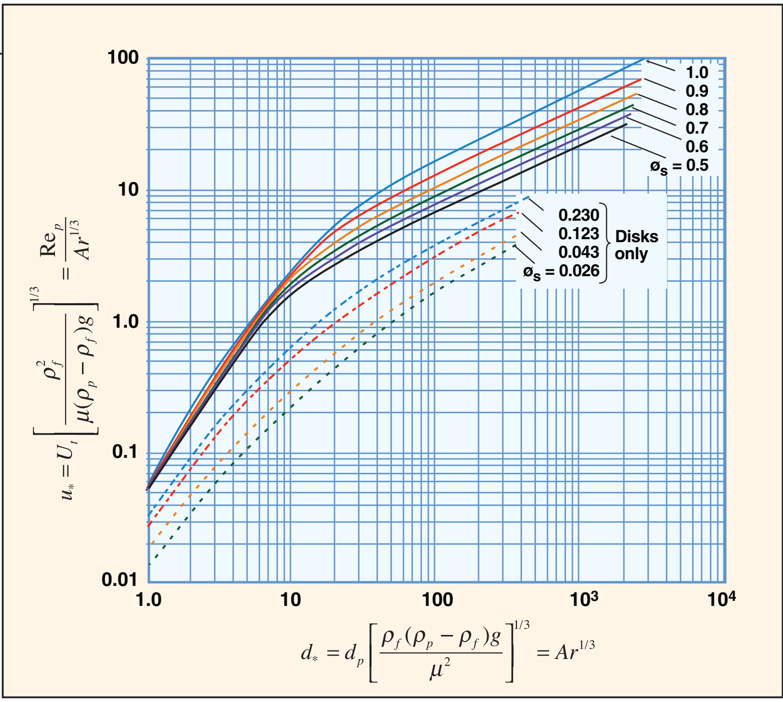

FIGURE 8. A dimensionless plot of characteristic velocity and particle size for isometric irregular particles and disk-shaped particles is provided (Adapted from [7])

spherical particle (ϕ_s = 1) can also be calculated using Equation (12):

$$u_* = \left[\left(\frac{18}{(d_*)^2}\right)^{0.824} + \left(\frac{0.321}{d_*}\right)^{0.412}\right]^{-1.214} \quad (12)$$

For non-spherical isometric particle (0.5 < ϕ_s ≤ 1), use Equation (13):

$$u_* = \left[\frac{18}{(d_*)^2} + \frac{2.3348 - 1.7439\phi_s}{(d_*)^{0.5}}\right]^{-1} \quad (13)$$

Terminal velocity of the particle in an infinite medium can then be calculated using Equation (14):

$$U_t = u_*\left[\frac{\mu(\rho_p-\rho_f)g}{\rho_f^2}\right]^{1/3} \quad (14)$$

Richardson-Zaki Correlation for hindered settling. For multi-particle systems, the presence of neighboring particles affects the settling characteristics of all particles. The most widely accepted correlation for hindered settling was proposed by Richardson-Zaki [*9*]:

$$\frac{U_{t\varepsilon}}{U_t} = \varepsilon^n \quad (15)$$

The value of exponent n depends on the particle's Reynolds number (Re_p):

4.65	$0 < Re_p \le 0.2$
$4.35Re_p^{-0.03}$	$0.2 < Re_p \le 1$
$4.45Re_p^{-0.1}$	$1 < Re_p \le 500$
2.39	$Re_p > 500$

Drag coefficient (C_D). Once terminal velocity is determined, the drag coefficient at the terminal velocity can be calculated using empirical correlations proposed by Haider and Levenspiel [*6*].

Spherical particles:

$$C_D = \frac{24}{\mathrm{Re}_p}\left[1 + 0.1806\,\mathrm{Re}_p^{0.6459}\right] + \frac{0.4251}{\left(1 + \frac{6880.95}{\mathrm{Re}_p}\right)} \quad (16)$$

Non-spherical (isometric) particles:

$$C_D = \frac{24}{\mathrm{Re}_p}\left[1 + (8.1716e^{-4.0655\phi_s})\mathrm{Re}_p^{0.0964+0.5565\phi_s}\right] + \frac{73.69\,\mathrm{Re}_p\, e^{-5.0748\phi_s}}{\left(\mathrm{Re}_p + 5.378e^{6.2122\phi_s}\right)} \quad (17)$$

Where:

$$\mathrm{Re}_p = \frac{d_p U_t \rho_f}{\mu} = \frac{d_p U_t \rho_f}{\mu}$$

Worked example:

Data:

Particle size (volume equivalent diameter), d_p = 1 mm = 0.001 m

Particle sphericity, ϕ_s = 0.7

Particle density, ρ_p = 2,500 kg/m^3

Fluid density, ρ_f = 1,000 kg/m^3

Fluid viscosity, μ = 1.002 cP = 1.002 x10^{-3} kg/(m.s) or (N s/m^2)

Solution:

d_* = 24.226

u_* = 4 (graphical)

u_* = 3.891 (equation)

U_t = 0.096 m/s

Re_p= 95.57

C_D = 1.250

Packed-bed hydrodynamics

Packed-bed voidage. A packed bed of particles always has free space or voids between the particles. The relative amount of voids, which is called voidage (ε_b), depends on the nature of packing and can be determined using Equation (18). Regular hexagonal packing (ε_b = 0.26) and regular cubic (ε_b = 0.48) define the two bounds of voidage for mono-sized spherical particles.

$$\varepsilon_b = \frac{\text{Volume of voids}}{\left(\begin{array}{c}\text{Volume of voids}\\ + \text{Volume of particles}\end{array}\right)} \quad (18)$$

Bulk density, particle density and bed voidage are inter-related:

$$\rho_{bulk} = \rho_p(1 - \varepsilon_b) \quad (19)$$

$$\varepsilon_b = 1 - \frac{\rho_{bulk}}{\rho_p} \quad (20)$$

Using Brown's data [*1*] (d_p > 500 µm), we have developed the following correlations for a randomly packed bed (Figure 9):

$$[\varepsilon_b]_{\text{Loose Packing}} = 1.0473e^{-0.952\phi_s} \quad (21)$$

$$[\varepsilon_b]_{\text{Normal Packing}} = 1.0704e^{-1.087\phi_s} \quad (22)$$

$$[\varepsilon_b]_{\text{Dense Packing}} = 1.0845e^{-1.235\phi_s} \quad (23)$$

When the bed diameter is greater than 30 times the particle diameter, the wall effects can effectively be neglected. It has also been observed that the local voidage at the wall (extending up to 6 particle diameters) will be lower than the bulk value. It is interesting to note that the packed-bed voidage is independent of particle size, as long as the interparticle forces are relatively insignificant, which is the case for most coarse, granular materials.

Pressure drop across the packed bed. There are two major approaches for modeling pressure drop across packed beds — using the channel-flow analogy model and using discrete-particle analysis. The channel-flow analogy models the flow similar to frictional flow in pipe channels where the tortuosity and variations in channel diameter are taken into consideration. The classic approaches of Carmen, Kozney and Blake are good examples of this approach (see Yang [*13*] for details).

Conversely, the discrete particle-analysis approach, which includes the analysis of the impact of drag forces and boundary layers on individual particles, is suitable for applications with higher Reynolds number and higher voidage values.

Ergun equation. The empirical approach proposed by Ergun in 1952 [*3,7,13*] has found widest acceptance, as it is based on a large amount of diverse data for Geldart Class A and B particles. He retained the basic dimensionless variables used in the channel-flow analogy but proposed empirical constants for the viscous and kinetic terms.

$$\frac{\Delta P_{frictional}}{H} = 150\frac{(1-\varepsilon_b)^2}{\varepsilon_b^3}\frac{\mu U_f}{d_p^2} + 1.75\frac{(1-\varepsilon_b)}{\varepsilon_b^3}\frac{\rho_f U_f^2}{d_p} \quad (24)$$

The first term is the viscous term, and the second term is the kinetic term.

$$U_f = \frac{M_f}{\rho_f(\frac{\pi}{4}D^2)} \quad (25)$$

$$\frac{\Delta P_{bed}}{H} = \frac{\Delta P_{frictional}}{H} \pm \rho_f g \quad (26)$$

Use (+) for upflow and (–) for downflow configurations.

For a bed of spheres with uniform size, the particle size (d_p) can be unambiguously specified as the diameter of the sphere. For a bed of non-spherical (isometric) particles of uniform size, the equivalent volume diameter ($d_{sv}=\phi_s.d_v$) should be used for d_p. When the bed is composed of particles of different sizes and shapes, one must estimate a relevant equivalent-mean particle size (d_{svm}), which will result in the same specific pressure drop per unit volume as the given bed. The equivalent-mean diameter is given by Equation (27):

TABLE 3. PRESSSURE DROP CALCULATIONS USING ERGUN'S EQUATION

	Contribution, %	Pa or N/m²	in. H_2O	lb/in.²	lb/ft²
Viscous effect	20.4	9,744.89	39.16	1.41	203.63
Kinetic energy effect	69.3	33,007.54	132.65	4.79	689.74
Static head	10.3	4,905.00	19.71	0.71	102.50
Upflow pressure drop =		47,657.43	191.52	6.92	995.87
Downflow pressure drop =		37,847.43	152.10	5.49	790.88

TABLE 4. PRESSSURE DROP CALCULATIONS USING GIBILARO'S EQUATION

	Contribution, %	Pa or N/m²	in. H_2O	lb/in.²	lb/ft²
Viscous effect	18.0	8,601.74	34.57	1.25	179.75
Kinetic energy effect	56.0	26,676.69	107.20	3.87	557.45
Static head	10.3	4,905.00	19.71	0.71	102.50
Upflow pressure drop =		40,183.43	161.48	5.83	839.69
Downflow pressure drop =		30,373.43	122.06	4.41	634.70

$$d_p \cong \frac{1}{\sum \frac{x_i}{d_{pi}}} \quad (27)$$

Where x_i is the weight fraction corresponding to particle size d_{pi}. The calculation procedure is similar to the one outlined for d_{svm} earlier.

Since experimental measurement of bed voidage (ε_b) is fairly simple and accurate, it is always recommended that the measured value be used. It can also be calculated using Equations (21) to (23).

The sphericity of a sphere is 1. For irregular particles with an arbitrary shape, it is difficult to calculate sphericity from first principles. However, the effective sphericity of a bulk solid for packed-bed applications can be back-calculated from experimental measurement of pressure drop, which can then be used for subsequent predictions.

Worked example. Calculate the pressure drop across a bed of irregular particles:

Particle size, d_v = 2 mm = 0.002 m
Particle sphericity, ϕ_s = 0.8
Packed bed voidage, ε_b = 0.45
Bed height, H = 0.5 m
Fluid density, ρ_f = 1,000 kg/m³
Fluid viscosity, μ = 1.002 cP
= 1.002 x10⁻³ kg/(m.s) or (N s/m²)
Superficial velocity, U_f = 0.10 m/s
The calculations are summarized in Table 3.

Gibilaro equation. Gibilaro and others [*4*] proposed an improved equation to calculate pressure drop. It gives better predictions in both turbulent and laminar flow regimes for packed beds and expanded beds (ε_b> 0.5).

$$\frac{\Delta P_{frictional}}{H} = \left(\frac{17.3}{\text{Re}_p} + 0.336\right)\frac{(1-\varepsilon_b)}{\varepsilon_b^{4.8}}\frac{\rho_f U_f^2}{d_p} \quad (28)$$

Where:

$$\text{Re}_p = \frac{d_p U_f \rho_f}{\mu}$$

The guidelines for choosing a representative particle size (d_p) are the same as for Ergun's equation.

Worked example. The worked example for Gibilaro's equation uses the same data as shown for the example for Ergun's equation, and the results are tabulated and shown in Table 4.

Fluidized-bed hydrodynamics

Flow regime identification. Extensive literature is available to provide guidance on how to identify the flow regimes for two-phase (gas-liquid) systems. For gas-solid flow, various flow-regime maps have been proposed using combinations of gas velocity, pressure drop, voidage, slip velocity, solids loading, Froude number and Reynolds number. The most comprehensive and practical flow-regime map was proposed by Grace [*5*] and later modified by Kunni-Levenspiel [*7*]. They plotted dimensionless superficial velocity (u_*) versus dimensionless particle diameter (d_*) (Figure 10), and demarcated regions corresponding to the major flow regimes observed in gas-solid systems. This map applies to upflow conditions only. The approximate boundaries of Geldart's classification can also be iden-

TABLE 5. FLOW REGIME IDENTIFICATION	
Gas velocity (U_f), m/s	**Flow regime**
0.002	Packed bed
0.004	Minimum fluidization
0.15	Bubbling bed
0.80	Turbulent bed
1.70	Fast fluidized bed/ Pneumatic transport
5.0	Pneumatic transport

TABLE 6. COEFFICIENTS FOR GENERALIZED VERSION OF MINIMUM FLUIDIZATION CORRELATION [*7, 11, 12*]		
Researcher	**C_1**	**C_2**
Wen and Yu	33.7	0.0408
Chitester et al.	28.7	0.0494
Grace	27.2	0.0408
Saxena and Vogel	25.3	0.0571
Babu et al.	25.25	0.0651
Richardson	25.7	0.0365
Thonglimp	31.6	0.0425
Bourgeois	25.5	0.0382
Lucas	25.2 – 32.1	0.0357 – 0.0672

tified in the same plot. Once the x, y pair is located (Figure 10), the expected flow regime can be identified. Dimensionless particle diameter as x-axis:

$$d_* = d_p\left[\frac{\rho_f(\rho_p-\rho_f)g}{\mu^2}\right]^{1/3} = Ar^{1/3} = \left(\frac{3}{4}C_D\,\mathrm{Re}_p^2\right)^{1/3} \quad (29)$$

Dimensionless superficial gas velocity as y-axis:

$$u_* = U_f\left[\frac{\rho_f^2}{\mu(\rho_p-\rho_f)g}\right]^{1/3} = \frac{\mathrm{Re}_p}{Ar^{1/3}} = \left(\frac{4}{3}\frac{\mathrm{Re}_p}{C_D}\right)^{1/3} \quad (30)$$

Worked example. Identify the flow regimes at various superficial gas velocities:

Data:

Particle density, ρ_p = 2,000 kg/m^3

Gas density, ρ_f = 1.3 kg/m^3

Gas viscosity, μ = 0.018 cP = 1.8 x10^{-5} kg/(m.s) or (N s/m^2)

Particle size, d_p (= d_{svm}) = 80 µm = 80 x 10^{-6} m

Acceleration due to gravity, g = 9.81 m/s^2

Calculated d_* = 3.426. Geldart classification: Type A. The results are summarized in Table 5.

Minimum fluidization velocity. While the most reliable estimation of minimum fluidization velocity (U_{mf}) is obtained experimentally (Figure 4), numerous researchers have proposed correlations for predicting it based upon fluid and particle properties [*2, 7, 11, 12, 13* and *14*].

We know that at the condition of minimum fluidization, the pressure drop across a bed is equal to the weight of the bed per unit cross-sectional area. Wen and Yu [*11*], using Ergun's equation as the basis and making empirical substitutions for bed voidage and sphericity based on available data, proposed the following equation:

$$\mathrm{Re}_{p,mf} = \sqrt{(33.7)^2 + 0.0408Ar} - 33.7 \quad (31)$$

Where:

$$Ar = Ga = \frac{d_p^3\rho_f(\rho_p-\rho_f)g}{\mu^2}$$

$$\mathrm{Re}_{p,mf} = \frac{d_pU_{mf}\rho_f}{\mu}$$

For bulk materials with finite size distribution, it is recommended that readers use surface-volume mean diameter (d_{svm}) as given by Equation (4) as the representative particle size d_p.

Re-arranging Equation (31), minimum fluidization velocity can be calculated as follows:

$$U_{mf} = \frac{\mu}{d_p\rho_f}\sqrt{(33.7)^2 + 0.0408Ar} - 33.7 \quad (32)$$

Subsequently, numerous researchers

NOMENCLATURE

- ***Ar*** Archimedes number ($d_p^3\left[\frac{\rho_f(\rho_p-\rho_f)g}{\mu^2}\right]$), dimensionless
- ***A_p*** Projected area of particle, m^2
- ***C_1*** Coefficient in the minimum fluidization velocity correlation (Eq. 33)
- ***C_2*** Coefficient in the minimum fluidization velocity correlation (Eq. 33)
- ***C_D*** Drag coefficient, dimensionless
- ***d_v*** Diameter of sphere of equivalent volume as the particle, m
- ***d_s*** Diameter of sphere of equivalent surface as the particle, m
- ***d_{sph}*** Diameter of sphere, m
- ***d_{sv}*** Diameter of sphere of with same surface to volume ratio as the particle, m
- ***d_{svm}*** Mean diameter of bulk solid with finite size distribution, m
- ***d_**** Dimensionless particle diameter
- ***d_{50}*** Median particle diameter corresponding to 50% on cumulative size distribution curve
- ***d_{95}*** Particle diameter corresponding to 95% on cumulative size-distribution curve
- ***D*** Vessel diameter, m
- ***F*** Drag force on a particle, N
- ***g*** Acceleration due to gravity, 9.81 m/s^2
- ***Ga*** Galileo number (same as Archimedes number), dimensionless
- ***H*** Bed height of packed bed, m
- ***M_f*** Mass flowrate of fluid, kg/s
- ***n*** Richardson-Zaki exponent, dimensionless
- ***ΔP_{bed}*** Total pressure drop across a packed bed, Pa
- ***$\Delta P_{distributor}$*** Pressure drop across gas distributor in a fluidized bed, Pa
- ***$\Delta P_{frictional}$*** Frictional pressure drop across packed bed due to fluid flow, Pa
- ***Re_p*** Reynolds number based on particle ($d_pU_f\rho_f/\mu$), dimensionless
- ***S_p*** Surface area of particle, m^2
- ***U_{mf}*** Minimum fluidization velocity, m/s
- ***U_f*** Superficial fluid velocity, m/s
- ***U_r*** Relative velocity between particle and fluid medium, m/s
- ***U_t*** Terminal velocity, m/s
- ***$U_{t\varepsilon}$*** Terminal velocity under hindered settling conditions, m/s
- ***u_**** Dimensionless velocity
- ***V_p*** Volume of particle, m^3
- ***x_i*** Weight fraction of particles with average particle size of d_{pi}

Greek symbols

- ε Voidage, dimensionless
- ε_b Bed voidage, dimensionless
- ϕ_s Sphericity, dimensionless
- ρ_f Fluid density, kg/m^3
- ρ_p Particle density, kg/m^3
- ρ_{bulk} Bulk density, kg/m^3
- μ Fluid or gas viscosity, kg/m.s

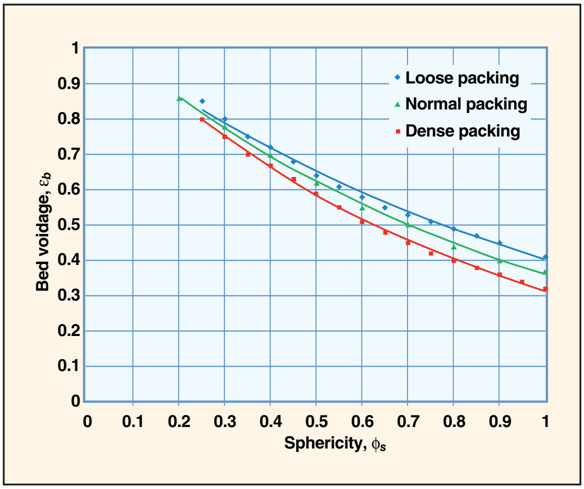

FIGURE 9. The relationship between bed voidage and particle shape is shown here

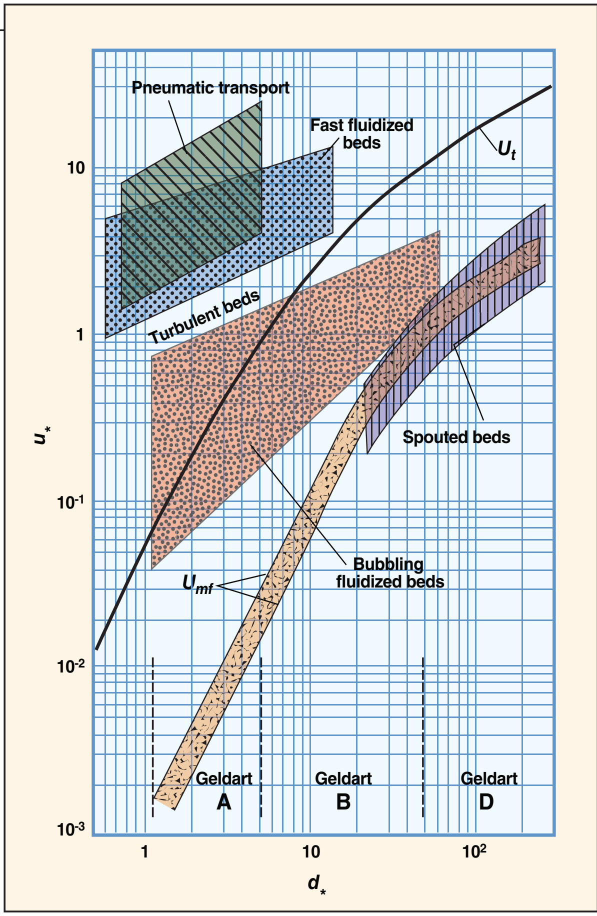

FIGURE 10. Shown here is a flow regime map, according to Grace [5] and Kunni-Levenspiel [7]

have correlated their respective data sets and come up with alternate constants (Table 6). A generalized version of Wen and Yu's correlation can be written as follows:

$$Re_{p,mf} = \sqrt{(C_1)^2 + C_2 Ar} - C_1 \quad (33)$$

$$U_{mf} = \frac{\mu}{d_p \rho_f}\sqrt{(C_1)^2 + C_2 Ar} - C_1 \quad (34)$$

For Geldart A and B materials, Wen and Yu's correlation is recommended, while Chitester and others [7] is recommended for Geldart D materials.

Wen and Yu's approach, while widely used and accepted, still remains controversial. It should be noted that they reported 34% standard deviation for their data set. Therefore, sufficient safety factors must be used when designing processes based on any of these correlations. Whenever feasible, it is recommended that minimum fluidization velocity be experimentally measured.

Worked example.

Data:

Particle density, ρ_p = 2,000 kg/m^3

Sphericity, ϕ_s = 0.75

Gas density, ρ_f = 1.3 kg/m^3

Gas viscosity, μ = 0.018 cP = 1.8 x10^{-5} kg/(m.s) or (N s/m^2)

Particle size, d_p = 200 µm = 200 x 10^{-6} m

Acceleration due to gravity, g = 9.81 m/s^2

Solution:

Archimedes number, Ar = 629.37

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Minimum fluidization velocity (per Wen and Yu) = 0.0262 m/s

Complete fluidization velocity. Complete fluidization velocity is calculated by substituting d_{svm} (or Sauter mean diameter) by d_{95} in the correlation for minimum fluidization. This velocity is often used to define the operating point of fluidized bed processes.

Comment on distributor design. To achieve uniform distribution of gas in a fluidized bed, it is recommended that the pressure drop across the distributor be at least 30% of the bed pressure drop, or at least 10 in. H_2O column (2,500 Pa) on an absolute basis. More in-depth discussion on distributor design can be found in Yang [*12*].

$$\Delta P_{distributor} \geq (0.3) \Delta P_{bed}$$

$$\Delta P_{distributor} \geq 2500 \quad Pa$$

Summary

Despite eight decades of research and development of powerful computer tools, the core of fluidization technology remains largely empirical. Scaleup and design of large-scale processes based on small-scale cold flow data still remains a challenging problem.

In this article, we have touched upon key concepts of fluidization technology and summarized key equations for particle characterization, particle and bed hydrodynamics. For in-depth understanding of the subject, the books by Geldart [*3*], Kunni-Levenspiel [*7*], Yang [*11, 12*] and Zenz-Othmer [*14*] are excellent resources. ■

Edited by Suzanne Shelley

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Feature Report

Control Valves: An Evolution In Design

Emily Hoop
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Understanding the design features of globe-style control valves can help in selection for specific applications

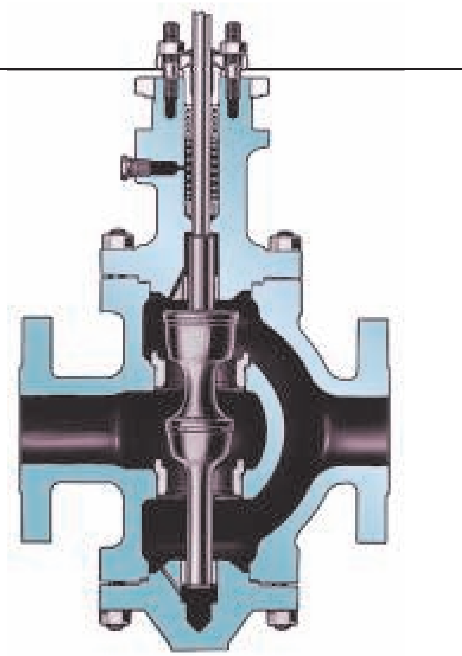


FIGURE 1. The typical globe-valve design prior to the 1960s included a heavy, thick-walled body casting with two internal ports and a top-and-bottom guided valve plug

Globe-style control valves are in virtually every chemical processing line where pressure and flow must be controlled. And for the most part, they perform as required, day in and day out, requiring little to no thought or attention. In short, control valves are not an everyday topic of discussion.

In fact, the globe valve provides a direct contrast to today's consumer electronics where major changes seemingly are announced and touted every year. While these valves represent an evolution of gradual change, significant improvements in control capability, reliability and breadth of application have been made in recent years.

Until about 45 years ago, globe valves with their massive body castings and rugged stem-guided valve plugs prevailed across the chemical process industries (CPI). Yet despite their wide usage and decades of service, the valves of that era were quickly replaced by a new, efficient-in-design globe-valve body that utilized interchangeable, drop-in trim packages to meet a wide range of control needs. This article answers the "what" and "why" questions about the changes in control valve design, and in doing so, offers readers a better understanding of what valve features are available and how they may apply to particular application needs.

Background

A historic disruptive innovation was brought to market in the mid-1960s with the introduction of cage-style trim. Prior to that time, the control valve shown in cross-section in Figure 1 was typical of the globe design offered by valve manufacturers. It featured a heavy, thick-walled body casting with two internal ports and a top-and-bottom guided-closure member, or valve plug. Single-port valves were offered as well, and their body castings mirrored that of the large, double-port design. For decades these valves provided adequate service in a wide variety of applications. So why the dramatic 1960s change in body shape, mass and trim design?

The answer, quite simply, is economics. That double-ported valve required a great number of machining operations. Both the bonnet and bottom flanges were drilled and tapped. The internal webs were also bored and threaded in order to accommodate screwed-in seat rings. Assembling the dual-port valve body required extra effort to ensure that when the valve plug moved to the closed position, its seating surfaces contacted the seat rings simultaneously. All of these machining and assembly procedures required time and effort that built cost into the final valve product.

The 1960s-design globe valve with its cage-style, drop-into-place internals avoided many of these cost creators. Its body casting minimized material use while still complying with all design codes and requirements. It eliminated the machining and assembly of the previous design's bottom flange and internal seat-ring ports. And since the new trim style relied upon the flow cage to control valve-plug movement, the potential for misaligned valve-plug guides was gone (Figure 2).

Benefits for the user

While the valve manufacturers realized a cost reduction in the new versus old design, so did the valve user.

Tight shutoff reduces lost product. Improved reliability meant reduced maintenance costs and increased plant efficiencies. Double ported valves offered ANSI/FCI Class II shutoff, while the cage-designed valve provided a huge step change to ANSI/FCI Class VI shutoff capability. Recapturing this lost process equated to money back in the user's pocket. Maintenance became less of an issue with cage-style trim. For the most part, a changeout of trim components required pulling out the old and dropping in the new — a relatively simple procedure.

Protecting your investment with anti-cavitation trim. Prior to the cage-style valve, answers to specific control problems, such as cavitation

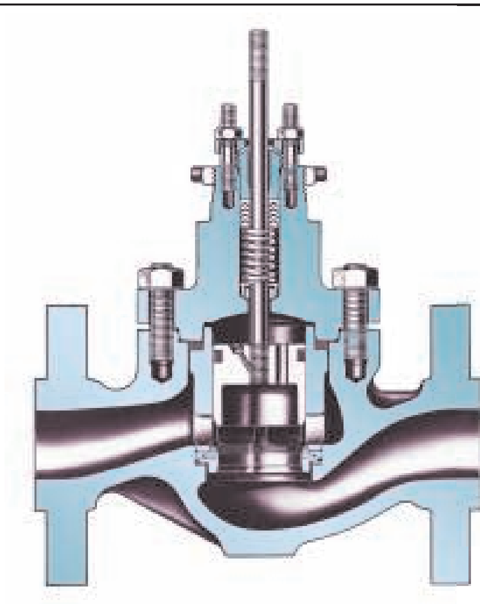


FIGURE 2. This 1960s globe-valve design has cage-style trim

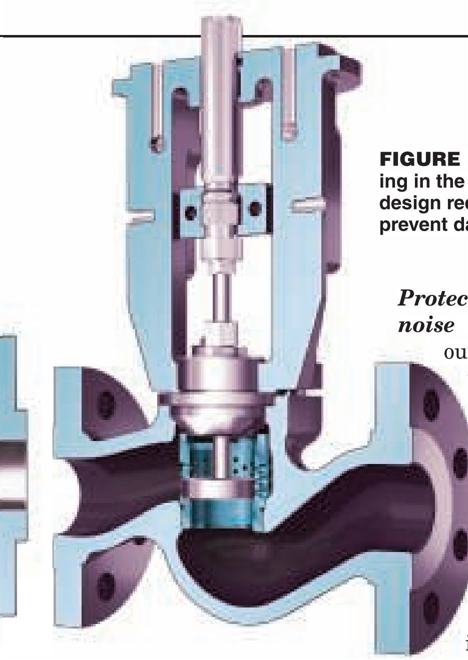


FIGURE 3. Drilled-hole shape and spacing in the cage wall along with flow-down design reduces and isolates cavitation to prevent damage

and operating noise extremes, involved use of expensive and often less-than-successful solutions. With simple trim changes, these problems could now be solved with cost-effective and reliable solutions.

Staging the pressure drop so that the pressure remains above the liquid's vapor pressure can prove effective in avoiding cavitation. With the pre-1960s valve, staging often involved the use of an orifice plate downstream of the main valve or the use of two valves in series. However, these techniques typically displaced cavitation from the main valve to the downstream restriction and did not effectively control the cavitation in the system. They also increased valve size, as less pressure drop was available to process the same amount of flow. Cavitation control was often less than successful, and the continual need to replace damaged piping components proved costly.

The cage-style valve delivered an answer to this cavitation dilemma with its specialized cages. For example, one cage design contains a multitude of highly engineered, shaped holes that improves the flow performance. The holes are radially aligned to flow cavitating jets of liquid to collide in the center of the flow stream, thereby avoiding damage to valve and pipe surfaces (Figure 3).

A more-extreme pressure-drop cage trim is designed specifically for liquid applications where pressure drops are above 207 bars (3,000 psi) and cavitation is a serious problem. It stages the pressure drop across successively larger flow areas, such that more than 90% of the overall pressure drop is taken in the first stages where there is little danger of bubble formation. Cavitation is completely avoided, thus protecting the valve, and providing an answer to the high cost of valve trim replacement.

The evolution of the specialty, anti-cavitation trims has extended to services where the fluid may have entrained particulate matter that could plug trim passages or cause erosion damage to conventional anti-cavitation trims. Used frequently in high pressure-drop applications up to 4,200 psid, this trim design employs a combined axial and radial flow path with large openings that allow particulate matter up to ¾ in. in diameter to pass through the valve. Due to the need for tight shutoff in many applications, its multi-stage design features a protected seat where the shutoff function of the valve is separate from the throttling areas of the trim. All significant pressure drops are taken downstream of the seating surface, and the seating surfaces are not worn away by throttling control action. The result, once again, is that replacement trim costs are avoided.

Continued product evolution of that mid-60s valve innovation created answers to other long-standing control valve problems.

Protecting your investment with noise attenuation trim. Throughout the CPI, steam applications with high pressures and large pressure drops can be noise generators that cause equipment damage and control issues. Because it can affect plant availability and profitability, control valve noise is a concern shared by plant operators and maintenance personnel. Equally significant is the fact that high noise levels can cause health concerns for personnel whose workday keeps them on the plant floor.

The prevalent noise source of aerodynamic flow is fluid turbulence within the control valve body. Before cage-style trim, noise control techniques did not consider the reduction of flow turbulence as an answer. Instead, they centered on the use of acoustic wrap on the valve and adjacent piping, which served only to mask the noise. While this approach may have been adequate in protecting personnel who were working close to the valve, the noise would reappear downstream relatively unabated.

In the late 1960s and early 1970s, studies focusing on the mechanisms and abatement of control valve noise led to the development of different strategies to control fluid-generated noise. Today, putting these strategies to work are cage-style trims that utilize unique flow-passage shapes and multi-stage pressure reduction — capabilities not possible with previous generation valve designs.

A principle noise-reduction strategy is to break the aerodynamic flow stream into many small, parallel flow passages that ensure exit jet independence as flow exits the cage. This technique reduces the power of the noise source as it shifts the frequencies to a higher, more easily dissipated range. Up to 18 dB(A) of attenuation is typical.

Yet another cage architecture utilizes drilled hole technology to deliver excellent noise reduction for a wide range of vapor, gas and steam applications. Providing up to 30 dB(A) of attenuation, these cages also employ jet independence and frequency shifting. The design of this style flow cage gives the added benefits of flexibility of size, pressure class, materials of construction, rangeability and attenuation.

At the top of the noise attenuation hierarchy is the laser-cut, stacked-disk cage assembly (Figure 4) that provides up to 40 dB(A) attenuation in even the most severe applications. It employs unique passage shapes that stage pressure reduction to reduce acoustic efficiency and turbulence. Utilizing the expanding area principle to compensate for volumetric expansion of depressurizing gas, the velocity is managed through the valve. The parallel flow passages ensure exit jet independence, avoiding jet recombination and providing efficient coupling into the valve body. This stacked-disk cage design actually shifts the frequency spectrum, which reduces the audible acoustic energy and strain energy in piping. Combined with the complementary body design of the control valve, the solution prevents impingement on the body wall and offers enough cavity size and shape to control secondary noise sources.

Cavitation and noise control trims are but two examples of how control valve capabilities have evolved since the 1960s globe-valve revolution.

Environmental challenges

Continued studies into the mechanisms of fluid flow brought answers to other tough applications, such as extreme high-pressure control and related clearance flow problems. Cryogenic liquefied natural gas (LNG) services needed answers on how to ensure continued valve operation and survival at temperatures down to –321°F (–196°C), and valve metallurgists helped provide those answers. Environmental mandates required answers to valve-related fugitive emissions. Extended studies and evaluation programs led to packing systems that not only perform beyond minimum requirements, but also ensure smooth and continued valve operation.

While control valves have always been essential to the CPI, today the demands are different thanks to global competition and continued pressure to boost plant performance and improve process reliability. As never before, the control valve has a direct impact on a facility's operational excellence — a combination of profitability, plant efficiency, quality and safety — putting it at the top of the process engineer's list of critical control equipment.

Looking ahead, will there be another control-valve design revolution to match that of the 1960s? The basic concept of a globe valve with drop-in, cage-style trim continues to provide dependable process control over an extreme range of applications. However, while change and development of the globe-style control valve march ahead at a slow and measured pace, that's not the situation with valve-related instruments.

The digital valve controller

The introduction of the digital valve controller some 15 years ago marked a step-change in control valve operation and maintenance by enabling functionality that goes far beyond that of the traditional analog or pneumatic positioner.

Today, the role of the digital valve controller is to ensure control valve performance and reliability, first by accurately establishing and maintaining a control valve's operating position to reduce process variability, and second by diagnosing the operating health of the assembly to allow predictive and effective control-valve maintenance.

For example, the digital valve controller — when interfaced with advanced asset-management applications — provides a way to increase plant reliability and productivity while reducing costs. Diagnostic software utilized with the controller serves as a configuration, calibration and diagnostic tool. Of particular importance is that the software provides feedback regarding control valve operation, resulting in the identification of poorly functioning valves that are impacting process efficiency.

As an example, in one of many such instances when valve diagnostic software was utilized to evaluate 188 valves at a major chemical plant in Texas, only 14 of those valves actually needed service. By evaluating, diagnosing and prioritizing control valves for maintenance prior to a plant turnaround, the user realized substantial cost savings.

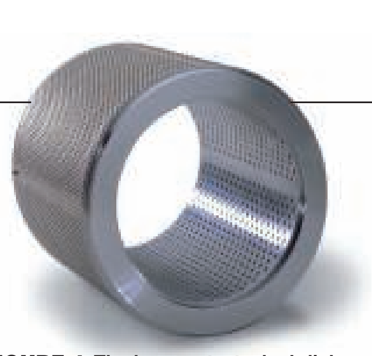


FIGURE 4. The laser-cut, stacked-disk cage design is a concept in multi-path, multistage acoustic energy management that reduces valve-caused aerodynamic noise

This ability to analyze a control valve's operating condition, aptly called performance diagnostics, enables performance monitoring of the entire valve assembly (not just the digital valve controller) while the valve is actively controlling the process. Examples of identifiable issues include the following:

- Low air supply or pressure drop
- Incorrect regulator setting
- Dirty air supply
- External air leak (actuator diaphragm or tubing)
- Calibration shift
- Valve stuck
- Piston actuator O-ring failure
- Excessive valve-assembly friction
- Excessive valve-assembly deadband
- Elastomer failure
- Broken actuator spring

Performance diagnostics continuously analyze the valve assembly and passively gather data without disturbing or interrupting the control valve while it is in the process. These diagnostics may be used to help detect problems; and when identified, the diagnostic provides a description and severity of the problem, a probable cause and a recommended course (or courses) of action.

Dynamic performance diagnostics are run optimally as part of a plant shutdown. These full-stroke tests vary the digital valve-controller setpoint and plot valve operation to provide insight into the dynamic performance of the valve/actuator assembly. Performed while the valve is isolated from the process, the tests include valve signature, dynamic error band, step response and stroke check.

FIGURE 5. This compact chemical-service control valve is equipped with an integrated digital valve controller that features non-contact, linkage-less technology

Since a process control plant, regardless of industry, makes money based on its ability to minimize variability and maximize availability, the digital valve controller becomes an essential control valve component thanks to its ability to maintain control valve position, provide assembly diagnoses and enable predictive maintenance.

The digitally integrated valve

While keeping up with the latest revision of our consumer electronics, our culture has grown accustomed to products that are intuitive. These products allow us to do our jobs faster, more efficiently and most often with fewer resources. A recent innovation was the design of the digitally integrated control valve (Figure 5). The valve, actuator and digital valve controller were designed together, providing optimized performance and using the theoretical minimum of parts needed. Alloy constructions became much more affordable to the CPI user than previous valve designs, including the 1960s cage-style design. Reliability and maintenance were improved and, of course, the cost to the user reduced yet again.

This concept offered a tidy and compact solution, having eliminated external tubing and reducing the overall envelope dimensions. Now the digital valve controller could sense the valve stem position without using mechanical linkages inherently prone to wear. A magnet array connected to the valve stem slides through a Hall-effect sensor in the digital valve controller to detect valve travel. The digital valve controller paired with this control valve provides a local pushbutton for calibration. This feature brings the control valve into a new realm of intuitive use for instrument and control technicians.

The decision to design this product may have been driven by economics, but it was made possible by means of modern tools and processes previously not available. Tools — such as computer aided design (CAD) software — improved the ability for foundries to make consistent patterns to capture the design intent. Today, patterns are made directly from 3D models to ensure accuracy. Finite element analysis (FEA) is used to calculate stresses to optimize casting weight. Fluid dynamic modeling is used to analyze flow geometry for an optimal performing design. Manufacturing processes also evolved to a new level of efficiency. Not only are the tools carefully defined for each step of assembly, but also the process in which the product is tested throughout assembly, both improve the overall quality. Another level of precision and quality is achieved by using the lost wax-casting process to achieve design goals. These modern processes finally provided the means to execute the ideal control-valve design for CPI users — smaller, lighter and less expensive.

Wireless valve control

Wireless technology in process control is becoming a game-changer. It lowers implementation costs, creates new approaches to valve monitoring and control strategy, and expands access to areas within the plant that were previously out of reasonable reach.

While the simplicity and economic advantages of wireless are changing new-project and new-installation wiring practices, the largest target of opportunity lies with valves that are already installed. Plants that implement wireless feedback gain the competitive advantages of reduced operating costs, improved product quality, greater product throughput and increased levels of worker safety.

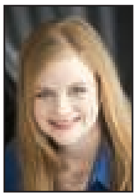
Available today are smart wireless adapters for use on digital valve controllers that utilize the HART communications protocol. The adapter provides an easy way to access otherwise "stranded" valve diagnostics. The wireless adapter also can be used to pass along important valve operating and maintenance information, including valve friction, pneumatic leaks (air mass-flow test), and instrument problems (I/P [going from an electric signal to a pneumatic signal] and relay integrity test), that can be viewed and analyzed to improve process performance.

Wireless valve monitoring is available today. Wireless valve control is not. Yet many plant operations are embracing today's position monitoring and looking toward wireless valve automation and control in the near future. Designers of control strategies will take increasing advantage of wireless instrumentation to expand the reach of automated valve control as well as gain increased valve-health awareness. The digital communication link with globe valves has decreased the cost of commissioning thanks to auto-tune and auto-calibrate features.

The possibility of wireless control will greatly reduce commissioning cost. Performance diagnostics improve the reliability of globe valves by communicating impending problems so that repair can be planned and executed prior to an unplanned outage. Once again, the driving force of globe valve evolution is economics, reducing the total cost of ownership. This, in all likelihood, is the next control valve revolution. ■

Edited by Dorothy Lozowski

Author



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Process Lead Responsibilities In Design Projects

Picking the right people for the job, and knowing what is required of them is essential for the success of a project

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Vista Projects

Arbitrarily, process leads can be categorized into three different sub-categories or levels. Level one process leads are those who directly interact with the client to achieve the results required of the project, and are therefore accountable for any and all mishaps. Additionally, these leads supervise other lead process engineers who in turn supervise a team of their own.

In the second level, process leads only supervise a group of lead process engineers in charge of their own teams but they don't communicate with the client directly. At the lowest level, process leads are in charge of a group of non-lead process engineers. Each of the process engineers in levels two or three can be named as sub-leads.

In this article, we are mainly focused on groups two and three and will not discuss the relationship between the process lead and the client.

Every lead must satisfy project needs, team needs and the individual needs of his or her team members. The focus of this article is on project needs.

Project needs

Each project has three main aspects: quality, cost and schedule. A project should be done with the quality required by client (which is not necessarily the "highest" quality) in the specified time and for the cost anticipated. Violation from any of these aspects will decrease the success of the project. A process lead addresses these requirements by doing three things: Planning, budgeting, and scheduling.

Planning means assigning the right person to the right task. This can be done by realizing each person's skills (and desires) and having a clear understanding about the nature of each task.

Scheduling tasks means preauthorizing each task to meet the project deadlines.

Budgeting can be money budgeting or man-hour budgeting. In man-hour budgeting, a process lead should be able to estimate the required time needed to finish each task.

Planning: Person for the task

Process engineer's skills. Engineers are commonly categorized into three levels: senior, intermediate and junior. A balance must be created in the mix of each of these categories within the team.

At the same time, however, it may be more beneficial for the lead to categorize his or her team within four other categories, as follows:

1. Group one consists of individuals with the ability to both determine the methodology in which results can be achieved as well as the skills required to do so.
2. Group two consists of individuals with the skills required to achieve results once they have been given the methodology in which it can be done.
3. Group three consists of engineers who require both the method, and the means to do so, perhaps through an example or demonstration.
4. Lastly, group four consists of engineers who require the method, the means, an example or demonstration, and step-by-step supervision to ensure the accuracy of their results.

Another way to categorize process engineers is based on either their capability to work in front-end engineering design (FEED) and Pre-FEED stages of a project, or their ability to work in the detailed engineering stage of projects. Generally, process engineers who work in FEED/Pre-FEED stages are more senior-level engineers. They are the engineers who have the high level of skills in doing studies, cost estimations, calculations and so on. Usually they are engineers with expertise in one area of the chemical process industries (CPI). For example we can have a process engineer for FEED stage of a petroleum-refining, water-treatment or ink-making project. It not popular to have a process engineer in FEED stage to be able to work in two totally separate process industries.

On the other hand, process engineers in the detailed engineering stage are more "general" process engineers with less experience or seniority. Generally they are good in piping and instrumentation diagram (P&ID) development and calculations. To be a good process engineer, it is good to have a mix of two areas of process engineering. For an engineer working exclusively in FEED/Pre-FEED stage of project, it is difficult to design a plant with good operability.

Specialists versus generalists. When considering specific task assignments, the lead must determine whether his or her team members are specialists with experience in only certain topics or generalists with a less thorough knowledge of all general topics. It is most efficient to encourage "semi-specialists" who possess a general understanding of all topics as well as thorough understanding of one or two limited topics. In this way, we are "building" a person who can give specialist ideas in some topics, while at the same time preventing a major loss for the group after he or she might leave the group. One way of "building" such persons is by assigning 60% of the tasks to a person in one topic.

Information routes in a team. There is an inherent executive hierarchy in the workplace where the individual at the top (hereafter known as level A) oversees the few immediately below him or her in the pyramid (level B), and each of those individuals supervise those immediately below them (on level C). As a result, it is more efficient for each person on level C to abide by a "filtering rule" that requires only the result of their work to be reported to individuals in level B, whose knowledge of the level-C individual's process may be unnecessary and unnecessarily time-consuming. Subsequently, the persons on level B will only report their results to level A, foregoing the disclosure of any unnecessary details.

Conversely, when assigning tasks the person on level A will present the supervisors on level B with a vague idea of what he or she requires of them and trust the supervisors with creating the details and determining the approximate deadlines that accompany it. As a direct result, what may be considered a detailed version of person A's idea on level B, will still be added upon in the work of those working on level C.

All these guidelines can help each level of the workplace hierarchy run smoothly and efficiently to create an ideal result.

In summary it can be said that ideally, ideas travelling from the peak of the pyramid down grow less ambiguous and more clear, while results achieved at the bottom of the pyramid and travelling upward undergo a decrease in unnecessary and excessive details (Figure 1).

Every lead must satisfy project needs, team needs and the individual needs of his or her team members

Delegating tasks to the team. Following every project meeting, the lead must update and delegate the responsibilities assigned to his team by the project managers, and to assign internal deadlines while keeping in mind potential time-consuming back-and-forth communication that may arise. Therefore, the internal deadlines might exist before the actual deadlines to account for any such problems.

Project information and requirements that the lead's team must be made aware of, should be filtered and their target audience must be identified. One way of doing this is transferring the "required" information for the project schedule to a simple Gant chart (for example, in Excel), which can be distributed to process engineers in an internal process meeting.

When no deadline is specified, it is in everyone's best interest for the lead to determine an arbitrary deadline for the task assigner's approval in order to prevent future conflicts.

For every task, a lead should communicate clearly with his (or her) process engineers about his expectations to hold them accountable. He needs to tell them about the quality of work. The level of details, the deadline and the approximate hours needed should be defined.

Deliverables features

Three main aspects of a project (quality, cost and schedule) can be applied to each task/deliverable in the project. Each deliverable should meet the required quality within the specified manhours and in the required time frame. Furthermore, the quality of a deliverable can be translated to accuracy and completeness of the document.

Accuracy and completeness. The accuracy and the level of completeness of documents presented to the client are not quantifiable qualities, but rather subjective ones. It is therefore the process lead's responsibility to sense the importance of the level of accuracy conveyed in a document. In this case, document accuracy is dependent on two parameters, the first being the time-criticality of the document and the second being the scope of the document.

Time-criticality. It is sensible to place the accuracy of a document required at the beginning of a project low on the engineer's list of priorities, because throughout the course of the project, a document created at the preliminary stages will undoubtedly undergo many revisions. Therefore, a large quantity of time spent on such a document will be inefficient and unnecessary.

As an example, the first draft of a document marked IFR (Issue For Review) is not in need of such painstaking accuracy as the revision marked IFC (Issue For Construction), due to their placements within the project timeline.

An alternate aspect of this parameter for criticality is the occasional need for the creation of a document before other tasks can begin. The lead needs to understand that the importance of the accuracy of the starting document is understandably not crucial in phase one of a project where it may be simply a hypothetical placeholder. However, in the final phases, such a document would require a higher grade of accuracy simply due to its proximity to the end of the project. Inaccurate data in the final stages of a project can prove to be disastrous for both the firm and the client.

Document scope. The second parameter is the target of any given document: equipment, instruments or software adjustments. If a document is relevant to the design of equipment — which are expensive and in certain cases may be long lead items — then it is of the highest grade criticality. For instruments, which a process group usually specifies, a "range" rather than a single design number is given.

Instruments are therefore of lower criticality and in less need of accuracy. Meanwhile, software adjustments, which hold little to no financial burden, are of the lowest criticality.

As an example, in tank design a process engineer needs to provide the exact physical dimensions, but only a range of measurements in regards to level-meter, and simply a set point for the high-level tank alarm, which could easily be adjusted at a later point in the project with minimum cost impact.

Instructions for preparing documents. In creating documents and completing tasks, the engineer must abide by several sets of guidelines and standards of procedures dictated by various sources, within a hierarchy of importance. The guidelines presented may only be followed in the case that they do not interfere with or contradict the sets of guidelines superior to themselves.

At the first and most supreme level there may be governmental rules and regulations that must be obeyed, followed by the instructions from the clients, then any project-specific standards that must be met, the engineering firm's own set of rules, and lastly the industrial common practices that may not have been addressed by any of the above guidelines.

These industrial common practices may be verified through the checking of credible and up-to-date published material, such as scientific peer-reviewed journals, or industrial magazines and articles presented in scientific conferences. It should be noted that information retrieved from the internet lack credibility and should only be relied on when obtained from credible online scientific journals. However, it is important to remain cautious when interpreting information retrieved from published material, as it may prove to be detrimental to make assumptions or to extrapolate — and in certain cases, even interpolate — from the information provided. At the same time, any theories formed must undergo laboratory, pilot, and industrial-scale testing in order to ensure credibility and to be qualified for use in design. The absence of any of these tests jeopardizes the credibility of the information.

On a different note, it is important to understand that even at the governmental level, ambiguity may be present within the rules and regulations dictated. In such cases, a case-specific interpretation may be required through discussion — be it oral or written — that must be recorded with the results of the discussion for future reference and the advisement of new employees. These records may be presented to the client as job specification upon the completion of the project.

Preparing deliverables. In the field of engineering, it can be said that all critical documents undergo three different steps before being considered approved or completed. First, they must be originated by a process engineer, then they must be checked by another individual with experience in the topic covered by the document, and lastly they must be officially approved by a third process engineer who may or may not be the process lead.

It is imperative to remember, however, that it is not the responsibility of the *checker* to scrutinize every aspect of the document. As a general rule of thumb, the checker should only spend a tenth of the time spent creating the document to check it; if more time is required, the document might be in need of a complete revision by the *originator* and may even be reassigned to another individual completely. The checker will check for faulty assumptions and inaccurate methodology utilized in the document before passing it along to be officially approved. Though at the highest level, the *approver* will spend even less time on the document, sparing only the briefest of glances to ensure the result "appears" logical before signing off on the document. Therefore, it is advisable for the *originator* to double, and even triple-check his or her work before passing it along to the *checker*.

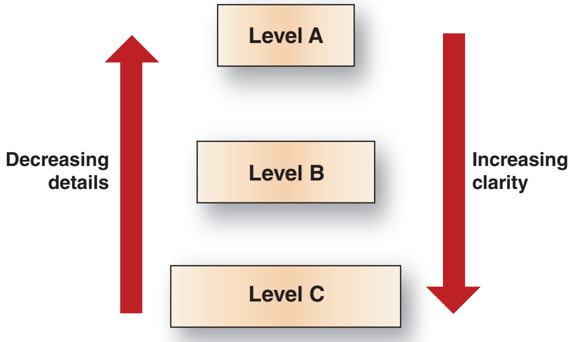

FIGURE 1. Ideas travelling from the peak of the pyramid down grow less ambiguous and more clear, while results achieved at the bottom of the pyramid and travelling upward undergo a decrease in unnecessary and excessive details

Scheduling: Task deadlines

In determining achievable deadlines, it is important to know the total required man hours to finish a task, which comprise three elements. Firstly, time must be allotted for the technical content of the task to be created. Secondly, the time required for the determination and transferring to the appropriate format and lastly, time must be allotted for gaining the required approvals and signatures and official issuing.

Accelerating a task. In some cases, tasks may be in need of acceleration in order to meet the deadline. To accelerate a task there are two alternatives available: boosting human resources and simplifying the task.

Boosting human resources may include the short-term external/internal hiring of additional personnel, encouraging employees to work over-time, or reassigning tasks to the semi-specialists.

For the other alternative, it may be appropriate to develop calculation templates, algorithms, decision-making matrices, or bulleted-type instructions to simplify the task.

Unscheduled tasks. A reality of working as a process lead is the presence of unscheduled tasks that may be requested by various outside players. In such cases, overly flexible process leads will always accept these tasks while overly "tough" leads will always decline them. However there are various available paths a lead can take in such a case.

Firstly, the request and the suggested deadline can be accepted if it will not negatively impact the team nor hinder the completion of the scheduled task.

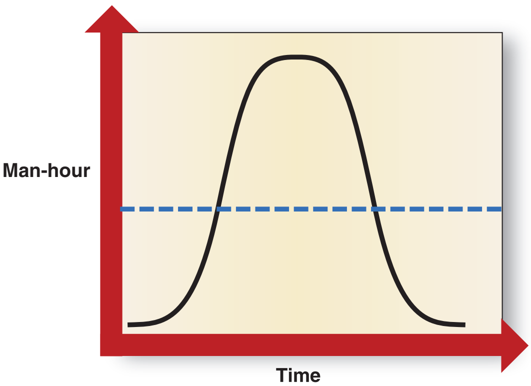

FIGURE 2. Manhour usage is not linear over time, but follows a bell curve

Secondly, the request and the deadline may both be accepted, but at the cost of quality and accuracy, should the other party accept these terms. In this case, a less accurate or incomplete form of the deliverable will be passed to the "internal customer" if it is discussed and agreed beforehand.

Thirdly, the request may be accepted with an adjusted deadline that will neither impact the team nor the completion of the scheduled tasks.

And lastly, the request can be respectfully denied for various reasons that include — but are not limited to — the discussed task not being part of the team's scope of responsibility or it jeopardizing the completion and quality of the scheduled tasks. In this case, the lead should remain loyal to the scheduled tasks, even though this denial may go against the lead's personal character and generosity.

Budgeting: Manhours

Regarding manhour estimates, it is important for the lead to realize that the numbers resulting from such a calculation often refer to the estimated amount of time intermediate engineers will require to complete the task. Should a team be comprised mainly of junior or senior engineers, the man-hour estimations will need to undergo an adjustment befitting the efficiency of the team.

At the same time, it is important to understand that given 100 estimated man-hours within a period of ten days for a specific task, an engineer will not necessarily be able to fulfill a flat number of ten hours per day for each of the ten days. Rather, it is more realistic to presume that in the first few days only a handful of manhours will be put forward for the task, whereas in the next several days the engineer might be capable of completing more than the ten estimated hours per day. This number will decrease once more in the final days, until the task is completed. In this way, it is wiser to visualize that a graph depicting the rate of manhour usage is not a straight line — or a constant rate — but rather a bell curve (Figure 2).

As a result, it may be wise to consider alternate tasks for the engineer during the off-peak stages of the task. During this time, the engineer may be capable of assisting other tasks or even other projects at the peak of their own respective bell curves. Organization for the purpose of simplifying future projects may also be beneficial, as may be training sessions and team-building activities and so on.

Consequently, when at the peak of a task's bell curve, a lead may utilize others during their off-peak stages, ask his or her own team to work overtime or attempt a higher level of efficiency, or request a short-time hire. The last should be viewed as a last resort due to its tarnishing of a company's reputation in hiring and letting go an individual within a short period of time.

Interdisciplinary communication

In communicating with others, it is important for the lead to ensure his or her team members can make distinctions between various modes; for example, at the most informal level of communication, a verbal interaction is sufficient. In regards to more formal interactions, Emails may be more appropriate and at the most formal level, the most effective solution would be to interact through Email with the supervisor copied to (as a "CC" recipient of) the exchange. In doing so, the lead can ensure that each mode of communication is appropriate to the interaction so that, hypothetically, the supervisor would not be unnecessarily informed of minute details. Additionally, overly formal Emails in regard to what is in essence a casual interaction may cause alienation and result in friction between team members.

When communicating with people across different disciplines, such as materials or piping, it is important to keep in mind that the same word when used by various persons can mean different things. For example, one can use the term "trim" to refer to a internal part of a valve, while another individual will use the same term to refer to tank attachments.

At the same time, it is important for members of each discipline to keep in mind the needs, standards and scope of interest of others.

For example, when a person from a materials group asks for velocity of liquid in pipes, he or she is looking for a rough range of velocities and if a process engineer prepares an accurate list of velocities with decimal points, it will be waste of time.

As an extension of this, it is important to remember that when discussing a hypothetical pump, a mechanically oriented person will refer to it as the "centrifugal pump" while a process engineer will use "crude oil pump" and an individual from the piping discipline will allude to "the pump in building A".

Therefore it is imperative to clarify the specifics when interacting with other disciplines, and to keep in mind the terminology and "language" utilized by each discipline. ■

Edited by Gerald Ondrey

Author

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Fractionation Column

Writing your employees' resumes

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

My June 2011 editorial (*CE*, p. 27) recommended the hiring of happy people. It included a photograph of the present FRI technician staff. After a recent safety meeting, I handed all staff members fresh copies of their resumes. Once they picked their jaws off the floor, I explained:

"I wrote, from scratch, seven different resumes for the seven of you. I started with job descriptions. All of these new resumes look very good. I purposely used many catch phrases like 'gas chromatography' and 'gamma scanning' to catch the attention of prospective employers. I want you all to learn as many things at FRI as you possibly can. We will teach you. We will pay for training courses. We do not want any of you to leave us, but we understand that there might come a time where your spouse insists that your entire family rejoin her Aunt Helen in Nova Scotia and..."

I offered to help the FRI technicians to update their resumes at a future date. I promised to provide positive recommendations if I am ever called upon to provide reference. I am happy to say that every technician seemed to understand that the resume writing work that I performed was for them — not against them. They fully understood, maybe for the first time, that they were working for a great company, and they were indeed learning many things.

Some technicians thought it might be "funny" to take the new resumes home to their spouses and state, "I had a not-so-good day at work today, honey. At a meeting with the technical director, he handed me a new job resume that he had authored just for me. Does Nova Scotia have a football team?"

All of the FRI technicians are above-average performers, with very above-average attitudes. I am wondering how such a resume-writing exercise would work with a below-average performer. It might cause such a person to realize that he or she has a good job working for a not-so-bad person. It might improve his or her own outlook. Unfortunately — and I wish that I did not have to say this — I have not seen many leopards change their spots.

I need to update the job descriptions of the FRI engineers. When I do, I will use the opportunity to author new resumes for them too. With this particular gang, there is no protectionism. All of them are 100% willing to share everything they know with their colleagues. Their new resumes will be impressive. I hope that these resumes do not fall into the hands of distillation companies who are looking for distillation experts.

In your own work, it might prove to be a valuable exercise to write resumes for your employees. Meanwhile, it might be even more groundbreaking if you considered how it would read if your boss authored one for *you*. ■

Mike Resetarits
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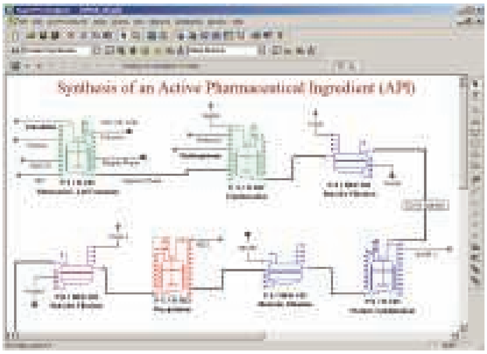

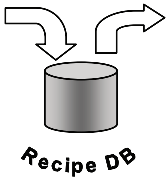

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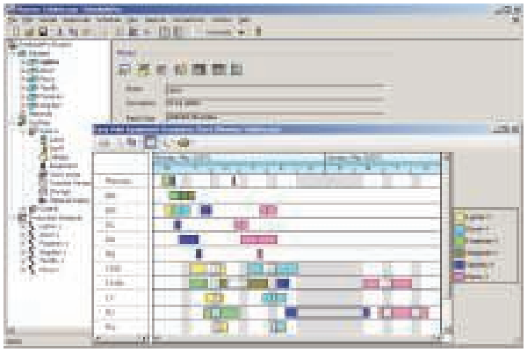

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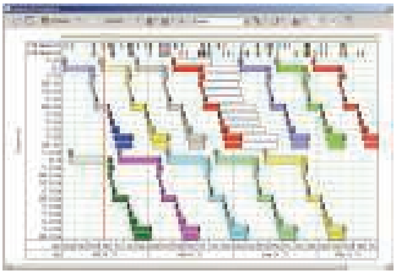

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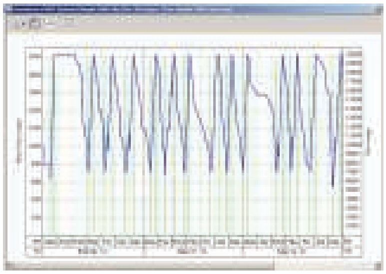

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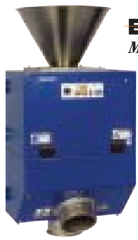

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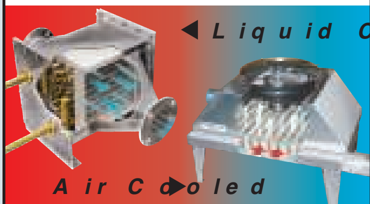

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Kevin Nolan becomes European managing director for **Wall Colmonoy** (Pontardawe, Wales), which specializes in materials engineering.

Frank Palucci joins **Finish Thompson, Inc.** (Montreal) as director of global alliances.

Jerry Pyatt is promoted to president and CEO of natural resources firm **The Doe Run Co.** (St. Louis, Mo.), replacing *Bruce Neil*, who is retiring.

Brian Cohen becomes president and CEO of **Aeration Industries International** (Chaska, Minn.)

Powder Systems Ltd. (Mumbai, India) appoints *Vaibhav Dalvi* as sales and service manager.

Vincent Donovan becomes head of the BioPharmaceutical Process Solutions division of **EMD Millipore** (the life science division of Germany's Merck KGaA), in its Bedford, Mass., office.

Mike Cook becomes the technical services director for the mechanical field services group of **HPI, LLC** (Houston), a supplier of turbomachinery. ■

Suzanne Shelley

BUSINESS NEWS

PLANT WATCH

BASF plans to expand vinylformamide capacity in Ludwigshafen and ...

July 5, 2012 — BASF SE (Ludwigshafen, Germany; www.basf.com) is planning to expand the manufacturing plant for vinylformamide (VFA) in Ludwigshafen. In addition, it intends to increase the polymerization capacity at this site and build a new polymerization line for VFA in China for further processing of the feedstock from Ludwigshafen. This facility will be built at the Zhenjiang site, Jiangsu province. The total investment is in the three-digit million euro range. Production is scheduled by the end of 2014.

...to build a butadiene extraction plant in Antwerp

July 4, 2012 — BASF SE plans to build a butadiene extraction plant at its Verbund site in Antwerp, Belgium. The plant will have a production capacity of 155,000 metric tons per year (m.t./yr) and is scheduled to start up during 2014. The investment amount will be in the high double-digit million euro range.

Ineos Technologies has been selected by Sibur for four PE units

June 29, 2012 —Ineos Technologies (Lyndhurst, U.K.; www.ineos.com) has licensed its Innovene G and Innovene S processes for the manufacture of linear low density and high density polyethylene (PE) products to the ZapSibNeftekhim production complex of Sibur in Tobolsk, Russia. The two 400,000-ton/yr Innovene G plants and the two 350,000 -ton/yr Innovene S plants will produce a full range of Ziegler monomodal, Ziegler bimodal, chromium and metallocene products. The ZapSibNeftekhim plants will be positioned to deliver specialty and commodity PE products for the Russian and export markets.

Evonik plans new facility in Brazil for feed additive for animal nutrition

June 19, 20120 — Evonik Industries AG (Essen, Germany; www.evonik.com) intends to build a facility for the biotechnology production of Biolys in the Brazilian town of Castro in the state of Paraná. Biolys is a source of the amino acid L-lysine that is used as a feed additive in animal nutrition. The plant will be built at a site owned by the U.S.-based company Cargill and is scheduled to become operational in 2014. Both companies have signed a letter of intent, according to which Cargill will provide the infrastructure at the site and will supply Evonik with locally manufactured raw materials.

Dow invests in water technology manufacturing in China

June 7, 2012 — The Dow Chemical Company (Midland, Mich.; www.dow.com) has announced plans to invest in a world-class manufacturing facility for its Filmtec reverse osmosis (RO) elements in Huzhou, China. The new facility will be online in 2013. The facility joins Dow's ultrafiltration manufacturing facility in Huzhou and ion-exchange resin facility in Qingpu.

MERGERS AND ACQUISITIONS

Gevo and Beta Renewables sign JDA to develop process for cellulosic isobutanol

July 10, 2012 — Gevo, Inc. (Englewood, Colo.; www.gevo.com), a renewable chemicals and next-generation biofuels company, and Beta Renewables, a joint venture between Chemtex and TPG, have signed a joint development agreement (JDA) to develop an integrated process for the production of bio-based isobutanol from cellulosic, non-food biomass. The project would integrate technologies from both companies with anticipated production plants to be located where cellulosic feedstocks will be readily available.

DeZurik to acquire Hilton Valve to create a broad-ranging valve-supply company

June 29, 2012 — DeZurik, Inc. (Sartell, Minn.; www.dezurik.com) has reached a definitive agreement to acquire Hilton Valve, Inc. DeZurik will acquire all Hilton products and production capability, while Hilton operations will remain in its Redmond, Wash. facility. The Hilton name will be retained as a brand of DeZurik, Inc. Consolidated sales activity will be coordinated between DeZurik and Hilton with continuing product technical and project engineering support provided by Hilton.

SABIC signs research agreement with German research organization

June 23, 2012 — The Saudi Basic Industries Corp. (SABIC; Riyadh, Saudi Arabia; www.sabic.com) and Fraunhofer-Gesellschaft, a German organization for applied research, have signed a multiyear agreement to mutually develop advanced technologies into innovative solutions in areas such as lightweight construction and renewable energy. SABIC is especially interested in research cooperation in fields such as lightweight products including polymeric materials and composites, with applications in the automotive and aerospace industry. SABIC also has a strong interest in solar energy technology.

GTC Technology signs MOU with Beijing Sanju for cooperation in sulfur removal

June 21, 2012 — GTC Technology US, LLC, (Houston; www.gtctech.com), has announced a memorandum of understanding (MOU) with Beijing Sanju Environmental Protection and New Material Co., for cooperation in sulfur removal technologies. The MOU expands GTC's platform of acid-gas removal technology and allows GTC to expand its offerings to applications of less than 1 ton/day of sulfur removal.

Cabot corporation plans to acquire Norit N.V.

June 21, 2012 — Cabot Corp. (Boston, Mass.; www.cabot-corp.com) has entered into an agreement to purchase Norit N.V. from affiliates of Doughty Hanson & Co. Managers Ltd. and Euroland Investments B.V. for $1.1 billion. Cabot expects the acquisition to be financed with a combination of approximately $200 million of cash and $300 million of borrowings under its existing revolver. In addition, the company plans to issue approximately $600 million of long-term debt prior to closing. The transaction is expected to close in 2012 and is conditional upon Dutch works council consultation and advice and approval of the competition authorities in the U.S. and Germany.

AkzoNobel completes demerger of Pakistan activities

June 14, 2012 — AkzoNobel (Amsterdam, the Netherlands; www.akzonobel.com) has completed the restructuring of its activities in Pakistan by formally establishing AkzoNobel Pakistan Ltd. as a separate legal entity from ICI Pakistan. The split means that the company has started the formal sale process to divest its 75.81% shareholding in ICI Pakistan. The new AkzoNobel Pakistan Ltd. business is focused on three core areas — decorative paints, performance coatings and specialty chemicals. Jehanzeb Khan has been appointed as its CEO. The coatings activities of ICI Pakistan were transferred to AkzoNobel Pakistan Ltd. through a legal process of demerger. ICI Pakistan's business now comprises polyester fiber, soda ash, life sciences and chemicals. ■

Dorothy Lozowski

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

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

2010 — 2011 — 2012 —

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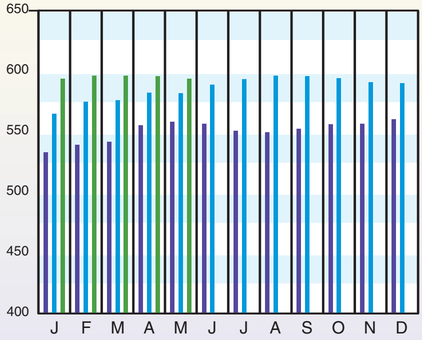
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	May.'12 Prelim.	Apr.'12 Final	May.'11 Final
***CE* Index**	593.8	595.9	581.9
Equipment	726.2	730.2	707.5
Heat exchangers & tanks	683.6	686.9	673.0
Process machinery	680.1	680.7	663.7
Pipe, valves & fittings	926.7	935.7	861.8
Process instruments	428.9	430.8	441.8
Pumps & compressors	928.1	921.8	905.4
Electrical equipment	515.2	514.9	503.0
Structural supports & misc	763.8	774.2	755.7
Construction labor	322.9	320.7	325.2
Buildings	527.7	527.1	518.6
Engineering & supervision	328.3	328.4	332.9

Annual Index:

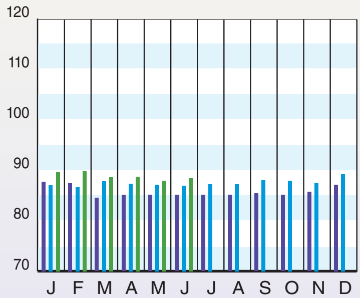
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7



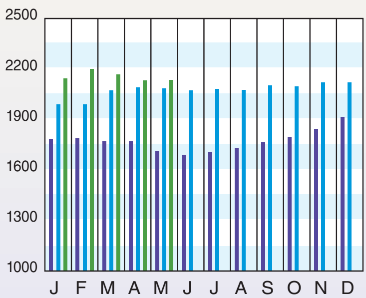
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS				YEAR AGO	
CPI output index (2007 = 100)	Jun.'12 =	88.4	May.'12 =	87.9	Apr.'12 =	88.7	Jun.'11 =	86.9
CPI value of output, $ billions	May.'12 =	2,133.8	Apr.'12 =	2,132.6	Mar.'12 =	2,167.3	May.'11 =	2,085.9
CPI operating rate, %	Jun.'12 =	76.3	May.'12 =	75.9	Apr.'12 =	76.6	Jun.'11 =	75.0
Producer prices, industrial chemicals (1982 = 100)	Jun.'12 =	312.7	May.'12 =	324.4	Apr.'12 =	329.6	Jun.'11 =	339.6
Industrial Production in Manufacturing (2007=100)	Jun.'12 =	94.7	May.'12 =	94.0	Apr.'12 =	94.7	Jun.'11 =	89.7
Hourly earnings index, chemical & allied products (1992 = 100)	Jun.'12 =	156.7	May.'12 =	157.6	Apr.'12 =	160.5	Jun.'11 =	157.6
Productivity index, chemicals & allied products (1992 = 100)	Jun.'12 =	104.5	May.'12 =	104.0	Apr.'12 =	104.7	Jun.'11 =	107.5

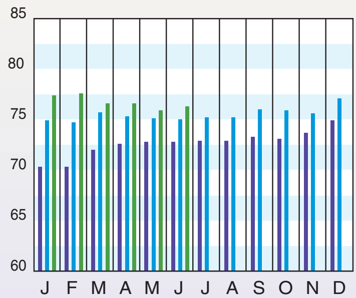
CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



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

CURRENT TRENDS

Capital equipment prices, as reflected in the *CE* Plant Cost Index (CEPCI; top), dropped 2% from April to May (the most recent data). Meanwhile, all of the Current Business Indicators from IHS Global Insight (middle), including the operating rate, increased slightly from May to June.

According to the American Chemistry Council (ACC; Washington, D.C.; www.americanchemistry.com), in its most recent weekly report at *CE* press time, overall prices for chemicals fell by 1.0% in June after rising 0.5% in May. June prices fell for pharmaceuticals (–0.6%) and other chemistry (excluding pharmaceuticals; –1.2%), ACC says. Prices for basic chemicals fell by 1.4% as declining prices for organic chemicals (–1.1%), inorganic chemicals (–0.1%), synthetic rubber (–7.8%), and plastics resins (–2.6%) were only partially offset by a gain in manmade fiber prices (+2.8%). Feedstock costs fell 21.3% in June following a 3.3% decline in May. Specialty chemical prices fell 0.7%, with similar declines in coatings and other specialties. Small increases occurred in agricultural chemicals (0.9%) and consumer chemistry (0.2%).

Compared to last year, prices for basic chemicals, inorganic chemicals, specialty chemicals, synthetic rubber and plastic resins are up, ACC says. Prices for bulk petrochemical and organics, however, are off compared to a year ago, down by 1.2%. ■

3rd Annual

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