# CHEMICAL ENGINEERING

November 2010

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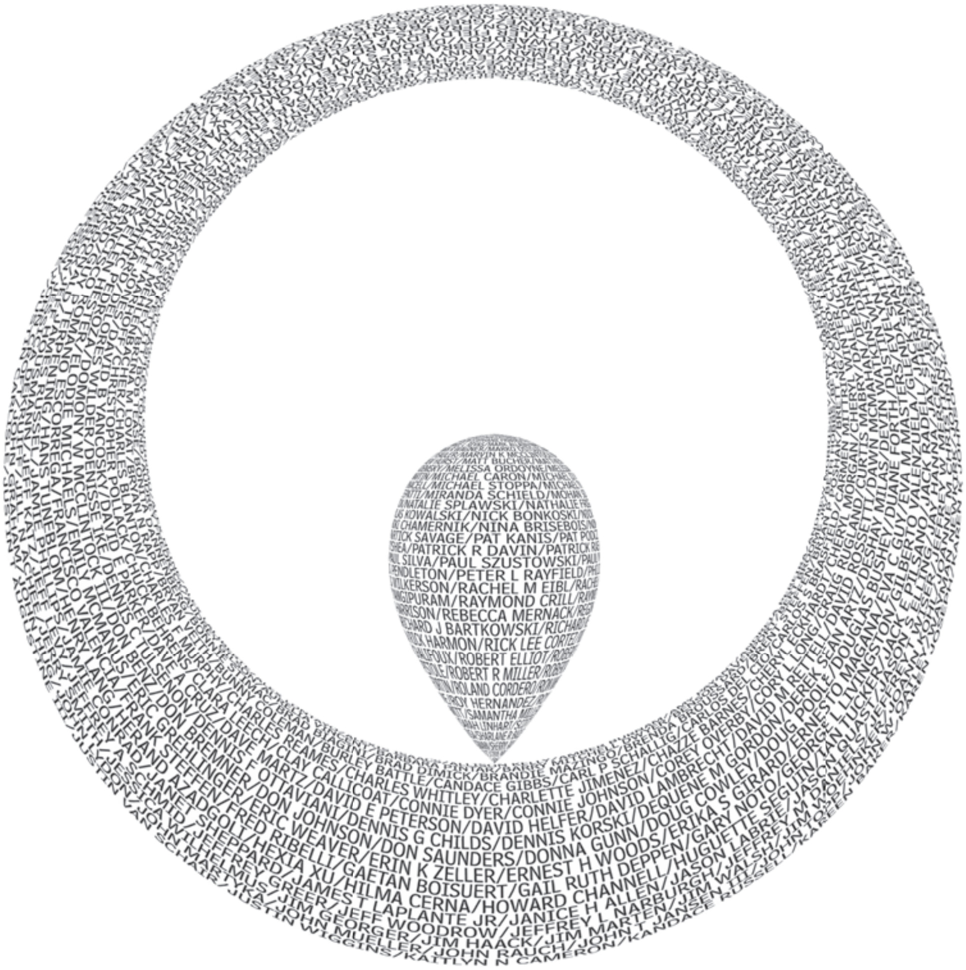

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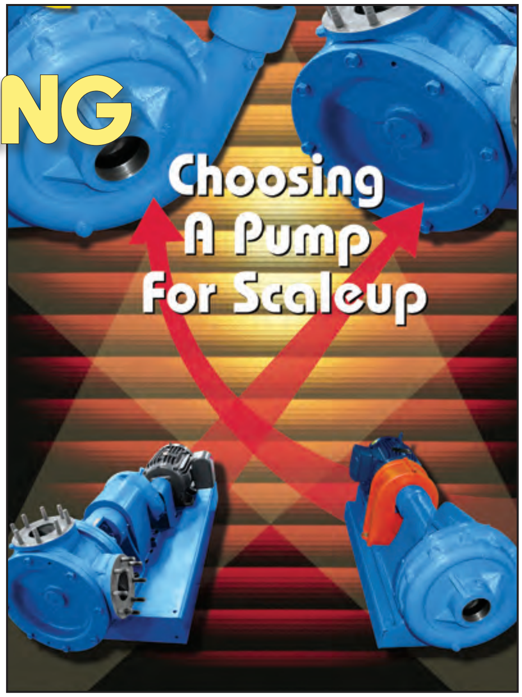




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1 American Society of Civil Engineers, "Design of Blast Resistant Buildings in Petrochemical Facilities," ASCE Task Committee on Blast Resistant Design, New York, NY, 1997.
LARRY
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CHEMICAL ENGINEERING

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## Editor's Page

# A passion for breakthroughs

Last month, I had the rare honor of sitting down with about 40 students from Booker T. Washington High School's engineering magnet school (Houston), who are all on the path toward careers in science and engineering. While the experience itself was inspirational, it also caused me to reflect — again — on what defines inspiring chemical engineering practice.

My encounter was at a student outreach event that was hosted by Honeywell Process Solutions (HPS; Phoenix, Ariz.; www.honeywell.com/ps) and held in conjunction with ChemInnovations Conference and Expo. Following his keynote address, a variety of hands-on activities and tours of the exhibit hall highlighting process equipment, instrumentation and other related service providers, Norm Gilsdorf, the president of HPS, gave the students an inspiring view of the exciting challenges and places where his chemical engineering career has taken him. As an engineer for UOP, LLC, Gilsdorf has literally seen the world and experienced extraordinary things.

By the end of the day, it was clear to me that prior to this event, none of these students could have answered in any practical sense "What does a chemical engineer do?" To be honest, I had been in the same boat, myself, until at least the end of my first year of college. My reasons for selecting a ChE education in the first place were, quite simply, based on my prowess in two subjects: chemistry and math. In fact, a recollection that is laughable to me now is that I naively entered my university's ChE program — after one year in the architectural engineering program — in search of less ambiguity and more-definitive "right answers".

I've since realized that a chemical engineer who pursues only right answers will quickly become unsatisfied and attain mediocre accomplishments at best. Truly stellar careers in our profession are studded by breakthroughs, as illustrated in the announcement of this magazine's 2010 Personal Achievement Awards (see pp. 17–22).

While each and every breakthrough is unique by definition and can come in a variety of forms, one common denominator can be found in them all: a willingness to take risks and do things differently than they have been done before. That requires a creative mind, a characteristic that is not included in the average engineering stereotype.

And despite the instantaneous revelation that the word breakthrough implies, its achievement does not come to fruition overnight. It usually takes somewhere between seven and ten years to innovate, a period Andre Argenton, Global R&D strategy leader for the Dow Chemical Co. and a fellow keynote speaker, referred to as the valley of death. As ominous as it sounds, emerging from this pit does not mark the end of the challenge.

In the chemical process industries, breakthroughs of two kinds are required: the first is inventing the novel process or technology to be used, while the second is convincing the right people to adopt it. I know that many of you have found that the second of these breakthroughs is the hardest to achieve. This is true even if you're *only* trying to implement a promising, new third-party technology that has been proven elsewhere. The reality is that the greater the potential gain, the greater the change that is required, and therefore, the greater the resistance that must be overcome.

So, while there is no general formula for achieving a breakthrough, I think that ChemInnovations' final keynote speaker, John Hillman, an engineer and inventor who has an inspiring first-hand story of his own, said it best: Above all else, it takes passion. And that is something that stellar chemical engineers have in abundance. ■

*Rebekkah Marshall*

## Letters

### Questions about aluminum process

*August*, Chementator, This new process promises substantial savings for aluminum production, p. 9: The reaction of aluminum carbide and aluminum oxide to aluminum and carbon monoxide is so hugely endothermic that it cannot possibly take place at the moderate temperatures quoted.

**Richard Durrant**
U.K.

**Source's reply**

It is true that the reaction of aluminum carbide and aluminum oxide is hugely endothermic and needs a high level of energy to proceed. However, according to thermodynamics (using JANAF data), this reaction starts to produce a measurable value of CO gas at 1,527°C and operates at one atmosphere CO pressure at about 2,080°C temperature.

In the conventional carbothermic processes, strong kinetic barriers hinder the reaction, and to overcome these barriers, temperatures higher than 2,250°C are required. So, any process that can reduce these barriers can produce metal at 1 atm CO at about 2,080°C temperature.

In the Thermical process, these barriers are removed and in addition, metallic aluminum present in the charge ($xAl\text{-}A_2O_3 + Al_4C_3$) plays a role in enhancing the reaction rate. At the same time, using hydrocarbon gas as a carrier and carbon supplier dilutes the generated CO in the reactor. When natural gas is used as the carbon source, the hydrogen generated in the charge production zone enters into the metal production zone and dilutes the CO gas generated in metal production zone. As the hydrogen passes through the reaction zone, the CO content of the gas increases and the off-gas leaves the reaction zone with $2H_2 + CO$ composition. Therefore, a lower temperature is needed to produce metal at 1 atm.

The company website (www.calsmelt.com) contains the patent texts in the Thermical IP section. Calsmelt is now ready to build a pilot plant to test the process.

**Yaghoub Sayad-Yaghoub**
Calsmelt Pty Ltd., Melborne, Australia

**Postscripts, corrections**

*May*, Bookshelf, p. 9: The price quoted for "Stoichiometry 5th ed." By B.I. Bhatt and S.B. Thakore was incorrectly listed as $66.16. The correct list price for the book is $41.50. ■

**Do you have —**

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

**If so** — Send them, for our Letters column, to

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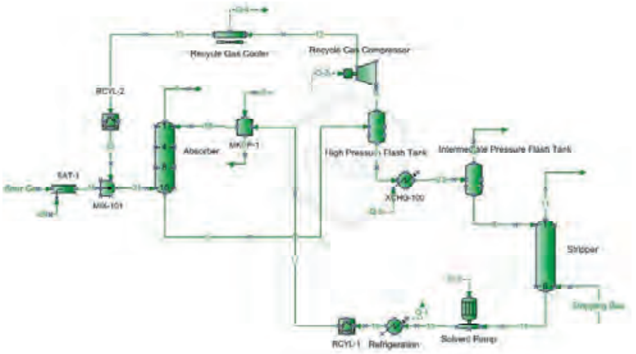
# PROCESS INSIGHT

## Comparing Physical Solvents for Acid Gas Removal

Physical solvents such as DEPG, NMP, Methanol, and Propylene Carbonate are often used to treat sour gas. These physical solvents differ from chemical solvents such as ethanolamines and hot potassium carbonate in a number of ways. The regeneration of chemical solvents is achieved by the application of heat whereas physical solvents can often be stripped of impurities by simply reducing the pressure. Physical solvents tend to be favored over chemical solvents when the concentration of acid gases or other impurities is very high and the operating pressure is high. Unlike chemical solvents, physical solvents are non-corrosive, requiring only carbon steel construction. A physical solvent's capacity for absorbing acid gases increases significantly as the temperature decreases, resulting in reduced circulation rate and associated operating costs.

**Typical Physical Solvent Process**




### DEPG (Dimethyl Ether of Polyethylene Glycol)

DEPG is a mixture of dimethyl ethers of polyethylene glycol. Solvents containing DEPG are marketed by several companies including Coastal Chemical Company (as Coastal AGR®), Dow (Selexol™), and UOP (Selexol). DEPG can be used for selective $H_2S$ removal and can be configured to yield both a rich $H_2S$ feed to the Claus unit as well as bulk $CO_2$ removal. DEPG is suitable for operation at temperatures up to 347°F (175°C). The minimum operating temperature is usually 0°F (-18°C).

### MeOH (Methanol)

The most common Methanol processes for acid gas removal are the Rectisol process (by Lurgi AG) and Ifpexol® process (by Prosernat). The main application for the Rectisol process is purification of synthesis gases derived from the gasification of heavy oil and coal rather than natural gas treating applications. The two-stage Ifpexol process can be used for natural gas applications. Methanol has a relatively high vapor pressure at normal process conditions, so deep refrigeration or special recovery methods are required to prevent high solvent losses. The process usually operates between -40°F and -80°F (-40°C and -62°C).

### NMP (N-Methyl-2-Pyrrolidone)

The Purisol Process uses NMP® and is marketed by Lurgi AG. The flow schemes used for this solvent are similar to those for DEPG. The process can be operated either at ambient temperature or with refrigeration down to about 5°F (-15°C). The Purisol process is particularly well suited to the purification of high-pressure, high $CO_2$ synthesis gas for gas turbine integrated gasification combined cycle (IGCC) systems because of the high selectivity for $H_2S$.

### PC (Propylene Carbonate)

The Fluor Solvent process uses JEFFSOL® PC and is by Fluor Daniel, Inc. The light hydrocarbons in natural gas and hydrogen in synthesis gas are less soluble in PC than in the other solvents. PC cannot be used for selective $H_2S$ treating because it is unstable at the high temperature required to completely strip $H_2S$ from the rich solvent. The FLUOR Solvent process is generally limited to treating feed gases containing less than 20 ppmv; however, improved stripping with medium pressure flash gas in a vacuum stripper allows treatment to 4 ppmv for gases containing up to 200 ppmv $H_2S$. The operating temperature for PC is limited to a minimum of 0°F (-18°C) and a maximum of 149°F (65°C).

### Gas Solubilities in Physical Solvents

All of these physical solvents are more selective for acid gas than for the main constituent of the gas. Relative solubilities of some selected gases in solvents relative to carbon dioxide are presented in the following table.

The solubility of hydrocarbons in physical solvents increases with the molecular weight of the hydrocarbon. Since heavy hydrocarbons tend to accumulate in the solvent, physical solvent processes are generally not economical for the treatment of hydrocarbon streams that contain a substantial amount of pentane-plus unless a stripping column with a reboiler is used.

| Gas Component | DEPG at 25°C | PC at 25°C | NMP at 25°C | MeOH at -25°C |
|---|---|---|---|---|
| $H_2$ | 0.013 | 0.0078 | 0.0064 | 0.0054 |
| Methane | 0.066 | 0.038 | 0.072 | 0.051 |
| Ethane | 0.42 | 0.17 | 0.38 | 0.42 |
| $CO_2$ | 1.0 | 1.0 | 1.0 | 1.0 |
| Propane | 1.01 | 0.51 | 1.07 | 2.35 |
| n-Butane | 2.37 | 1.75 | 3.48 | - |
| COS | 2.30 | 1.88 | 2.72 | 3.92 |
| $H_2S$ | 8.82 | 3.29 | 10.2 | 7.06 |
| n-Hexane | 11.0 | 13.5 | 42.7 | - |
| Methyl Mercaptan | 22.4 | 27.2 | 34.0 | - |

### Choosing the Best Alternative

A detailed analysis must be performed to determine the most economical choice of solvent based on the product requirements. Feed gas composition, minor components present, and limitations of the individual physical solvent processes are all important factors in the selection process. Engineers can easily investigate the available alternatives using a verified process simulator such as ProMax® which has been verified with plant operating data.

For additional information about this topic, view the technical article "A Comparison of Physical Solvents for Acid Gas Removal" at http://www.bre.com/tabid/147/Default.aspx. For more information about ProMax, contact Bryan Research & Engineering or visit www.bre.com.

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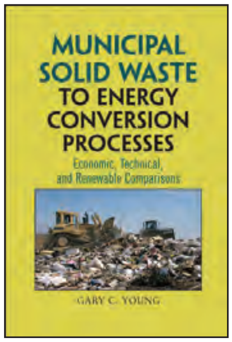
## Bookshelf




**Municipal Solid Waste to Energy Conversion Processes: Economic, Technical and Renewable Comparisons. By Gary C. Young. John Wiley and Sons, Inc. 111 River St., Hoboken, NJ 07030. Web: wiley.com. 2010. 384 pages. $89.95.**

Reviewed by Tom McGowan, TMTS Associates Inc. Atlanta, Ga.

This book on converting municipal solid waste (MSW) to energy focuses on new developments in the area, with an emphasis on plasma gasification and combustion processes, as well as the use of gasification to produce power, fuels and chemicals.

The early chapters cover waste-to-energy (WTE) power production and the production of liquid fuels, and provide an economic analysis of multiple-plant configurations and size. Such analysis is the author's strong suit, with much of the material related to case studies of various WTE plants.

Chapter 4 offers good insight into scaling factors, showing that plants of more than 500-ton/d capacity exhibit progressively better economics. Chapter 6 covers issues related to the cost evaluation of MSW collection and transfer.

The Chapter 8 discussion of a Japanese facility contains a somewhat flawed analysis, in my opinion. For instance, the facility has no net power to export at 60% of capacity, due to plasma torch and auxiliary power use, and despite the author's assumption of 100% capacity, these parasitic power losses will remain.

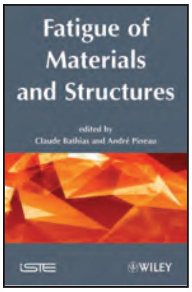
Chapter 9 is particularly strong, however, and offers a detailed look at the makeup of MSW, as well as heating values, ultimate analysis and other items required when engineering these plants. It also helps readers understand the requirements for associated air-pollution control.

Chapter 10 details processes for handling ammonia, liquid fuels and hydrogen, and the vitrification of ash, while chapter 11 reviews commercial gasifier reactors and plasma-arc gasifiers, as well as associated gas cleanup and gas-turbine internal-combustion engines that run on clean gas.

My own experience with WTE and power production from waste fuels is in line with the analyses provided in this book: Viability hinges on high power buy-back rates, high population density and high local landfill-tipping fees. For example, the case study presented in Chapter 2 shows that a $56.17/ton tipping fee is required to break even at a $0.043/kWh power buy-back rate. This tipping fee is at the upper end of the range. It is also high compared to the $35/ton benchmark tipping fee used in the book, which is reasonable for many locations. Meanwhile, government incentives, grants and renewable energy credits — or lack thereof — can make or break a project.

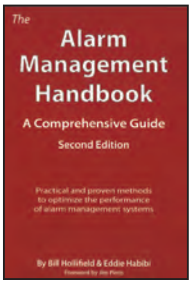
Perhaps the most important item addressed by the book is the question of "Why plasma?" since WTE plants can combust MSW without using ultra-high-temperature plasma. The author's view is that plasma produces a vitrified ash product, which he claims can be sold for $15/ton for road building, and perhaps for higher-grade products, such as rock wool. Sale of this byproduct for road building can have a significant impact on overall plant economics, as it not only brings in revenue, but also avoids landfilling (the typical fate of MSW ash).

In my opinion, the issue of siting and permitting is not addressed sufficiently. In the past, WTE plants were nearly impossible to site, and difficult to permit. This has eased somewhat, so added discussion of this trend would have strengthened the book.




**Update on Engineering and Structural Adhesives.** By David Dunn. iSmithers Rapra, Shawbury, Shrewsbury, Shropshire, SY4 4NR, U.K. Web: polymer-books.com. 2010. 198 pages. $125.00.

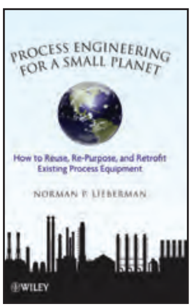
**Fatigue of Materials and Structures.** Edited by Claude Bathias and André Pineau. John Wiley and Sons, Inc., 111 River St., Hoboken, NJ 07030. Web: wiley.com. 2010. 512 pages. $240.00.




**The Alarm Management Handbook, 2nd ed.** By Bill Hollifield and Eddie Habibi. PAS, 16055 Space Center Blvd. Suite 600, Houston, TX 77062. Web: pas.com. 2010. 256 pages. $89.95.

**$CO_2$ Capture: Technologies to Reduce Greenhouse Gas Emissions.** By Fabrice Lecomte, Paul Broutin and Etienne Lebas. Editions Technip, 25 rue Ginoux, 75015 Paris, France. Web: editionstechnip.com. 2010. 204 pages. $30.00.


**Comprehensive Membrane Science and Engineering.** Edited by Enrico Drioli and Lidietta Giorno. Elsevier, Inc., 30 Corporate Drive, 4th floor, Burlington, MA 01803. Web: elsevier.com. 2010. 2,000 pages. $1,065.00.




**Process Engineering for a Small Plant: How to Reuse, Repurpose and Retrofit Existing Process Equipment.** By Norman Lieberman. John Wiley and Sons, Inc., 111 River St., Hoboken, NJ 07030. Web: wiley.com. 2010. 263 pages. $80.00.

**Industrial Network Security.** By David Teumim. ISA, 67 Alexander Drive, Research Triangle Park, NC 27709. Web: isa.org. 2010. 130 pages. $69.00. ■

*Scott Jenkins*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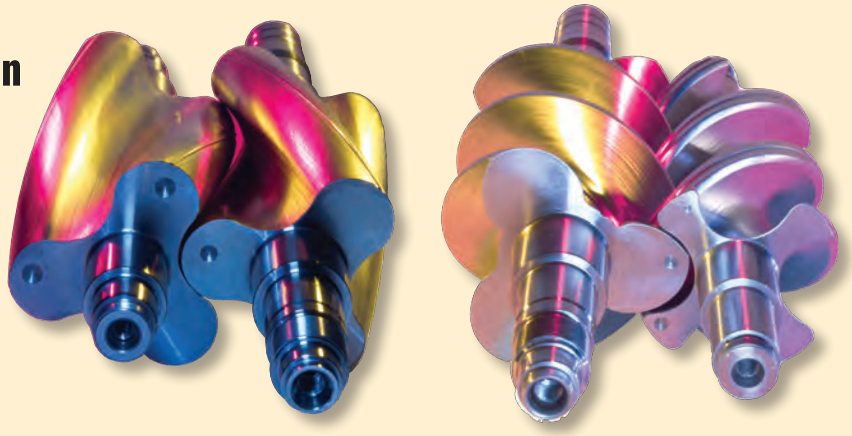
## A new twist in compressor design reduces energy consumption



Aerzen Maschinenfabrik GmbH (Aerzen, Germany; www.aerzen.com) has commercialized the first rotary lobe compressor, the Delta Hybrid, which combines the technologies of both a rotary lobe blower and a screw compressor. This union reduces the energy consumption by up to 15% compared to conventional compressors, says the company. Whereas the Roots principle of isochoric compression is most suitable for low-pressure applications, and the screw compressor, with its internal compression, is most suited to high-pressure ranges, the combination makes it possible to generate positive pressure or vacuum in air and neutral gas applications.

A 3+3 twisted rotor profile (photo, left) is used for low pressures (up to 800 mbar) and a 3+4 rotor profile (photo, right) is used for pressures up to 1,500 mbar. The inlet air is sucked in on the cold side and discharge-silencer isolation helps maintain a low inlet temperature, thereby increasing the compressor efficiency. The belt-driven Delta Hybrid offers the advantage of exact sizing to match the demand. As a result, the units are energetically comparable to turbo compressors while having the advantages of a positive displacement machine, such as adaptability to variable operating conditions.

In addition to energy savings, the Delta Hybrid has features for extending the operating life and reducing maintenance. The Series incorporates a patented bearing system that extends the bearing life ($L_{h10}$) to over 60,000 operating hours (at a differential pressure of 1,000 mbar). And new sealing solutions at the drive shaft and the rotor chamber have been designed to minimize the natural wear.

The patented Delta Hybrid Series covers the flow range of 110 to 4,100 $m^3/h$, with 12 machine sizes for positive pressures up to 1,500 mbarg, and vacuum to –700 mbar.

## The direct synthesis of aqueous $H_2O_2$ solutions

A microreactor system for producing hydrogen peroxide from $H_2$ and $O_2$ has been developed by Sohei Matsumoto and Tomoya Inoue at the Research Center for Ubiquitous MEMS and Micro Engineering, National Institute of Advanced Industrial Science and Technology (AIST; Tsukuba, Japan; unit.aist.go.jp/umemsme/cie), in collaboration with Mitsubishi Gas Chemical Inc. (MGC, Tokyo, (www.mgc.co.jp), with funding from the New Energy and Industrial Technology Development Organization (NEDO). The system integrates micro-electromechanical systems (MEMS) and microreactor technology from AIST with catalyst technology of MGC, and produces aqueous $H_2O_2$ (10% or more) by the three-phase catalytic reaction of $H_2$ and $O_2$ at room temperature and a pressure of 1 MPa. Alternative direct routes to $H_2O_2$ require a higher (5–10 MPa) pressure to improve the mass transfer and lower (5–10°C) temperatures to control the explosive reaction, says Inoue.

AIST's reactor is fabricated in glass using MEMS technology, and features 600-µm, structured reactor channels packed with a solid catalyst. Gas and liquid distributors ensure a uniform distribution of the liquid phase (water) and also makes it easy to number up for future scaleup, says Inoue. AIST and MGC developed a $Pd/TiO_2$ catalyst, which achieves an $H_2O_2$ yield of 40% (based on $H_2$), and is responsible for the higher (10%) $H_2O_2$ concentration of the product compared to 6% achieved by existing $Pd/Al_2O_3$ catalysts, he says.

So far the system has a very small production capacity (about 30 g/d). AIST and MGC expect to increase capacities to 10 kg/d in the next two years. They also plan to use the technology for producing fine chemicals.

### A new SM process

Exelus Inc. (Livingston, N.J.; www.exelusinc.com) received a $500,000 grant from the U.S. Dept. of Energy (DOE; Washington, D.C.) to help pilot the company's styrene monomer (SM) process (*CE*, January 2007, p. 13). The funds are part of DOE's Small Business Innovation Research XLerator program, designed to help develop scaled-up manufacturing processes.

The ExSyM process involves the side-chain alkylation of toluene with methanol to produce styrene. Conventionally, styrene is produced through the alkylation of benzene with ethylene to produce ethyl benzene, which is then dehydrogenated catalytically to generate the SM. ExSyM offers lower feedstock costs, and avoids the energy-intensive dehyrdrogenation reaction. The company estimates feedstock costs could decrease by 30% (about $300/ton) with its process, and energy consumption would be significantly less as well.

### GE to buy Dresser

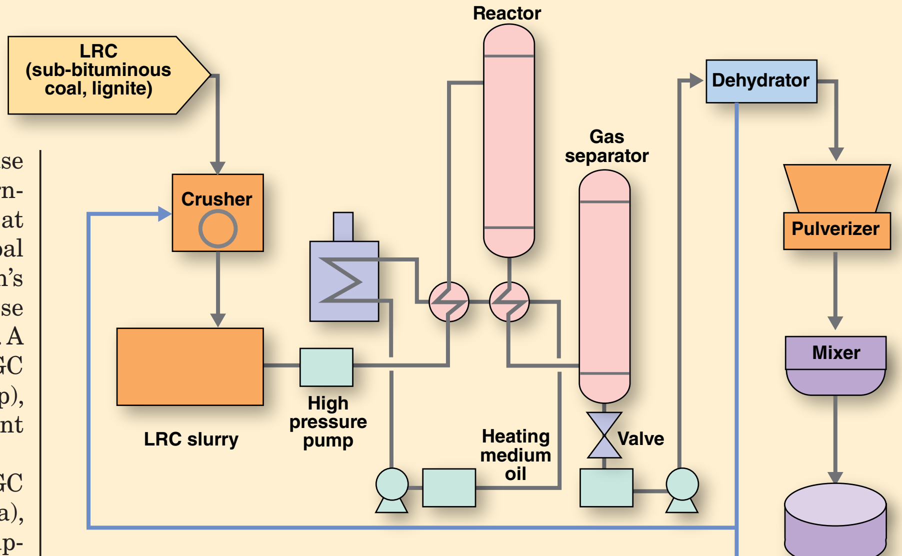
All the businesses of Dresser, Inc. (Dallas, Tex.; www.dresser.com) will be acquired by GE (Atlanta, Ga.; www.ge.com) for $3 billion. Included among the Dresser brands are Masoneilan control valves, Consolidated pressure-relief valves and Roots blowers and compressors.

*Note*: For more information, circle the 3-digit number on p. 58, or use the website designation.

## Coal slurry fuel

In order to shift the country's energy base from petroleum, the Indonesian government has implemented a policy aimed at shifting to coal. Because low-rank coal (LRC) accounts for about 80% of the nation's coal resources, effective utilization of these reserves will be vital to its energy security. A step in this direction is being taken by JGC Corp. (Yokohama, Japan; www.jgc.co.jp), which is to construct a demonstration plant for upgrading low-rank coal into fuel.

The project, a collaboration between JGC and Indonesia's Sinarmas Group (Jakarta), will employ a process that uses heat to upgrade low-rank coal into a fuel tradenamed JCF (JGC Coal Fuel). In the process (flowsheet), high-pressure water is used to cause low-rank coal to mature artificially. This matured coal is then converted into slurry. JCF can be used in place of petroleum products to power boilers for industrial or energy generation purposes. It also has potential applications for power-generation engines, coal gasification or as a component in biomass-combustion plants.




JGC has started construction on the demonstration plant at Karawang, near Jakarta, in cooperation with Sinarmas Group. When the facility is completed in 2011, it will have a capacity to produce 10,000 ton/yr of JCF.

### Acrylamide catalyst

A new catalyst that achieves a 99% conversion of acrylonitrile to acrylamide has been developed by Toshiyuki Oshiki, lecturer at Okayama University Graduate School of Natural Science and Technology (www.gnst.okayama-u.ac.jp) with support of New Energy and Industrial Technology Development Organization (NEDO; Kawasaki) and Japan Science and Technology Agency (JST; Tokyo). The high activity is comparable to that of the best laboratory catalyst — a Pt-based catalyst reported by A.W. Parkins in 1995 — but is 1/100th the cost, says Oshiki. In the laboratory, a 99% yield of acrylamide is achieved after reacting acrylonitrile in water for 0.5–1 h over the patent-pending, metal complex catalyst at 80°C. Oshiki is having discussions with acrylamide producers for evaluating the catalyst at the 100-g scale.

## Carbon nanotube 'paper' could reduce Pt content in fuel cells

One of the biggest factors hindering widespread adoption of polymer exchange membrane fuel-cells (PEMFCs) is the high price of the platinum metal needed to catalyze the reduction-oxidation chemistry in the fuel cell. In a step toward reducing platinum content, a Florida State University (FSU; Tallahassee, Fla.; www.fsu.edu) researcher has demonstrated effective performance of a carbon-nanotube-supported platinum catalyst in a PEMFC that uses less than half of the Pt metal found in conventional fuel cells.

Jim Zheng and colleagues developed a double-layered carbon nanotube (CNT) and nanofiber film (buckypaper) to support Pt nanoparticles as the catalyst material. The interwoven CNTs form a highly porous and electrically conductive three-dimensional network, onto which Pt nanoparticles are coated. Because the nanoparticles locate mostly on the accessible external surface of the membrane, the Pt utilization can exceed 90%, Zheng says, while in conventional fuel cell membranes, only 40% of the catalyst surface participates in the reaction. The FSU team's PEMFC has a platinum load of 0.2 mg/cm$^2$, compared to the 0.45 mg/cm$^2$ in conventional fuel cell membranes. The group was able to generate a power output of 0.88 W/cm$^2$ from the fuel cell, nearing a 2015 goal set forth by the U.S. Dept. of Energy (DOE; Washington, D.C.) of 1.0 W/cm$^2$.

## Making MOFs on an industrial scale

BASF SE (Ludwigshafen, Germany; www.basf.com) has developed an industrially viable process for synthesizing metal organic frameworks (MOFs), and plans to scaleup the process within the next two years. MOFs are crystalline compounds consisting of metal ions or clusters coordinated to often rigid organic molecules to form one-, two-, or three-dimensional structures with nanometer-sized pores that allow them to store $H_2$ or other high-energy gases. BASF has been working on MOFs since their discovery in the 1990s by professor Omar Yaghi at the University of Michigan at Ann Arbor (he's now at UCLA).

In BASF's process, a metal oxide and citric acid are simply mixed in water in a stirred-tank reactor, which leads to the production of cubic MOFs with the metal atoms at the corners of the organic frame. The key to making the synthesis viable on a large scale is that an organic solvent is not required, making the process safer and environmentally friendly. The company is able to achieve large surface areas and high porosity, which enables the MOFs to hold relatively large amounts of gases. The pore size and polarity can be adjusted for specific applications. MOFs produced by this process at BASF's pilot plant are being trialed for natural gas storage in heavy duty vehicles.



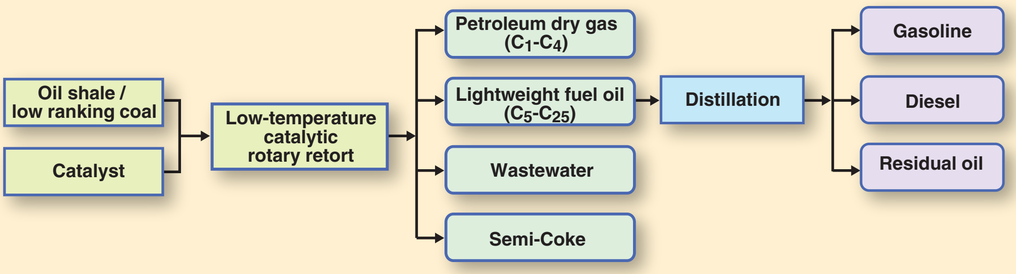
**Circle 7 on p. 58 or go to adlinks.che.com/29256-07**

## An oil shale process will be commercialized in China

Construction has started in Qinzhou, China, on the first commercial plant to use a new process for producing fuels from oil shale, to be imported from Indonesia. The process was developed by China Chemical Economical Cooperation Center (CCECC) and AuraSource, Inc. (Chandler, Ariz.; www.aurasourceinc.com), which is building the plant in a joint venture with two Hong Kong partners. When the plant starts up, toward the end of 2011, it will convert 1 million metric tons per year (m.t./yr) of shale to three products: syncrude ($C_5$–$C_{25}$ oil), which will be upgraded to 250,000 m.t./yr of gasoline and diesel fuels by local refineries; 120,000 m.t./yr of dry gas (90%+ methane), and 600 m.t./yr of "semi-coke."

AuraSource's process (flowsheet) is a relatively low temperature operation in which shale is indirectly heated in a retort to less than 480°C, using a proprietary catalyst and additives that are mixed with the shale. Spent shale, containing unburned carbon, will be used to produce a "coal-water slurry" via another AuraSource technology, called AuraCoal. The spent shale will be ground up, then ash and non-carbon material will be separated from the carbon by a proprietary gravity-separation process, says Philip Liu, the company chairman. The powdered carbon will be slurried in water to obtain a heavy-oil equivalent that will be used to heat the retort and by local power plants.

Liu says the venture promises to be "very profitable," with a product cost of $20/bbl of crude oil equivalent. He adds that the process is environmentally-friendly, with no waste and relatively low water consumption and carbon dioxide emissions. So far, the process has been tested in a 20-m.t. pilot plant. Liu says that AuraSource has applied to the U.S. Bureau of Land Management (Washington, D.C.) for an oil shale lease.




## Making syngas from coal in one step

A combined coal-gasification and methane-reforming process using coal char as catalyst has been developed by a team from the Chinese Academy of Sciences [Qingdao Institute of Bioenergy & Bioprocess Technology (english.qibebt.cas.cn), and the Institute of Coal Chemistry (english.sxicc.cas.cn)] and from the Center for Energy, University of Western Australia (UWA; Perth; www.uwa.edu.au).

Team leader professor Dongke Zhang, of UWA, says conventional steam-methane reforming entails some drawbacks, such as production of a high $H_2$-to-CO ratio in synthesis gas (syngas). In the $CO_2$ catalytic reforming of methane, the deactivation of the catalyst due to carbon deposition is a serious problem, he says. The new process has the advantages that the $H_2$-to-CO ratio in the syngas is adjustable, there is no need for an expensive metal catalyst or tubular reactors, and the process has a high energy efficiency compared with conventional steam reforming.

Various aspects of the new process have been studied in the laboratory, including $CH_4$ cracking over coal char, $CO_2$ and steam reforming of $CH_4$ over coal char, and the effect of chars made from different types of parent coals, including lignite, a bituminous coal, and anthracite. Coal chars were prepared by devolatizing coal in nitrogen in an electrically heated, fixed-bed reactor made of quartz, at 1,173K for 30 min.

Experiments were performed in a fluidized-bed reactor operating at atmospheric pressure and a temperature of 1,070–1,223K. Under these conditions, the bed of char undergoes gasification while catalyzing the methane-reforming reactions. Experiments demonstrated that the coal char greatly promotes the reforming reaction, and the highest initial methane conversion reaches nearly 90% at 1,223K.

### PVC-free wire coating

Dow Wire and Cable (Houston, Tex.; www.dow.com/wire) recently launched the world's first halogen-free compounds able to meet key global standards for coating flexible electric cords. Marketed as Sustain halogen-free compounds, they are available in both insulation and jacketing grades, and are designed as alternatives to polyvinyl chloride (PVC) for manufacturers of wires for appliances and electronics.

"The electronics industry has been seeking alternatives to PVC for making wires," explains Thorne Bartlett, director of new business development at Dow Wire and Cable. Responding to the trend, Dow introduced the proprietary materials, which are based on thermoplastic polyolefin and thermoplastic elastomer compounds and have favorable flame retardant properties. The materials can yield product with a similar look and feel to PVC-based cords. With a well-designed extrusion line, the Dow product can achieve production rates equivalent to those of PVC. The price of the new product is substantially higher than conventional compounds, but adds only a minimal amount to the end cost of electronic devices.

### Controlled nucleation

SP Scientific (Warminster, Pa.; www.spscientific.com) has signed a license agreement to utilize Praxair's (Danbury, Conn.; www.praxair.com) ControLyo nucleation on-demand technology, which provides pharmaceutical and biotechnology companies with precise control over the freeze-drying process for drug development. Praxair developed ControLyo for the control of the freezing step of lyophilization. Up to now, this freezing step was uncontrolled due to the random nature of the nucleation or crystal-forming process. ControLyo controls the nucleation temperature to within 1°C of its freezing point, thereby improving product quality and yield, and reducing cycle times by as much as 40%, says Praxair.

# A less-expensive process for leaching Ni from laterite

A hydrometallurgical process for nickel laterite deposits — believed to be the only process capable of treating any laterite deposits, from limonitic to saprolitic ores, in a single flowsheet — has been developed by Direct Nickel Pty. Ltd. (DNi; Sydney, Australia; www.directnickel.com). Researchers from CSIRO's Minerals Down Under Flagship (www.csiro.au), are supporting DNi's efforts at the Australian Minerals Research Center in Perth, Western Australia. The DNi process is now being optimized in the laboratory and will be put to the test in a demonstration program using a purpose-built plant that is due for completion in mid-2011. DNi and CSIRO are in discussions with engineering companies interested in building the new pilot minerals-processing facility at CSIRO's Waterford laboratories in Perth.

The front end of the DNi process involves a tank leach process operating at atmospheric pressure and moderate temperature. Whereas current processes for treating laterite-nickel ores consume large quantities of sulfuric acid — much of it requiring costly neutralization after use — the DNi process uses nitric acid, which is continuously recycled. The high recovery of $HNO_3$ (exceeding 95%) is a unique feature of the process. $HNO_3$ consumption is about 30 kg/m.t. of feed material compared to 300–1,000 kg/m.t. for $H_2SO_4$-based leaching processes.

After leaching, the insoluble residue is neutralized and sent to a waste disposal facility, and the leachate processed to extract the individual metals. Processing leads to a marketable mixed-hydroxide product containing nickel and cobalt. Extraction efficiencies exceed 95% of Ni and 85% of cobalt. Coproducts are $Fe_2O_3$, $Al_2O_3$ and MgO.

Graham Brock, project manager for DNi, says alternative processes, such as high-pressure acid leaching, are uneconomic when the magnesium content of the ore reaches about 3%, whereas there is no upper limit in the DNi process. The process is highly efficient, with operating and capital costs close to half of existing processes, says the company.

## Biomass-to-chemicals

Avantium (Amsterdam, the Netherlands; www.avantium.com) has developed a proprietary catalytic process to convert carbohydrates into furanic building blocks tradenamed YXY. The company has started construction of a pilot plant at the Chemelot site in Geelen, the Netherlands. When the unit starts up in the first quarter of next year, it will produce YXY building blocks for making materials (bottles, carpets, textiles fibers, coatings and plasticizers) and fuels. The pilot plant is partially funded (€1 million) by the Dutch Ministry of Agriculture.

## EAF productivity

Siemens VIA Metals Technologies (Linz, Austria; www.siemens.com/metals) has developed a contact-free method to measure the liquid-steel-bath temperature of electric arc furnaces (EAF). In contrast to

(*Continues on p. 16*)

(Continued from p. 15)

conventional methods, which are usually taken through the open slag door — either manually or with manipulators — the the RCB (refining combined burner) Temp system enables temperature measurements to be performed at short intervals, so the best time to tap can be determined more precisely. As a result, power-on and power-off times are reduced, thereby increasing the EAF's overall productivity, says the firm. Operator safety is also improved by eliminating potentially hazardous work near the furnace.

In RCB Temp, a measuring gas is blown through a lance into the liquid metal. An optical sensor records the measuring signal and an algorithm calculates the temperature. ❏

## Commercial debut slated for a new MMA process

Evonik Industries' business unit Performance Polymers (www.evonik.com) is planning to construct a new plant for the production of methyl methacrylate (MMA) monomer, using its newly developed proprietary Aveneer process. When the plant starts up in 2014, it will produce 150,000–200,000 m.t./yr of MMA using, for the first time, the Aveneer process. The location of the new facility will be decided in 2011.

The conventional acetocyanohydrin (ACH) route to MMA, which is widely used in Europe and the U.S. — including Evonik's 230,000 m.t./yr facility in Worms, Germany — is a three-step process using ammonia, natural gas, acetone and methanol as feedstock. First, methane from natural gas is converted to HCN. In the second step, acetone is reacted with HCN to form ACH. Sulfuric acid is then used to convert cyanohydrin into a hydrogensulfate ester salt of the methacrylamide, which then undergoes methanolysis to produce MMA, with ammonium hydrogensulfate as a byproduct. The ACH route's main drawbacks are the large volumes of $H_2SO_4$ needed and the $NH_4HSO_4$ and other byproducts generated, that have to be recycled in a sulfuric acid recovery (SAR) unit.

The Aveneer process uses the same starting materials as the ACH process, but without sulfuric acid. Instead, three heterogeneous catalysts — developed in-house — are used to perform the reactions. The reaction takes place in the presence of tailor-made heterogeneous catalysts operating at moderate pressures and temperatures, explains Steffen Krill, director of process R&D at Evonik Industries' Performance Polymers Business Unit. The corresponding catalysts have shown excellent lifetimes following two years of continuous operation and high throughput in the company's pilot plant in Worms, he says.

Eliminating the need for $H_2SO_4$ leads to a significant reduction in investment costs as well as in the operating costs associated with operating and maintaining the $H_2SO_4$ plant, such as energy and maintenance costs. Aveneer has the additional advantage of being able to produce MMA and methacrylic acid (MAA) simultaneously, with yields of 95% — up to about 10% higher than conventional routes. ■

# *CE* PERSONAL ACHIEVEMENT AWARD

## The winners are waste management expert Tom McGowan and green chemistry pioneer Kris Mani

Much attention over the past two years has been focused on alternative energy and green chemistry. So it is particularly appropriate that *Chemical Engineering*'s (*CE*) 2010 Personal Achievement Award recognizes two individuals with expertise in those fields. Last month, at an award ceremony held at the ChemInnovations Conference and Exhibition in Houston, Tom McGowan, a longtime consultant in biomass energy, combustion, air pollution control and more, was joined by Kris Mani, developer of a novel process for potash, in accepting the awards from Rebekkah Marshall, *CE*'s editor-in-chief.

The aim of the *CE* Personal Achievement award, which the magazine has offered biennially since 1968, is to honor individuals for distinguished careers (see Table 1). It complements *CE*'s Kirkpatrick Award for Chemical Engineering Achievement, presented in alternate years, which honors companies — as opposed to individuals — for specific chemical-process technology.

The *CE* Awards have saluted excellence in diverse areas — research, development, design, plant operations, management and other activities. The distinction can emerge in less-ordinary ways, such as government service. The one major criterion is that the career must have related, fully or largely, to the use of chemical engineering principles in solving industrial, community or other problems.

Tony Ruppe

**Award winners Kris Mani (center left) and Tom McGowan (center right) posed with *CE* editor-in-chief Rebekkah Marshall and publisher Mike O'Rourke at ChemInnovations**

### Thomas McGowan

Tom McGowan is president and founder of TMTS Associates Inc. (Atlanta, Ga.; www.tmtsassociates.com), a firm that specializes in thermal systems and air pollution control. Prior to founding TMTS, McGowan spent 10 years employed by the environmental services firm RMT/Four Nines Inc.

For 35 years, McGowan has made significant contributions in the areas of combustion, air-pollution control, solids handling and industrial ventilation, including drying, combustion and gasification of biomass. His functions have ranged from process and project engineering, to process safety and sales.

McGowan holds a master's degree in industrial management from the Georgia Institute of Technology (Atlanta, Ga.; www.gatech.edu) as well as B.S.ChE and M.S.ChE degrees from Manhattan College (New York; www.mancol.edu). He is a registered engineer in Georgia and several other states and is OSHA 1910.120 Haswoper-certified.

The holder of a U.S. patent for an air-supply grate and ash-removal system for a wood gasifier (U.S. patent No. 4,601,730), McGowan has contributed to "Perry's Chemical Engineers' Handbook," 7th ed., as well as the "McGraw Hill Standard Handbook of Hazardous Waste Treatment and Disposal," 2nd ed.

McGowan is the primary author of the Air and Waste Management Association (AWMA; Pittsburgh, Pa.; www.awma.org) publication "NOx Control for Stationary Sources," and a co-author of "The Industrial Wood Energy Handbook," (Van Nostrand, 1984). He has authored numerous magazine articles and journal papers on a diverse range of topics, including energy, pollution control, waste treatment, thermal processes and solids handling.

*CE* received numerous pieces of correspondence in support of McGowan's nomination for this award. Among the supporters is Don W. Green, emeritus distinguished professor of chemical and petroleum engineering at the University of Kansas (Lawrence, Kan.; www.ku.edu).

Green commented that "Tom has had a long and distinguished career as a chemical engineer. The breadth of technical and management activities in which he has engaged is very, very impressive. He exemplifies the best of chemical en-

**2010 AWARD WINNERS**

Thomas McGowan

Kris Mani

gineering practice."

Gary Collison, principal at Golder Associates (Atlanta, Ga.; www.golder.com), says his company has relied on McGowan's expertise in combustion and incineration, and knowledge of thermal treatment systems, biomass energy systems and thermal desorption technology. McGowan has helped guide the company and its clients through the labyrinth of environmental regulations, as well as to prepare contract documents for competitive bids, and select contractors, Collison wrote.

Collison's letter of support also spoke to McGowan's "recognized expertise in the combustion industry" and his "open and independent technical approach."

Other supportive letters pointed out McGowan's mix of technical knowledge, vast experience and ability to express himself clearly.

McGowan is an asset to the chemical and combustion engineering community, says Richard Trudeau, vice president at Environmental Soil Management Companies (ESMI; Fort Edward, N.Y.; www.esmicompanies.com), and his career has aided the advancement of technology across several fields.

### Kris Mani

Dr. Kris Mani currently serves as president and chief executive officer of NSR Technologies, Inc. (Decatur, Ill.; www.nsr-tech.com), an innovative, research-driven chemical technology and manufacturing company, which he founded in 2006.

Mani was driven to found the company partially because he saw a need for technology that would lead to greener and cleaner production of hazardous chemicals. To meet this market opportunity, he raised more than $12 million from outside investors to fund the construction of the world's first chemical plant to manufacture commercial grade caustic potash (45–50 wt.% potassium hydroxide solution) via membrane electrodialysis technology and chromatographic separation.

It is widely thought that financing and building the facility, particularly noteworthy in an era of offshore manufacturing and intense competition from suppliers in China and Southeast Asia, reflect not only Mani's perseverance and commitment to innovation, but the strength of his technological achievements and business skill.

**TABLE 1.**

| Award year | Name(s) of winners |
|---|---|
| 1968 | James Fair |
| | M.F. Gautreaux |
| | H. Russell Sheely |
| | Claude Talley |
| 1970 | Page Buckley |
| | John McWhirter |
| | Arthur Morgan Jr. |
| | William Tucker |
| 1972 | Robert Heitz (1st prize) |
| | Arnold Ayers (merit) |
| | Harold Kaufman Jr. (merit) |
| 1974 | Alan Micheals (1st prize) |
| | Frank Trocino (merit) |
| | John Anderson (merit) |
| 1976 | Donald Garrett |
| | Lee Gaumer |
| | Tom Nicklin |
| | Morgan Sze |
| 1978 | Bernard S. Lee |
| | Fernando Oré |
| | Charles Sternling |
| | Utah Tsao |
| 1980 | David K. Beavon |
| 1982 | John M. Googin |
| 1984 | William M. Burks |
| 1986 | Frederick A. Zenz |
| | A.D. Reichle |
| | Richard A. Conway |
| 1988 | L.K. Doraiswamy |
| | Raphael Katzen |
| | Robert Maddox |
| 1990 | Francis G. Dwyer |
| | George E. Keller |
| | Trevor Kletz |
| 1992 | Joseph Jacobs |
| | Bodo Linnhoff |
| 1994 | Lowell B. Koppel |
| 1996 | Paul Quencau |
| 1998 | Ernest Henley |
| | Hanns Paul Hoffman |
| | Dan Steinmeyer |
| 2000 | Michael Lockett |
| | John Pelton |
| 2002 | Lawrence Evans |
| | Henry Kister |
| 2004 | No award given |
| 2006 | No award given |
| 2008 | Brian W.S. Kolthammer |
| | Shyam Lakshmanan |

The processes used at NSR Technologies are substantially more environmentally friendly than alternative production methods. Currently, commercial strength KOH is manufactured via the chlor-alkali route.

NSR's technology is 40% more energy efficient than chlor-alkali production, and its process is suitable to

## PAST WINNERS OF THE *CE* PERSONAL ACHIEVEMENT AWARD

| Affiliation(s) of winners | Basis of award / Area of expertise |
|---|---|
| Monsanto Co. | Fluid separations technology |
| Ethyl Corp. | Synthetic straight-chain alcohols |
| Badger Co. | Fluidized-bed reactor design |
| Texaco Inc. | Stiff boron filament |
| Dupont | Process control |
| Union Carbide Corp. | Wastewater treatment |
| U.S. Dept. of Agriculture | Food processing |
| The Lummus Co. | Petrochemical technology |
| Dow Chemical Co. | Membrane technology |
| Allied Gulf Nuclear Services | Nuclear fuel processing |
| DCA Food Industries Inc. | Food production |
| Alza Corp. | Pharmaceutical engineering |
| Bohemia Inc. | Wood byproducts processing |
| Union Carbide Corp. | Solid waste processing |
| Garrett Energy R&D Inc. | Flash pyrollysis of coal |
| Air Products and Chemicals Inc. | Natural gas liquefaction |
| Peabody Holmes Ltd. | Sour gas; hydrocarbon reforming catalysts |
| CE Lummus Co. | Catalytic hydroliquefaction |
| Institute of Gas Technology | Coal-to-fuels and coal-to-chemicals processes |
| Occidental Research Corp. | Oxy hemihydrate process |
| Shell Development Co. | Mass transfer effects |
| CE Lummus | Process commercialization (various projects) |
| Ralph Parson Co. | Petroleum refining |
| Union Carbide Corp. | Nuclear chemistry |
| Stauffer Co. | Technology transfer and licensing |
| F.A. Zenz, Inc. | Fluid-particle dynamics |
| Exxon Research and Engineering Co. | Hydrocracking, fluid-catalytic cracking, catalyst technology |
| Union Carbide Corp. | Environmental stewardship |
| National Chemistry Laboratory (India) | Reaction engineering |
| Consultant | Wood-chemical process development |
| Oklahoma State University | Gas and liquid desulfurization |
| Mobil Research & Development Corp. | Zeolite catalysts |
| Union Carbide Corp. | Separations technology and chemical engineering education |
| Consultant | Chemical plant safety |
| Jacobs Engineering Group | Managerial and technical accomplishments |
| Linnhoff March Ltd. | "Pinch" process technology |
| Setpoint Inc. | Process control and information-systems planning |
| International Nickel Co. | Pyrometallurgy |
| University of Houston | Computer-aided design |
| University of Erlangen-Nürnberg | Chemical engineering education and reaction engineering |
| Monsanto Co. | Polymer processing |
| Praxair | Distillation and heat-transfer technologies |
| Praxair | Crystal formation and growth, flame coating, waste-to-fuel, aluminum refining |
| Aspen Tech | Process modeling and simulation |
| Fluor Corp. | Distillation and absorption troubleshooting |
| – | – |
| – | – |
| Dow Chemical Co. | Kinetic modeling of catalyst systems |
| See Sen Chemical Bhd | Plant improvement and efficiency |

manufacture potassium hydroxide or sodium hydroxide (caustic soda). Also, the process does not involve the production or combustion of chlorine gas (*CE*, August 2009, p.14; www.che.com/chementator/An-alternative-to-chlor-alkali_4956.html).

To develop the plant, which now generates millions of dollars in annual revenues, Mani used his considerable technical know-how, an innovative design and entrepreneurial spirit along with a raft of more than 40 process and equipment patents that Mani himself was instrumental in establishing.

It is the first innovative and viable alternative to KOH production since the development of chlor-alkali, more than a quarter century ago. NSR Technologies is one of only five KOH producers in the U.S., and the company competes against several Fortune 500 industrial companies.

Prior to establishing NSR, Mani held research and development, as well as management positions, at Archer Daniels Midland Co. (ADM; Decatur, Ill.; www.adm.com). He began his career as a researcher at Allied Signal Corp., (now Honeywell Inc.; Morristown, N.J.; www51.honeywell.com). During his tenure, he assumed positions of increasing management responsibility in electrodialysis and water purification.

Mani holds M.S.ChE. and Ph.D.ChE. degrees from Northwestern University (Evanston, Ill.; www.northwestern.edu).

"Mani has demonstrated a rare sense of expertise and commitment to advancing the profession and application of chemical engineering," says Thomas Binder, senior vice president for research at ADM in a letter of support.

Mani has "consistently demonstrated an exceptional technical core competency, coupled with a vision to multitask and work hard on complex and divergent projects. He embraces all projects with enthusiasm and has a deep interest to learn and develop, personally and professionally."

Binder adds that Mani's remarkable achievement of financing and building a commercial chemical plant "shows a deep commitment to innovation, technology and advancing the field of chemical engineering."

### Submit nominations

The *CE* Personal Achievement Awards are given out biennially, and nominations for the 2012 award will be accepted beginning in January 2012. If you would like to nominate a candidate to join Mani and McGowan on the growing list of individuals to be awarded the *CE* Personal Achievement Award, send a letter or email to *CE* with the following information:

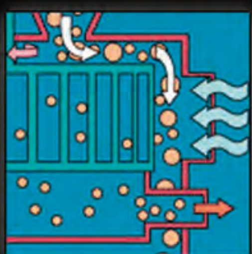
- Name, job title and address of the candidate
- Your name and address
- A summary of around 500 words that describes the nominee's career and illustrates his or her creativity and general excellence in the practice of chemical engineering. At least some of the activity must have taken place during the three-year period ending December 31, 2011. Without divulging confidential information, try to be specific about key contributions

*CE* encourages those submitting nominations to ask others to provide information in support of the nominee.

Scott Jenkins
*Chemical Engineering*
110 William St., 11th Floor
New York, NY 10038
Email: awards@che.com ■

*Scott Jenkins*









MB Industries

FIGURE 1. Blast-resistant modules like this provide protection for personnel in the event of an onsite explosion



# EXPLOSIVE SOLUTIONS

## From the first line of defense to the last, explosion prevention and protection firms are upping their game to preserve yours

Following the devastating explosion at the Imperial Sugar Co.'s Georgia factory that killed 14 people, injured many more employees and leveled the facility in February 2008, it was determined by he U.S. Occupational Safety and Health Admin. (OSHA; www.osha.gov) officials and the U.S. Chemical Safety Board (CSB; both Washington, D.C.; www.csb.gov) that the catastrophe could have been prevented had the manufacturer taken available steps to reduce the presence of sugar dust in its facility.

As a result of these findings, the U.S. regulatory climate turned a watchful eye toward combustible dust in the workplace, culminating in the announcement by new OSHA Chairman George Miller that a new standard on combustible dust is to be expected in the near future as part of the agency's Reissued Combustible Dust National Emphasis Program (see box on p. 26). This announcement, combined with the current increase in OSHA inspections with regard to combustible dust in targeted industries, has spurred a lot of interest in explosion prevention and protection equipment in the chemical manufacturing industry, which is third behind the wood and food industries on OSHA's list of targets.

Currently OSHA is using applicable NFPA Standards 68, 69 (which define how to protect) and 654 (which defines where to protect) to inspect high-priority industries until their own standard is issued. "Basically any facility that is working with powders, drying materials from a wet to dry state, using dust collectors or air material separators or anywhere there is a process risk for a dust combustion event to take place needs to start thinking about proper protection," says Bob Korn, director of sales, Fike Corp. (Blue Springs, Mo.; www.fike.com).

While it is difficult for processors to decide how to go about meeting a standard that doesn't yet exist, explosion prevention experts say that now is the time to start making decisions. "Most people believe that using equipment that meets the current NFPA codes is going to be an acceptable way to meet the OSHA standards," says Geof Brazier, director of product and market development, BS&B Safety Systems (Tulsa, Okla.; www.bsbsystems.com). However, he notes that there will be at least one major difference. According to current NFPA standards, if the facility met previous versions of the code, it is still in compliance with NFPA. OSHA, however, will likely rule that all facilities be up to date with the most recent version of NFPA if this is the chosen path to meet worker safety expectations. The current OSHA National Emphasis Program references all of the current NFPA standards for this purpose.

This change in grandfathering means that existing facilities will be scrutinized as closely as new construction, so all facilities with a risk for dust explosions need to start planning and working now in an organized, systematic manner to implement a risk protection plan.

"Now is the time to get your risk analysis and risk management plans in place and start looking at prevention and protection equipment," says Brazier. "Starting now will allow processors to implement their plans and equipment on a budget and make in-

### THE LAST LINE OF DEFENSE

On March 23, 2005, a fire and explosion occurred at BP's Texas City Refinery in Texas City, Tex., killing 15 workers and injuring more than 170 others. The fatalities and injuries occurred mainly to people who were operating out of commercial trailers located in a blast zone at the time of the explosion. "It was actually the debris that killed those people," says Ray Onofrio, vice president of sales and leasing in North America for MB Industries (Rayne, La.; www.mbindustries.com). "The trailers themselves turned into debris fields."

As a result of this accident, some new documents, Recommended Practices (RP) 752 and 753, were created by OSHA and dictated the use of blast-resistant structures in blast zones. To determine which areas of a facility are high-risk blast zones, processors need to hire an engineering firm to perform a site analysis and create a map with various blast levels, based upon the proximity to processing areas with potentially hazardous operations taking place. Each area that is considered a blast zone is given a potential psi level and then a duration damage level for which adequate protection is required. Some of these blast zones may require permanent shelters, such as laboratory areas or permanent office space located on the processing floor, and others may require temporary structures during turnarounds or maintenance periods.

Several companies, including MB Industries and A Box 4 U (Wichita, Kan.; www.abox4u.net) provide blast-resistant modules for purchase and/or lease so that if there is an explosion, the people inside the building will be protected from the blast. ❏

## BEYOND DUST

While many explosions are dust related, process incidents can also be caused by flame propagation and over pressurization (or implosion) of tanks. In this area of protection, API (American Petroleum Institute) 2000, recently co-branded as ISO 2830, provides information for processors on how to determine the required venting capacity based on their specific application.

Prior to being co-branded as an ISO standard, the earlier API2000 code was developed specifically for the oil and gas industry, so it did not fully cover other industries. However, since the co-branding, some changes have been made that may have an impact on the use of flame arrestors with vent valves and the methods used to size valves in industries outside oil and gas, says Mitch Anderson, director of operations with Groth Corp. (Stafford, Tex.; www.groth.com).

"The previous version shied away from the use of flame arrestors in oil and gas processing because of the risk of plugging, but in the chemical industry where there's a cleaner process and the material may be more flammable, the latest standard suggests the addition of a flame arrestor where there's less chance of plugging," says Anderson.

Sizing issues may arise, as well. While vents that are already in place according to previous versions of the code are grandfathered, new methods of sizing may change venting requirements going forward with new process lines or installations, explains Anderson.

And, because environmental safety is as of nearly equal importance as personnel safety when it comes to tank venting, it is necessary to keep emissions in mind when selecting valves based on these new additions to the code.

For this reason, Groth offers products that protect the environment as well as personnel and equipment. For example, the 1800A Series full-lift-type valve is for applications requiring low fugitive emissions and operation near tank MAWP (maximum allowable working pressure). This relief valve attains full stable lift at 10% overpressure.

Also intended to protect from overpressure is the 3000-Series Blanket Gas Regulators, which ensure that a constant gas pressure is maintained in the vapor space of a storage tank. A blanket gas regulator supplies an inert gas to prevent a vacuum from developing when liquid is removed from a tank, to maintain the desired blanket pressure when the temperature drops and to prevent outside air from contaminating the tank or creating a flammable or explosive environment. Because it prevents outside air and moisture from entering the storage vessel and reduces the evaporation of the stored product, the result is conserved product and greatly reduced emissions, as well as protection from external fires. ❑

BS&B Systems


**FIGURE 2. The Type IPD Explosion Suppression System provides protection where dust suspended in air represents an explosion hazard**

Rembe

**FIGURE 3. The Q-Rohr-3 guarantees indoor venting without any flames or dust propagation, allowing protection for equipment that is hard to access or free standing in the process area**

formed decisions about which type of equipment is right for their facilitiy and their needs."

And, there are several choices to be made when it comes to dust explosion prevention, starting with the choice between active and passive systems. Passive systems include explosion vents that function completely based upon the design and construction of the item. There is no circuitry or logic for making decisions. Included in this group are explosion vents and flameless explosion vents. Active systems include explosion suppression systems, which use sensing detectors to identify that an explosion has started. There's a logic decision in the controller that activates the rapid release of an agent into the offending equipment to prevent a full explosion from developing.

### Venting versus suppression

There are pros and cons to each type of system. "We see many advantages of venting over suppression systems," says Gerd Mayer, president of Rembe, Inc. (Charlotte, N.C.; www.rembe.us), which offers both types of equipment. "Suppression systems are subject to a lot of faults and if you don't actually have an explosion situation and the suppression system is emptied, a facility can be knocked out of production for several days because everything, not just the dust collector, will have to be cleaned as the agent spreads all over the processing line. If you're in a food, chemical or pharmaceutical plant, you don't want suppression agents in your product."

Also, there are high maintenance costs associated with suppression systems, says Mayer. NFPA 69 explains that a suppression system should be checked a minimum of four times a year because the agent-containing bottles can lose pressure, which would result in faulty or no activation during an event.

"In many cases vents are chosen because they are an inexpensive and readily available way to retrofit an installation to meet standards," explains Christopher Driesel, engineering manager with Oseco (Broken Arrow, Okla.; www.oseco.com). "Active systems are more expensive over the longterm cost of ownership because of the necessary inspections and maintenance involved."

However, it is important to remember that venting systems are not "fit and forget." Brazier says that the latest generation of NFPA standards is very clear that even passive systems do have a requirement for periodic inspection. "This is something that the end user community is very weak in embracing," he says.

Inspection here is necessary because several factors could affect the operation. For instance, process material can build up inside the vent, causing it to become heavy, which may result in an inability to open fast enough, or at all, during an event. Another example is when a process changes, which can have significant consequences to the protection equipment if the material being processed was changed to one with higher combustion characteristics and previously employed safety measures might not be enough to con-

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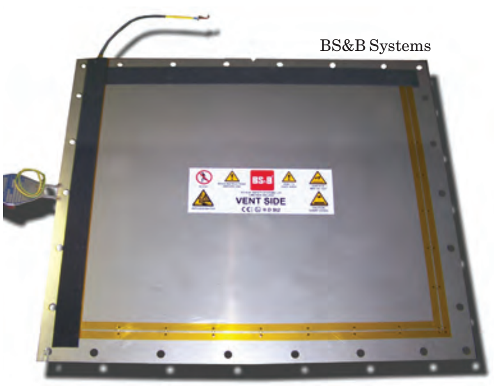



**FIGURE 4. This Type VIS vent integrity sensor brings continuous monitoring capability to explosion vents**

trol the current hazard. "A good guideline is that having partial protection might be the same as having no protection," points out Brazier.

Providers of both kinds of systems are working hard to improve upon the faults of their equipment. Oseco, for example, now offers the MV explosion vent with an all-metal (no fluoropolymer) design using a stainless-steel membrane. No holes or slits are visible, which makes the MV suitable for applications where product buildup may be a concern.

And as flameless venting continues to be favored where a fireball can't be released, many equipment providers are coming up with new models. Rembe's Q-Rohr-3 guarantees indoor venting without any flames or dust propagation. Therefore appliances that are hard to access or standing free in production areas can be protected without reconstruction work to walls or buildings. The company says the vent is maintenance free, making it a very economical comparison to similar active quenching systems.

Fike offers Flamquench flameless venting solutions that extinguish flames from vented explosions — not allowing flames to leave the device where secondary explosions could be ignited — without ducting, limitations on location of the process equipment or the use of other explosion protection systems.

Also to help make sure vents are working properly, BS&B offers the Type VIS vent integrity sensor, which brings continuous monitoring capability to explosion vents. VIS technology comprises an electrically isolated supervisory circuit placed beneath the explosion-vent gasket arrangement. The circuit passes over each of the controlled points of weakness that determine the vent relief pressure. The VIS circuit runs along the three opening sides of the vent. The sensor provides a signal when any one burst control member (present in all BS&B explosion vent types) is compromised, allowing personnel to take immediate action when normal operating conditions threaten vent integrity.

In the suppression system arena, BS&B also provides the Type IPD Explosion Suppression System for protection where dust suspended in air represents an explosion hazard. The early stages of the pressure rise associated with a dust explosion are detected by the unitized sensor, which is mounted to the equipment to be protected.

When at least two of the three individual pressure sensors respond, an electrical signal activates the explosion suppression cannons installed on the equipment, causing the pulverized suppression agent (food-compatible sodium bicarbonate) to be energized and discharged into the equipment, extinguishing the early stages of combustion before it builds into a deflagration, which can generate a pressure exceeding the strength of the process equipment.

Making the choice between these or any other passive and active protection systems rests with the processor. "It's all about looking at the unique attributes of each individual application, considering the concerns of each application and the way they want to conduct their business when it comes to identifying which of these many options is the right choice for a specific scenario," says Brazier. "There needs to be a good fit between the business intentions and the technology selection in order to get the job done safely." ■

*Joy LePree*

## OSHA ACTION

Following the events at Imperial Sugar, OSHA immediately reissued its Combustible Dust National Emphasis Program. The executive summary, quoted below from the Reissued OSHA Directive CPL-03-00-008, explains how the agency plans to handle its inspections and what industries and materials will likely be targeted.

OSHA is reissuing the directive on the Combustible Dust National Emphasis Program to increase its enforcement activities and to focus on specific industry groups that have experienced either frequent combustible dust incidents or combustible dust incidents with catastrophic consequences. OSHA initiated its previous Combustible Dust National Emphasis Program on October 18, 2007. As a result of a recent catastrophic accident involving a combustible dust explosion at a sugar refinery, OSHA has decided to intensify its focus on this hazard. The Agency will increase its activities in outreach, training, the creation and dissemination of guidance and educational materials and cooperative ventures with stakeholders, as well as enhancing its enforcement activities through this amendment to the National Emphasis Program (NEP).

The purpose of this NEP is to inspect facilities that generate or handle combustible dusts that pose a deflagration or other fire hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape; deflagrations can lead to explosions. Combustible dusts are often either organic or metal dusts that are finely ground into very small particles, fibers, fines, chips, chunks, flakes, or a small mixture of these. Types of dusts include, but are not limited to: metal dust, such as aluminum and magnesium; wood dust; plastic dust; biosolids; organic dust, such as sugar, paper, soap and dried blood; and dusts from certain textiles. Some industries that handle combustible dusts include: agriculture, chemicals, textiles, forest and furniture products, wastewater treatment, metal processing, paper products, pharmaceuticals and recycling operations (metal, paper, and plastic).

In situations where the facility being inspected is not a grain handling facility, the laboratory results indicate that the dust is combustible, and the combustible dust accumulations not contained within dust control systems or other containers, such as storage bins, are extensive enough to pose a deflagration, explosion, or other fire hazard, then citations under 29 CFR 1910.22 (housekeeping) or, where appropriate, 29 CFR 1910.176(c) (housekeeping in storage areas) may generally be issued. Combustible dusts found in grain handling facilities are covered by 29 CFR 1910.272.

For workplaces not covered by 1910.272, but where combustible dust hazards exist within dust control systems or other containers, citations under section 5(a)(1) of the OSH Act (the General Duty Clause) may generally be issued for deflagration, other fire, or explosion hazards. National Fire Protection Association (NFPA) standards (listed in Appendix A of this directive) should be consulted to obtain evidence of hazard recognition and feasible abatement methods. Other standards are applicable to the combustible dust hazard. For example, if the workplace has a Class II location, then citations under 29 CFR 1910.307 may be issued to those employers having electrical equipment not meeting the standard's requirements. ❑

## Fractionation Column

# Hazards of column entry

Mike Resetarits is the technical director at FRI (resetarits@fri.org), a distillation research consortium headquartered in Stillwater, Okla. Each month, Mike shares his first-hand experience in this column

In obtaining a degree or even a professional license in chemical engineering, there is little, if any, mention of facial hair. Nevertheless, that aspect of my appearance was surprisingly pivotal at one particular moment in my career.

At that time, I had zero facial hair — no moustache, no beard, and no long sideburns — and I was a liquid-liquid extraction expert. It was therefore obvious to everybody (except me) that I was the best candidate to put on a face mask and put my head into a hydrocarbon atmosphere.

I was troubleshooting a benzene-toluene-xylene liquid-liquid extraction column in Canada. The column was designed by a committee of six engineers. Like many designs by committee, the extractor design performed non-optimally. Production was stuck at 80% of the target value. The entire committee, including myself, was at the production site on-and-off for many months performing troubleshooting work.

On one particular troubleshooting visit, Joe was with us. This was Joe's first visit to the site. He was trying desperately to avoid being associated with the difficult column. The troubleshooting team had a new theory: the feed tray was plugged with solids. Production personnel had reluctantly agreed to shut the column down for a few hours, and open the manhole at the feed location and allow an engineer wearing a breathing apparatus to look briefly at the feed tray to see if it was plugged.

The breathing apparatus provided an oxygen supply. I had never ever used such an apparatus, and I was not given any training regarding its use.

It was winter. It was past dusk. The troubleshooting team, including Joe, climbed halfway up the 120-ft tall tower. The manhole cover bolts had all been removed, but the manhole was still closed. Inside the column were hydrocarbon vapors. There was no oxygen inside the column.

With assistance, the breathing apparatus was strapped on my back, and the mask was placed over my hairless face. The straps were pulled tight so that I would only be breathing air from the tanks, rather than vapors from inside the column.

I was ready. The manhole cover was swung open. The other engineers stepped back. I put the top half of my body inside the column. The warmth of the vapors felt good. Using a flashlight, it was soon clear that the feed tray was not plugged. I looked and looked — and looked too long. I passed out, and I fell out of the column. The seal on my mask had not been perfect. I had been breathing hydrocarbons along with the oxygen. Had I fallen into the column, somebody other than I might have authored this short story.

My troubleshooting colleagues knew immediately what had happened. They closed the manhole cover. They ripped the mask off my face. They slapped and shook me to consciousness. It was cold on the side of the column 60 ft up. It did not matter. I could neither stand nor walk for about 30 min.

There was no way for anybody to help me physically with the ladder descent. Eventually, I felt well enough to stand and climb down the vertical ladders that were affixed to the side of the column. When I got to the ground, I was weak and my legs were wobbly.

Let the history books show that I was lucky to have fallen out of the column rather than into it. More importantly, let the importance of fit-testing a breathing apparatus be underlined in safety books and procedures. ■

*Mike Resetarits*

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

# Viscosity Measurement

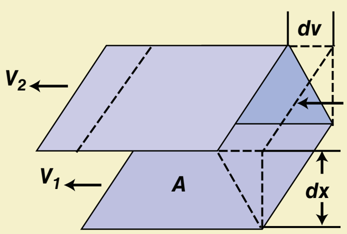
Measurement of fluids' viscosity in the chemical process industries (CPI) can represent a useful "product dimension" for manufacturers. Understanding a material's flow characteristics is valuable in predicting several parameters relevant to many CPI processes, including pumpability, pourability, performance in a dipping or coating operation, ease of handling or processing. The relationship between rheology (study of the flow of matter) and other properties often makes viscosity measurement a sensitive and convenient method for detecting changes in other product parameters, such as density, stability, solids content or molecular weight.

## VISCOSITY FRAMEWORK

Viscosity is a measure of a fluid's internal friction. Caused by intermolecular attraction, viscosity can be thought of as resistance to flow. This friction becomes apparent when a layer of fluid is made to move in relation to another layer. More friction requires more force to effect this movement, called shear. Shearing occurs when fluids undergo physical movement or distribution, such as in pouring, spreading, spraying and mixing.

### Flow of layers

Isaac Newton defined viscosity by considering the model represented in Figure 1. Two parallel planes of fluid of equal area *A* are separated by a distance *dx* and are moving in the same direction at different velocities $V_1$ and $V_2$.




Newton assumed that the force required to maintain this difference in speed was proportional to the difference in speed through the liquid, or the velocity gradient. The velocity gradient, $dv/dx$, represents the change in speed at which the layers move with respect to each other. It describes the shearing the liquid experiences, and is thus called shear rate [*1*]. Its units are reciprocal seconds ($s^{-1}$).

The term $F/A$ indicates the force per unit area required to produce the shearing action ($dynes/cm^2$).

Viscosity is the ratio of shear stress to shear rate.

### Fluid behavior

Many fluids, like water or gasoline, exhibit Newtonian behavior, which is to say that their viscosity remains constant with varying shear rates. Viscosity of a Newtonian fluid depends only on temperature and pressure, but not on the forces acting on the material. For Newtonian fluids, plotting shear stress versus shear rate (a rheogram) yields a straight line that passes through the origin. The slope is equal to the viscosity.

However, many materials in the CPI behave in non-Newtonian ways, so that the rate of shear is not linearly proportional to the corresponding stress. For many applications in the CPI, expressions of viscosity as a single value fail to capture the full picture of the many factors that affect viscosity. Non-Newtonian viscosity behavior include the following:

- ***Pseudoplasticity*** (shear-thinning) occurs when a fluid's viscosity decreases with increasing shear rate. Many emulsions, polymer melts and solutions, paints, blood and some solid suspensions exhibit this property
- ***Thixotropy*** is a situation where a fluid's viscosity decreases over time under constant shear stress. Clay suspensions used as drilling muds, mayonnaise and some paints and inks behave this way
- ***Rheopectic*** behavior is the less-common opposite of thixotropy — shear stress increases at constant shear rate. A gypsum suspension in water is an example
- ***Dilatant*** (shear-thickening) fluids show increasing viscosity with increasing shear rate. Dilatant behavior is observed in starch suspensions in water, quicksand and in some high molecular-weight polymers used in drilling muds

TABLE 1. VISCOSITIES OF COMMON MATERIALS

| Material name | Temperature (°C) | Viscosity (cP) |
|---|---|---|
| Ethanol | 20 | 1.1 |
| Water | 0 | 1.79 |
| Water | 20 | 1.0 |
| Water | 100 | 0.28 |
| Sulfuric acid | 25 | 24.2 |
| Motor oil (SAE 30) | 20 | ~450 |
| Blood | 37 | 3–4 |
| Corn syrup | 25 | 1,380 |
| Milk | 20 | ~3 |
| Ethylene glycol | 25 | 16.1 |
| Acetone | 20 | 0.30 |
| Olive oil | 20 | 81 |
| Honey | 20 | 10 |
| Glycerin | 20 | 1,420 |
| Peanut butter | 20 | ~250,000 |
| Air | 18 | 0.019 |
| Glass | 20 | $10^{18}$ – $10^{21}$ |

## VISCOSITY MEASUREMENT

When testing materials that flow, it is important to think about how the material will be processed and handled when in use. Analytical procedures for simulating the shearing action with an instrument is the key to predicting flow behavior.

Rotational viscometers are a common tool, wherein a spindle with a defined geometry is inserted into the fluid to be measured. The spindle rotates at various fixed speeds, shearing the material at constant shear rates. The viscometer measures the torque resistance experienced by the spindle at different rotational speeds.

As temperatures increase, most materials exhibit a decrease in viscosity. To ensure the consistency of results, it is critical that the temperature be closely defined when making viscosity measurements.

Rheometers are related, but relatively more complex, instruments that function across a very wide range of shear rates, enabling the simulation of real processes that occur over vastly different timescales, such as in sedimentation and spraying.

### Yield stress

For many CPI applications, yield stress is an important parameter to measure. Yield stress is the force required to cause a material to begin flowing. For example, yield stress represents the force that must be overcome when a pump is switched on. The startup torque required for a pump must be calculated to ensure proper sizing.

Controlled stress rheometers are the tools of choice in measuring yield stress. The method is to run a "shear ramp," where increasing torque is applied to the spindle until rotation of the instrument is observed. Such a test can yield a numerical value that can be used by process engineers to determine yield stress of the material. This information can, in turn, be used in pump sizing calculations for startup torque and full flow conditions.

### References

1. Brookfield engineering educational website, www.brookfieldengineering.com/education, 2010.
2. McGregor, Robert G., Viscosity: The basics, *Chem. Eng.*, August 2009, pp. 34–39.
3. "Perry's Chemical Engineering Handbook," 7th ed. McGraw Hill, 1997.

# NOVEMBER New Products

Exair


Halogen Valve System


Dolomite Centre


Cole-Parmer

**This monitor detects toxic and hazardous gases**

The Jupiter gas-detection system model HVS4000 (photo) monitors and reports information about hazardous and toxic gases to Scada systems. It is a microprocessor-based instrument capable of detecting a wide range of toxic gases in ppm quantities, including ammonia, carbon monoxide, ozone, chlorine dioxide and sulfur dioxide. The HVS4000 can also detect oxygen deficiency. Built with intrinsically safe inputs for use in hazardous locations, the system is certified as explosion-proof. Product features include a sensor-life indicator, an easy-to-read display, two settable internal relays and dual Modbus connections. — *Halogen Valve System Inc., Irvine, Calif.*
**www.halogenvalve.com**

**An air nozzle that resists corrosion and high temperature**

The ¾ NPT Super Air Nozzle (photo) delivers 4.5 lb of strong blowing force for blowoff, cooling and drying applications located in corrosive, high-temperature, food and pharmaceutical environments. According to the company, the force generated by the stainless-steel nozzle is more than five times that of other air nozzles. The NPT nozzle is ideal for blowing heavy materials and for situations where the air nozzle cannot be mounted close to the target surface. The design of the air nozzle directs the compressed air to a single point of convergence to deliver a concentrated stream of high-velocity airflow. It meets OSHA standards for sound level, and is designed to prevent blocking. At 80 psi, the air consumption is 91 $ft^3$/min. — *Exair Corp., Cincinnati, Ohio*
**www.exair.com**

**A laboratory pH meter with an expanded range**

The Oakton 2700 Series pH meters have an expanded range; they are capable of measuring pH values from –2.000 to 20.000 with accuracies of ±0.002 and a resolution of 0.001. The pH meter has an oversized, backlit display. The meters can stamp all calibration data and stored data with time and date, according to good laboratory practices (GLP). Other instruments in the series can measure ion concentration, dissolved oxygen and more. — *Cole-Parmer, Vernon Hills, Ill.*
**www.coleparmer.com**

**Measure flow and pressure in microfluidic systems**

Mitos Sensor units (photo) are designed to measure flow and pressure in microfluidic systems. Capable of displaying results in realtime, the sensors have low internal volumes, and are designed to minimize interference with the liquid flow. The Mitos Sensor system includes a display unit, which interfaces with each of five flowrate sensors and one pressure sensor. The pressure sensor can measure pressures between –0.5 and 30 bar. The sensor units can be used to develop instrument systems for applications in environmental monitoring, petrochemicals, food and beverage, agriculture, chemicals and other industries. — *Dolomite Centre Ltd., Royston, U.K.*
**www.dolomite-microfluidics.com**

**Stirred reactors for high-pressure chemistry research**

The HPR Series reactors (photo, p. 28D-2) are designed for researchers

*Note*: For more information, circle the 3-digit number on p. 58, or use the website designation.

Supercritical Fluid Technologies


Endress+Hauser

interested in performing pressurized chemical reactions for synthesis or process development. The stirred reactors range in size from 50 mL to 4 L, and may be operated at up to 10,000 psi and 350°C. The reactors are equipped with a magnetically coupled impeller for optimal mixing. These benchtop models are ideal for studies on catalysis, polymerization, hydrogenation, oxidation, isomerization and dehydrogenation. Supplied as ready-to-use equipment, the reactors fit into a fume hood. — *Supercritical Fluid Technologies, Newark, Del.*
**www.supercriticalfluids.com**

**Measure molecular interactions with this system**

The Autolab Twingle (photo, p. 28D-4) is a dual-channel surface-plasmon resonance system that allows users to perform high-accuracy measurements of molecular and kinetic interactions. The versatile, double-channel system can make simultaneous electrochemical measurements and is an ideal sensor for a research laboratory. Features of the Twingle include highly flexible data and control software, easy sample recovery and customizable kinetic evaluations and sample control. In addition, the company says, the instrument has a small footprint and an affordable price. — *Metrohm USA Inc., Riverview, Fla.*
**www.metrohmusa.com**

**Measure multiple parameters with this analytical platform**

The Liquiline CM442 (photo) is a four-wire, two-parameter transmitter for analytical sensing applications. The device can accept data from two sensors and measure any combination of parameters, including turbidity and suspended solids, dissolved oxygen, pH, chlorine and conductivity. Using one instrument for measuring two process variables saves money and

## New Products

Metrohm USA



Kinematica

space. Liquiline's sensor inputs have a digital interface with plug-and-play capabilities, allowing users to interchange sensors quickly for calibration or other purposes. — *Endress+Hauser, Inc., Greenwood, Ind.*
**www.us.endress.com**

### Share data across systems with new modeling software

OpenPlant Modeler V8i 3-D plant modeling software (photo, p. 28D-5) enables realtime seamless sharing and data interoperability across different organizations and systems using an internationally recognized standard (ISO 15926; Realtime Interoperable Network Grids) — the first commercially available software to do so, according to the developer. Designed to address workflow requirements of globally distributed-and-sourced plant projects, OpenPlant Modeler V8i and related products extend integration among multiple infrastructure disciplines and improve team collaboration. OpenPlant Modeler provides functionality for piping and equipment, and serves all other disciplines involved in real-world plant design projects, including civil, construction, environmental, HVAC, process design, electrical and others. — *Bentley Systems Inc., Exton, Pa.*
**www.bentley.com**

### Avoid lumpy powder dispersion with this machine

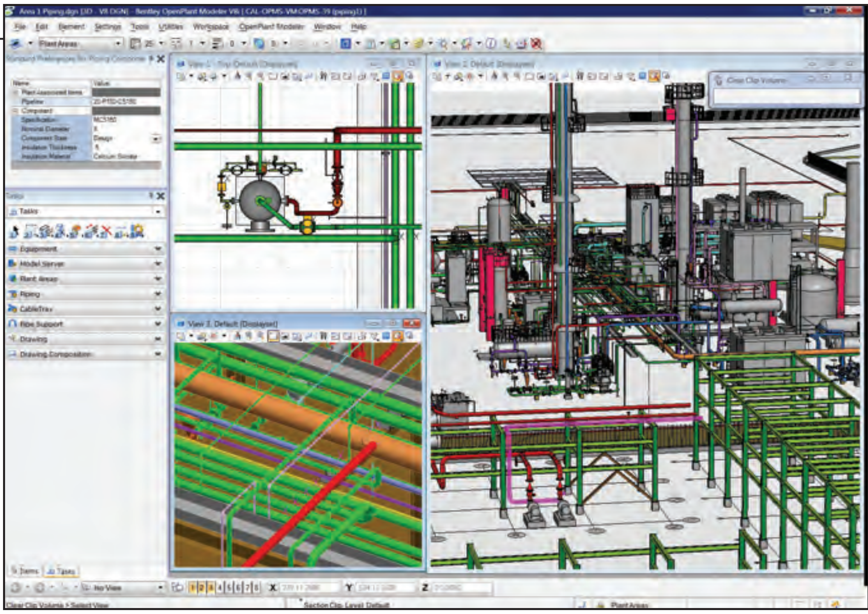
The Megatron MT-VP powder dispersing/induction machine (photo) generates strong suction that prevents formation of lumps during the powder induction and wetting phase. The absence of lumps prevents plugging of the powder supply line, and improves the dispersing efficiency. Designed to be used both in pilot plant and production environments, the Megatron efficiently disperses powders into a flowing liquid regardless of density, and is appropriate for chemical, pharmaceutical and foodstuffs applications. — *Kinematica Inc., Bohemia, N.Y.*
**www.kinematica-inc.com**

### This flow switch has no moving parts

The FS10A Flow Switch/Monitor is designed to continuously verify flows within liquid or gas process analyzer sampling systems. The small and lightweight instrument has no moving parts for reliable, virtually maintenance-free operation. The instrument is appropriate for a wide range of process- and emissions-sampling systems, including gas chromatographs, mass spectrometers, optical spectrometers and others. The FS10A is based on a thermal dispersion system that relates temperature differentials to mass flow. The corrosion-resistant instrument can operate across a wide flow range (50 to 10,000 $cm^3/h$). Beyond tripping at a designated flow level, the instrument can also monitor flow for greater predictive power and calibrations can also be stored. — *Fluid Components International LLC, San Marcos, Calif.*
**www.fluidcomponents.com**

### Deliver gas pulses accurately with this instrument

The MicroPulse is a solid-state means of producing small pulses of various gases. It is intended as an alternative to mechanical syringes. The compact instrument contains a miniature heat



Bentley Systems

exchanger and precision temperature controller that can be fitted into process-control circuits without adding volume. MicroPulse delivers up to 1.75 mL of gas at standard temperature and pressure. Advantages of the device include: no moving parts, no need for compressed-air source, and the application to which it is connected can initiate a flow pulse automatically at any interval. — *Intertech Development Co., Skokie, Ill.*
**www.intertechdevelopment.com**

**These pumps are ideal for oil, fuel, water and acid transfer**

The UP Series of self-priming gear pumps is available in configurations that make them ideal for water processing, as well as oil, fuel or antifreeze transfer. The pumps also work well with seawater, acids and alkaline solutions. There are six models in the series, all with different flow and pressure capabilities. The pumps are available with nickel-plated bronze or polytetrafluoroethylene (PTFE) gears, and stainless-steel or brass pump bodies. — *Clark Solutions Inc., Hudson, Mass.*
**www.clarksol.com**

**Additional control options for these valves**

Spira-Trol control valves have extended options to ensure that the valves can be optimized for a specific customer application. Pneumatic-piston actuators have been added to the diaphragm and electric actuator ranges. The free-float design provides users with longer stem-seal life and improved valve shut-off performance.

# New Products

Spiroflow Systems



Omega Engineering

Spira-trol valves also now feature better capacities and a balanced trim option for high differential pressures. The valves are now additionally available in 6- and 8-in. sizes, due to high demand, says the company. — *Spirax Sarco Inc., Blythewood, S.C.*
**www.spirax.com**

**These flowmeters are designed for conductive liquids**
The FMG600 Series electromagnetic flowmeters (photo) are designed for measurement of conductive liquids. With no moving parts and a PTFE lining, the FMG600 meters can handle applications involving wastewater, pulp, foodstuffs and slurries. Standard outputs include analog, frequency, and RS485 communications. An optional sanitary tri-clamp mounting system allows use of the FMG600 flowmeters in applications not previously open to magmeters. Local- and remote-display models are available. — *Omega Engineering Inc., Stamford, Conn.*
**www.omega.com**

**This vibration transmitter delivers detailed information**
The CSI 9420 is a smart, wireless vibration transmitter that delivers detailed information for machinery analysis to vibration experts, such as direct alerts on high vibration caused by cavitation or bearing defects, and high-resolution spectra. The CSI 9420 connects easily to any machine, and its wireless capabilities make the instrument ideal for monitoring equipment in remote or hard-to-reach locations. The vibration transmitter has shown effectiveness in several applications, says the company, including monitoring petroleum refinery pumps, cooling towers, compressors, agitators in settling ponds, and all types of motors, pumps and fans. — *Emerson Process Management, St. Louis, Mo.*
**www2.emersonprocess.com**

**A new pump family offers two types of impellers**
The SL Submersible Pump range offers two types of impellers to handle a wide range of process and wastewater applications. The SuperVortex Impeller provides free passage of solids up to 4 in. in diameter, making it ideal for liquids containing solids, fibers or sludge. The Channel Impeller is designed particularly for large flows of raw sewage. In addition to numerous customizing possibilities, the SL series features an efficient motor that is sealed with a moisture-proof plug, and a short rotor shaft to reduce vibrations. — *Grundfos Pumps Corp., Olathe, Kan.*
**www.grundfos.us**

**Clean this bulk bag discharger easily**
The Model T11 Bulk Bag Super Discharger (photo) is designed for critical applications where hygiene and rapid dismantling of components without tools are essential to avoid microbial growth and cross-contamination between batches. The T11 can be custom-made to meet requirements for the pharmaceutical, dairy and food-and-beverage industries. Constructed entirely from stainless steel with no dead pockets, the T11 can be pressure-washed, steam-cleaned or manually washed or sterilized. The T11 features a dust cabinet that fully contains the bag during discharge, and a pharmaceutical-quality, dust-tight seal between the bag neck and the inlet of the transfer hopper. — *Spiroflow Systems Inc., Charlotte, N.C.*
**www.spiroflowsystems.com**

**Detect high solids level with customized extended rotaries**
This firm has introduced a series of extended rotaries for top-of-bin mounting when the rotary is used as a high-level alarm. These vertically extended rotaries are desirable, because solid material will tend to be higher at the filling point and operators want to prevent filling the bin to the very top. The company custom manufactures extended rotaries to the length requested (up to 144 in.). The BMRX and Maxima+ fail-safe rotaries feature a durable motor with a de-energized operation that shuts down the motor when material is present to reduce wear and the operating temperature, thereby prolonging the motor life. — *BinMaster, Lincoln, Neb.*
**www.binmaster.com**

**This particulate matter transmitter handles harsh environments**
A new loop-powered particulate matter (PM) transmitter (photo, p. 28D-7) from this company can function in harsh environments and applications,

Filtersense

such as coal flyash, carbon black, cement kilns, spray dyrers and chemical processing. The EPA-compliant product features heavy-duty construction, single-piece mounting, advanced induction sensing, and a protected probe. The product can detect leaks and emissions from baghouses, cartridge dust collectors and cyclones. — *Filtersense, Beverly, Mass.*
**www.filtersense.com**

**Ball valves with three seating options — graphite, metal and soft**
Ultra-Seal Series 300 ball valves are two-piece, full-bore, flanged, seat-supported ball valves designed in accordance with ASME B16.34 and ISO 14313/API 6D standards. The series offers three seating options — graphite, metal and PTFE (polytetrafluoroethylene) soft seat — which allows engineers to select seat designs for temperatures as low as –196°C and as high as 450°C. For applications involving abrasive or corrosive fluids, the Series 300 valves are available with a range of coating materials, including tungsten carbide, nickel alloy and chromium carbide. The PTFE soft-seated design is recommended for maximum chemical compatibility with minimum coefficient of friction. — *Tyco Flow Control, Princeton, N.J.*
**www.tycoflowcontrol.com**

**This cooling-water treatment covers more water conditions**
GenGard 8000 is the latest offering from this company's GenGard family of cooling-water treatment technology. The new version of the product has expanded its capability to handle a wider range of pH values for cooling water, including neutral to alkaline water. The GenGard 8000 chemistry reduces the need to add sulfuric acid to cooling water systems. The new GenGard product gives process engineers the ability to use lower quality water in applications requiring cooling water, the company says, and also avoids corrosion and fouling problems. GenGard 8000 is designed for use with this company's process control and automation platform. — *GE Power and Water, Trevose, Pa.*
**www.gewater.com**

**Manufacture of this HDPE is environmentally friendly**
Vestolen A Rely 5922R and 5924R are the first two grades of high-density polyethylene (HDPE) for piping that are manufactured in this company's state-of-the-art facility in Germany, where their production places less stress on the environment by reducing air emissions, electricity usage and

sewage generation. Rely 5924R delivers low-sag performance for large-diameter pipes and high-pressure pipes with low standard-dimension rates. Rely 5922R HDPE offers resistance to slow-crack-growth propagation in high-pressure pipe applications. — *Saudi Basic Industries Corp. (Sabic), Riyadh, Saudi Arabia.*
**www.sabic-europe.com**

**Measure hydrocarbon dewpoint with this gas chromatograph**
The Danalyzer 700XA gas chromatograph offers a fully automated hydrocarbon-dewpoint-monitoring method, allowing natural-gas distributors and others in the oil-and-gas industry to obtain accurate measurements of a parameter that is difficult to assess because of a host of factors, such as gas composition, contaminants and corrosive compounds. Monitoring hydrocarbon dewpoint enables natural gas operators to avoid condensation that can over-pressurize the pipe. The 700XA combines two detectors and a controller within a single housing, reducing complexity and cost. The instrument exhibits high precision over a wide range of conditions, says the company. — *Emerson Process Management, St. Louis, Mo.*
**www.emersonprocess.com**

**Track and manage assets throughout their lifecycle**
This firm has launched its next generation Asset Lifecycle Information Management solution, Asset Hub 6.0. Asset Hub improves productivity and reduces operational, safety and compliance risk over the full operating lifecycle of critical assets. New features to Version 6 include a Public API that significantly improves performance and reduces the cost of asset data interoperability with third party systems. Asset Hub 6.0 also features robust performance improvements for creating and managing maintenance task lists and bills of materials data. — *NRX Global, Toronto, Ont.*
**www.nrx.com**

Dryco

**This dehumidifier is suitable for hazardous locations**
The XDH2000 (photo) is a patented, explosion-proof dehumidifier for mobile applications. Designed with a smaller footprint for hazardous chemical locations, the XDH2000 uses silica gel-impregnated desiccant technology. The company says the product is capable of twice the output of competing units with half the energy draw. — *Dryco, Downers Grove, Ill.*
**www.xdhtechnology.com**

**Close gas lines when the temperature gets too high**
FireBag thermo-activated shut-off devices turn off gas supply when ambient temperatures reach 212°F, preventing the spread of fire that can lead to gas explosions. The FireBag will meet the temperature and leakage requirements of ANSI/API 607 for natural gas, propane and butane. When the outside temperature reaches 203–212°F, metal alloy in the FireBag that keeps plug and cartridge together melts, and the spring pressure pushes against the gas opening to close it completely. Once triggered, the shutoff device works up to 1,697°F for one hour. No fire or heat detectors are required. — *Assured Automation, Clark, N.J.*
**www.assuredautomation.com** ■

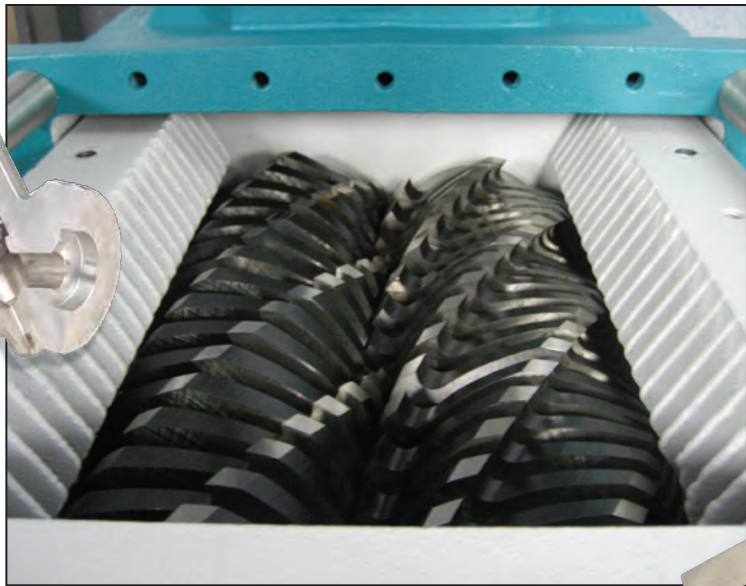
*Scott Jenkins*

Conval

BinMaster

# NOVEMBER New Products

Perten Instruments Group

Netzsch Mohnopumpen

**Analyze plant matter quickly, without grinding**

With an analysis time of only 6 s, the DA 7200 near infrared (NIR) analysis system (photo) and a new calibration feature offers many benefits for forage analysis (plant matter). The unit can analyze forage samples as they are — without grinding required. The calibrations include fresh and dried or ground samples and are accurate for samples in both states. A Feed Calibration package is available for laboratories or feed mills requiring grains, feed and forage analyses. — *Perten Instruments Group, Stockholm, Sweden*
**www.perten.com**

**This macerator features a cartridge of blades**

The Taskmaster twin-shaft macerator (photo) does not have individually installed cutting blades, but single elements made of special steel comprising six cutters and six spacing rings. To achieve the required particle size, different blade designs are available. The inline design makes the Taskmaster suitable for direct installation into the pipeline. It can be connected to a horizontal pipeline or a pump inlet of the firm's NEMO pump or Tornado rotary-lobe pump, where the flange is set to 90 deg. The unit allows flowrates of up to 300 $m^3$/h with dry solids content of up to 10%. Due to the intersecting cutting cartridges, even coarse solids can be macerated. — *Netzsch Mohnopumpen GmbH, Waldkraiburg, Germany*
**www.netzsch.com**

**A leak-free bellows valve with twice the Cv**

The new double-length bellows valve completes this firm's line of single- and double-bellows seal valves (photo). This new double-length bellows allows for the same zero emissions as the single bellows with over double the Cv in the same pipe size. Available in 1/2- to 4-in. sizes in Y, T and angle configurations, these valves are suitable for applications where packed valves may not reliably contain light gases or hazardous system fluids due to leakage in the stem-packing seal area, or stuffing-box-wall packing seal area. — *Conval, Inc., Somers, Conn.*
**www.conval.com**

**Detect high solids level with customized extended rotaries**

This firm has introduced a series of extended rotaries (photo) for top-of-bin mounting when the rotary is used as a high-level alarm. These vertically extended rotaries are desirable as solid material will tend to be higher at the filling point and operators want to prevent filling the bin to the very top. The company custom manufactures extended rotaries to the length requested (up to 144 in.). The BMRX and Maxima+ fail-safe rotaries feature a durable motor with a de-energized operation that shuts down the motor when material is present to reduce wear and the operating temperature, thereby prolonging the motor life. — *BinMaster, Lincoln, Neb.*
**www.binmaster.com**

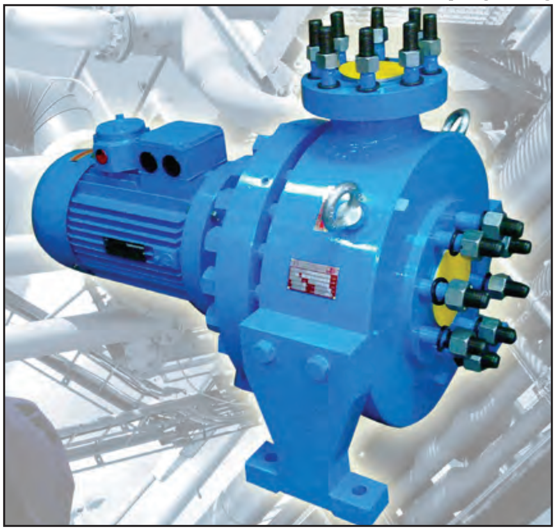
**Mag-drive pumps safely transfer hazardous fluids**

The 3M magnetically driven centrifugal pumps (photo, p. 28I-2) have no glands, seals or valves and therefore provide leak-free operation in heavy-duty operation, such as pumping heat transfer oils and liquefied gases, and at temperatures ranging from –150 to 450°C. Other applications include transferring alkalis, hydrocarbons, toxic and explosive chemicals in the chemical industries. In the food and beverage sectors, the pumps are suitable for handling clean-in-place (CIP) chemicals, such as sodium hydroxide,

*Note*: For more information, circle the 3-digit number on p. 58, or use the website designation.

nitric acid and hydrogen peroxide, and for pumping water-treatment chemicals. — *Pump Engineering Ltd., Littlehampton, U.K.*
**www.pumpeng.co.uk**

Pump Engineering



### Metering pumps for very high flowrates

The new piston diaphragm pumps of the series R510.1 and 511.1 (photo) deliver flowrates of 65 to 1,900 L/h at pressures up to 220 bar. The pumps are qualified for a wide range of applications, including the petrochemical industry. The stroke mechanism of the pumps has been designed as variable eccentric drives, which provides a number of benefits, including: it enables a linear and precise stroke-length setting, thus enabling precise metering even with high flowrates and high pressure; the harmonic movement sequence — even for partial stroke operation — produces significantly less pulsation than other metering pumps; and the stroke can be adjusted from 0 to 100% using a hand wheel or actuator. The pumps are available for explosion-protected areas and are in accordance with API Standard 675. — *Seybert & Rahier (SERA) GmbH + Co. KG, Immenhausen, Germany*
**www.sera-web.com**

### Contact-free level sensing with this ultrasonic device

With the ultrasonic sensor ASV UFM (photo), contact-free level sensing of liquids and dry bulk goods can now be quickly and easily integrated into site installations. The compact device continuously controls the filling level by means of an integrated ultrasonic sensor. Users can choose between a 4–20-mA current output feeding directly into a PLC, or a relay version with four user-programmable outputs. Other components, such as pumps, can therefore be operated either via a central PLC unit or directly by the integrated relay. The programming and display of the settings is done by means of an optional plug-in controller display unit, which can be used to set up several sensors by simply copying the controller units' program pre-setting onto the various sensors. — *ASV Stübbe GmbH & Co. KG, Vlotho, Germany*
**www.asv-stuebbe.de**

### Higher resolution improves the details of 3D models

Aveva Review is an established application for 3D design communication. It creates high-quality, photo-realistic renderings of 3D models that can be used by all stakeholders in a project to carry out design reviews and analysis. The newest release, Review 12.1, is now available in both 32- and 64-bit versions, and provides a number of enhancements, including: improved model streaming, which enables massive model files to be easily viewed over internet connections; 64-bit technology, which dramatically increases the size and detail of models that can be handled; and display of the master coordinate grid used in the design, which enables users to determine the absolute positions of features in the 3D view. — *Aveva Group Plc., Cambridge, U.K.*
**www.aveva.com**

### Keep in compliance with this TOC sensor

The enhanced CheckPoint Pharma on-line TOC (total organic carbon) Sensor can measure TOC in hot (up to 90°C) or ozonated water, and will operate at ambient temperatures up to 55°C. The sensor has a dynamic range of 0.21 to 1,000 ppb and provides three analog outputs for simultaneous TOC, raw conductivity and temperature measurements to support regulatory requirements. A new USB printer support provides an affordable way to meet 21 CFR Part 11 compliance. All backup sensor data are stored in memory and users can define a data range for faster data downloads. — *GE Power & Water, Boulder Col.*
**www.geinstruments.com**

SERA

ASV Stübbe

### Space-saving I/Os with eight channels

The newly developed input-output (I/O) modules reflect the market trend toward ever-smaller sized devices for installation in control cabinets. The space-saving digital I/O modules with eight channels and IP 20 protection are just 12 mm wide, for installation on DIN rails. The devices are supplied as a complete module with connector and labeling, and offer ease of use and a diagnostic function. They can operate over the temperature range from –25 to 55°C. — *Phoenix Contact GmbH, Blomberg, Germany*
**www.phoenixcontact.com**


1/4 NPT


For more than eighty years, we at **Costacurta** have been constantly and resolutely committed to the development and manufacture of special steel wire and plate components used in many different industrial processes. Every day at **Costacurta**, we work to improve the quality of our products and services and the safety of all our collaborators, paying ever-greater attention to the protection of the environment.

Within the wide range of **Costacurta** products you will also find some, described below, that are used specifically in the *oil, petrochemical and chemical industries:*

- *RADIAL FLOW AND DOWN FLOW REACTOR INTERNALS;*
- *GAS-LIQUID AND LIQUID-LIQUID SEPARATORS;*
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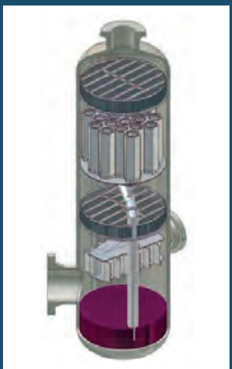
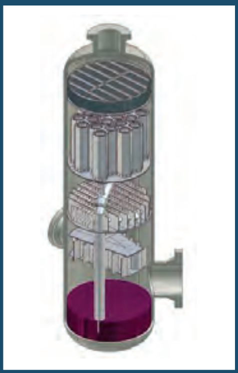
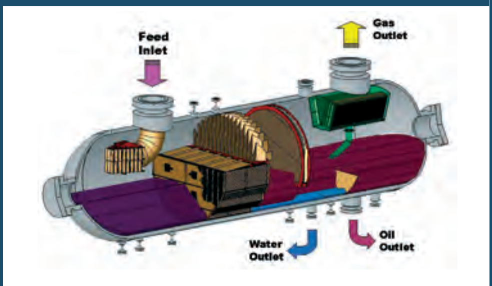
For more information visit our website or contact the **division 'C' components for the oil, petrochemical and chemical industries** at **tcsc@costacurta.it**.





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## New Products

Ocean Optics

**Temperature control keeps these field spectrometers steady**

The SteadiQ field-portable spectrometer (photo) provides a temperature-controlled atmosphere, helping to stabilize temperature effects and eliminate temperature drift in inclement conditions or extreme temperatures from –20 to 50°C. Available in both ultraviolet (200–1,100 nm) and visible-near infrared (400–2,500 nm) versions, the SteadiQ interfaces directly with the firm's range of spectrometers. — *Ocean Optics, Duiven, the Netherlands*
**www.oceanoptics.eu**

**Positioners that perform partial stroking**

As part of its wide range of control valves, this firm offers a range of electro-pneumatic positioners that allow stroke tests to be performed without disrupting the process line. For example, the Type 3730-3 positioner (photo) incorporates an emergency shutdown (ESD) function to enable stroke testing without interrupting the process. It can be mounted on the valve in addition to the solenoid valve, or replace it, and enables the valve to be moved precisely to follow the set point within the working ratio. The partial stroke test is completely integrated into the positioner to detect a sticking valve caused, for example, by corrosion. — *Samson Controls (London) Ltd., Redhill, U.K.*
**www.samsoncontrols.co.uk**

**Track and manage assets throughout their lifecycle**

This firm has launched its next generation Asset Lifecycle Information Management solution, Asset Hub 6.0. Asset Hub improves productivity and reduces operational, safety and compliance risk over the full operating lifecycle of critical assets. New features of Version 6 include a Public API that significantly improves performance and reduces the cost of asset data interoperability with third-party systems. Asset Hub 6.0 also features robust performance improvements for creating and managing maintenance task lists and bills-of-materials data. — *NRX Global, Toronto, Ontario, Canada*
**www.nrx.com**



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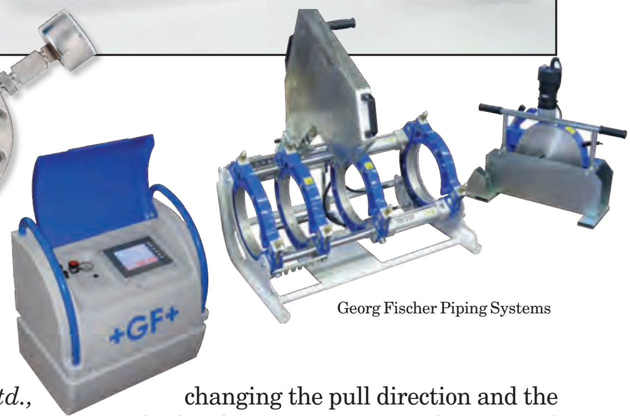
## New Products


LEWA

Concoa



Georg Fischer Piping Systems

aphragm metering pumps (photo) is said to offer the best price-performance ratio in its class (80 bar, 120°C, 300 L/min), and meters reproducibly and precisely thanks to the proven variable eccentric drive. Different stroke frequencies of the drives allow adaption to diverse fluids and process requirements. The design of the hermetically tight diaphragm pump is based on the manufacturer's well-known technology using the PTFE sandwich diaphragm with diaphragm monitoring, the patented diaphragm-protection system and optimized check valves. The pump also complies with API 675 safety standards. — *LEWA GmbH, Leonberg, Germany*
**www.lewa.de**

### Close gas lines when the temperature gets too high

FireBag thermo-activated shut-off devices shut off gas supply when ambient temperatures reach 212°F, preventing the spread of fire that can lead to gas explosions. The FireBag will meet the temperature and leakage requirements of ANSI/API 607 for natural gas, propane and butane. When the outside temperature reaches 203–212°F, metal alloy in the FireBag that keeps plug and cartridge together melts and the spring pressure pushes against the gas opening to close it completely. Once triggered, the shutoff device works up to 1,697°F for one hour. No fire or heat detectors are required. — *Assured Automation, Clark, N.J.*
**www.assuredautomation.com**

### Prevent the passage of fluids and debris during welding

Inflatable stopper bags are an easy and cost-effective way to seal a pipe and avoid penetration of liquids, gases or any kind of debris or contamination. They are available in sizes from 2 to 80 in. (50–2,000 mm), but other sizes can be made on request. The inflatable bags can be produced in different designs from a variety of materials, including canvas and polyurethane-coated nylon. Versions with internal spines for better stability of the air bag are also available. — *Weldwide Solutions Ltd., Llanelli, U.K.*
**www.weldwidesolutions.com**

### Monitor and control gas flowrates with these devices

This new series of Mass Flowmeters and Controllers (photo) is designed to accurately monitor and control the flow of a wide range of gases. Series MFM Thermal Mass Flowmeters and MFC Thermal Mass Flow Controllers have a maximum working pressure of 500 psig and are supplied with correction factors for air, helium, hydrogen and carbon dioxide. Made from 316L stainless-steel bar stock, the units have flow ranges from 0–10 mL/min to 0–20 L/min, and an accuracy of ±1% of full scale. — *Concoa, Virginia Beach, Va.*
**www.concoa.com**

### A new line of butt-fusion machines

This firm's trench machines are used for onsite fusion of plastic piping, and are now available in three versions: TM 160, 250 (photo) and 315. The key components of the fusion machine are the heating element, facer, clamping brackets and unit, and rapid-action couplings. The optimized cross-sectional profile of the clamping points makes for easy handling, while reducing weight and increasing stability. The design of the top clamp enables fast and easy fixation, alignment and removal of pipes. Rotating the machine around the longitudinal axis creates a second working position, without changing the pull direction and the hydraulic connection. For documented quality control of the joints, the necessary accessories are offered for fusion data traceability. Weld-fusion execution is compared with the selected standard and then a printout of the parameters can be started. — *Georg Fischer Piping Systems, Schaffhausen, Switzerland*
**www.piping.georgfischer.com**

### A smaller size of standardized silica beads is now available

This firm has extended its range of glass microspheres from 10 microns down to 1.5 microns with the addition of a new certified range of silica microspheres. In addition to their use in particle sizing, these silica microspheres have applications in areas such as drug delivery, respiratory studies and filter testing. Supplied as dry powder in sets of five with each vial containing 0.2 g, they can be used as either a wet suspension or in dry form. — *Whitehouse Scientific Ltd., Waverton, U.K.*
**www.whitehousescientific.com**

### Corrosives are not a problem for this concentration sensor

Thanks to an innovative tantalum coating, the sensors of the LiquiSonic range of ultrasonic concentration and density instruments withstand aggressive process fluids, such as sulfuric, hydrochloric and hydrofluoric acids at temperatures over 130°C. As a cost-effective alternative to sensors completely made of tantalum, users can rely on the stability of the coat-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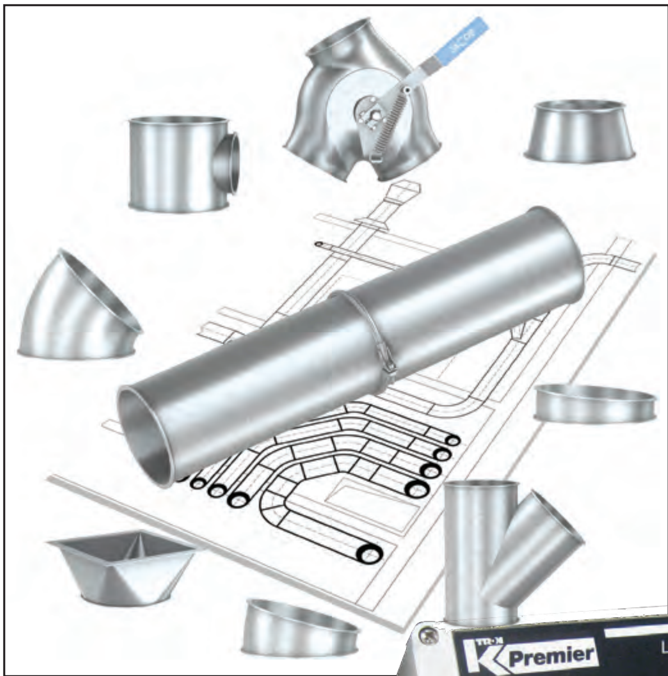
Chemvac Pumps

## New Products

GEA Wiegand

Fr. Jacob Söhne




K-Tron

ing and the accuracy of temperature and concentration measurement, says the firm. Although the coating thickness can range from 10 to 100 µm, a thickness of 30–50 µm is recommended for corrosive applications. With ATEX Eex de IIC T3, T4, T5 or T6 approved protection, the LiquiSonic sensor is suitable for use in hazardous areas. — *SensoTech GmbH, Magdeburg-Barleben, Germany*
**www.sensotech.com**

**This conveying controller handles more than one task**

The new Premier LSR Controller (photo) consolidates several applications into one system, allowing the LSR controller to control either a Premier self-contained loader or a single central receiver for pneumatically conveying a wide range of bulk materials. The controller is locally mounted with all 24-V d.c. unit devices pre-wired. An auto-switching power supply accepts 115 or 23 V a.c. The front panel of the controller includes a potentiometer to set draw times, and an on/off switch. Multicolored LEDs indicate power/alarm, loading status and dump status. The enclosure can be made of polycarbonate or stainless steel. — *K-Tron Ltd., Niederlenz, Switzerland*
**www.ktron.com**

**This jet scrubber is submerged**

The submerged jet scrubber (photo) is an advanced development of the jet scrubber, combining the separation of particles with physical and chemical absorption. It consists of a wash pipe with or without wall rinsing, a specially designed gas distribution, a flow tube and a liquid feed tank. To increase the efficiency, the submerged jet scrubber can be provided with additional scrubber nozzles for dust separation and absorption. All components are designed to be modular, easy to install and allow fast and easy maintenance. For applications in the field of hot gas, a special quench can be added to the individual components so that the unit is converted to a submerged jet quench. The advantage of the submerged jet scrubbers in comparison to jet or Venturi scrubbers is their wide range of applications at significantly lower investment and operating costs. Exhaust or fluegas can be reliably cleaned, even under varying operating conditions. — *GEA Wiegand GmbH, Ettlingen, Germany*
**www.gea-wiegand.de**

**Hot galvanized pipe systems for abrasive bulk materials**

A new hot-galvanized pipework system (photo) is now available with 3-mm wall thickness, which is specially designed for conveying bulk goods in outdoor areas. The standard hot-galvanized range includes 500-, 1,000- and 2,000-m lengths of straight pipes, segments, cone pieces, 45-deg forks, spouts (square to round) and inspection pieces. Also included in the range is a hot-galvanized two-way valve with manual or drive operation. The components are available in common diameters DN 200, 250 and 300 mm. The 3-mm wall thickness makes the easy-to-install pipe system suitable for conveying abrasive bulk materials, such as pellets, grains and other coarse materials. — *Fr. Jacob Söhne GmbH & Co., Porta Westfalica, Germany*
**www.jacob-rohre.de** ■

*Gerald Ondrey*

## WHO'S WHO


Rose


Guertin


Venarge


Pace


Löbbert

*Steve Rose* becomes engineering manager at **EagleBurgmann USA** (Houston), manufacturer of seals, packing and expansion joints.

**Applied Manufacturing Technologies** (Orion, Mich.), supplier of automation design, engineering and consulting, names *Edward Turley* control department manager.

Specialty chemicals company **Lanxess** (Leverkusen, Germany) promotes *Hubert Fink* to head of the basic chemicals unit, *Michael Zobel* to head of semi-crystalline products, and *Jean-Marc Vesselle* to head of the ion exchange resins unit.

**Wilden Pump & Engineering** (Grand Terrace, Calif.) promotes *Rob Guertin* to marketing manager.

*Thomas Venarge* becomes president of **APV Engineered Coatings** (Akron, Ohio).

*David Vinzant* becomes vice president of sales at software supplier and consultancy **PAS** (Houston).

*Ivan Zytynski* is named marketing manager at **Bete Ltd.** (East Sussex, U.K.), a distributor of spraying nozzles and related systems.

*Louis Pace* joins specialty chemical company **The HallStar Co.** (Chicago) as executive vice president.

*Gerd Löbbert* becomes executive vice-president polyolefins for chemical and plastics company **Borealis AG** (Vienna, Austria). ■

*Suzanne Shelley*

# Process Pump Control

## Understanding how pumps are controlled is important for overall process control and to minimize risks during the scaleup of new processes

**John Hall**
Viking Pump Inc.

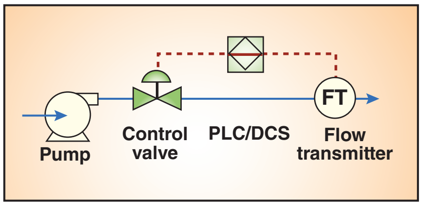



**FIGURE 1.** Centrifugal pumps are typically controlled by a system like the one shown here

When automating fluid handling processes, it is critical to ensure that you are using the best type of pump for the process, and to understand how to control the type of pump you are using. The two major classes of process pumps — centrifugal and rotary positive displacement — require completely different control techniques. It is important to understand each pump type's limitations, and when developing new processes, it is particularly important to know which types are the most controllable to minimize scaleup risks from laboratory to pilot, and ultimately, to commercial scale.

Centrifugal pumps are part of a larger group of rotodynamic pumps that use centrifugal force to develop head (measured as the height of a column of liquid), with flow as the result. Rotary positive displacement pumps are part of a larger group of positive displacement (PD) pumps that create expanding and collapsing fluid cavities to develop flow, with pressure as the result. Major categories of rotary PD technologies are gear, vane, lobe and screw pumps (for more on these, see Selecting a Positive Displacement Pump, *Chem. Eng.*, August 2007, pp. 42–46).

While the majority of process pumps in use today are centrifugals, the inherent controllability and scalability of rotary PD pumps makes them a good choice for: continuous processes; batch processes with high variability; and scaleup of new processes. To compare and contrast the two major pump technologies in this article, we use a hypothetical application with both an ANSI end-suction radial-flow centrifugal pump and an internal-gear rotary PD pump, handling a 20-centistoke (cSt) viscosity liquid with a specific gravity (S.G.) of 1, at 68°F (20°C), a design flowrate of 300 gal/min (68 $m^3$/h), maximum flowrate of 450 gal/min (102 $m^3$/h), and head of 144 ft (43.9 m), equivalent to 62 psi (4.2 bar). This system uses 4–20-mA analog signals for measured values and control outputs.

### Centrifugal pump control

With centrifugal pumps, pump speed is usually constant, and flow is generally controlled by changing the system head (pressure) with an adjustable control valve downstream of the pump. For automatic process control, generally a flowmeter transmits a signal proportional to the measured flowrate to a programmable logic controller (PLC) or distributed control system (DCS), which then sends a control signal to the valve, adjusting it to change the system head, which in turn causes the pump to achieve the desired flowrate (Figure 1). A 2009 survey of process pump users by the author's employer found that more than 80% of automatically controlled, centrifugal process pumps use some variation of this control scheme.

One inherent limitation of ANSI centrifugal pumps is that they generally should not be operated more than 15% away from the pumps' best efficiency points (BEPs), a location on the pump curve that represents its highest operating efficiency. Impeller thrust causes accelerated wear on bearings and seals. Figure 2 shows a centrifugal pump whose BEP is at 300 gal/min, resulting in a (theoretical) maximum allowable control range from 255 to 345 gal/min (Δ90 gal/min, in the shaded area), which does not even allow use to the stated desired maximum flowrate of 450 gal/min. In practice, most centrifugal pumps are regularly operated over the entire length of their curves. With that in mind, it is not surprising that in the 2009 survey of pump users, the top two stated needs were "longer pump life" and "longer lasting bearings and seals."

Figure 2 also illustrates how susceptible centrifugal pumps are to minor changes in system head. In this case, a 23-ft (10 psi) change in system head results in a 150-gal/min change in flowrate, which exceeds the pump's maximum allowable control range of 90 gal/min. This illustrates two key problems with centrifugal process pumps: 1) the allowable control ranges are quite limited, and 2) they are very susceptible to changes in system head caused by things other than the control valve. For example, a demand from another part of the process, a change in head of the line the pump is metering into, or operating two pumps in parallel, will all greatly impact the ability to maintain the desired flowrate into the original process.

Figure 3 illustrates a third issue of controllability. The control valve response is not directly proportional to the control signal. In this case, a 1-mA change in control signal (representing 6% of the control range) causes a 15%

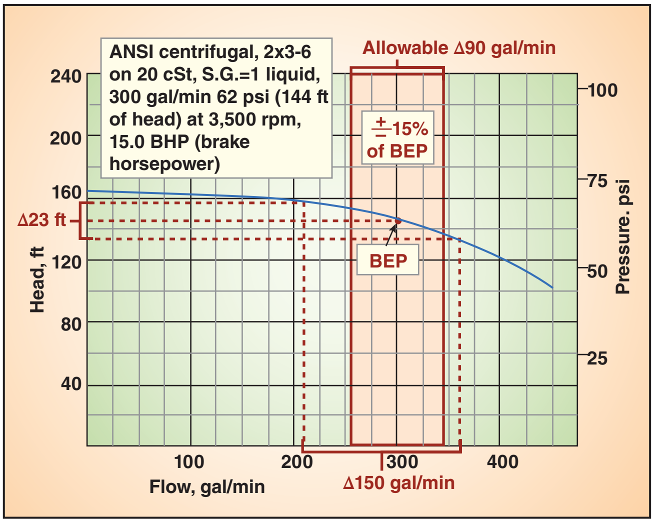



**FIGURE 2.** The best efficiency point (BEP), as shown on this centrifugal pump's performance curve, represents the pump's highest operating efficiency

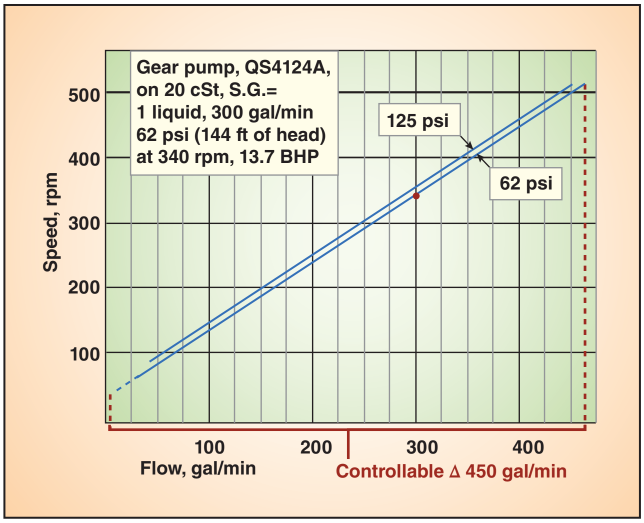



**FIGURE 5.** The rotary PD pump-performance curve illustrates flowrate versus speed for a given pressure

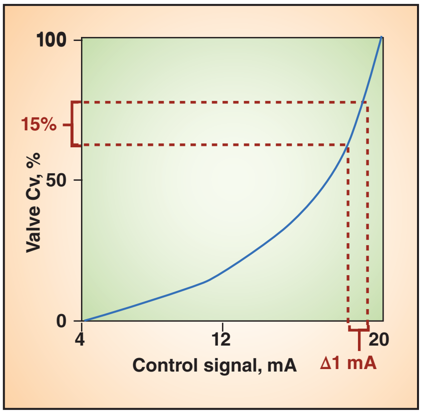



**FIGURE 3.** This control valve curve shows that the control valve response is not directly proportional to the control signal

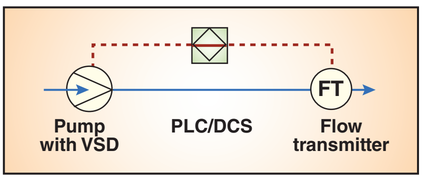



**FIGURE 4.** Rotary positive-displacement pumps are generally controlled by adjusting speed with a variable speed drive (VSD), as shown here

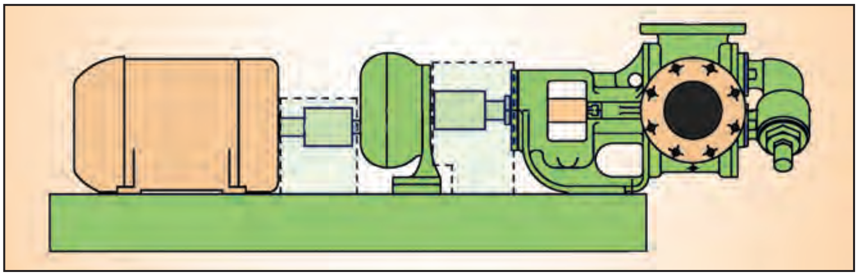


**FIGURE 6.** The rotary PD pump unit consists of the motor (left), gear reducer (center) and internal gear pump (right)

change in the valve's flow coefficient ($C_v$), another factor contributing to the difficulty in controlling this process.

An increasingly popular control option is to use variable speed drive (VSD) systems with centrifugal pumps. Increasing or decreasing speed allows a broader range of control by shifting the performance curve and BEP. But you must consider what those changes do to the pump's performance according to the affinity laws for centrifugal pumps, because changing one variable (speed) has significant impact on other variables (flow, head and power). The affinity laws state that with impeller diameter held constant, flow is proportional to shaft speed, head is proportional to the square of shaft speed, and power is proportional to the cube of shaft speed.

Some pump manufacturers offer VSD systems that optimize pump efficiency and control. These systems are superior to simply applying an independent VSD to a centrifugal pump.

## Rotary PD pump control

With rotary pumps, flow is directly proportional to speed, and is generally controlled by adjusting speed with a VSD, as illustrated in Figure 4. Rotary pumps do not have the requirement of operating near the BEP. Flowrate is largely independent of pressure, so large changes in system pressure have only minimal impact on pump flowrate.

The rotary PD pump performance curve as shown in Figure 5, illustrates flowrate versus speed for a given system pressure. In the case of the rotary PD process pump, to achieve the desired maximum flowrate of 450 gal/min (102 $m^3$/h), the pump speed should be 495 rpm, so normally a gear reducer (Figure 6) would be installed between the motor and pump to reduce the motor's full load speed to 495 rpm at the pump. At the design flowrate of 300 gal/min (68 $m^3$/h), the pump speed is 340 rpm.

Because the pump speed is directly proportional to flowrate, a 1-mA (6%) change in control signal results in an equivalent 6% change in flowrate over the entire range of the pump's performance curve, making this an easy-to-control process (Figure 7).

Unlike centrifugal pumps, rotary PD pumps cannot be controlled by changing system head because they can de-

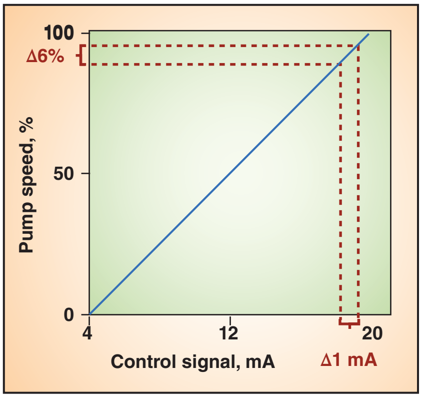



**FIGURE 7.** Rotary PD pump flow is proportional to speed, which is proportional to control signal

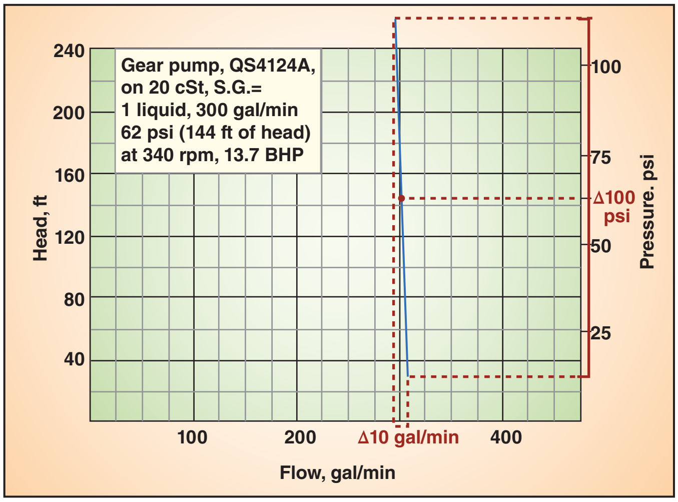



**FIGURE 8.** This rotary PD pump-performance curve shows that a 100-psi change in system pressure results in a 10-gal/min change in flowrate

velop infinite pressure until something in the system releases it — normally a pressure relief valve that is integral to the pump (illustrated at the far right side of Figure 6). The PD pump-performance curve illustrated in Figure 8 shows that a 100-psi change in system pressure results in only a 10-gal/min change in flowrate (whereas a 23-ft or 10-psi change in system head caused a 150-gal/min change in flow on the centrifugal curve, Figure 2).

A rotary PD pump's performance curve is theoretically vertical, but the minimal slope shown (Figure 8) is due to slip through the pump, between the internal clearances of the rotating elements, from the discharge (high pressure) side to the inlet (low pressure) side. As viscosity increases, the slip becomes negligible and the slope approaches that theoretical vertical line. Many rotary PD pump systems are operated without a flowmeter at all, since speed is proportional to flow, especially at higher viscosities.

Figure 5 illustrates why a flowmeter is needed if the pump is to be operated at very low flowrates, regardless of viscosity. The curve (solid line) is cut off at the far left side, because slip becomes a larger percentage of the flowrate at very slow speeds. The pump can still be controlled to the far left side of the curve (dashed line) beyond the cutoff point with the use of a flowmeter, since the controller will adjust the speed as needed to compensate for slip, to maintain the desired flowrate all the way down to 1% of rated capacity, providing true 100:1 turndown capability.

## Process control comparison

Three things should be evident. First is that process control methods for centrifugal and rotary PD pumps are completely different, and the process designer must understand those differences. Second is that the allowable control range for rotary PD pumps comprises the entire length of the curve, while centrifugal pumps' ranges should be limited to an area near the BEP to maintain reliability. And third is that rotary PD pump systems are inherently easier to control because capacity is directly proportional to speed, regardless of changes in system head.

The general public would suppose that process plants have computerized recipes that automatically mix this liquid with that one, and the end product is consistent every time. In fact, there is incredible variation in both chemical and biological processes. Feedstocks change daily based on cost and availability. Product specifications change depending on customer requirements, and processes are continually modified as product demands change from day to day. The systems employed must be capable of adapting to all of these variations to ensure product quality and minimize waste.

The process designer should always consider the best type of pump for the process. This review of controllability suggests that centrifugal pumps are better suited to simple batch processes and tank transfer applications with limited variability than to continuous processes, where two liquid streams must be blended in constant proportions within restrictive control limits. Rotary PD pumps, in contrast, are equally suited to both batch and continuous processes, as well as those with large variation due to changing feedstocks and recipes.

## Pump selection for scaleup

Nowhere is a broad range of control more important than in the development of new processes, whether chemical or biological, for fuels, pharmaceuticals or in other chemical process industries (CPI). New processes are generally developed in a laboratory, scaled up to a pilot plant to test the commercial viability, then scaled further, either to "demonstration scale" or to full commercial scale production. There are always unforeseen problems and variables, because few technologies are completely scalable directly from laboratory to commercial process. Selecting scalable pumps helps to eliminate those unforeseen variables, simplifies calculations and allows for testing extreme process variations.

To effectively manage risk, each stage of process development from laboratory to pilot to commercial scale should strive to use process equipment that is both scalable (that is, nearly identical in operation from very small to very large scale), and versatile (capable of handling a wide range of materials, flowrates, pressures and temperatures).

Some pumps are great for commercial scale work, but don't scale down very well to laboratory or pilot processes. Centrifugal pumps offer flowrates to thousands of gallons per minute, yet have limited low-flow capabilities that make scaling difficult. The smallest ANSI- or DIN-standard pumps deliver about 30 gal/min at their BEP, so they cannot be accurately scaled down to flowrates suitable for laboratory work with any level of performance equivalent to their larger sizes. Smaller "hardware store" pumps have very limited head capabilities, generally not more than 30 ft. And centrifugal pumps' limited turndown ranges may be suitable for some very consistent processes, but not for newly developed processes that are subject to change.

Other PD pumps are great for laboratory scale work, but don't scale up well. Examples are reciprocating metering (dosing) pumps, which can deliver low flowrates with up to 1,000:1 turndown for the laboratory, but whose largest sizes are limited to about 10 gal/min (2.3 $m^3/h$). Similarly, peristaltic (hose) pumps are very popular in laboratory work because of the ease of tubing replacement, and they are also excellent for commercial scale processes up to several hundred gallons per minute when they are handling solids and slurries on an intermittent basis. But, they are generally considered too maintenance intensive for continuous process duties or for use on "easy" liquids, because they usually require several hose and coolant replacements per year. Air-operated diaphragm pumps are very popular for batch processes where a load cell on a receiving tank measures mass of delivered fluid, but they are not well suited to continuous flow measurement and control due to their inherently pulsating flow which is difficult to measure, and to variations in air supply pressure, which limits repeatability.

Rotary PD pumps are uniquely capable of handling each of the process scaleup requirements, with flow ranges from milliliters to thousands of gallons per minute, independent of changes in system pressure and with the controllability advantages described above. Timed rotary lobe and circumferential piston pumps offer the added benefit of hygienic designs for biological processes that must avoid contamination. ■

*Edited by Dorothy Lozowski*

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Feature Report

# Connecting Process Simulators to the Control Room

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Chemstations

**Kenichi Matsuoka**
Inpex

## The benefits are no longer restricted to high-end integrations or large projects. Here is how to do it in small-to-medium sized projects and why

One of the best ways to realize value from your process data is to use those data — both real-time and historical — in a process simulator. The many applications for doing so are generally categorized into offline and online categories.

Offline applications, where the simulator is not directly connected to the control system, use process data to validate dynamic simulations of the process, or to improve steady-state model fidelity. The goals of online applications include checking current performance, using the simulator as a software sensor, and even monitoring sensors. With online applications, results of the simulation can be used by the control system.

In the past, combining control system data with process simulation models was restricted to high-end integrations, such as dynamic matrix control (DMC) and realtime optimizers. As a result of improvements in computer hardware, software, and open standards for data exchange, it is now possible for the average engineer (and the average computer) to make useful connections between simulation models and control systems (Figure 1).

This article discusses possible applications, provides some illustrative examples and addresses what is needed to connect the systems.

### About process simulators

Process simulators are heat- and mass-balance software programs that model process unit operations. Traditional simulators are steady-state models; they calculate 'snapshot' results based on the assumption that feedstreams and specifications are constant, with no holdup, delay or transient conditions in the process being modeled. Dynamic simulators, in contrast, do account for holdup, delay, and some transient conditions. Some vendors build a dynamic simulator on top of their steady-state programs, while others have separate standalone programs for dynamics.

### About modern DCS

Modern distributed control systems (DCS) connect data from sensors, control systems and operator panels. Data historians record the information for future analysis. Computer network connections allow access to DCS information from other systems and software.

### Reasons for integration

***Improve steady-state models by reconciling them with data from the plant historian/DCS.*** Allow the optimization package of your simulator to change specifications for the model until it agrees (statistically) better with plant data. An optimization package can do this more accurately than trial-and-error manual adjustments by the user. It is possible to automate this process so that the simulator model data are regularly reconciled against the DCS data.

***Validate test-control logic.*** Validate test-control logic in a dynamic model by using the model with historical data. Specify disturbances at the time they occurred in real life, and determine whether the model responds the same way the real-life equipment responded. A validated model can be used to test changes to the control logic in a virtual plant. It can also be used to try to forecast the current system's response to disturbances.

***Use a simulation as an online software sensor to predict values that are difficult to measure.*** A simulation model could, for example, be used to predict conversion from a reactor or liquid composition of a stream, based on more easily measured variables and unit operation calculations. Depending on application and confidence in the model, this approach could be used as a "for information only" value by operators, or it could be used as part of closed-loop control. It is also possible to perform sensor validation, to determine whether the values that your sensors report are consistent with each other.

Additional possibilities include creating a simplified operator training simulator (OTS), startup and shutdown models based on historical data, data filtering and statistical sensor validation, dynamics optimizations, and modeling predictive control using the simulator as a model for the controllers.

### Example applications

***Historical data in dynamic simulations.*** A natural gas pipeline had two looped branches. A third loop was being added to expand capacity (Figure 2). There was a concern that the controllers for the three branches would battle each other, causing oscillations that would affect the flow to custom-

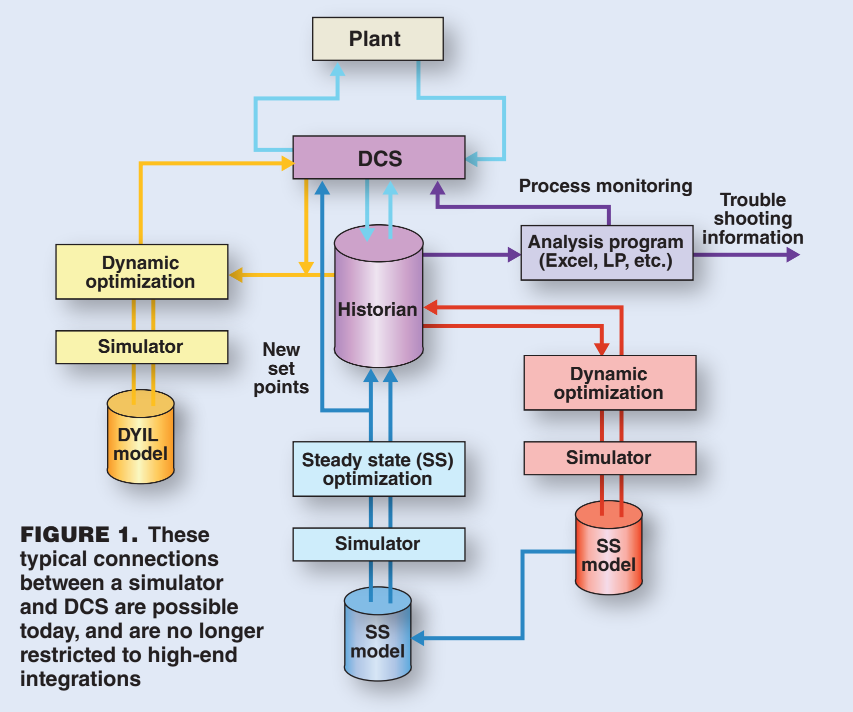


**FIGURE 1.** These typical connections between a simulator and DCS are possible today, and are no longer restricted to high-end integrations

ers. Such behavior was experienced when the second branch was brought online; manual tuning was required.

A dynamic simulation for the two-loop system was developed. Historical data were used to validate the model. The model was tested to see if it produced the same response that occurred during 24 hours of actual operations. The use of historical data led to a high level of confidence that the simulation model could be used to predict system response.

The first step for this project was to make a steady-state process simulation model that performed hydraulic calculations to solve pressure and flowrates simultaneously. Next, a dynamic simulation of the model was run, using the proportional-integral-derivative (PID) terms from the actual equipment. Historical data for end-user demand were incorporated into the model, allowing calculations at each time step to predict pressures based on actual flow. The control system reacted to the pressures throughout the network. Historical data on valve positions, controller output and pressures in the network were compared with the simulated results.

As a final step, the third branch was added to the model and used to develop the control logic. Upon commissioning, the behavior was found to be well predicted by the model.

***Online software sensor.*** A chemical producer integrated a steady-state simulator as a "software sensor" for its control system. Real-time data from the DCS was sent to the simulator model. The model performed calculations using the sensor data as input specifications, and results were sent back to the DCS as tag values. Results included temperatures in the process, conversion at a reactor and recommended makeup water for the final column. This information was displayed to the operator panel, and recorded in the data historian.

Use of a process simulator as a sensor significantly reduced the amount of required instrumentation, and the number of analytical samples required. Use of the simulator as a software sensor led to improved control of the process, reducing off-specification product.

***Data reconciliation and online sensor validation in a heat exchanger network.*** A company wanted to calculate fouling factors throughout a heat exchanger network. The control system provided values from the flowmeters and thermocouples in the network.

The company's engineers developed a simulation to perform rigorous heat exchanger calculations, based on geometry of the exchangers. Data reconciliation was used to adjust the simulation to best fit the sensor data. From this baseline case, the fouling factors were calculated by using current sensor data and adjusting performance of the exchangers. Additionally, the results of reconciliation suggested that sensors might need calibration.

***Simulator as OTS or online future predictor — advanced process control (APC) in a water tank.*** A mixed-integer linear-program (MILP) controller was developed to optimize control of a valve in a water purification system. Four large tanks were connected in series, with a single control valve in the series. Liquid level differences provided the driving force for flow between the tanks. Excessive operation of the valve would cause increased turbidity in the water, complicating water treatment, so the valve needed to change position at a slow rate. The MILP was developed with the goal of predicting the future setpoint and moving the valve earlier than with traditional control.

A dynamic model of the network was developed, including the APC control logic. A custom interface was programmed for an operator training system, using the model as a calculation engine.

Using data from the DCS, the model was used to "predict the future" based on current conditions and assumption of typical demands for the next several hours. This approach improved operator confidence in the control system; before changing control to manual, the operator could simulate the future and see what might happen if he or she allowed the control system to do its work.

## How to make the connection

***Develop a simulator model.*** Developing a high-fidelity process simulation model is the first step. A high-fidelity simulation is one that is able to calculate results similar to observed results, based on rigorous specifications and geometry calculations. For example, using outlet temperature as a heat exchanger specification is a low-fidelity approach; using a heat transfer coefficient (or calculating it rigorously from geometry and fluid properties) and calculating outlet temperature is a high-fidelity approach. For pumps, a high-fidelity model specifies a performance curve (head developed versus volumetric flowrate). For control valves, a high-fidelity model specifies valve *Cv* (sizing term) and position.

When a valve is opened on a high-

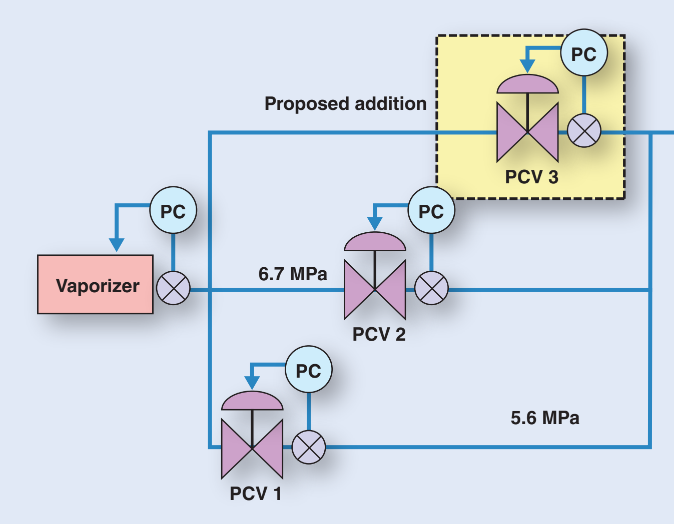


**FIGURE 2.** Dynamic simulation, using historical data, proved useful for expansion of this flow network and the development of its control logic

fidelity model, the result should see downstream temperatures go up (or down) as they would in the real process. With a low-fidelity model, the downstream temperature may be explicitly specified as the output of a heat exchanger. Changing the valve position in such a model will not affect the downstream temperature — although it may result in a calculated heat duty that is not feasible for the process.

It's not necessary to model an entire facility. Look for units where a benefit can be derived by connecting operations data with a model. Consider starting with units that are easier to model, such as utilities.

Regardless of the reason you plan to connect your simulator with DCS data, be sure to validate the model with historical data. Don't simply assume that your model is accurate.

***Connect DCS data with the simulator model.*** You'll need to determine the best method to obtain data from the DCS; try to avoid manual entry, which is tedious and error-prone. Arguably the easiest data interface to set up depends on the ability of both software packages to support data transfer with Excel. In this setup, have your DCS transfer data to Excel, and have your simulator receive data from Excel. Consider using Excel Visual Basic for Applications (VBA) or scripting languages from your DCS or simulator to automate the process. If this is an automated process, you will need to define the conditions used to send data to the simulator and trigger the calculations.

Other options for data transfer include open process control (OPC), a direct Microsoft component-object model (COM) interface between programs, or a custom program to handle moving data from one source to the other as needed.

***Implement additional features to your project.*** Depending on your intended application, you might want to reconcile the model with sensor data, send calculated values to the control system, build a custom user interface, or even develop a custom program to coordinate the interaction. Even simple implementations with Excel can use a custom interface, with a drawing similar to the supervisory control and data acquisition (SCADA) displays and push buttons to send data to and from the simulator. More complicated implementations might involve modification of the operator panel displays to include simulation results, or custom programs with streamlined user interfaces.

## Determining capabilities

Leading process simulators have the ability to interface to data via Excel, Microsoft COM interface (allowing other programs to automate the simulator), and even OPC (allowing direct connection to DCS/data historian). It is also possible to use programming to send keystrokes to your simulator if it does not support links to other programs.

Most of the modern offerings for control system and data-historian software support connections via OPC and Excel. Even older versions often support connections via Excel.

## Who does the implementation?

Although it's possible for one person to implement such a data connection, in most cases a team of two to four people will be involved. The process simulation models will need to be developed by someone well skilled in simulation. Typically, a few years' experience in modeling will be required to be able to develop a high-fidelity simulation. A deep understanding of the control system is not required. Good skill with computers is a must for the team member who will be connecting information between the simulator and DCS. Depending on the implementation, some degree of programming knowledge may be necessary.

## Expected economic benefits

The economic benefits vary by process, and are sometimes difficult to quantify. How much money could you save if you had better control of your process? What is the value of tuning the control system in a virtual plant rather than in a real plant? How would your bottom line improve if your DCS registered alarm conditions further in advance, based on predictive models? The real economic potential lies in your answers to these questions.

## Conclusions

Improvements to computer hardware, software, and data-interface standards now make it possible to combine process simulators with control system data for small- and medium-sized projects. This allows engineers to have better models for their processes, and better control of their processes. As technology continues to improve, we should expect to see more interfaces between these systems. ■

*Edited by Rebekkah Marshall*

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# Predict and Prevent Air Entrainment in Draining Tanks

**The proper use of vortex breakers at tank outlets can prevent entrained vapors from flowing downstream**

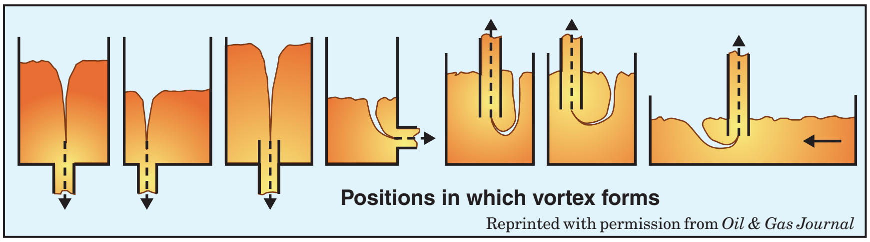


**FIGURE 1.** Various vortex configurations can form in draining tanks. They vary by tank geometry and the position of the drainage outlet (from Patterson [1])

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and **Marvin T. Briscoe, Jr.**
Eastman Chemical Co.

When tanks are draining, the potential may exist for a swirling vortex to form leading from the liquid surface to any of the bottom-exit or side-exit nozzles connected to downstream piping (Figure 1). One important aspect of the vortex is whether it will entrain air or other gases into the discharge flow. Such vapor entrainment can lead to a host of problems, ranging from vacuum collapse of the supply tank, to over-pressurization of the receiving tank, to a disruption of the vapor seal between the tanks. Meanwhile, if the entrained vapor is allowed to collect into pockets in elevated pipe loops, it can lead to two-phase flow, which can form liquid slugs that could damage downstream equipment. Similarly, if the flow from the tank is to the suction inlet of a pump, these gas pockets may result in surging, stalling (air-locking) or vane erosion. During continuous operations, such as when a tank is being filled and emptied at the same rate, or when a reboiler is being operated on the side of a column, vapor entrainment may cause pulsating or inconsistent flow.

According to publications available in the open literature, a variety of "vortex breaker" designs have been suggested and are reviewed below. When placed over the tank drain, they help to block or prevent the formation of vortexes. However, what is missing from the literature is useful guidance on when to use a vortex breaker. In general, vortex breakers should also be used judiciously to reduce capital and maintenance costs, and because they may be susceptible to fouling or plugging by solids.

Later, this article presents design information and rules-of-thumb for avoiding gas entrainment that have been gathered from the literature. It also provides several expanded design charts to help users both determine when the potential for vapor entrainment could arise, and evaluate various operating conditions or proposed tank and piping design choices.

## Vortex breaker designs

Eastman Chemical Co. (the authors' employer) uses the vortex breaker design from Process Industry Practices (PIP) [2], as the company standard. This vortex breaker design relies on a baffle arrangement, either flush with the bottom of the tank, or suspended just off the tank bottom if the nozzle extends above the tank bottom. Figure 2 shows a 4-bladed design. For typical applications, the dimensions are expressed as a function of the diameter of the discharge nozzle ($D$), with the overall width of the device being $2D$, and the height of the blades equal to $D$, as shown.

Another vortex breaker design (from Patterson [1]) is shown in Figure 3. On the left is Patterson's circular plate of diameter $4D$, used for tanks with bottom drainage. It is suspended a distance of $D/2$ off the bottom. Shown at right is Patterson's design for tanks using vertical-suction pipes. It uses a circular solid plate with a $4D$ diameter to block vortexes from the surface.

Megyesy [3], who references Patterson [1], shows 2- and 4-baffle designs that use the same relative dimensions as the design from PIP, but Megyesy's design also includes a square top grating — instead of the Patterson's circular solid plate — with dimensions $4D$-by-$4D$. It too is suspended a distance of $D/2$ off the bottom and the baffles extend a small distance into the drain nozzle. Like Patterson, Rousseau [4] suggests the use of larger circular plates of $4D$ diameter, suspended a distance of $D$ off the bottom of the tank, compared to the PIP design in which the plate has a diameter of $2D$, located $D/2$ off the bottom.

Similar to Megyesy [3], Waliullah [5] recommends a square section of grating ($4D$ by $4D$) that is suspended a distance of $D/2$ off the bottom of the tank, and also puts limits on the grating's $4D$-by-$4D$ size based on the tank diameter. Waliullah also proposes a 4-bladed "cross vortex breaker," similar

**Author's note:** Information contained in this work has been obtained from sources believed to be reliable. However, neither Eastman Chemical nor the authors guarantee the accuracy or completeness of any information published herein and neither Eastman Chemical nor the authors shall be responsible for any errors, omissions, or damages arising out of use of this information. Note that some of the later design information was not in the non-dimensional Froude Number format and some assumptions may have been made to make that conversion.

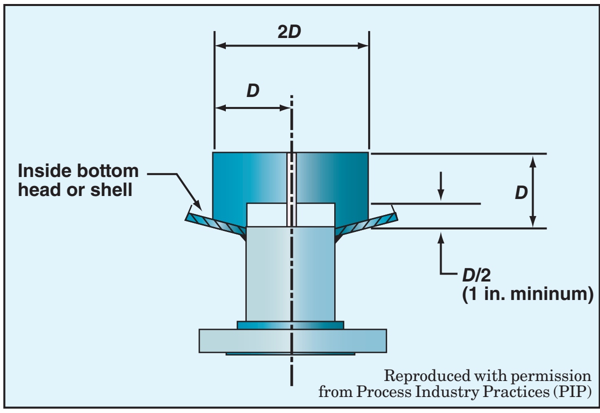


**FIGURE 2.** This vortex breaker (PIP [2]) consists of a baffle arrangement that suspended or flush with the tank bottom

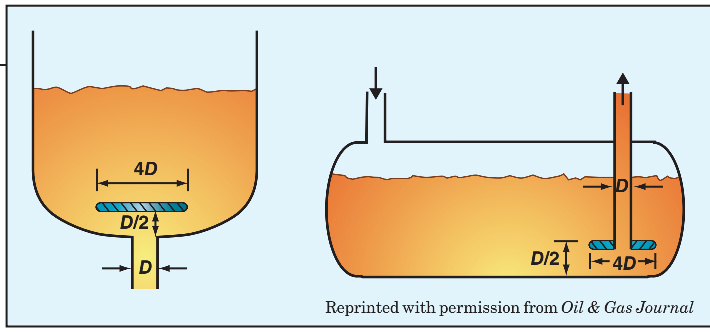


**FIGURE 3.** Shown here are two alternate vortex breaker designs from Patterson [1], for tanks with bottom drainage (left) and vertical-suction discharge (right)

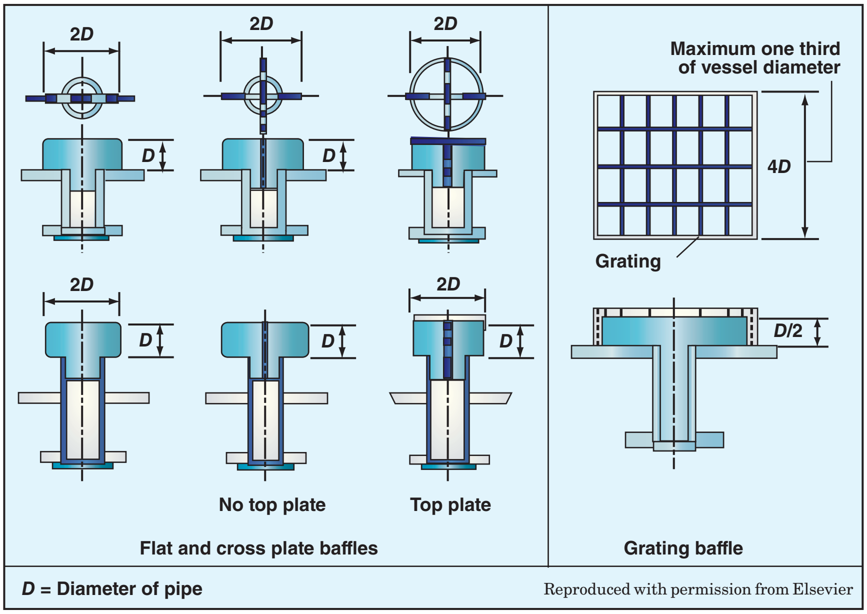


**FIGURE 4.** The vortex breaker design from Arnold [10] combines a 2- and 4-bladed cross pattern with a top plate that is either solid or made from porous grating

to, but larger than the PIP design with a height ranging from 5 in. to 1.25*D*, and a width of 3.5*D* to 5*D*. Kister [6] references Patterson [1] and Waliullah [5] but provides no new data.

McGuire [7] repeats the circular 4D plate suspended *D*/2 above the tank bottom, like Patterson [1], but also shows a 4-bladed, cross-pattern on top of a nozzle, extended above the tank bottom. However, this reference provides no recommended dimensions. McKetta [8] shows a 4-bladed design (4*D* dimension, suspended *D*/2 above the tank bottom) that is within the Waliullah [5] range.

The vortex breaker design provided by Voss [9] shows a circular plate suspended above the tank bottom of similar size as before, plus an "X-bar" shape that is used to form the 4-bladed cross-pattern. The author says the blades should be "several inches high," rather than related to the drain pipe's diameter. In Figure 4, Arnold [10] suggests both the 2- and 4-bladed cross-pattern (2*D* diameter, suspended *D* off the tank bottom, as with PIP [2]), plus the grating (4*D* x 4*D* x *D*/2, as with the design by Waliullah [5]). Arnold also suggests a combined design shown in Figure 4 (labeled "top plate") of both the 4-bladed cross-pattern and the horizontal top plate. Arnold shows the top plate being made solid as well as from porous grating, as shown. Note that Arnold's blades protrude a short distance down into the drain pipe.

Borghei [11] provides a detailed analysis of different configurations of the cross-baffle plate design, varying the design from 8 to 16 baffles, the dimensions of each blade, the distance from the exit pipe, and the height off the bottom. Silla [12] references Patterson [1], showing the familiar 4-bladed design, with the option of a solid plate or grating on top. The online reference manual provided in Ref. [13] from Goulds Pumps covers designs seen before, but also shows a critical submergence trend for vortexing to appear for different flowrates.

Lastly, Rotonics Manufacturing [14] shows an "anti-siphon" device online that's also listed as an "anti-vortex" device for side-exit nozzles. It is designed by cutting off half of an extended pipe end, to form a single curved baffle of sorts. One could imagine this "half-pipe" being extended off the bottom of a tank from a bottom-exit nozzle, but offering no construction advantage over the designs reviewed above.

## Gas-entrainment potential

Many of the following references (from designs discussed in the literature) discuss "irrotational" or "vortex-less" draining scenarios. It is not clear how the experimental work maintained a non-swirling drain flow (without the addition of baffles or guides) and it is expected that industrial situations would have enough disruptions to make non-swirling flows unrealistic. The discussion that follows on the subsequent references will be treated without regard to whether non-swirling or swirling flows were studied.

Using Perry's "Chemical Engineering Handbook" [15] as a starting point, the Kalinske [16] work from the early 1940s covered vertical drains and overflow pipes. Perry next points to a 1977 paper from McDuffie [17], as well as the 1968 work by Simpson [18]. Simpson [18] consolidated the Kalinske [16] data with the 1938 work by Souders [19] on the limits of self-venting, weir-like flow down a drain, and the 1959 theoretical evaluation of critical submergence by Harleman [20]. The Simpson [18] graphical comparison used linear-scale axes but plotted non-dimensional parameters of the Froude Number versus the ratio of submergence-to-pipe-diameter.

By comparison, McDuffie [17] changed the design chart to log-log scales, which allowed for better resolution at low ranges, and converted the exponential equations to straight lines. McDuffie [17] fitted an equation to the Kalinske [*16*] data (Simpson [18] did not) and noted that the 1971 work of Anderson [*21*] closely followed Souders' equation [*19*]. Simpson [*22, 23*] continued the reviews in 1969 and 1978, but included no new entrainment information.

Equation (1) from Souders [*19*] predicts when a drain pipe would be running full with no gas entrainment versus the ability of a lower vessel being able to self-vent gas back to the original draining tank. In plotting Equation (1), *Fr* values (Froude Number, defined below) above the equation would imply self-venting occurring, while smaller *Fr* values would suggest flow with no gas entrainment, a condition referred to as running full. Note that this equation is only for *H/D* values (liquid height over exit-pipe diameter) less than 0.25. This equation is plotted in Figure 5 (left side).

$$Fr = 2.36\left(\frac{H}{D}\right)^{1.5} \quad (1)$$

where *Fr* is the Froude Number (the dimensionless ratio of inertia to gravity forces), defined as:

$$Fr = \frac{V}{\sqrt{g'D}} \quad (2)$$

$$g' = \frac{g(\rho_L - \rho_G)}{\rho_L} \quad (3)$$

where:

$H$ = the height (or depth) of the liquid's free surface over an exit pipe's entrance, ft

$D$ = the exit pipe diameter, ft

$V$ = the average velocity in drain pipe, ft/s

$g$ = gravity's acceleration constant, ft/s$^2$

$g'$ = approximates $g$ for gas/liquid flows

$\rho$ = the gas-phase and liquid-phase densities, lb/ft$^3$

The non-dimensional *Fr* is the ratio of the downward drag force of entrained bubbles versus the upward buoyancy force. If the downward drag is not great enough, the bubbles could float upward against the draining pipe flow, and not be caught in the downward flow. The definition is based on the possible case of another liquid resting on top of the draining liquid and being entrained in the drainage flow of the lower liquid. Some use *S* instead of *H* to represent the "submergence" distance of the outlet pipe below the free surface. Users should keep all units consistent.

McDuffie [*17*] states that when *H/D* is above 0.25, and when *Fr* is greater than about 0.3–0.55, gas will become entrained in the draining liquid flow, a condition to be avoided, while for lower *Fr* values the flow will have no vapor entrainment (running full). McDuffie's regression [*17*] of Kalinske's data [*16*] is Equation (4) and Harleman's derivation [*20*] is Equation (5), both related to determining the transition between vapor entrainment versus running full. McDuffie [*17*] also showed new data that followed Equation (6). Note the similar exponents. McDuffie [*17*] also reviewed Anderson's 1971 self-venting equation [*21*] with its leading coefficient of 2.31 being only slightly different from Souders' 2.36 value [*19*], but with identical exponents.

$$Fr = 4.4\left(\frac{H}{D}\right)^{2.0} \quad (4)$$

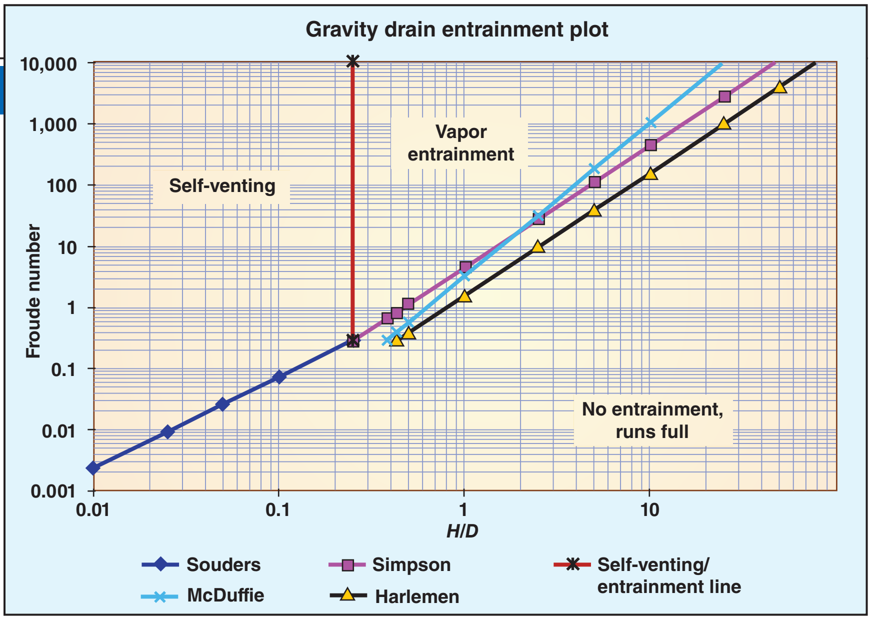


**FIGURE 5.** A plot of Equations (1, 4, 5 and 6) distinguishes the locations of the three flow conditions: self-venting, vapor-entrainment, and no-entrainment/runs full. Plotting the conditions of a draining tank helps to predict which regime the flow is in and suggest when a vortex breaker is needed to help prevent vapor entrainment

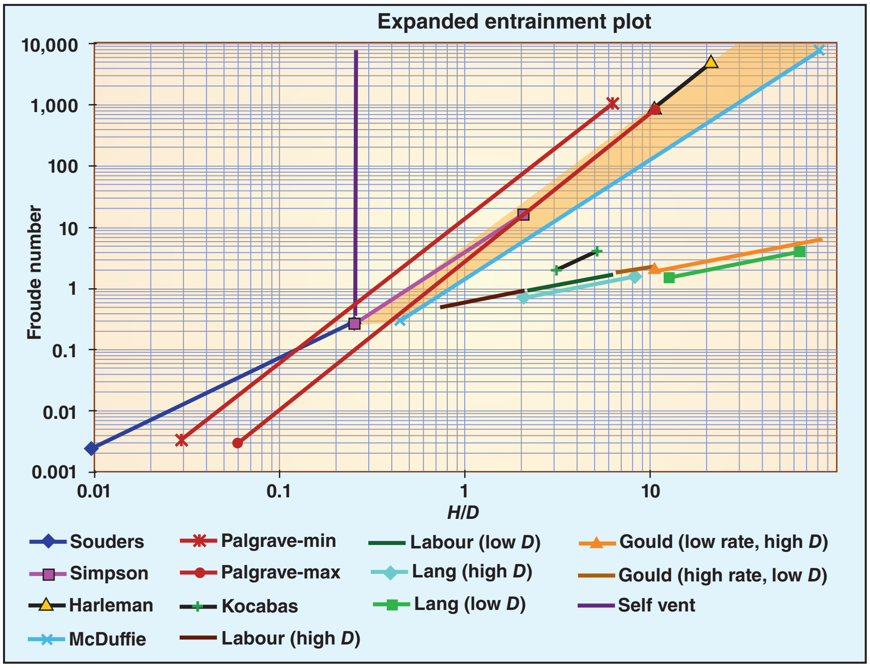


**FIGURE 6.** Shown here is the expanded master chart with additional rules of thumb added from data gathered from the literature. Disagreement among data sets can be undertood with closer inspection of the original test methods (this is shown in Figures 7–10)

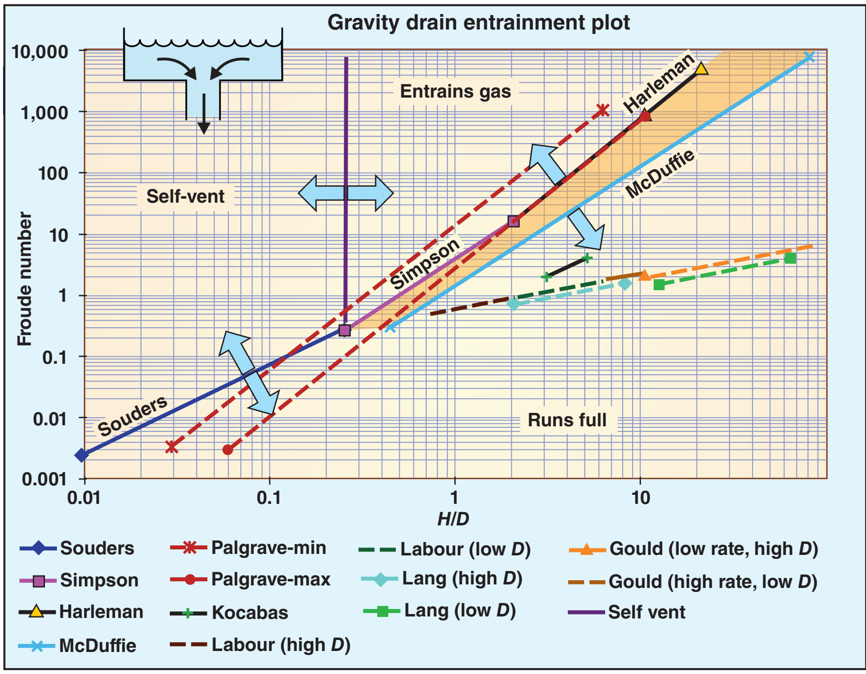


**FIGURE 7. This is a repeat of the gravity-drain scenario in Figure 5, but includes all of the additional information, shown as dashed lines to de-emphasize them**

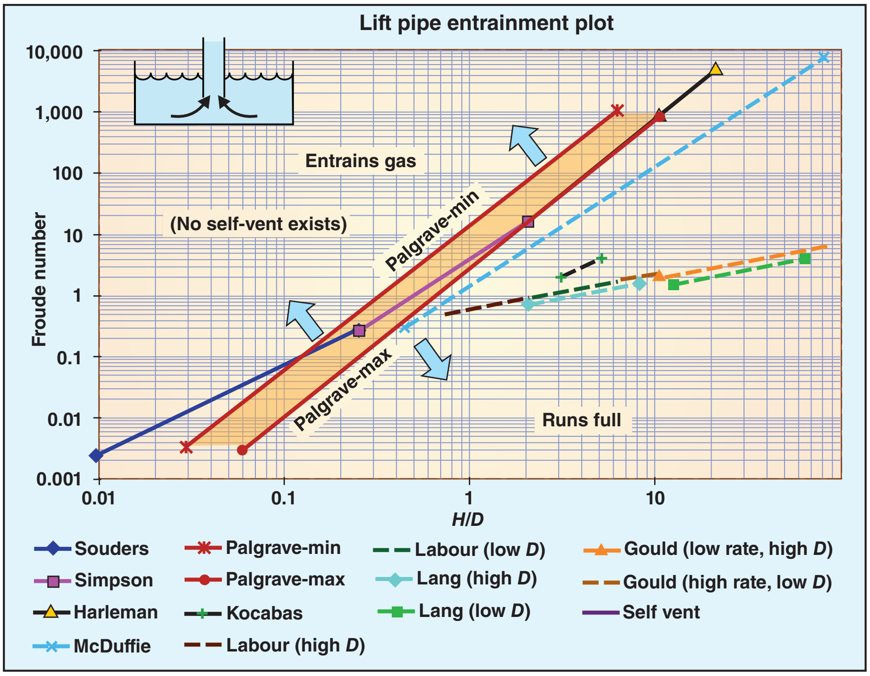


**FIGURE 8. This new master chart shows two curves from Palgrave *[28]* and represents tanks that rely on suction-lift discharge pipes. The chart no longer has a Self-vent region because rising bubbles that disengage from the liquid will float up the lift pipe**

$$Fr = 3.2\left(\frac{H}{D}\right)^{2.5} \quad (5)$$

$$Fr = 1.6\left(\frac{H}{D}\right)^{2.0} \quad (6)$$

In plotting the design equations, neither McDuffie [*17*] nor Simpson [*18, 22* and *23*] nor even Perry [*15*] labeled all of the three different flow conditions that could exist depending on the tank's operating scenario (found by plotting the *Fr* and *H/D* values). Figure 5 shows Equations (1, 4, 5 and 6) using log-log scales with the newly added vertical line at *H/D* = 0.25 to mark all three possible flow conditions. To the left of *H/D* = 0.25, only the self-venting and running-full conditions can occur. To the right of *H/D* = 0.25, the upper region switches to the gas-entrainment condition (hence the need of the vertical divider at *H/D* = 0.25), while the lower region remains running full.

Note that while the design Equations (4, 5 and 6) may differ by the leading coefficient or exponent, they still cover a similar part of the log-log plot of Figure 5 (Part of this variation could reflect differences in the experimental setup). Users of Figure 5 must decide whether the upper part of the disputed area (formed by the overlapping of Equations (4) and (5), or the lower part via Equation (6), represent a "conservative" design. If the desire is to avoid gas entrainment at all costs, then the lower-bound should be used, as it is a more-conservative scenario.

It should also be pointed out that in all the design equations, the tank's diameter does not appear in the design relationships using the *Fr* and the *H/D* notation. The assumption is that this diameter is much larger than the exit pipe's diameter *D* and thus does not affect the predictions (the actual experiments may have violated this expectation).

As noted earlier, to avoid operational problems associated with vapor entrainment, operation in the regimes labeled "Self-venting" or "No entrainment, runs full" is recommended. This is especially true when vortex breakers cannot be used due to cost considerations or constraints such as a high risk of fouling or plugging.

In an attempt to update the information shown in Figure 5, additional literature searches were conducted but revealed only two new topic areas that were not included previously. The recent publications tend to center around the use of computational fluid dynamics (CFD) modeling to analyze the shape of the "bathtub vortexes" that would lead to gas entrainment in draining tanks. These papers are mostly interested in accurately modeling the shape of the vortex's free surface and predicting when the vertex of the vortex dips down to the entrance level of the drain pipe.

When comparing the references in the CFD papers, all tend to refer to other vortex-shape modeling work (for instance, see Stepanyants [*24*]). In these papers, the main concern is the reduced flow-carrying capability of the drainage pipe when the vortex is occupying a percentage of the open cross-sectional area in that pipe — the issue of gas entrainment seems to be

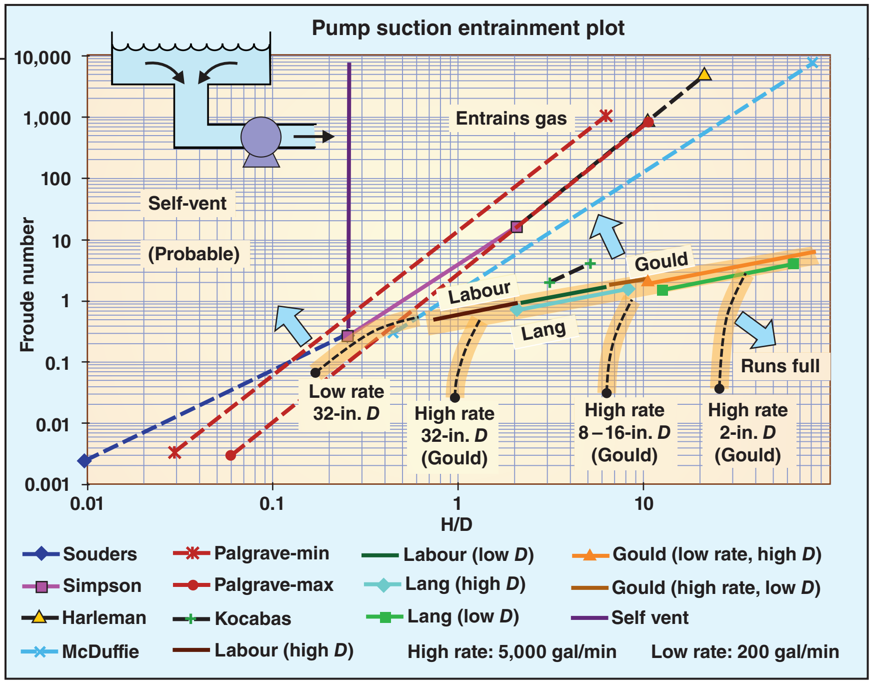


**FIGURE 9. This revised master chart for tanks using a pump to discharge liquid from a center drain (rather than discharge being gravity-driven) reflects data from Lang [26], Goulds Pump Care [27] and Labour [29]. The basic data agree but with a different slope for the gravity-driven data. The Self-venting region still exists but due to a lack of data in the cited references, its location is uncertain**

a side concern. The only experimental data set from the CFD papers that is related directly to the air-entrainment work (Lubin [*25*]) is also quite dated (pre-1980). Converting Lubin's critical height equation [*25*] to the *Fr* versus *H*/*D* notation duplicates Equation (5) above from McDuffie [*17*].

The other group of references found tended to be presented as "rules of thumb" to avoid gas entrainment during tank discharge. These were presented in various dimensional formats, but have been converted here to the consistent non-dimensional *Fr* versus *H*/*D* form so an expanded "master design chart" presented here can be reviewed. Lang Engineering [*26*] presents minimum submergence distances versus the average velocity in the outlet nozzle. To make the conversion to the *Fr* versus *H*/*D* convention, a series of diameters were chosen to calculate a set of non-dimensionalized data to be plotted later.

The online pump-care manual from Goulds Pumps [*27*] displays the critical submergence versus nozzle velocity, similar to the Lang [26] data, but with an additional flowrate effect on the low end of their data. Again, by calculating a series of pipe diameters, the *Fr* and *H*/*D* notation can be deduced for later plotting.

Palgrave [*28*] showed a chart for critical submergence versus flowrate (gal/min). The two curves may be showing an error band for the uncertainty of the transition to gas entrainment. By assuming a series of pipe diameters, the *Fr* and *H*/*D* values can be calculated.

Labour-Taber [*29a*] has posted an online white paper by L. Bachus (which cites Ref. [*29b*] as the data source) that shows two design charts. One is for velocity versus submergence (which will need assumed diameters to continue this comparison) but the other plot, although it appears to have pipe diameter data, is missing the units for the horizontal axis, making it unusable. The units of gal/min are expected to be the units for the missing label on the graph as an alternate presentation of their first graph. Conversion to *Fr* versus *H*/*D* notation would still be needed.

Kocabas [*30*] studied gas entrainment in a draining tank evaluating both still-flow versus laterally moving flow, as well as, a solid-bottom versus a porous-bottom. For all of the experimental variations presented in Ref. *30*, only three data points applied to the still-flow/solid-bottom configuration to allow it to be compared to all the other data collected here. Combining the new data reviewed above onto the original master design chart results in a rather confusing Expanded Entrainment Plot, which is shown in Figure 6.

Closer review of the added literature revealed that the data presented by Palgrave [*28*] were only for a "lift pipe" (as shown in the right side of Figure 3), and the information provided by Lang-Goulds-Labour [*26, 27* and *29*] was all for pump-suction flows, as opposed to gravity-driven, bottom-exiting flows. This implies that Figure 6 actually contains three separate design charts: (1) gravity-driven draining flow from the bottom of the tank; (2) lift-pipe upward-suction flow (perhaps to a pump); and (3) pump-suction flow from the bottom of the tank. Note that Figure 6 is the basis for Figures 7 through 10. As each subsequent scenario is being discussed, the other design curves are included for reference, but dashed to de-emphasize them.

Figure 7 repeats the "gravity drain only" data from Figure 5, but with a shading over the disputed design equations. Note in Figure 7 the short line pointing out the three data points of Kocabas [*30*], which has a different slope compared to the other gravity-drain data. It is not known why this short curve stands alone when the experimental setup should have matched the previous gravity-drain data.

Figure 8 represents the lift-pipe condition where no self-venting is possible (as the trapped bubbles would just float up the exit lift-pipe), so only two-flow regimes are shown. The band between minimum and maximum conditions may just represent an error-band for uncertainty in the experimental data. The slopes are similar to the original gravity-driven flow equations and the shaded region overlaps the same general region of uncertainty.

Figure 9 shows the remaining data that all have a pump-suction flow condition. Note the three data sets generally agree with a significantly different slope from the gravity-only flow in Figure 7. The self-venting region may exist for this configuration; however, it is not covered by any of the data. The Goulds' data [*27*] showed "tails" on their data for high rates at different pipe diameters that have been included in the *Fr* versus *H*/*D* non-dimensional format. High suction rates penalize the operation by reducing the region that ensures no gas entrainment at the lower liquid heights, and those "tails" limit the "running full" coverage. Only by continuing to increase the liquid level can gas entrainment be avoided.

One other data set from the literature has not been discussed. Patterson [*1*] showed limited data for the critical submergence if the tank was recirculating its flow rather than just emptying (draining) its contents. The author stated that an emptying tank needs about three times the critical submergence to avoid gas entrainment compared to a recirculating tank. It is reasonable to assume the returning flow disrupts the formation of a steady vortex of whirlpool and thus allows the free-surface level to be lower (closer to the exit nozzle). However, trying to add his data to the master design chart in *Fr* versus *H/D* notation showed confusing trends (Figure 10), suggesting that his actual experimental setup should be investigated further. A recirculating tank is worthy of further study as it could be a frequently encountered operating condition.

## Design application

Recently, Eastman Chemical needed to have the bottom nozzle of a new distillation column evaluated for possible gas entrainment. The column was a retrofit with a higher expected capacity compared to the previous column. The bottom nozzle supplies both the thermosiphon reboiler and the bottom draw-off. Operation at previous rates had not exhibited any flow problems.

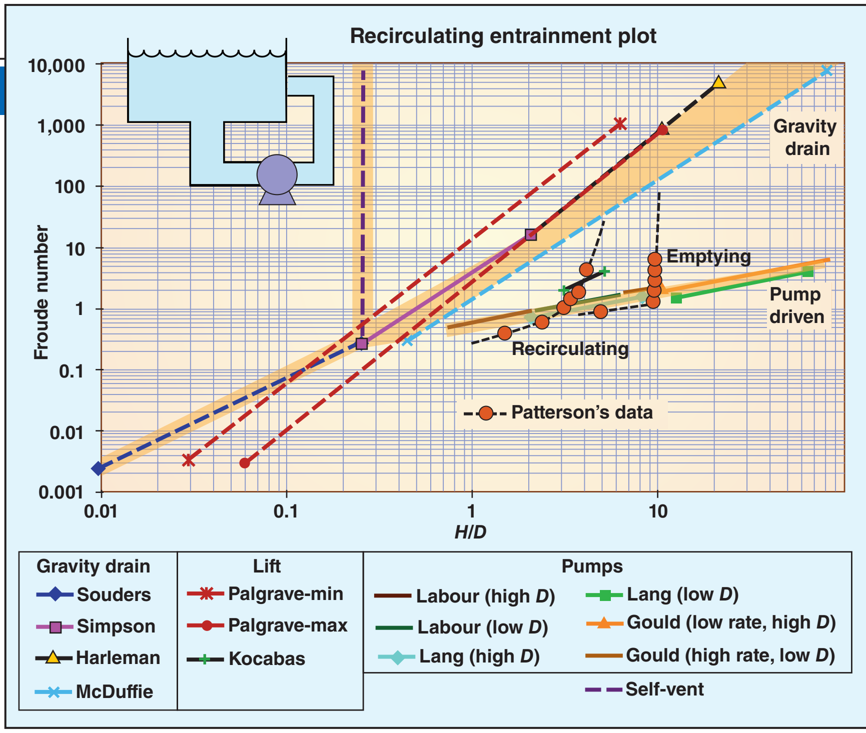


**FIGURE 10. Shown is an additional master chart plotted with an approximate depiction of the data provided by Patterson [1]. Notice the left-end of the new data has a slope similar to the pump-driven curve discussed previously. No description of the piping arrangement was provided (so it is not clear whether the recirculating piping re-enters the tank on the side or from the top)**

The maximum size of the bottom nozzle was limited due to building structural supports that could not be modified. This maximum nozzle size was below that required for the self-venting flow correlation, per Kister [*6*].

In this application, the use of a vortex breaker could be problematic due to possible flow restriction or plugging. Using the gravity-drain master chart of Figure 5 created in a spreadsheet, operational data for a given design can be converted into the non-dimensional format and plotted on the regime chart (Figure 11).

The recirculation rate, potential nozzle size, and operating level were varied to generate the three design operating ranges. Operation in these ranges (as shown in Figure 11) could be problematic because all except operation at low level indicate the potential for vapor entrainment, and in no situation does it run full. However, since this design uses recirculating flow, Patterson's data [*1*] shown in Figure 10 suggest the actual *H/D* may be equivalent to three times that shown


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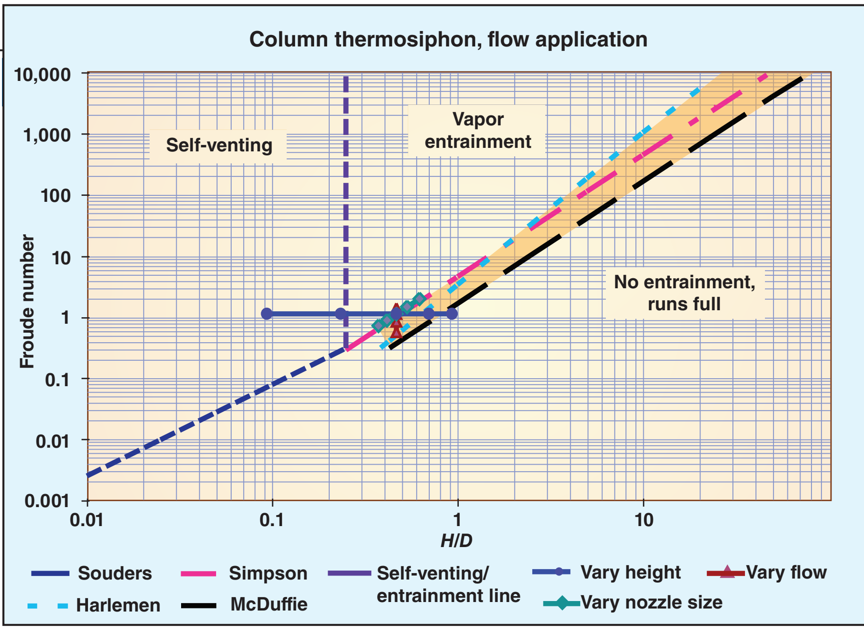


**FIGURE 11. Using production and design data from an actual tank, it is possible to block out the three possible operating ranges — Self venting; No entrainment, Runs full; and Vapor entrainment — as a function of different liquid heights and flowrates. This master design chart lets the user see the operating conditions under which the tank faces the increased risk of vapor entrainment**

in Figure 11. This would shift operation to the right (into the favorable "No entrainment, Runs full" regime), but would be based on inconsistent recirculating data as compared to the other pump and gravity-flow data.

Because this correlation has not been applied much to date within Eastman, and this particular application fell into a potential problem area, a removable vortex breaker was fabricated for the column and started up without any problems. Eastman has begun routinely using this correlation to check the need for vortex breakers in equipment designs. ■

*Edited by Suzanne Shelley*

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# Steam Generation Thermodynamics

**Brad Buecker**
Kiewit Power Engineers Co.

## Efficiency improvements can quickly be identified with back-of-the-envelope calculations

Although proper water treatment and conditioning for combined-cycle units and standalone steam generators are vitally important for reliability in the chemical process industries (CPI), a well maintained and operated steam generator can also save the facility much money with regard to efficient performance. This article outlines some of the primary thermodynamics behind steam generator heat transfer.

### Thermodynamic definitions

The word thermodynamics conjures up visions of complex mathematics to many people, even to some with technical backgrounds. Yet, relatively simple formulas from thermodynamics can be used to explain much about steam generator fundamentals.

Thermodynamics is built around three laws, which are sometimes jokingly defined as, "You can't get something for nothing," (first law) and "You can't break even" (second and third laws). In actuality, the first law is that of conservation of energy. It says that energy used within a system is neither created nor destroyed but only transferred. The classic energy equation for a simple system (defined as a control volume in textbooks) [*1, 2*] is:

$$Q - W_s = \dot{m}_2\left[\frac{V_2^2}{2} + gz_2 + u_2 + P_2v_2\right] - \dot{m}_1\left[\frac{V_1^2}{2} + gz_1 + u_1 + P_1v_1\right] + \frac{dE_{c.v.}}{dt} \quad (1)$$

Where,

$Q$ = Heat input per unit time
$W_s$ = Shaft work, such as that done by a turbine per unit time
$\dot{m}_2$ = Mass flow out of the system per unit time
$\dot{m}_1$ = Mass flow into the system per unit time
V = Fluid velocity
$(\dot{m}_2V_2^2 - \dot{m}_1V_1^2)/2$ = Change in kinetic energy
$gz_2 - gz_1$ = Change in potential energy
$u_2$ = Internal energy of the exiting fluid
$u_1$ = Internal energy of the entering fluid
$P_2\upsilon_2$ = Flow work of fluid as it exits the system ($P$ = pressure, $\upsilon$ = specific volume)
$P_1\upsilon_1$ = Flow work of fluid as it enters the system
$dE_{c.v.}/dt$ = Change in energy within the system per unit time

While this equation may look complicated, it can be easily understood through a few definitions and simplifications. First, in many systems and especially steam generators, potential and kinetic energies are minor compared to other energy changes and can be neglected. Second, in a steady flow process such as a steam generator, the system does not accumulate energy, so $dE_{c.v.}/dt$ is zero. Removing these terms from Equation (1) leaves the internal energy of the fluid ($u$) plus its flow work ($P\upsilon$) capabilities. Scientists have combined these two terms into the very useful property known as enthalpy ($h$). Enthalpy is a measure of the available energy of the fluid, and enthalpies have been calculated for a wide range of steam and saturated liquid conditions. These values may be found in the standard ASME steam tables, where saturated water at 0°C has been designated as having zero enthalpy. Using these simplifications and definitions, the energy equation for steady state operation in a turbine reduces to:

$$Q - W_s = \dot{m}\left(h_2 - h_1\right) \quad (2)$$

But this equation represents the ideal scenario, and here is where the second law steps in. Among other things, the second law describes process direction. A warm cup of coffee placed on a kitchen table does not become hotter while the room grows colder. Human beings grow old, and so on.

A foundation of the second law is the concept of the Carnot cycle, which says that the most efficient engine that can be constructed operates with a heat input ($Q_H$) at high temperature ($T_H$) and a heat discharge ($Q_L$) at low temperature ($T_L$), in which

$$\frac{Q_H}{T_H} - \frac{Q_L}{T_L} = 0 \quad (3)$$

This equation represents a theoretically ideal engine. In every process known to humans, some energy losses occur. These may be due to friction, heat escaping from the system, flow disturbances, or a variety of other factors. Scientists have defined a property known as entropy ($s$), which, in its simplest terms, is based on the ratio of heat transfer in a process to the temperature ($Q/T$), where $T$ is in Kelvin. In every process, the overall entropy change of a system and its surroundings increases. So, in the real world,

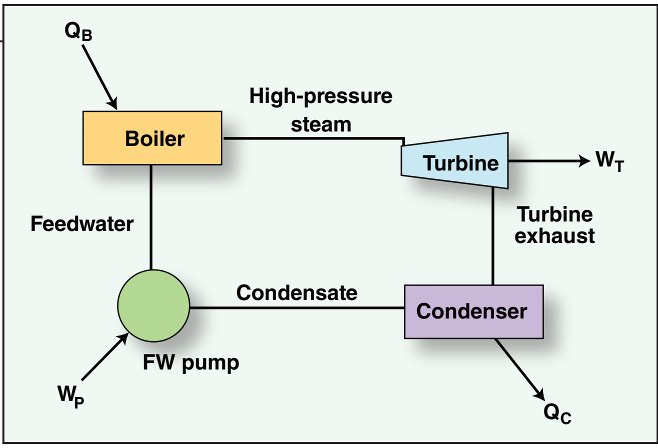


**FIGURE 1.** A basic steam generation system with isentropic turbine

Equation (3) becomes

$$\frac{Q_H}{T_H} - \frac{Q_L}{T_L} < 0 \quad (4)$$

While entropy may seem like a somewhat abstract term, it is of great benefit in determining process efficiency. Like enthalpy, entropy values are included in the steam tables.

Two important points should be noted about the Carnot cycle, and by logical inference, all realworld processes. First is that no process can be made to produce work without some extraction of heat from the process ($Q_L$) in Equation (3). $Q_L$ in a conventional steam generator is heat removed in the condenser.

Second, the efficiency (η) of a Carnot engine is defined as

$$\eta = 1 - \frac{T_L}{T_H} \quad (5)$$

So, as input temperature goes up or exhaust temperature goes down, efficiency increases.

## System components

So how does all of the above discussion apply to a heat recovery steam generator (HRSG) or a standalone steam generator? The following sections build upon a simple steam-generator design to show the effects of common thermodynamic principles. First is an examination of condenser performance.

## Condensers

During the time I spent at two coal-fired utilities, I was asked on a number of occasions why turbine exhaust steam must be condensed. Why not transport it directly back to the boiler? Beyond the issue of piping difficulties is that of efficiency. Consider the simple system, shown in Figure 1, with a turbine that has no frictional, heat or other losses, which means no entropy change (isentropic).

In actuality, turbines are typically 80 to 90% efficient, but this factor does not need to be included here to show the importance of condenser performance. Let us call this Example 1, and use the following conditions:

- Main steam (turbine inlet) pressure — 1,000 psia
- Main steam temperature — 1,000°F
- Turbine outlet steam pressure — atmospheric (14.7 psia)

The steam tables show that the enthalpy of the turbine inlet steam is 1,505.9 Btu per pound of fluid (Btu/$lb_m$). Thermodynamic calculations indicate that the exiting enthalpy from the turbine is 1,080.9 Btu/$lb_m$ (steam quality is 93%). Equation (2) (the first law, steady-state energy equation) becomes for the turbine, $W_T = \dot{m}(h_1 - h_2)$. Accordingly, the unit work available from this ideal turbine is (1,505.9 Btu/$lb_m$ – 1,080.9 Btu/$lb_m$) = 425.0 Btu/$lb_m$. To put this into practical perspective, assume steam flow ($\dot{m}$) to be 1,000,000 lb/h. The overall work is then 425,000,000 Btu/h = 124.5 MW.

Now consider a second example, where the system has a condenser that reduces the turbine exhaust pressure to 1 psia (approximately 2 in. of mercury). Again assuming an ideal turbine, the enthalpy of the turbine exhaust is 923.4 Btu/$lb_m$. The unit work output equates to 1,505.9 – 923.4 = 582.4 Btu/$lb_m$. At 1,000,000 lb/h steam flow, the total work is 582,400,000 Btu/h = 170.6 MW. This represents a 37% increase from the previous example. Obviously, condensation of the steam has an enormous effect upon efficiency. Remember, Equation (5)? This is a practical illustration of how the condenser lowers $T_L$.

Think about this example from a physical perspective. Calculations indicate that the steam quality at the turbine exhaust (at 1 psia condenser pressure) is 82%. This means that 18% of the steam has condensed to water. However, the remaining steam takes up a specific volume of 274.9 $ft^3/lb_m$. The corresponding volume of water in the condenser hotwell is 0.016136 $ft^3/lb_m$. Thus, the condensation process reduces the fluid volume over 17,000 times. The condensing steam generates the strong vacuum in the condenser, which actually acts as a driving force to pull steam through the turbine.

Let's take this concept a step further in Example 3. Consider if waterside fouling or scaling (or excess air in-leakage) causes the condenser pressure of the previous example to increase from 1 psia to 2 psia. Calculations show that the work output of the turbine drops from 582.4 to 546.1 Btu/$lb_m$. So, at 1,000,000 lb/h steam flow, a rise of 1 psia in the condenser backpressure equates to a loss of 36,300,000 Btu/h or 10.6 MW of work. This is a primary reason why proper cooling-water chemical treatment and condenser-performance monitoring are very important [3].

## Superheating

Consider the common drum boiler (this includes most HRSGs), where the steam leaving the drum(s) is saturated. If this steam were to be immediately injected into a turbine, very little work would occur, as the steam would immediately begin condensing to water upon passage through the blades. For this reason, all high-pressure steam generators include superheaters. The temperature to which the steam is raised above saturation represents the degree of superheat. An important point to remember is that it takes nearly 1,000 Btu to convert a pound of water to a pound of steam. As the examples in the previous section illustrated, only about one third of the energy in superheated steam is available for work in conventional steam turbines. However, research into more temperature-resistant superheater and reheater tube materials continues, in direct application of Equation (5). Modern supercritical boilers are closing in on 45% overall efficiency, and of course combined-cycle units can reach nearly 60% ef-

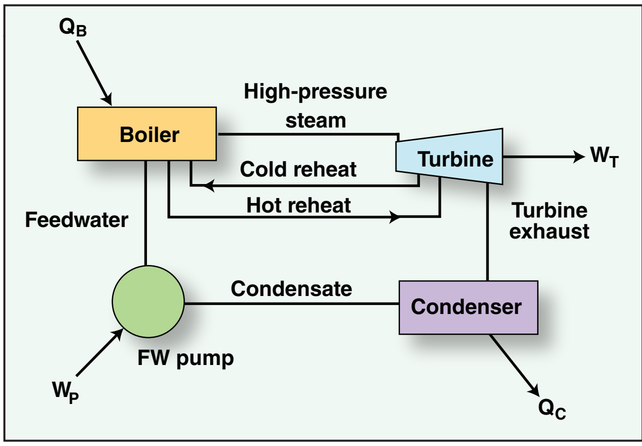


**FIGURE 2.** A steam generator with reheater

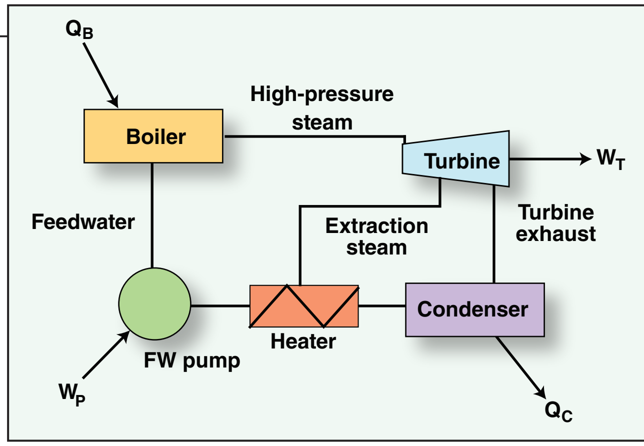


**FIGURE 3.** A steam generator with a single, tube-in-shell feedwater heater

ficiency where electrical production is split between the combustion and steam turbines.

## Reheating

Ideally, superheat energy is just completely consumed at the last, low-pressure turbine blades. A delicate balance is necessary to extract all of the available energy from the steam but prevent excessive condensation in the low-pressure turbine blades, as the water droplets will cause serious blade damage. The latter aspect is an important basis behind steam reheating and operation at high pressures. Thermodynamics shows that work and efficiency of a steam generator improve with increased pressure. As a fourth example, let's increase the steam pressure to 2,000 psia from Example 2, where the condenser pressure was 1 psia. The main steam enthalpy becomes 1,474.1 Btu/lb$_m$ and the turbine exhaust enthalpy is 871.0 Btu/lb$_m$. The turbine work output rises to 603.1 Btu/lb$_m$ (176.7 MW at 1,000,000 lb/h steam flow), and the efficiency increases from 40.6% to 42.9%. (Efficiency gain through higher pressure is a primary reason why supercritical [>3,208 psia steam pressures] have become popular for modern coal-fired boilers.) But, at 2,000 psia the turbine exit steam quality is only 77%. This means that 23% of the fluid exits as condensed water droplets. Such high moisture content can damage low-pressure turbine blades. A rule of thumb suggests 10% moisture at the turbine exhaust as an upper limit.

Reheating the steam helps to alleviate this difficulty. Figure 2 shows a steam generator and turbine with a reheat system. Main steam is at 2,000 psia, 1,000°F, and has an enthalpy of 1,474.1 Btu/lb$_m$. The steam extraction (cold reheat) pressure is 300 psia, which equates (isentropically) to a cold reheat temperature of 485°F and enthalpy of 1,248.1 Btu/lb$_m$. Assume no pressure drop through the reheater and a hot reheat temperature of 1,000°F, producing reheated steam with an enthalpy of 1,526.5 Btu/lb$_m$. Calculations show that the reheating process improves the turbine exhaust steam quality from 77% to 90%. Because the steam quality increases, the turbine exhaust enthalpy increases slightly to 1,003.9 Btu/lb$_m$.

Calculation of the work output, boiler heat input, and efficiency of this example becomes slightly more complicated, as in this case work is done by two, separate steam feeds to the turbine, and heat is added to two, separate steam systems in the boiler. The unit work equation is $w_t$ = (inlet steam enthalpy – cold reheat enthalpy) + (hot reheat enthalpy – turbine exhaust enthalpy).

In this case, $w_t$ = (1,474.1 – 1,248.1) + (1,526.5 – 1,003.9) = 748.6 Btu/lb$_m$. As can be seen, reheating considerably increases the work output as compared to the non-reheat example. The boiler heat input, $q_b$, is defined as (main steam enthalpy – feedwater enthalpy) + (hot reheat enthalpy – cold reheat enthalpy). For this example, $q_b$ = (1,474.1 – 69.7) + (1,526.5 – 1,248.1) = 1,682.8 Btu/lb$_m$. An obvious conclusion is that reheat increases the energy output but also the fuel requirements to the boiler. The efficiency calculates to 44.5%, which is 2% higher than the non-reheat example. The increased fuel requirement is counterbalanced by increased work output and better steam quality of the turbine exhaust. A well-designed reheat system can reduce moisture to low levels in the turbine exhaust steam. Supercritical units may have two reheaters to maximize turbine performance.

## Feedwater heating

Regenerative feedwater (FW) heating is an integral process at electric utilities, but feedwater heaters may be limited or non-existent in industrial steam-generator networks. However, we will briefly examine the efficiency gains that feedwater heating provides for illustrative purposes. We will again build upon Example 4, and include a single feedwater heater, as shown in Figure 3.

A general rule of thumb suggests that for a single heater, the extraction steam flowrate should be designed to raise the feedwater temperature to a point halfway between the condensate temperature and saturation temperature of the boiler. For multiple heaters, the temperature increase should be divided as equally as possible.

In this scenario (condenser pressure of 1 psia and boiler pressure of 2,000 psia) the condensate temperature is 69.7°F and the boiler saturation temperature is 636.0°F. The midway point between these two temperatures is 353°F. If steam is extracted from the turbine at a pressure of 500 psia, energy-mass-balance calculations show that the flowrate to the heater should be 20.8% of the total steam flow. The extraction steam enthalpy is 1,299.7 Btu/lb$_m$. The heat exchange produces feedwater with an enthalpy of 325.0 Btu/lb$_m$. The turbine work equals the enthalpy difference between the main steam and extraction point (1,474.1 – 1,299.7 Btu/lb$_m$), plus the remaining steam (79.2%) that passes to the turbine exhaust (0.792×[1,299.7 – 871.0] Btu/lb$_m$). In this case, the turbine work equates to 513.8 Btu/$lb_m$. This is less than the work obtained in Example 4 (603.1 Btu/$lb_m$), which had no feedwater heater. One might logically ask how feedwater heating improves the process. The benefits are efficiency related. The heat input required by the boiler to produce the required steam is only 1,149.1 Btu/$lb_m$ (1,474.1 – 325.0), as the feedwater temperature is much warmer. Thus, the efficiency of this system is (513.8/1,149.1) × 100 = 44.7%. This represents an 11% increase from Example 4. The principal concept behind the efficiency gain is that much of the heat re-used in the feedwater heater would have otherwise been exhausted to the condenser cooling water. Multiple feedwater heaters, especially in larger systems, increase efficiency even further, but at some point equipment costs offset efficiency gain. Six heaters are common in large, subcritical, utility systems, where five might be closed heaters with one deaerator. HRSGs often have just one heater, in the form of a deaerator integrally tied in with the low-pressure steam generator.

## Final remarks

The efficiency values outlined in the previous examples are greater than normal because no accounting was made of heat losses in the boiler, inefficiencies in the turbine, frictional losses in the piping, and other entropy-related factors. Nonetheless, these examples illustrate the fundamental principles and importance behind the operation of several important steam-generating components or subsystems. My colleagues and I have personally been involved with condenser performance-improvement projects that have resulted in net savings of $500,000–1,500,000/yr at just one plant. To borrow an old phrase, such savings "are not chicken feed." ■

*Edited by Gerald Ondrey*

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## Author

**Brad Buecker** recently joined Kiewit Power Engineers Co. (9401 Renner Boulevard, Lenexa, KS 66219. Phone: 913-928-7000; Fax: 913-689-4000; Email: brad.buecker@kiewit.com as a process specialist. He has nearly 30 years of experience in or affiliated with the power industry, much of it in steam generation chemistry, water treatment, air quality control, and results engineering positions with City Water, Light & Power (Springfield, Ill.) and Kansas City Power & Light Company's (La Cygne, Kansas) station. He has an A.A. in pre-engineering from Springfield College in Illinois and a B.S. in chemistry from Iowa State University. He is a member of the ACS, AIChE, ASME, and NACE.

# Mechanical Centrifugal Air Classifiers

## Improved understanding of air classification systems and their application can help in selecting the right device

**Joseph Muscolino**
Sturtevant Inc.

Mechanical centrifugal air classifiers are used extensively to process aggregates, ceramics, chemicals, foods, minerals, metals, plastics, flyash and other materials. They are normally employed when the particle size that you need to separate is too fine to screen. The air-classified product can be either the granular coarse discharge with very little fines and dust, or it can be the fines discharge with very little coarse material.

Air classifiers eliminate the blinding and breakage issues associated with screens. They work by balancing the physical principles of centrifugal force, drag force, collision and gravity to generate a high-precision method of classifying particles according to size and density. For dry materials of 100-mesh and smaller, air classification provides the most effective and efficient means for separating a product from the feed stream, for dedusting, or, when used in conjunction with grinding equipment, for increasing productivity.

Air classifiers can only be used for dry processing. In order to effectively remove fine powders, the surface moisture of the feed must be very low.

### Air classifier advantages

Mechanical centrifugal air classifiers are masters of accuracy. They are a good choice when the separation curve or cutpoint is too fine for screens (200–400 mesh or finer), when the capacity is too large for screens (up to 800 ton/h) and when easy adjustability is required to meet various product specifications.

One of the most significant advantages of a classifier is its dry process. For dedusting aggregates, dry processing eliminates the need for water or settling ponds, saving money and land, and benefiting the environment.

Air classifiers do not handle the more aggressive work that pulverizers do and they operate at much lower speeds, so the equipment is less susceptible to wear. With the addition of protective liners, air classifiers can be used to economically process even abrasive powders, such as silica, flyash and ceramics.

Air classifiers have the ability to separate powders as coarse as 80 mesh (180 µm), and as fine as 2–3 µm. The fineness of air-classified products is controlled by a precise balance among the quantity of rejector blades, the speed at which the rejector blades operate, the velocity of the airflow and the rate at which the material is fed. Even with fragile powders, air classifiers rarely fracture or degrade particles because they do not operate at pulverizer speeds and most of the feed never makes contact with the rotating parts.

Air classifiers can be used as a single sizing device in an open circuit where the feed is split into a fines discharge and a coarse discharge. This equipment can also be used in closed-circuit with mills. In this case, use of the air classifier maximizes the capacity of the mill and reduces the mill's energy consumption because the mill does not have to serve as the sizing device (Figure 1).

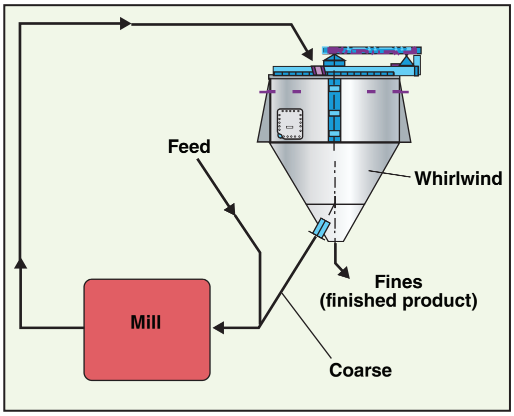


**FIGURE 1. Mechanical centrifugal air classifiers can serve as sizing devices, where the feed is split into coarse discharge and fines**

### Applications

Mechanical centrifugal air classifiers are useful in many applications, including the following:

- Dedusting undesireable fines in many types of aggregate stone, such as limestone, granite, trap rock, sandstone, basalt, diabase rock, gabbro, sand and gravel
- Reducing the fines load on a water flotation system for extracting precious metals from many types of minerals, including iron, gold, phosphate or illmenite ores
- Upgrading the fineness of milled limestone, silica, feldspar, refractory slag, fused glass, kyanite, zirconia, alumina, lithium carbonate, copper oxide and others
- Removing undesireable contaminants in flyash, coal, kaolin, hydrated lime, diatomaceous earth and mica
- Increasing the protein content in wheat flour, chick-pea flour, poultrymeal animal feed and others

### Separation by density

While density does play a role in air-classifier separation, the internal air currents are mostly affected by the overall mass and weight of the particles in the feed. Lighter and smaller particles are removed by the airflow, while heavier and larger particles are not entrained in the airflow. If the lower-density material also has a finer

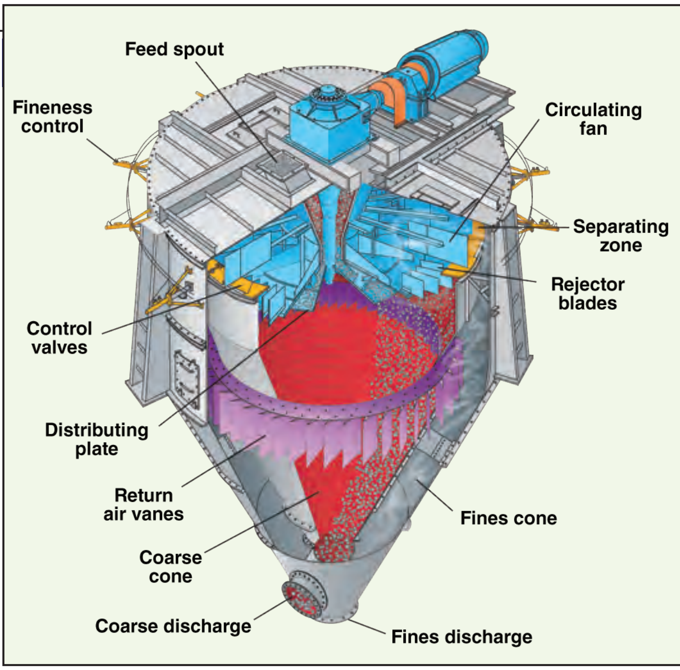


**FIGURE 2. Internal-fan air classifiers do not require airlocks, cyclones or baghouses to collect separated fines**

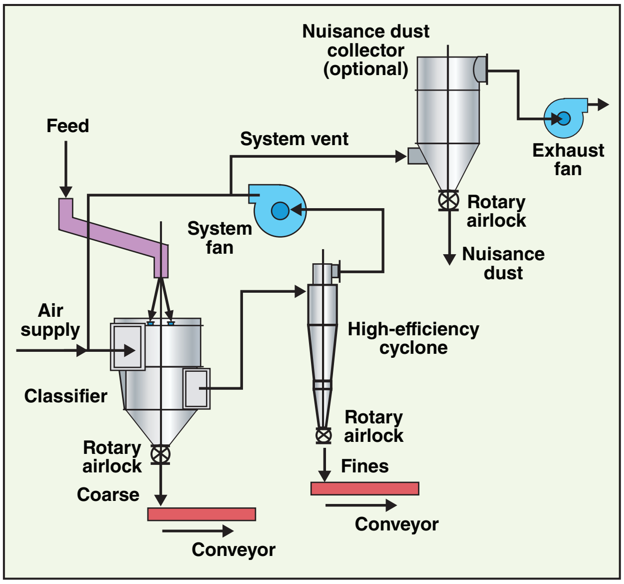


**FIGURE 3. External-fan air classifiers use a variable-speed rotor with multiple, closely spaced rejector blades for ultra-fine applications**

particle size, then air classifiers can be very effective. However, large particles with low density can have a similar mass and weight as some small particles with high density. This can reduce the effectiveness of an air classifier's density separation.

## Effects of moisture

Moisture effects are limited by surface moisture, rather than inherent moisture. Inherent moisture is naturally found inside particles of ores, minerals or stone sand after natural drying occurs in air. Inherent moisture does not hinder an air classifier's ability to remove fine powder or fine dust from coarse particles. For example, crushed coal is successfully air classified with inherent moisture as high as 10%.

Surface moisture, on the other hand, is found on the surface of ores, minerals or stone sand and comes from rainfall or from spraying water in an aggregate plant or quarry during dust suppression. Surface moisture is detrimental to the performance of air classifiers because the fine particles stick to the large particles and airflow is not enough to remove them. When surface moisture is very high, the water also centrifuges out and results in equipment clogging.

The performance of air classifiers in aggregate plants or quarries is limited by the surface moisture in the stone sand. The drier the rock is (1–2%), the more dust can be removed, often allowing air classifiers to replace water wash systems altogether. When higher surface moisture is present in stone sand (2.5–3.0%), the fines stick to the rock and larger air classifiers are required with more airflow than usual to be effective. When the surface moisture is very high (3.5–4.0% or more), the water centrifuges out and results in equipment clogging.

## Pneumatic feeding

Air classifiers can be fed pneumatically and, in some cases, can be incorporated into a pneumatic conveying line. However, in a pneumatic feed process, particles enter the air classifier at a much higher velocity than gravity-fed particles. When these particles approach the classifier rejector blades at high velocities, they are more likely to pass through, which requires a higher rejecter speed to stop these oversize particles. Higher rejector speed can then result in higher wear and lower efficiency in fines-removal.

## Cyclones or baghouses needed?

There are two categories of mechanical centrifugal air classifiers: Internal-fan models and external-fan models.

Internal-fan air classifiers recycle the air, and therefore, do not require airlocks, cyclones or baghouses to collect the separated fines. This design has a single shaft that controls three rotating elements — the feed distributing plate, particle-sizing selector blades and circulating fan (Figure 2).

The feed distribution plate imposes centrifugal force on the feed particles, moving them into the classification zone. Coarse particles fall down into the inner cone and exit at the coarse discharge. The circulating fan creates an upward draft of air that carries finer particles away from the feed and through the selector blades. Properly sized fine particles pass through the internal fan still entrained in air. Fixed vanes recycle the air back into the classifier, while the properly sized fine particles drop out of the airflow and slide down the fines cone, where they exit.

External-fan air classifiers (Figure 3) require cyclones or baghouses to collect the separated fines. This design uses a variable-speed rotor with multiple, closely spaced rejector blades for ultra-fine and ultra-efficient applications. The feed distribution plate imposes centrifugal force on the feed particles, moving them into the classification zone. Coarse particles fall down into the inner cone and exit at the coarse discharge point. The external fan creates a draft of air that carries finer particles away from the feed and through the rotor. Properly sized fine particles, entrained in air, pass through the rotor and exit the air classifier. A cyclone or baghouse is required to recover the classified particles out of the airflow.

### Controlling particle size

The most common methods of controlling particle size in mechanical centrifugal air classifiers are rejector speed, cage aperature size of rejector elements, airflow velocity and the ratio of feedrate to air.

Rejector speed controls the impact or collision force on the air-entrained particles as they attempt to exit the air classifier. Higher speed allows only the finest particles to pass through the rejector for collection. This increases the rejection of larger particles (Figure 4).

Airflow velocity generated by a fan controls the drag force on particles as they enter the classification zone. Higher airflow allows larger particles to be removed from the feed, while lower airflow allows only the finest particles to pass through the rejector cage for collection.

Rejector elements / cage-aperture controls impact the collision force on the air-entrained particles as they attempt to exit the air classifier. A greater quantity of rejector elements (blades or rods) makes the cage aperture smaller and allows only the finest particles to pass through the rejector for collection. This increases the rejection of larger particles.

Feedrate-to-air ratio controls the entrainment of particles in the airflow. A higher feedrate allows only the finest particles to pass through the rejector cage for collection. This increases the rejection of larger particles.

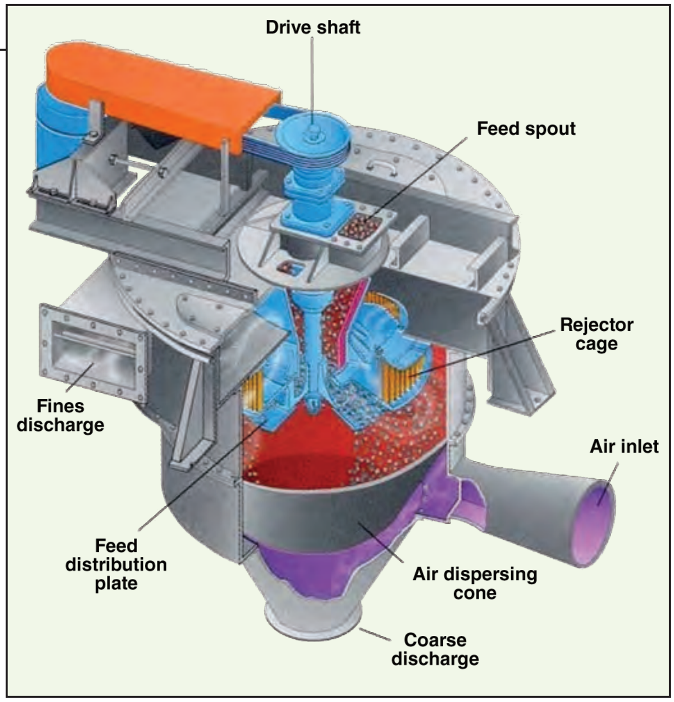


**FIGURE 4.** The most common ways to control particle size are rejector speed, rejector elements and aperature size, airflow velocity and feedrate-to-air ratio

### Measuring performance

The performance of mechanical centrifugal air classifiers can be evaluated by analyzing the cutpoint, tolerance, yield and efficiency.

Cutpoint is simply the desired particle size that is intended to be classified. This value can be measured in millimeter mesh or micron size. Tolerance is the percentage of oversized or undersized particles allowed in the finished product. Yield is the percentage of production rate per unit of feedrate. Efficiency is the percentage of the desired particle-size fraction recovered as product from the total amount available in the feed. ■

*Edited by Scott Jenkins*

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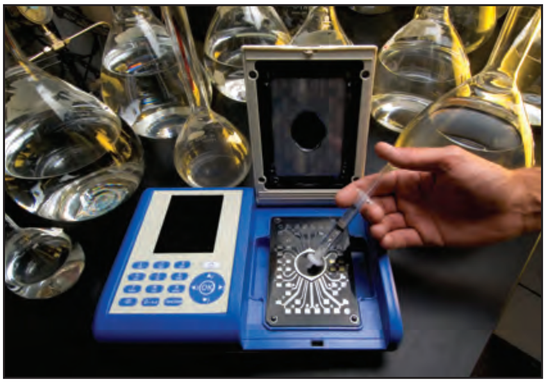

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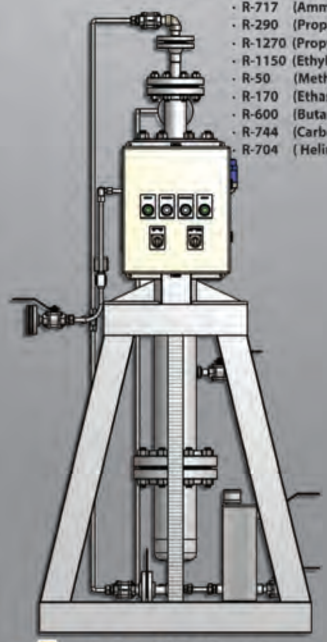
- R-170 (Ethane)
- R-600 (Butane)
- R-744 (Carbon Dioxide)
- R-704 (Helium)



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- • International section
- * Additional information in 2011 Buyers' Guide

**See bottom of next page for advertising sales representatives' contact information**

## Classified Index - November 2010

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November 2010

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06 Soaps & Detergents
07 Paints & Allied Products
08 Organic Chemicals
09 Agricultural Chemicals
10 Petroleum Refining, Coal Products
11 Rubber & Misc. Plastics
12 Stone, Clay, Glass, Ceramics
13 Metallurgical & Metal Products
14 Engineering, Design & Construction Firms
15 Engineering/Environmental Services
16 Equipment Manufacturer
17 Energy incl. Co-generation
18 Other______________

**JOB FUNCTION**

20 Corporate Management
21 Plant Operations incl. Maintenance
22 Engineering
23 Research & Development
24 Safety & Environmental
26 Other______________

**EMPLOYEE SIZE**

28 Less than 10 Employees
29 10 to 49 Employees
30 50 to 99 Employees
31 100 to 249 Employees
32 250 to 499 Employees
33 500 to 999 Employees
34 1,000 or more Employees

**YOU RECOMMEND, SPECIFY, PURCHASE**

**(*please circle all that apply*)**

40 Drying Equipment
41 Filtration/Separation Equipment
42 Heat Transfer/Energy Conservation Equipment
43 Instrumentation & Control Systems
44 Mixing, Blending Equipment
45 Motors, Motor Controls
46 Piping, Tubing, Fittings
47 Pollution Control Equipment & Systems
48 Pumps
49 Safety Equipment & Services
50 Size Reduction & Agglomeration Equipment
51 Solids Handling Equipment
52 Tanks, Vessels, Reactors
53 Valves
54 Engineering Computers/Software/Peripherals
55 Water Treatment Chemicals & Equipment
56 Hazardous Waste Management Systems
57 Chemicals & Raw Materials
58 Materials of Construction
59 Compressors

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16 | 31 | 46 | 61 | 76 | 91 | 106 | 121 | 136 | 151 | 166 | 181 | 196 | 211 | 226 | 241 | 256 | 271 | 286 | 301 | 316 | 331 | 346 | 361 | 376 | 391 | 406 | 421 | 436 | 451 | 466 | 481 | 496 | 511 | 526 | 541 | 556 | 571 | 586 |
| 2 | 17 | 32 | 47 | 62 | 77 | 92 | 107 | 122 | 137 | 152 | 167 | 182 | 197 | 212 | 227 | 242 | 257 | 272 | 287 | 302 | 317 | 332 | 347 | 362 | 377 | 392 | 407 | 422 | 437 | 452 | 467 | 482 | 497 | 512 | 527 | 542 | 557 | 572 | 587 |
| 3 | 18 | 33 | 48 | 63 | 78 | 93 | 108 | 123 | 138 | 153 | 168 | 183 | 198 | 213 | 228 | 243 | 258 | 273 | 288 | 303 | 318 | 333 | 348 | 363 | 378 | 393 | 408 | 423 | 438 | 453 | 468 | 483 | 498 | 513 | 528 | 543 | 558 | 573 | 588 |
| 4 | 19 | 34 | 49 | 64 | 79 | 94 | 109 | 124 | 139 | 154 | 169 | 184 | 199 | 214 | 229 | 244 | 259 | 274 | 289 | 304 | 319 | 334 | 349 | 364 | 379 | 394 | 409 | 424 | 439 | 454 | 469 | 484 | 499 | 514 | 529 | 544 | 559 | 574 | 589 |
| 5 | 20 | 35 | 50 | 65 | 80 | 95 | 110 | 125 | 140 | 155 | 170 | 185 | 200 | 215 | 230 | 245 | 260 | 275 | 290 | 305 | 320 | 335 | 350 | 365 | 380 | 395 | 410 | 425 | 440 | 455 | 470 | 485 | 500 | 515 | 530 | 545 | 560 | 575 | 590 |
| 6 | 21 | 36 | 51 | 66 | 81 | 96 | 111 | 126 | 141 | 156 | 171 | 186 | 201 | 216 | 231 | 246 | 261 | 276 | 291 | 306 | 321 | 336 | 351 | 366 | 381 | 396 | 411 | 426 | 441 | 456 | 471 | 486 | 501 | 516 | 531 | 546 | 561 | 576 | 591 |
| 7 | 22 | 37 | 52 | 67 | 82 | 97 | 112 | 127 | 142 | 157 | 172 | 187 | 202 | 217 | 232 | 247 | 262 | 277 | 292 | 307 | 322 | 337 | 352 | 367 | 382 | 397 | 412 | 427 | 442 | 457 | 472 | 487 | 502 | 517 | 532 | 547 | 562 | 577 | 592 |
| 8 | 23 | 38 | 53 | 68 | 83 | 98 | 113 | 128 | 143 | 158 | 173 | 188 | 203 | 218 | 233 | 248 | 263 | 278 | 293 | 308 | 323 | 338 | 353 | 368 | 383 | 398 | 413 | 428 | 443 | 458 | 473 | 488 | 503 | 518 | 533 | 548 | 563 | 578 | 593 |
| 9 | 24 | 39 | 54 | 69 | 84 | 99 | 114 | 129 | 144 | 159 | 174 | 189 | 204 | 219 | 234 | 249 | 264 | 279 | 294 | 309 | 324 | 339 | 354 | 369 | 384 | 399 | 414 | 429 | 444 | 459 | 474 | 489 | 504 | 519 | 534 | 549 | 564 | 579 | 594 |
| 10 | 25 | 40 | 55 | 70 | 85 | 100 | 115 | 130 | 145 | 160 | 175 | 190 | 205 | 220 | 235 | 250 | 265 | 280 | 295 | 310 | 325 | 340 | 355 | 370 | 385 | 400 | 415 | 430 | 445 | 460 | 475 | 490 | 505 | 520 | 535 | 550 | 565 | 580 | 595 |
| 11 | 26 | 41 | 56 | 71 | 86 | 101 | 116 | 131 | 146 | 161 | 176 | 191 | 206 | 221 | 236 | 251 | 266 | 281 | 296 | 311 | 326 | 341 | 356 | 371 | 386 | 401 | 416 | 431 | 446 | 461 | 476 | 491 | 506 | 521 | 536 | 551 | 566 | 581 | 596 |
| 12 | 27 | 42 | 57 | 72 | 87 | 102 | 117 | 132 | 147 | 162 | 177 | 192 | 207 | 222 | 237 | 252 | 267 | 282 | 297 | 312 | 327 | 342 | 357 | 372 | 387 | 402 | 417 | 432 | 447 | 462 | 477 | 492 | 507 | 522 | 537 | 552 | 567 | 582 | 597 |
| 13 | 28 | 43 | 58 | 73 | 88 | 103 | 118 | 133 | 148 | 163 | 178 | 193 | 208 | 223 | 238 | 253 | 268 | 283 | 298 | 313 | 328 | 343 | 358 | 373 | 388 | 403 | 418 | 433 | 448 | 463 | 478 | 493 | 508 | 523 | 538 | 553 | 568 | 583 | 598 |
| 14 | 29 | 44 | 59 | 74 | 89 | 104 | 119 | 134 | 149 | 164 | 179 | 194 | 209 | 224 | 239 | 254 | 269 | 284 | 299 | 314 | 329 | 344 | 359 | 374 | 389 | 404 | 419 | 434 | 449 | 464 | 479 | 494 | 509 | 524 | 539 | 554 | 569 | 584 | 599 |
| 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 | 165 | 180 | 195 | 210 | 225 | 240 | 255 | 270 | 285 | 300 | 315 | 330 | 345 | 360 | 375 | 390 | 405 | 420 | 435 | 450 | 465 | 480 | 495 | 510 | 525 | 540 | 555 | 570 | 585 | 600 |

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# BUSINESS NEWS

## PLANT WATCH

**Construction starts on new helium plant in U.S.**

October 13, 2010 — Air Products and Chemicals, Inc. (Lehigh Valley, Pa.; www.airproducts.com) and Matheson (www.mathesongas.com), a member of the Taiyo Nippon Sanso Corp. (TNSC) group, have announced that onsite construction has commenced on a new, jointly owned liquid-helium production plant near Big Piney, Wyo. The plant, designed to produce 200-million standard cubic feet (scf) per year at startup, with expectations for future expansion to 400-million scf/yr, would process crude helium produced by a natural gas processing facility that would be operated by Cimarex Energy Co. Production at the new Wyoming plant is anticipated to commence in 2011.

**Fluor to design two solar power plants in Spain**

October 13, 2010 — Elecnor S.A. (Madrid, Spain; www.elecnor.es) has awarded Fluor Corp. (Irving, Tex.; www.fluor.com) an engineering services contract for two new 50-MW concentrating solar-power (CSP) plants in Alcazar de San Juan, Spain (for more on CSP plants, see Solar's Second Coming, *Chem. Eng.*, March 2009, pp. 18–21). The project is under way with engineering expected to be complete by the 3rd Q of 2011.

**Ineos Technologies wins Innovene S PE technology license for the Russian market**

October 11, 2010 — Ineos Technologies (Lyndhurst, U.K.; www.ineos.com) has licensed its Innovene S Process for the manufacture of high-density polyethylene (HDPE) and linear low-density polyethylene (LLDPE) to the JSC Angarsk Polymer Plant of Rosneft in Angarsk, Russia. The 345,000-metric ton per year (m.t./yr) plant will produce a full range of Ziegler and Chrome monomodal and bimodal products. The companies have begun the engineering phase of the project.

**Solvay to expand compounding capacity in China**

October 10, 2010 — Solvay S.A. (Brussels, Belgium; www.solvay.com) will build a specialty polymers compounding plant at its site in Changshu in the province of Jiangsu, China. Startup of the plant is expected in the last quarter of 2012. The plant will satisfy the growing demand for specialty polymers in China and requires the investment of €21 million.

**Chiyoda awarded EPC contract for polycrystalline silicon plant in Malaysia**

October 6, 2010 — The Tokuyama Corp. (Tokyo; www.tokuyama.co.jp) group has awarded an engineering, procurement and construction (EPC) contract for a polycrystalline silicon plant in Malaysia to Chiyoda Corp. (Yokohama, Japan; www.chiyoda-corp.com/en) in collaboration with Chiyoda Sarawak Sdn. Bhd. (Sarawak, Malaysia). The 6,000-ton/yr plant will be located at the Samalaju Industrial Park, in Sarawak, Malaysia. Construction will begin in early 2011, with startup slated for spring, 2013.

**Haldor Topsøe and Linde supply technology for POSCO's SNG plant**

October 5, 2010 — The Linde Group (Munich, Germany; www.linde.com) and Haldor Topsøe A/S (Lyngby, Denmark; www.topsoe.com) have been selected as technology suppliers for the syngas treatment and methanation unit of Posco's (www.posco.com) synthetic natural gas (SNG) plant. The new plant will be erected in Gwangyang, South Korea and will have a nominal capacity of 500,000 m.t./yr of pipeline-ready SNG, which will be brought into operation by the end of 2013. It will be the first SNG plant in South Korea.

**Technip awarded two hydrogen-plant contracts in the U.S.**

October 1, 2010 — Technip (Paris, France; www.technip.com) has been awarded two lump-sum contracts by Valero Refining Co. and Diamond Shamrock Refining Co. (both part of the Valero group) for two hydrogen plants at their refineries in Memphis, Tenn. and McKee, Tex. The two 30-million-scfd hydrogen plants will produce high purity hydrogen and export steam. Technip is partnered with Performance Contractors Inc. for the installation of both hydrogen plants. The project is scheduled to be completed in the first half of 2012.

**Toyo-China wins contract for a new ETA plant**

September 29, 2010 — Toyo Engineering Corp. China, a wholly owned subsidiary of Toyo Engineering Corp. (Toyo; Chiba, Japan; www.toyo-eng.co.jp), has been awarded a contract for an ethanolamine (ETA) production plant to be constructed in Jiaxing, Zhejiang Province, China, by Honam Petrochemical Corp. (Korea; www.hpc.co.kr). The 50,000-ton/yr plant is scheduled for completion in the 1st Q of 2012.

**BASF to establish production of water-treatment and paper chemicals**

September 27, 2010 — BASF SE (Ludwigshafen, Germany; www.basf.com) has decided to establish a wholly owned production base for water-treatment and paper chemicals in Nanjing, China, with the construction of a 40,000-ton/yr quaternized-cationic monomers plant and a 20,000-ton/yr cationic-polyacrylamides plant. The two BASF plants are expected to start up production in the 3rd Q of 2012. They mark the first Asian manufacturing of these products for BASF.

## MERGERS AND ACQUISITIONS

**Wacker buys silicone-production plant in South Korea**

October 14, 2010 — Wacker Chemicals Korea Inc., a Wacker Chemie AG (Munich, Germany; www.wacker.com) subsidiary, is acquiring the Lucky Silicone brand from Henkel Technologies (Korea) Ltd. The two companies announced a purchase agreement, with the transaction's closing expected before year-end 2010. The transaction requires antitrust approval.

**BASF to establish Styrolution as a leading company in styrenics**

October 7, 2010 – As part of the strategic development of its styrenics business, BASF SE is establishing a separate company, Styrolution. BASF plans to carve out its businesses in styrene monomers (SM), polystyrene (PS), acrylonitrile butadiene styrene (ABS), styrene butadiene copolymers (SBC) and other styrene-based copolymers and establish separate companies. BASF will retain its global business in polystyrene foams. The SM and PS capacities in Ludwigshafen used to produce foams will also remain with BASF. The carve-out is to be completed by January 1, 2011.

**DyStar sells its Brunsbüttel, Germany site**

September 8, 2010 — CBW Chemie GmbH (Bitterfeld Wolfen, Germany; www.cbwchem.com) and WeylChem Group (www.weylchem.com) have reached an agreement with DyStar Colours Deutschland GmbH (Frankfurt; www.dystar.com) for the acquisition of DyStar's production site in Brunsbüttel, Germany. DyStar plans to transfer most of the production of reactive dyes to Asia at the beginning of 2012. ■

*Dorothy Lozowski*

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

**Novemberr 2010; VOL. 117; NO. 12**

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

# Economic Indicators

2010 2009 2008

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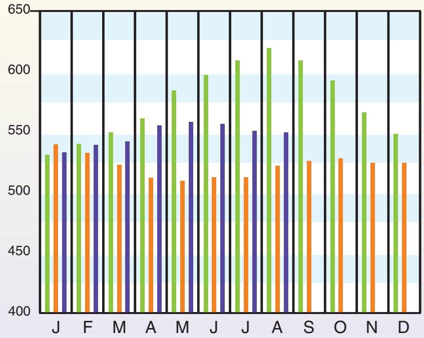
## CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

| (1957-59 = 100) | Aug.'10 Prelim. | July '10 Final | Aug.'09 Final |
|---|---|---|---|
| ***CE* Index** | 549.5 | 550.7 | 521.9 |
| Equipment | 657.3 | 659.2 | 615.8 |
| Heat exchangers & tanks | 605.8 | 611.1 | 560.9 |
| Process machinery | 621.8 | 626.0 | 599.1 |
| Pipe, valves & fittings | 827.1 | 821.7 | 752.0 |
| Process instruments | 416.9 | 416.8 | 400.7 |
| Pumps & compressors | 902.5 | 902.4 | 895.9 |
| Electrical equipment | 482.7 | 481.6 | 462.1 |
| Structural supports & misc | 675.6 | 679.7 | 630.8 |
| Construction labor | 330.1 | 328.7 | 327.5 |
| Buildings | 502.9 | 506.7 | 491.1 |
| Engineering & supervision | 337.9 | 338.4 | 346.0 |

**Annual Index:**
2002 = 395.6
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9

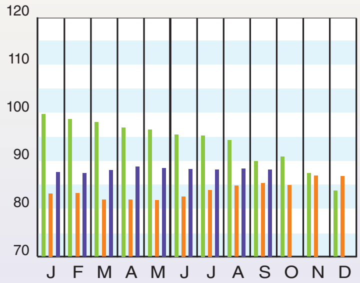
Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics



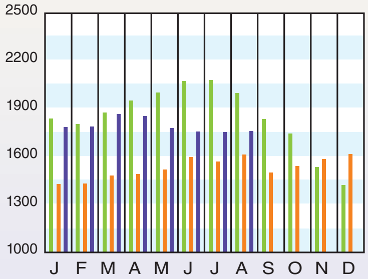

## CURRENT BUSINESS INDICATORS

| | LATEST | | | PREVIOUS | | | | | | YEAR AGO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CPI output index (2007 = 100) | Sep.'10 | = | 88.2 | Aug.'10 | = | 88.4 | Jul.'10 | = | 88.2 | Sep.'09 | = | 85.3 |
| CPI value of output, $ billions | Aug.'10 | = | 1,762.4 | Jul.'10 | = | 1,754.4 | Jun.'10 | = | 1,756.4 | Aug.'09 | = | 1,612.6 |
| CPI operating rate, % | Sep.'10 | = | 71.3 | Aug.'10 | = | 71.3 | Jul.'10 | = | 71.2 | Sep.'09 | = | 68.0 |
| Producer prices, industrial chemicals (1982 = 100) | Sep.'10 | = | 264.1 | Aug.'10 | = | 260.3 | Jul.'10 | = | 258.7 | Sep.'09 | = | 243.5 |
| Industrial Production in Manufacturing (2007=100) | Sep.'10 | = | 90.6 | Aug.'10 | = | 90.7 | Jul.'10 | = | 90.6 | Sep.'09 | = | 85.9 |
| Hourly earnings index, chemical & allied products (1992 = 100) | Sep.'10 | = | 160.2 | Aug.'10 | = | 158.2 | Jul.'10 | = | 153.7 | Sep.'09 | = | 150.4 |
| Productivity index, chemicals & allied products (1992 = 100) | Sep.'10 | = | 120.6 | Aug.'10 | = | 119.9 | Jul.'10 | = | 120.8 | Sep.'09 | = | 121.1 |

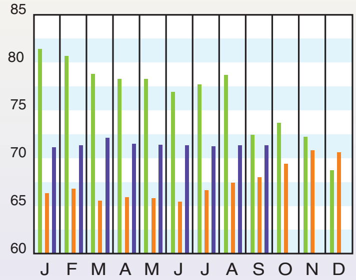
### CPI OUTPUT INDEX (2007 = 100)




### CPI OUTPUT VALUE ($ BILLIONS)




### CPI OPERATING RATE (%)

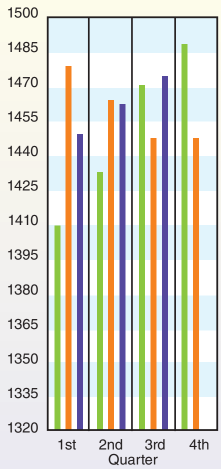



Current Business Indicators provided by Global Insight, Inc., Lexington, Mass.

## MARSHALL & SWIFT EQUIPMENT COST INDEX

| (1926 = 100) | 3rd Q 2010 | 2nd Q 2010 | 1st Q 2010 | 4th Q 2009 | 3rd Q 2009 |
|---|---|---|---|---|---|
| **M & S INDEX** | 1,473.3 | 1,461.3 | 1,448.3 | 1,446.5 | 1,446.4 |
| **Process industries, average** | 1,534.4 | 1,522.1 | 1,510.3 | 1,511.9 | 1,515.1 |
| **Cement** | 1,530.0 | 1,519.2 | 1,508.1 | 1,508.2 | 1,509.7 |
| **Chemicals** | 1,505.2 | 1,493.5 | 1,481.8 | 1,483.1 | 1,485.8 |
| **Clay products** | 1,518.3 | 1,505.6 | 1,496.0 | 1,494.3 | 1,495.8 |
| **Glass** | 1,428.5 | 1,416.4 | 1,403.0 | 1,400.1 | 1,400.4 |
| **Paint** | 1,542.1 | 1,527.6 | 1,515.1 | 1,514.1 | 1,515.1 |
| **Paper** | 1,444.5 | 1,430.1 | 1,416.4 | 1,415.8 | 1,416.3 |
| **Petroleum products** | 1,637.0 | 1,625.9 | 1,615.6 | 1,617.6 | 1,625.2 |
| **Rubber** | 1,579.3 | 1,564.2 | 1,551.0 | 1,560.5 | 1,560.7 |
| **Related industries** | | | | | |
| **Electrical power** | 1,419.2 | 1,414.0 | 1,389.6 | 1,377.3 | 1,370.8 |
| **Mining, milling** | 1,576.7 | 1,569.1 | 1,552.1 | 1,548.1 | 1,547.6 |
| **Refrigeration** | 1,804.8 | 1,786.9 | 1,772.2 | 1,769.5 | 1,767.3 |
| **Steam power** | 1,502.3 | 1,488.0 | 1,475.0 | 1,470.8 | 1,471.4 |

**Annual Index:**
2002 = 1,104.2 | 2004 = 1,178.5 | 2006 = 1,302.3 | 2008 = 1,449.3
2003 = 1,123.6 | 2005 = 1,244.5 | 2007 = 1,373.3 | 2009 = 1,468.6






## CURRENT TRENDS

Capital equipment prices (as reflected in the *CE* Plant Cost Index) declined for the third consecutive month in August, an unusual phenomenon given that equipment prices typically peak around August of each year. The operating rate from July to August was flat.

According to the third quarter 2010 Situation and Outlook Report from, the American Chemistry Council (ACC; Washington, D.C.; www.americanchemistry.com), total output of the global chemical industry is expected to grow by 8.9% in 2010, but then slow to a growth rate of 5.6% in 2011.

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

**Circle 35 on p. 58 or go to adlinks.che.com/29256-35**