CHEMICAL ENGINEERING

October 2009

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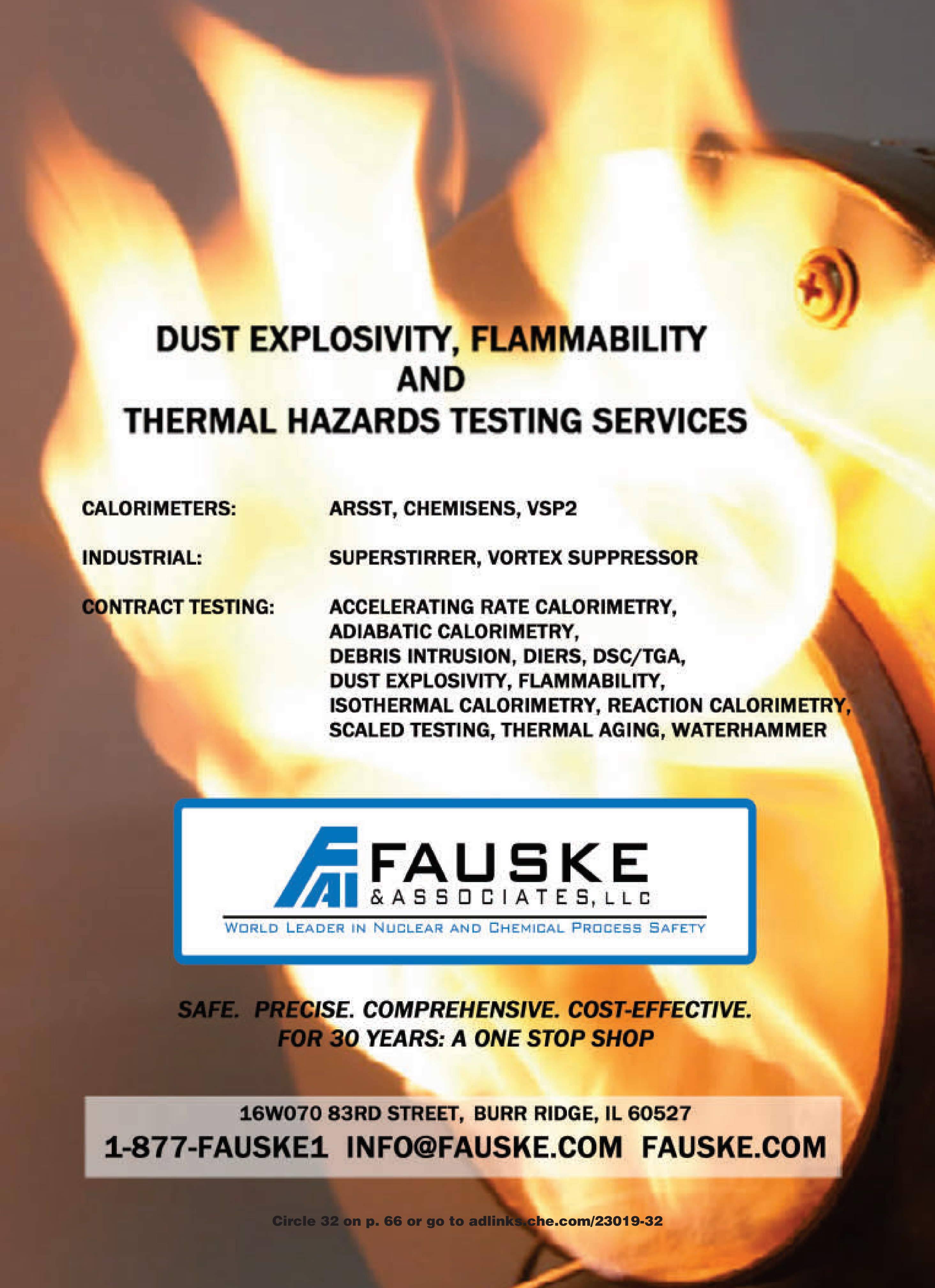
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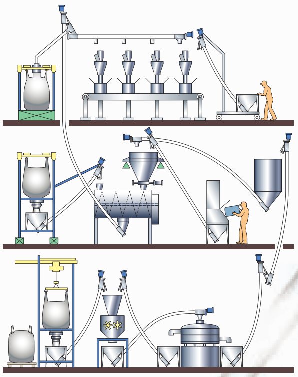

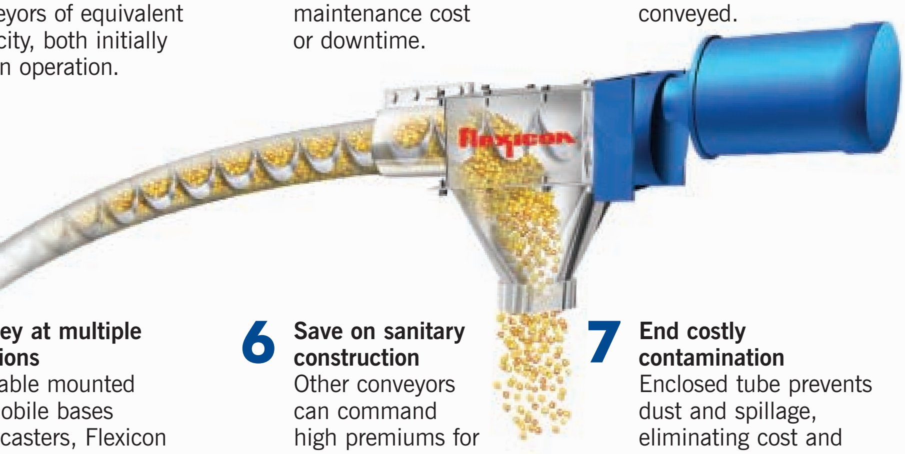

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COVER STORY

34 Cover Story **Estimating the Total Cost of Cartridge and Bag Filtration** When changeout and disposal costs are added to the purchase cost of filters, the total cost of disposable filters can more than quadruple. A proven method of reducing total life-cycle cost is larger surface-area filters

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32D-2 ChemShow Preview (Domestic Edition) This storage unit can survive a 5-psi blast without damage; Increase process capacity with this thin-film evaporator; This vacuum filter is certified to 0.12 microns; Clean-up and maintenance for this round separator is easy; These balances offer redesigned user interface; Get a large filter area with this belt filter; Filter viscous media with this ultrafiltration cassette; Increased process control offered with this absorption sensor; and more

32I-2 New Products & Services (International Edition) Scrub more H_2S with this new adsorbent; Hazmat suits that are certified for safety; Improve vessel cleaning with this new range of spray balls; Connect and disconnect fluid lines safely with this coupler; A wireless modem for gathering data remotely; For high throughputs, consider this dry vacuum pump; This standardized canned-motor pump has built-in protection; and more

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COMMENTARY

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COMING IN NOVEMBER

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Cover: David Whitcher


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Editor's Page

Don't wait to react

Last month, the chemical engineering profession began to feel its first aftershocks from an explosion that occurred nearly two years ago at a plant that most of you would be hard-pressed to recall. The delivery came in an accident report issued by the U.S. Chemical Safety Board (CSB; www.csb.gov). The report determined that the massive December 2007 explosion and fire at T2 Laboratories in Jacksonville, Fla. was caused by a runaway chemical reaction that likely resulted from an inadequate reactor-cooling system.

Concluding that T2 did not recognize all of the potential hazards of the process for making a gasoline additive, the report calls for improving the education of chemical engineering students on chemical reactivity hazards. In fact, the American Institute of Chemical Engineers (AIChE; New York; www.aiche.org) and the Accreditation Board for Engineering and Technology (ABET; Baltimore, Md.; www.abet.org) have been specifically petitioned to work together to include reactive chemical education in baccalaureate chemical-engineering curricula across the country.

Chemical testing by the CSB found that the recipe used by T2 created two exothermic, or heat-producing, reactions; the first was an intended part of producing MCMT but the second, undesired reaction occurred when the temperature rose above 390ºF, slightly higher than the normal production temperature. The cooling system likely malfunctioned due to a blockage in the water supply piping or a valve failure. Consequently, the temperature and pressure inside the reactor began to rise uncontrollably in a runaway chemical reaction. Approximately ten minutes after the initial cooling problem was reported, the reactor burst and its contents exploded. "This is one of the largest reactive chemical accidents the CSB has investigated," said Chairman John Bresland.

The CSB found that although the two owners of T2 had undergraduate degrees in chemistry and chemical engineering, they were likely unaware of the potential or the consequences of a runaway chemical reaction. The CSB noted that most baccalaureate-level, chemical-engineering curricula in the U.S. do not specifically address recognition or management of reactive hazards. The CSB has released a nine-minute safety video, "Runaway: Explosion at T2 Laboratories," containing a description of the causes, consequences, lessons and recommendations resulting from the accident.

In a statement issued by AIChE in reaction to the report, Scott Berger, executive director of AIChE's Center for Chemical Process Safety (CCPS) said, "As this terrible tragedy emphasizes, we agree with CSB that chemical engineering students should learn more about process safety and about chemical reactivity, in particular." Berger noted that CCPS produces prepared lectures and teaching materials on process safety for U.S. universities through its Safety in Chemical Engineering Education (SACHE) program. Professors can obtain educational materials from a Website to use in their classrooms. Meanwhile, SACHE offers an online process-safety-certification program directly to chemical engineering students.

While the heat of the report is being focused on academia, the reality is that the existing training deficit for practicing chemical engineers could take decades to flush itself out of the workforce. Meanwhile, recent staff reductions and the expanded responsibilities for each ChE raise the chances for additional gaps in process safety expertise. That being the case, it's up to each of us to be proactive and make sure that chemical engineers, young and old, stay current with the training they need. Our effort in that vein continues with the article on p. 49. ■

Rebekkah Marshall

Letters

More questions of pressure relief

The following two comments relate to the November 2008 article, "Pressure Relief System Design" (pp. 40–45).

1. On p. 40 the author writes: "Conventional pressure-relief valves are susceptible to back pressure. Such valves are not recommended when the *total* back pressure exceeds 10% of the set pressure." API Std 521 (Jan. 2007) states another criteria in section 5.4.1.3.1: "... Where conventional safety relief valves are used, the relief manifold system should be sized to limit the *built-up* back pressure to approximately 10% of the set pressure of each relief valve that may be relieving concurrently." Could you please clarify the confusion between total and built-up back-pressure?
2. Also, on p. 43, the *k* factor should be omitted from Equation (2) for the Mach number calculation under Isothermal conditions. See API Std 521 (Jan. 2007).

Lionel Sheikboudhou

Author replies

1. Conventional Pressure Relief Valves: In reality, conventional pressure relief valves are recommended when the built-up back pressure is within 10% of the set pressure. However, in actual practice, the picture is sometimes a bit more conservative. In many cases, in process data sheets, the built-up back pressure and the superimposed back pressures are not separately reported. Instead, the total back pressure is reported. The vendor also selects the relief valve based on this total back pressure.

Take the case of a relief valve which has a set pressure of 5 bar(g). The superimposed back pressure is 0.4 bar(g) and the built-up back pressure in case of the contingency is 0.2 bar(g). Going by the built-up back pressure criterion, a conventional relief valve should satisfy the duty. It works out to 4% of the set pressure ($0.2 \times 100/5 = 4$). However, if the total back pressure criterion is applied, it works out to 12% of the set pressure [$(0.4+0.2) \times 100/5$]. A conventional relief valve would not be suitable in this case, and the user would need to go for balanced bellows.

The total back pressure criterion is followed in many cases and results in a more conservative design.

2. The *k* factor in the Mach Number formula: The previous edition of API 521 had this *k* factor included in the formula for Mach Number. However, in the latest edition, it has been removed. In any case, *k* factors are in the range of 1.1 to 1.2 for hydrocarbons, and after taking the square root, the difference in Mach Numbers with *k* and without *k* would not be significant.

Siddhartha Mukherjee
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- Job-related problems or gripes to share?

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Calendar

NORTH AMERICA

Process Chemistry in the Pharmaceutical Indusry, with Special Emphasis on Continuous Manufacturing. American Chemical Society Professional Education (Washington, D.C.). Phone: 800-872-4508 ; Web: acsprospectives.org
Durham, N.C. **Nov. 2–4**

AAPS Annual Meeting and Expo. American Assn. of Pharmaceutical Scientists (Arlington, Va.). Phone: 703-243-2800; Web: aapspharmaceutica.com
Los Angeles **Nov. 8–12**

AIChE Annual Meeting. American Institute of Chemical Engineers (AIChE; New York). Phone: 800-242-4363; Web: aiche.org/conferences/annualmeeting/index.aspx
Nashville, Tenn. **Nov. 8–13**

Introduction to Biopharmaceutical Manufacturing. IBC Life Sciences (Westborough, Mass.). Phone: 800-858-4881; Web: ibclifesciences.com/courses
Boston **Nov. 9–10**

3rd Annual Behavior, Energy & Climate Change Conference. American Council for an Energy-Efficient Economy (ACEEE; Washington, D.C.), the Precourt Inst. for Energy Efficiency (Stanford University), and the California Institute for Energy and Environment (University of California) . Phone: 202-507-4034; Web: beccconference.org/09beccindex.htm
Washington, D.C. **November 15–18**

2009 Chem Show (53rd CPI Exposition). International Exposition Co. (Westport, Conn.). Phone: 203-221-9232; Web: chemshow.com
New York **Nov. 17–19**

2009 Eastern Analytical Symposium & Exposition. Eastern Analytical Symposium, Inc. (Montchanin, Del.). Phone: 203-485-4633; Web: eas.org
Somerset, N.J. **Nov. 16–18**

SOCMA 88th Annual Dinner. Society of Chemical Manufacturers & Affiliiates (SOCMA; Washington, D.C.). Phone: 202-721-4165; Web: socma.com
New York **Dec. 7**

Lab Automation 2010. Assn. for Lab Automation (Geneva, Ill.). Phone: 708-486-0747; Web: labautomation.org
Palm Springs, Calif. **Jan. (2010) 20–21**

3rd ACEEE Forum on Energy Efficiency in Agriculture. The American Council for an Energy-Efficient Economy (Washington, D.C.). Phone: 202-507-4033; Web: aceee.org/pubsmeetings/curmtgindex.htm
Madison, Wisc. **Feb. (2010) 7–10**

Corrosion 2010. NACE International (Houston). Phone: 281-228-6213; Web: nace.org
San Antonio, Tex. **March (2010) 14–18**

EUROPE

ExpoSolidos 2009, 5th International Exhibition for the Technology and Processing of Solids. Profei, S.L. (Barcelona); Phone: +34 932 386 868;
Web: exposolidos.com
Barcelona, Spain **Nov. 17–19**

New Horizons in Catalysis. Scientific Update (East Sussex, U.K.). Phone: +44 (0) 1435 873062; Web: scientificupdate.co.uk
Cologne, Germany **Dec. 3–4**

ASIA & ELSEWHERE

M-Plas 2009: 4th International Plastics and Rubber Trade Fair for Malaysia. Messe Düsseldorf North America (Chicago). Phone: 312-781-5180; Web: mplas.com/event.html
Kuala Lumpur, Malaysia **Nov. 4–7**

2009 Pacific Rim Summit on Industrial Biotechnology and Bioenergy. Biotechnology Industry Organization (Washington, D.C.). Phone: 202-962-9237; Web: bio.org
Honolulu, Hawaii **Nov. 8–11**

Power Bangladesh 2009. CEMS USA (New York), in association with CEMS Bangladesh (Dhaka). Phone: 347-543-5543; Web: powerbangladesh.com
Dhaka, Bangladesh **Nov. 12–14**

Inchem Tokyo 2009. The Japan Society of Chemical Engineers, and Japan Management Assn. (Tokyo). Phone: 03-3434-1410; Fax: 03-3434-3593; Web: jma.or.jp/inchem
Tokyo **Nov. 18–20**

East Asian and Pacific Area Corrosion Conference 2009. NACE International (Houston), in conjunction with NACE Malaysia. Phone: 281-228-6213; Web: nace.org.
Kuala Lumpur, Malaysia **Nov. 23–25**

9th ASCOPE Conference and Exhibition. The ASEAN Council on Petroleum (ASCOPE; Kuala Lumpur, Malaysia). Phone: +66 2 615 1255; Web: ascope2009.com
Bangkok, Thailand **Nov. 26–28**

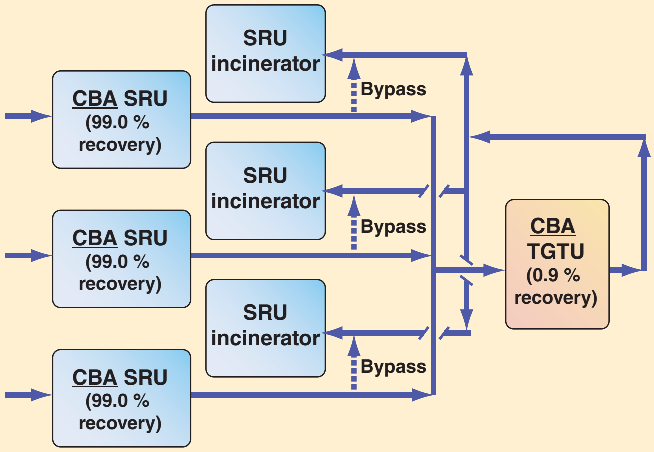
CPhI India. UBM International Media (Maarssen, Netherlands). Phone: +31 346 559 405;
Web: cphi-india.com
Mumbai, India **Dec. 1–3** ■

Suzanne Shelley

CHEMENTATOR

Edited by Gerald Ondrey — October 2009

World's largest refinery starts up a novel sulfur-removal system



Two sulfur-treatment technologies are being used together for the first time in a facility that is now starting up at Reliance Petroleum's Jamnagar Export Refinery (Jamnagar, India). Designed by Black & Veatch (B&V, Overland Park, Kan.; www.bv.com), the facility combines three Claus sub-dewpoint Cold-Bed-Adsorption (CBA) sulfur trains with a single, conventional amine-based tail-gas treatment unit to process up to 2,025 metric tons per day (m.t./d) of sulfur. The facility treats acid gases from a new, 600,000-bbl/d crude-processing expansion that makes the refinery the world's largest, with a total capacity of 1.2 million bbl/d.

Reliance wanted its new refinery to be identical to the original refinery, including the sulfur recovery facilities, which were designed by B&V in 1999. However, in the interim, sulfur recovery efficiency (SRE) requirements increased from 98.7% to 99.9%, so it was impossible to install a clone facility. The original refinery's CBA sulfur recovery complex, which has no tail-gas treatment unit (TGTU), could not achieve higher than 99.2% SRE.

"The unique pairing of three CBA trains with a common conventional tail-gas unit emerged as the best solution," says Angela Slavens, Black & Veatch's vice president and sulfur technology manager. She says the capital cost was comparable to using a more conventional application of three modified Claus sulfur recovery units (SRUs), each with a dedicated TGTU. However, the selected configuration provides for higher overall sulfur-complex-recovery efficiency on a yearly rolling average than the conventional approach, due to the fact that a shutdown of the common TGTU will result in a less significant effect on overall recovery efficiency than an upset or shutdown of just one of the three dedicated TGTUs for the Claus configuration.

The operating cost of the CBA system is lower than that of the conventional option because the common TGTU for the three trains uses approximately 60% less steam, 30% less power, and reduces personnel and maintenance costs by about 50%. Overall, Slavens notes that the novel configuration addresses Reliance's objectives because it minimizes changes to the original SRU design while also affording the numerous benefits described above.

This wastewater-treatment technology can cut sludge by 50% or more

A biological wastewater-treatment technology can reduce sludge by 50% or more in some situations compared to the amount generated by a traditional activated-sludge wastewater-treatment process, according to The Dow Chemical Co. (Midland, Mich.; www.dow.com). Actual sludge reductions vary based on the particulars of the water stream and the specific contaminants at the site.

The lowered sludge generation can significantly extend the life of a landfill and lower disposal costs. Dow began marketing the technology last month to the petroleum refining industry.

Known as Automated Chemostat Treatment (ACT), the technology was developed by BioPetroClean (New York; www.biopetroclean.com) as a more efficient way to reduce levels of total petroleum hydrocarbons (HCs) in either fresh or salt wastewater. ACT is based on the application of a customized bacterial cocktail to a wastewater tank. The bacteria mix is tailored for a specific application and a particular plant. The process depends on identifying and selecting indigenous HC-consuming species that are young and entering the log-growth phase of their lifecycle and subjecting them to a proprietary nutrient package that can be continuously adjusted inside a bioreactor.

"No two bug cocktails are the same," comments Peder Danielsen, commercial director at Dow. The faster-splitting bacteria maintain a lower cell concentration and allow more surface area for breaking down hydrocarbons, Danielsen explains. ACT is a once-through process with no recycling, as in activated sludge processes.

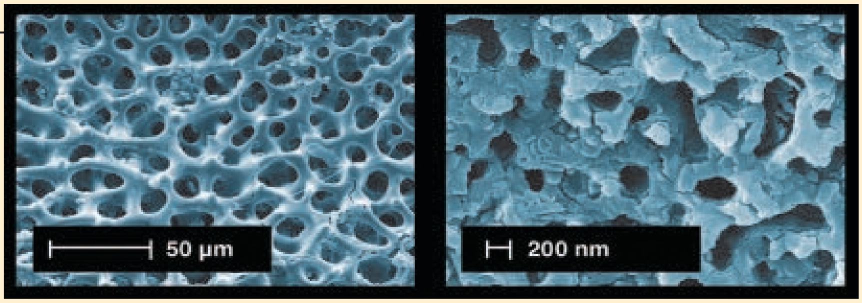
The bacterial cocktail and nutrient package is coupled with a control system capable of constant inline monitoring, which allows operators to avoid upsets in the bioreactor, and so improves process reliability. ACT, which has been successfully demonstrated at several locations around the world, can be applied to wastewater on a continuous basis, as well as applied on a one-time basis to a particular wastewater batch.

Retarded polymerization

A latent-acid catalyst that can be added to highly reactive pre-polymer resins enabling them to be stored for at least three months prior to controlled polymerization at 120°C has been commercialized by Bac2 (Southampton, U.K.; www.bac2.co.uk). Alternative catalysts typically retard violent polymerization reactions for just a few hours, or require activation temperatures above 200°C — levels that are impractical for most polymer manufacturing processes, says the company.

Dubbed CSR10, the catalyst is expected to be particularly useful where polymeric premix production is performed far away from molding operations, because it enables safer transportation and storage of the bulk materials and reduces handling costs, says the firm.

Note: For more information, circle the 3-digit number on p. 66, or use the website designation.



Imitating nature for improved CO_2 capture

Researchers from the University of Sydney (Australia; www.usyd.edu.au) are developing structures, analogous to some sea creatures, for capturing carbon dioxide that is released when producing hydrogen from biomass. The project, funded by German energy company E.ON AG (Düsseldorf), will use renewable sources such as wood and agricultural waste, and plastics, for producing H_2.

"We found that calcium-oxide-based sorbents were the most effective and *Echinodermata* — sea creatures which include starfish and sea urchins — already provided the perfect templates for the structure we sought," says team leader Andrew Harris, of the university's School of Chemical and Biomolecular Engineering. Those creatures have a skeleton of calcium carbonate (photo, left), which is ideal for carbon capture, he says.

The team aims to create a structure (photo, right) with much-smaller (less than 2 nm) and more-numerous pores, with an even greater capacity to capture CO_2, due to its large surface area. The structure, composed of calcium oxides, combines chemically with CO_2, to produce calcium carbonate. When heated to 700°C, the structure releases the CO_2. Since the structure has a high temperature resistance and is preserved, the process is reversible and can be applied many times. The team aims for up to 1,000 cycles.

Harris says some materials used for carbon dioxide capture, such as lime, are not as effective. When heated, its pores tend to collapse or coalesce and the lime cannot be used repeatedly.

This CO_2-capture process promises to have half the energy cost of MEA

Both carbon dioxide and sulfur components are removed from fluegas in a reversible process being developed at Pacific Northwest National Laboratory (PNNL, Richland, Wash.; www.pnl.gov). The process uses a solvent that combines liquid organic bases (amidine and guanidine) and alcohols to absorb CO_2 and sulfur compounds as ionic liquid alkylcarbonates, says David Heldebrant, lead research scientist for the project. The pollutants are stripped for disposal by heating the solvent to less than 140°C, then the solvent is recycled.

Heldebrant says the solvent has a gravimetric capacity of 19 wt.% for CO_2, compared to 7 wt.% for a monoethanolamine (MEA) solution, the conventional absorbent for CO_2. This is because MEA must be used in an aqueous solution, with a concentration limited to about 30% to avoid corrosion problems. In contrast, the organic solvent uses alcohol in place of water, so Heldebrant says the energy cost for stripping promises to be half that of an MEA system.

So far, the process has been tested in the laboratory. PNNL plans to scale up to 100 mL to do process design, then to the 1-L scale for tests on boiler fluegas.

Removing Hg from soil

An in-situ method that removes mercury from soil, sludge and other industrial waste has been patented (U.S. Patent 7 589 248) by scientists at Brookhaven National Laboratory (BNL; Upton, N.Y.; www.bnl.gov). The method shows promise as a simple and inexpensive way to decontaminate large areas tainted with low levels of Hg, where current Hg-extraction methods are expensive and impractical, says BNL.

In BNL's ISMS (in situ mercury stabilization) method, a porous rod containing a sulfur-based reagent (such as sulfur polymer cement, according to the patent), is inserted directly into the contaminated soil. Mercury then migrates to the rod — driven by the greater vapor pressure of Hg, as shown by laboratory testing — where it reacts with sulfur to form a stabilized mercury sulfide. After sufficient time, the rod can be removed for safe disposal at a hazardous waste facility.

So far, the method has been demonstrated in laboratory trials with Hg-contaminated sand. After 50 days, the Hg concentration in a 3-in.-dia. area around the rod is found to be 42 times lower than at the beginning of the test. Work is now underway to scale up to larger areas. BNL believes a single rod will eventually be able to remediate a "very large area of mercury contamination."

Salt anticaker

Last month, AkzoNobel (Amsterdam, the Netherlands; www.akzonobel.com) introduced mTA, a new anti-caking agent for salt. The product — a complex of iron and mesotartrate — is recommended for membrane chlorine electrolysis, instead of the current ferrocyanide. The company says that using mTA eliminates the risk of forming explosive nitrogen trichloride, lowers power consumption and increases the lifetime of membranes and electrodes. The use of the cyanide-free mTA also reduces the environmental impact of deicing salt.

Biosensor for bacteria

Researchers from Rovira i Vigili University (Tarragona, Spain; www.urv.cat) have developed a biosensor that can immediately detect low levels of *Salmonella typhi*, the bacteria that causes typhoid fever. The sensor is composed of carbon nanotubes and synthetic DNA fragments, which generate an electrical signal when they link up with the pathogen. A single Salmonella cell can be identified in a 5-mL sample, and the sensor can make quantitative measurements of up to 1,000 bacteria/mL. Measurements can be performed in real time. In contrast, traditional methods require 1–2 days.

Recycling Li

The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety has awarded €6.7 million to Chemetall GmbH (Frankfurt, Germany; www.chemetall.com) to set up a pilot plant for recycling of lithium ion batteries. Chemetall is part of a consortium of companies par-

(*Continues on p. 16*)

Circle 13 on p. 66 or go to adlinks.che.com/23019-13

Making acrylic acid from glycerin

Nippon Shokubai Co. (Nisshoku; Osaka, Japan; www.shokubai.co.jp) is developing a process for making acrylic acid from glycerin directly obtained as a byproduct from biodiesel-fuel (BDF) production. In 2007, Nisshoku demonstrated, under a grant from the Research Institute of Innovative Technology for the Earth (Kyoto, Japan; www.rite.or.jp), a process that co-produces BDF and glycerin with 98% purity from vegetable-based biomass, such as palm oil. The company has produced 20 ton/yr of fatty acid methyl ester (FAME) with 99 mol% yield, and 2 ton/yr of glycerin at their Tsukuba Research Laboratory. Now, it plans to use this glycerin to make acrylic acid, a precursor for making plastics, coatings, adhesives and elastomers.

In the process, glycerin is dehydrated over a new, supported acidic/basic catalyst to form acrolein, which is then oxidized into acrylic acid using the company's proprietary oxidation catalyst. In conventional routes, acrolein is made from propylene oxide by a two-step process.

Nisshoku is now optimizing the glycerin dehydration step at the laboratory scale, aiming to produce acrolein with a yield of 80–90 mol%, and is also investing ¥2 billion ($20 million) over 2009–2010 for a pilot facility, with support from the New Energy and Industrial Technology Development Organization (Kawasaki, Japan). The company plans to finish bench-scale test and pilot-facility design this year, and begin installation and operation of the pilot facility at its Himehi site for demonstrating acrolein production in 2010. The basic design of a commercial plant is planned for 2011, with a study for commercialization by 2012.

Dandelion rubber

Scientists at the Fraunhofer Institute for Molecular Biology and Applied Ecology (IME; Aachen, Germany; www.ime.fraunhofer.de) have genetically engineered Russian dandelions to make it easier to extract the plant's milky latex. The scientists identified the enzyme responsible for the rapid polymerization that occurs when dandelions are first cut, and switched it off. As a result, four to five times more latex can be obtained. If cultivated on a large scale, every hectare would produce 500–1,000 kg of latex per growing season, says IME.

Dandelion rubber — produced during World War II by Americans, Russians and Germans — has not caused any allergies so far, making it ideal for use in hospitals. This "new" rubber may also become important if the fungal infection afflicting South American and Southeast Asian rubber crops reaches epidemic proportions, causing a collapse of the natural latex industry, says IME.

For large-scale production of dandelion rubber (as well as other chemicals produced by the plant, such as inulin, a natural sweetener), the researchers are working to cultivate the engineered dandelion using conventional breeding techniques. This effort will take about five years, says IME.

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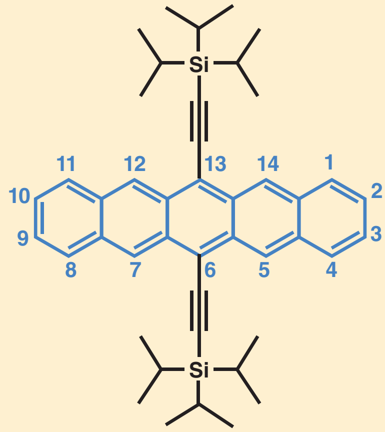


This newly commercialized, organic semiconductor is solutions-processible

The first commercially available, pentacene-based, organic semiconductor material is sufficiently soluble to render it amenable to solution-depositing methods, according to 3M (St. Paul, Minn.; www.3m.com). The company recently began marketing the product as semiconductor L-20856 (TIPS-pentacene) for low-cost transistors.

Substitution of the five-ring system at specific locations (diagram) allows sufficient solubility in a range of hydrocarbon and halogenated solvents. With enhanced solubility, the material can be coated onto substrates using solution deposition methods, such as spin-coating, spray coating and ink-jet printing.

The ability to utilize conventional solution-depositing methods in manufacturing electronic structures makes high-volume, low-cost production possible, explains Larry Ennett, 3M electronics-markets business-development manager. The manufacturing advantages make TIPS-pentacene attractive as a semiconductor material in applications where lower-cost transistors are desirable. These include displays for handheld electronic devices, sensors in radio-frequency identification (RFID) tags, instrumentation readouts and other display formats.

Manufacturing TIPS-pentacene-based electronics does not require the high-capital-cost equipment associated with the fabrication of traditional silicon-based semiconductors. Also, environmentally hazardous chemicals used in photolithographic etching are not necessary.

Developed and studied by Professor John Anthony at the University of Kentucky (Lexington, Ky.; www.uky.edu), the functionalized five-ring aromatic structure exhibits semiconductor performance comparable to amorphous silicon, as well as good stability in opaque containers. The p-type semiconductor has a solubility of 6.57 wt.% in toluene at 23°C. As a solid, TIPS-pentacene is highly crystalline, but can be solution-deposited onto flexible surfaces in thicknesses between 30 and 100 nm.

(Continued from p. 12)

ticipating in the LithoRec R&D project, which aims to develop recycling technologies for Li-ion batteries for electric cars (see also *CE*, September, pp. 16–20).

Existing recycling techniques focus on recycling the small Li-ion batteries used in portable electronics, with little or no recovery of lithium. No process currently exists to recycle car Li-ion batteries, especially the recovery of Li from the cathode and electrolytes, says Chemetall.

Recording operators

Last month, Longwatch, Inc. (Norwood, Mass.; www.longwatch.com) introduced the Operator's Console Recorder, a software module that automatically records images being shown of HMI (human-machine interface) or SCADA (supervisory control and data acquisition) operator's displays. The module takes its signals directly from from each HMI screen's video-software driver, so it records the actual video being sent to the HMI. The software can accommodate video signals from an unlimited number of HMIs to show what operators were watching at the time of an event, alarm or process upset. ❑

A photocatalyst moves closer to commercialization

This Fall, Sumitomo Chemical Co. (Tokyo; www.sumitomo-chem.co.jp) will begin shipping samples of Ilumio, a new photocatalyst, which is 10 times more effective than existing titanium oxide catalysts for deodorizing and antifouling under weak room light. The company plans to install a commercial facility at its Niihama Plant, which will have a production capacity of several tons per year when operational in the second half of 2010. Sumitomo will target the wall-paper, household and automobile interior materials markets, and anticipates near-term annual sales of ¥1 billion ($10 million) for Ilumio.

In 2008, the company developed a titanium-oxide-based Ilumio, and in collaboration with Ryu Abe, an associate professor at Hokkaido University (Sapporo, Japan), discovered that platinum-doped tungsten-oxide nanoparticles (100–150-nm dia.) dispersed in aqueous solution exhibited 10 times higher activity compared to that of the existing photocatalyst products. The WO_3-based catalyst demonstrated a high performance for decomposing volatile organic compounds, as well as for reducing the odors from smoke and diapers after 16 h exposure to fluorescent lamps. Because of Ilumio's superior hydrophilic properties, the company believes the catalyst can also provide antifogging and self-cleaning benefits compared to existing ultraviolet-radiation-driven TiO_2-based catalysts. Ilumio also exhibits antibacterial behavior.

Ilumio will be available in two forms: as an aqueous dispersion (as described above), and as a mixed binder-coating material.

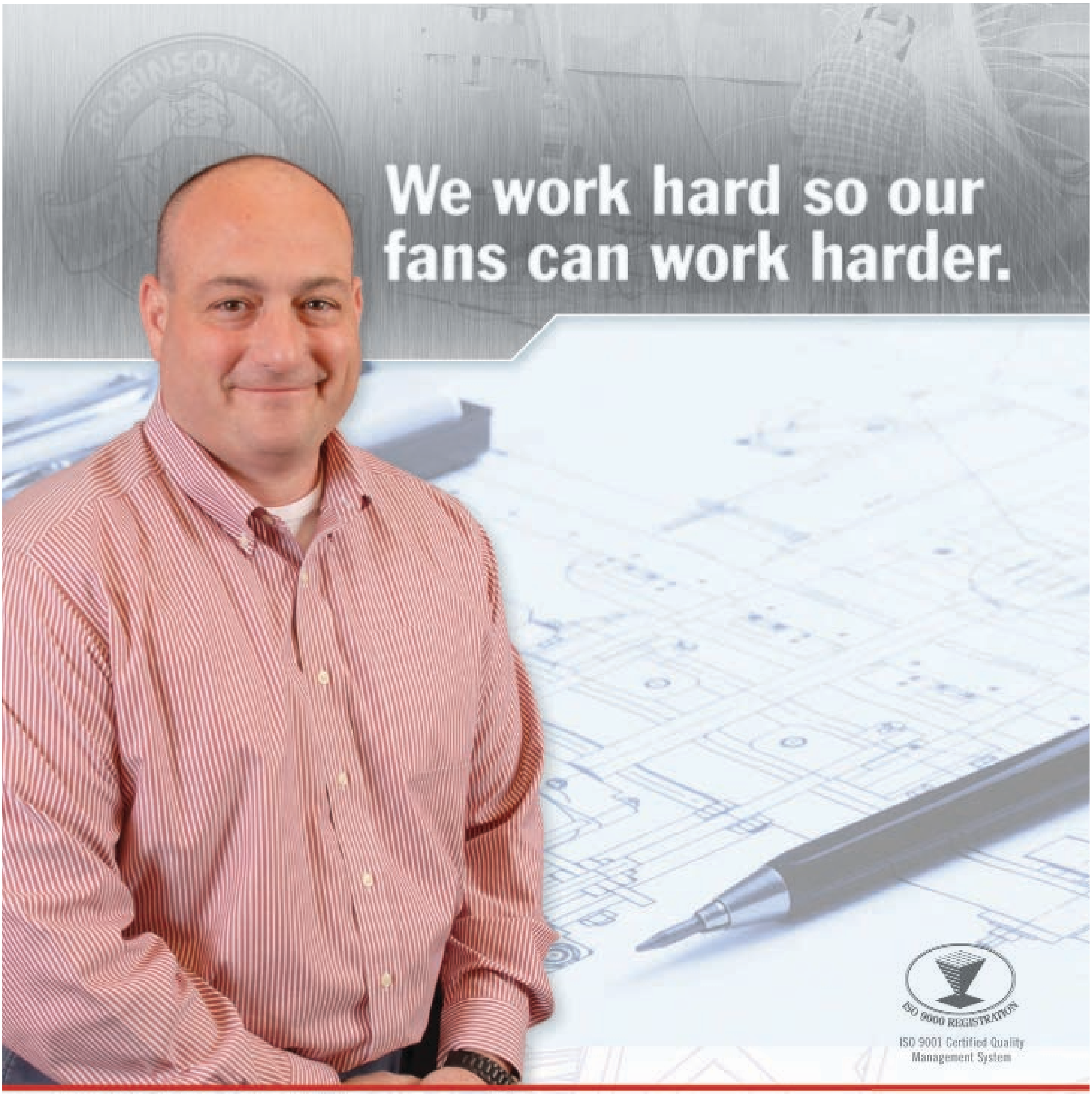
Modular design would shorten construction times for nuclear plants

Small-scale, factory-built nuclear power plants could dramatically reduce construction times and capital costs for nuclear-based power generation. A research team at Sandia National Laboratory (Albuquerque, N.M.; www.sandia.gov) is seeking an industry partner to commercialize a modular reactor design developed at the national laboratory.

The reactors would be built in a modular fashion, with standardized components manufactured in a factory and shipped to the plant site. If modular designs were to be adopted on a commercial scale, the per-unit costs are estimated at as low as $250 million for a 100 MWe plant, Sandia researcher Paul Pickard explains. Modular-plant, initial-capital-cost requirements would therefore be proportionally lower than current, larger-scale plant designs.

The research team estimates the small-scale nuclear plants could eventu-

(Continues on p. 18)


We work hard so our
fans can work harder.
ISO 9000 REGISTRATION
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Corn starch may have a future as a foam packaging material

Foams based on corn starch may one day be substituted for polystyrene foams through technology being developed by the Agricultural Research Service (ARS, Beltsville, Md.; www.ars.usda.gov). The ARS Western Regional Research Center (Albany, Calif.) is working on two processes. One makes a product similar to expanded polystyrene and the other a fiber-reinforced foam.

In the former process, corn starch powder is mixed with plasticizers and about 20% water and put through an extruder to produce a solid string. The material is dried and pelletized, then the pellets are pre-expanded, put into molds and heated to above 120°C to form molded shapes, such as cups or packaging material. In the second process, cellulose fibers from wood pulping are dispersed in an aqueous starch slurry at about 100°C. The mixture is cooled, more starch is added, along with plasticizer, and the material is extruded and pelletized. In this case the pellets are melted in a second extruder at about 170°C and emerge from the extruder as a string of expanded foam because of the sudden pressure drop. In a commercial process the material would be extruded as a sheet, from which dinner plates or other shallow containers could be produced under heat and pressure, says Gregory Glenn, a research plant physiologist.

An advantage of the technology is that it uses inexpensive starch, available from corn, potatoes or wheat, says Glenn. A drawback is that while the material "looks like polystyrene" it absorbs moisture, so the researchers are seeking a suitable water-resistant coating as part of the ongoing development. ■

MODULAR DESIGN

(*Continued from p. 16*)

ally achieve construction times of around one-half to one-third as long as the time needed to construct a large-scale reactor, although construction times vary greatly depending on locations and conditions. Other advantages to the small-scale design are efficiency, which eclipses other current nuclear designs, and times between refueling, which could be upwards of 10 years, compared to 18 months with large power plants.

Designed to produce 100 to 300 MW of power, the small-scale nuclear plants would be an order of magnitude smaller than traditional nuclear power plants. The Sandia system includes breeder reactor technology that generates and consumes its own fuel, with a liquid-sodium-cooled reactor core.

The modular construction model could work well in remote areas, where the electrical grid cannot accommodate large reactors, or for powering military bases. The design also allows for adapting to incremental needs of grids in developing areas.

EMPLOYMENT OUTLOOK

Soft economy means fewer chemical engineering jobs, but salaries hold steady

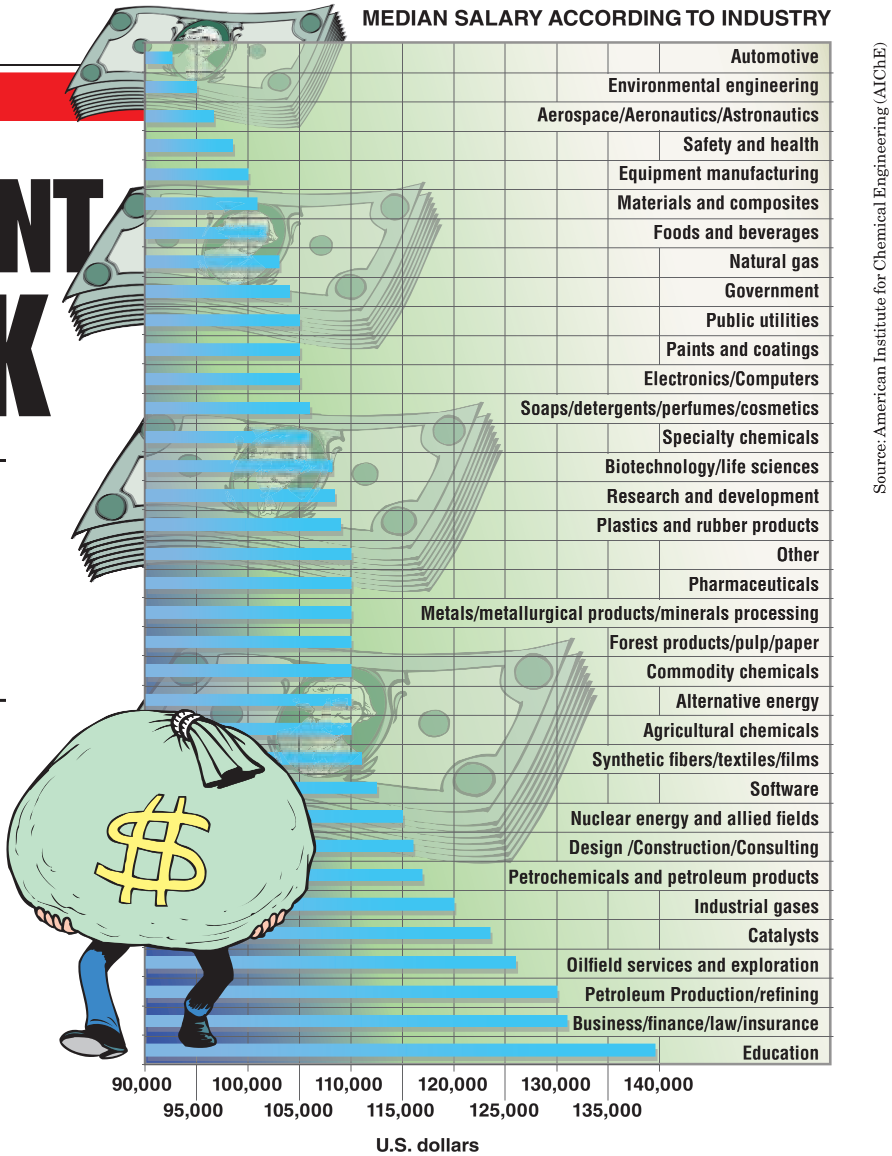


FIGURE 1. Median salaries by industry sector, according to data collected by AIChE. Several areas — electronics/computers, business/finance/law, automotive, forest products/pulp/paper, industrial gases, oilfield services, paints and coatings, safety and health, soaps/detergents/cosmetics, synthetic fibers — have a number of respondents lower than that considered necessary to ensure statistical accuracy

A continued economic contraction remains the dominant feature of the employment landscape for chemical engineers, with fewer job openings and choosier corporate hiring processes, but chemical engineering salaries are strong, according to those closest to the chemical engineering job front. Despite overall job losses in the chemical process industries (CPI), demand for creative chemical engineers with broad skill sets remain strong, which helps support higher salaries.

Larry Jacobsen, executive director of the National Society for Professional Engineers (NSPE; Alexandria, Va.; www.nspe.org), says chemical engineers with creativity, as well as experience that spans multiple areas within the CPI, will always be in demand because they have the ability to solve tough engineering problems.

Survey data from multiple sources indicate that salaries for chemical engineers have generally increased over the past two years. Respondents to the biannual survey of the American Institute of Chemical Engineers (AIChE; New York; www.aiche.org) report salary gains of 7% over 2007 (the last time the survey was conducted). The median chemical engineering salary for 2009 is $110,950 (compared to 103,730 in 2007). Data collected by the NSPE indicate that the 2009 median salary for chemical engineers in that pool is $105,000, a 2% increase over the 2008 value. Medians are considered the preferred measure of typical salaries, because, unlike the arithmetic mean, the median is not affected by extreme values.

While salaries have moved higher, the range of salaries for chemical engineers is significant, points out NSPE's Jacobsen. Top students from the best engineering schools will likely command significantly higher salaries than the rest. Similarly, companies pursuing the best performers in the workplace — especially those with the ability to bring knowledge and insight from one industry sector to another — will drive salaries higher. Data from the AIChE survey indicate that the median salary for the lowest decile of the responding population is $69,230, while the median salary among the top-paid tenth of the responding group is $180,000 (Table 1). Salaries across the spectrum have risen consistently for the past 15 years.

Consistent with expectations, earnings increased with work experience, the AIChE survey shows. The median salary for AIChE survey respondents with less than six years of time on the job is $72,500. The median salary moves to $88,000, $101,000 and $113,000 as experience grows to 6–10 years, 11–15 years and 16–20 years, respectively. The largest group of respondents to the AIChE survey had 26–30 years of work experience and showed a median salary of $130,000.

Recruitment landscape

Although experienced engineers seem to be enjoying solid compensation levels, companies looking to recruit and hire are often taking more time to make hiring decisions and exhibiting choosier behavior when evaluating candidates. Jessalyn Brodie, a recruiting specialist at Engineering Resource Group (ERG; Morris Plains, N.J.; www.engineeringresource.com) says the number of contract and permanent job openings for which the firm is conducting searches has dropped by two-thirds since last year. Rick Brandeis, senior partner at the recruiting firm CPS Inc. (Westchester, Ill.; www.cps4jobs.com) says his company has been conducting only 60%–70% of its usual business in the last few months. Patrick Ropella, founder of the chemical engineering recruiting firm Ropella Group (Milton, Fla.; www.ropella.com) adds that his firm has seen "replacement hiring" fall to half of last year's level, while "growth hiring" — indicating expansion of production — has fallen even more sharply, at "barely a tenth of what it was" in past years. Job losses and cost-cutting have meant that companies have a wider choice of candidates for jobs, a situation that for some time had been reversed, with job seeking engineers having a choice of multiple positions.

The fewer open positions can likely be attributed to several factors. Amid the economic slowdown, lower demand for chemicals and chemical products across the wider economy has resulted in cuts on CPI production lines. Analysis by the U.S. Bureau of Labor Statistics (Washington, D.C.; www.bls.gov) indicates that production cutbacks are responsible for the majority of job losses in the chemical industry as a whole. Smaller production levels and several cases of postponed facilities-expansion projects have resulted in net negative growth in job openings for chemical engineers. At the same time, those companies that are looking to hire for specific needs have been adopting somewhat of a "wait and see" attitude toward the process, says CPS Inc.'s Brandeis. Another factor that is playing out in the recessed economy is the delayed retirement of engineers from the "Baby Boomer" generation, says Ropella. "There was an anticipated increase in demand for highly trained people in the sciences as boomers started to retire," he explains, "but now many are working longer" because of the economic situation.

TABLE 1. BASE SALARIES ACCORDING TO YEARS OF WORK EXPERIENCE

Years experience	Number of respondents	First decile	First quartile	Median	Mean	Third quartile	Ninth decile
< 6	367	$55,000	$64,000	$72,500	$76,811	$88,000	$105,000
6 to 10	268	$67,805	$77,000	$88,000	$93,976	$108,225	$121,640
11 to 15	262	$75,300	$87,400	$101,100	$108,293	$120,000	$144,840
16 to 20	261	$80,000	$95,000	$113,000	$119,629	$133,000	$169,300
21 to 25	353	$84,700	$101,100	$119,400	$126,404	$145,065	$180,000
26 to 30	487	$92,800	$107,580	$130,000	$140,479	$160,000	$200,000
31 to 35	380	$87,000	$105,000	$125,000	$137,408	$159,450	$198,000
36 to 40	205	$96,300	$110,000	$135,000	$149,409	$175,500	$222,000
> 40	157	$50,000	$95,750	$125,000	$130,430	$172,466	$207,280

Source: American Institute of Chemical Engineering (AIChE)

A similarly mixed picture with regard to job openings and salaries emerges for chemical engineers beginning their careers. Andrea Koncz, communications manager for the National Assn. of Colleges and Employers (NACE; Bethlehem, Penn.; www.naceweb.org), says that compared to a year ago, there are fewer entry-level positions for chemical engineers with bachelor's degrees, but salaries offered for those positions compare very favorably to previous years. Surveys of recent college graduates in all fields show that the highest average starting salaries are commanded by petroleum engineers ($83,121) and chemical engineers ($64,902). Despite the lower number of job openings, Koncz has not observed a dramatic surge in students opting to attend graduate school rather than wading into the tough job market. Among chemical engineers, Koncz says the smaller number of chemical engineering graduates in the U.S. could boost demand for local candidates.

Recruiters show a cautiously optimistic side when looking toward the future. CPS Inc.'s Brandeis says the "worst is probably over" for the economic situation with regard to chemical engineering jobs. ERG chemical engineering recruiter Allan Berman senses a rebound also, pointing out that his company has observed a recent decrease in the number of recently laid off engineers approaching the company for job search help.

Job prospects show hot spots

The effects of the recession on the CPI have been the dominant force in shaping the employment landscape, but they have not been uniform across all industry sectors. Several subsections are particularly active, while others are slower than average, even given the economic downturn. Ropella comments that employment opportunities in areas of the CPI involved with renewable energy and the environment are particularly strong. Chemical engineers can find openings in biodiesel and ethanol production as well as in solar and wind power. Ropella adds that opportunities in water and waste treatment are also prevalent. However, recession-wary companies are cutting costs by canceling or postponing capital-intensive projects, so there are few new plants beginning construction, Ropella explains. ERG president Jim Terkevitch adds that chemical engineers can also find solid job prospects in the defense/aerospace and medical device industries.

Other areas where the job outlook is holding strong have to do with job functions rather than particular fields. Process control and process safety positions are relatively abundant, says Brandeis. Examples of other CPI sectors with relatively strong job out-

CAREER ADVICE

Engineering Resource Group's Allan Berman and Jessalyn Brodie offer some tips to chemical engineers for keeping a current job and for landing a new job. The two will present a job search strategy presentation at the November 2009 Chem Show in New York (See show preview, page 32D-2).

- Pay close attention to the current and anticipated project workload — if existing projects are diminishing and no new ones are starting up, it may be a good time to start a job search
- Organize resumes chronologically, not functionally, in one to three pages. The current reality is that resumes are often scanned electronically for keywords relevant to the position, so it's better to include more details
- Customize your resume to highlight experience most relevant to a specific position
- Emphasize your technical knowledge in answering interview questions, but if you don't know a certain area, say so and underscore your willingness to learn
- Ask questions during the interview to assess the company's long-term stability and growth potential
- Send post-interview thank-you notes, but don't restate qualifications in the note, just express interest in the position and thank the interviewer for his or her time
- Think twice about accepting counteroffers from your current company — no matter what your employer tells you when counteroffering, you may be viewed as disloyal and your working relationship will never be the same
- Show enthusiasm and be positive — The manner in which you speak is as important as what you say ■

looks include consumer-driven areas like personal care products, cosmetics, food-and-beverage and soaps-and-detergents industries. On the other hand, sectors with poorer job outlooks include suppliers of the automotive and housing industries, the pharmaceutical industry and the coatings and adhesives markets.

To a small extent, salaries reflect the number of job openings in certain areas. For example, median salary in a "down" industry like automotive was $92,600, according to engineers responding to the AIChE survey, while median salary for a "hot" area like alternative energy was $110,000. (note: number of respondents classifying themselves as "automotive" is relatively small). However, the salaries generally are defined by other factors than the number of openings. The industry areas with the highest (education, business/finance/law, and petroleum production) and lowest (aerospace, automotive, environmental) median salaries tended to fall into neither the category of greatest nor least hiring activity as observed by the recruiters.

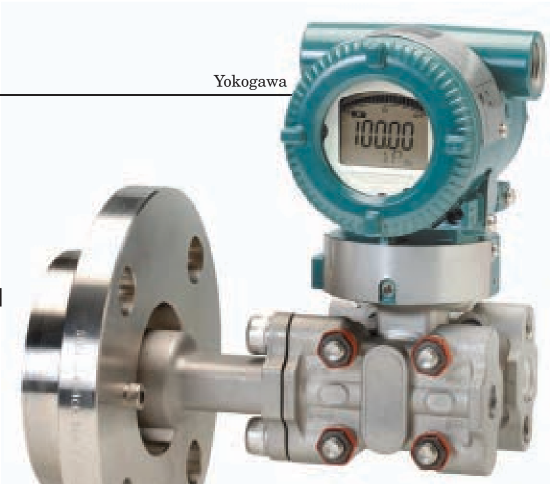
Function and geography

The AIChE salary survey indicates subtle variations in median chemical engineering salaries according to geographic area. For example, median salaries in the petroleum-heavy gulf states (Texas, Louisiana, Alabama, Mississippi) hover between $120,000 and $125,000, while those in the Rocky Mountain region, the plains states of the Midwest, and the southeastern U.S. come in around $15,000–$20,000 less. Median salaries in the middle Atlantic region, which includes states with high CPI presence, like New Jersey, as well as the Pacific region split the difference, with median chemical engineering salaries coming in at around $113,000–$114,000.

Variations in median salaries also appear significant between survey respondents who are divided by industry. Engineers in education reported the highest median salary ($139,560), and those in petroleum production and refining followed at $130,000. Engineers in the law, insurance or finance fields, were the only group whose median salary topped $130,000, although the number of respondents in that category was less than 20, compared with almost 200 in education and over 250 for petroleum refining. Other industries with higher median salaries include oilfield services and exploration ($126,000), catalysts ($123,000) and industrial gases ($120,000). Industries with median salaries over $110,000 include petroleum products ($116,900), nuclear energy ($115,000), software ($112,000) and synthetic fibers and films ($111,000). Industries with the lowest median salaries as reported include aerospace ($96,600), automotive ($92,600), environmental engineering ($95,000) and safety and health ($98,480). ■

Scott Jenkins

FEELING THE PRESSURE



Yokogawa

FIGURE 1. The EJX210A has a chemical diaphragm seal attached to it and is predominately used to measure level in a tank containing chemicals. The EJ910A shown is directly mounted and attached to a Junior orifice plate and installed in a pipeline

Enhanced pressure transmitters can help processors reduce maintenance and labor costs during the economic pinch

As the chemical process industries (CPI) continue to battle with cost containment, labor cost management and maintenance cost issues, there is additional pressure on engineering and maintenance staffs to deploy resources where they are needed the most. Though small in stature, pressure transmitters can actually play a sizeable role in this type of process optimization.

The reason is simple. Both pressure and temperature make up the largest majority of I/O points in most process plants. Pressure transmitters are used to take not only pressure-related measurements, but flow and level measurements as well, so, statistically speaking, technicians spend more time working on a process loop that has a pressure transmitter than any other type of process instrument, acknowledges Dave Matherly, product manager of advanced product solutions at Yokogawa Corp. of America (Newnan, Ga.).

Add to that the fact that cost cutting measures have resulted in a heavy maintenance load for the remaining electricians and mechanics and you end up with a situation where ease of instrument maintenance becomes paramount. For this reason, transmitter manufactures are striving to provide device enhancements and so-called reference class instruments that simplify the configuration, installation and maintenance of pressure transmitters, thus allowing labor to be managed more effectively.

Reducing maintenance labor

"In chemical plants, there are obviously a lot of maintenance costs associated with transmitters and, when a device starts going bad — regardless of how accurate a process needs to be — a reference-class device is becoming routinely specified. The technicians won't have to touch it for a while and they will get better performance from this class of instruments," explains Jim Shields, product marketing manager for Fluke Process Tools (Everett, Wash.). "On an as-needed basis, we see more and more chemical processors moving toward these devices because labor is more expensive than the acquisition cost of the device."

However, Shields warns that claims of nearly calibration-free reference-class devices must be taken with a grain of salt. "When they say no calibration is required, it really means no adjustment is required," he notes. "Calibration is a measured value to a traceable standard. A 'calibration-free' device is often one that is stable and doesn't need adjustment, but if it is in a safety shutdown circuit or critical process, the performance must still be verified via calibration every few months according to OSHA and other regulatory agency mandates."

In other words, even reference-class instruments will not be completely hands off and maintenance free for ten years, even if touted as requiring no adjustments or "calibrations" over that time period. However, they are still a lower-maintenance option, acknowledges Shields.

Along with reference-class devices, "smart" instruments can also help reduce costs. Over the years measurement devices have gone digital, which means they are more "intelligent" instruments with more diagnostic features and more secondary process variables, such as sensor, maximum pressure, and so on, says Thomas Reus, product manager for pressure measurement with JUMO GmbH & Co. KG (Fulda, Germany).

JUMO's dTRANS p20 transmitter is one example. Reus says its "intelligence" can help cut costs and simplify maintenance. For instance, the minimum/maximum function gives additional insight into the process history because in a level measurement application, for instance, the instrument shows the maximum and minimum level. The over- and under-range function permits the transmitter to give an additional signal on LCD (liquid-crystal display) and via HART protocol. This function can be used as a warning in the event of a too-high or too-low process variable. And, the self-diagnostic sensor detects certain types of sensor damage via permanent self-diagnostic routines. This makes the process or the application safer, more reliable and easier to troubleshoot, notes Reus.

Emerson is also working on intelligence and diagnostics with the launch of Phase 2 of the 3051S HART Diagnostic pressure transmitter later this year. The original transmitter in this line offered statistical process monitoring (SPM), which brought the diagnostic capabilities beyond the envelope of the transmitter. This function was enabled by hardware microprocessors, memory and smaller components that allow the unit to consume less power.

The newest version of this pressure transmitter will further broaden the "outside the envelope" diagnostics

JUMO

FIGURE 2. The JUMO dTRANS p20 includes high-end sensor technologies, which provide the basis for reliability, long-time stability and precision. The transmitters have a very simple operating concept, which allows installation and configuration with minimum effort. This transmitter also provides a modern "rotary-knob," which simplifies manual operation

with the inclusion of basic SPM, as well as the addition of power diagnostics and other features.

"The power diagnostic tool 'learns' the characteristics of the power in the loop," explains Dale Perry, pressure marketing manager with the Rosemount division of Emerson Process Management (Chanhassen, Minn.). "Once set, the transmitter learns at which milliamps the voltage should be, and if something happens within the loop, the transmitter will send an alert. It can tell users if the process is headed into a brown out or other dangerous condition."

This knowledge, along with the other diagnostics, helps the user determine if the transmitter is broken, or if there's something going wrong in the process, which allows time to correct the situation before a breakdown. "The information serves as a precursor to allow scheduled maintenance versus reactive," says Perry.

In addition there is a function within the transmitter that serves as a diagnostic log capable of recording and time stamping any occurring error. Whether the issue is a hardware transient or a failure transient, the operator sees an output spike, and because the transmitter logs and timestamps the variation, a technician can look into the diagnostic log and see if something happened outside the envelope of the transmitter or if it shows a hardware fault, which would require a new transmitter. "Such advanced diagnostics are extremely helpful when it comes to optimizing a process and streamlining maintenance activities," says Perry.

Simplifying diagnostics

While diagnostics can be a useful tool, if a technician doesn't understand what the diagnostic code means, it doesn't provide any real help. "When you get an error on most transmitters, a numeric code is provided. A technician has to locate a manual and look up the code to find out what it means. This takes a lot of time and effort and wastes maintenance labor hours," says Perry.

For this reason, several vendors are adding human-machine interface (HMI) capabilities to their lines of pressure transmitters. Most recently, Emerson's group of HMI-centered design experts developed a new interface that is user friendly and will be available on transmitters and other devices this fall. "Users won't get an array of lights and will only get a message if there's an actual error," notes Perry. "The rule on the interface is that if you get an error, you have to say what

the error is, describe the error and give troubleshooting tips and have a drawing available. Right on the new interface it has conditional graphics so that, on the fly, it will tell you the transmitter's status. When you click on the graphic it tells you what's wrong and what actions to take."

Setup also is simplified. "We have a number of methods, or a series of instructions, that users go through. These methods walk users along to simplify setup for each particular function," notes Perry.

The interface provides troubleshooting, pictures, methods and other media needed to lead users through setup and any customized applications. "This is a new frontier, and it will help make processors more productive," he says.

ABB (Austin, Tex.) also offers an HMI to help with labor issues. "Many of our customers are trying to handle the demographic shift from older, experienced workers, who are used to analog products, to younger workers who are digitally oriented and are more interested in the suite of information available than in how the measurement is made," explains Allen Hood, pressure product manager with ABB.

The HMI, he says, provides a more "dynamic" way to get information at the local device/instrument level for both types of workers. Because the HMI display is common for all of ABB's newer products and is available on some other ABB product lines, it allows customers to avoid the expense of using a handheld communicator. Instead, there is a touch display that gets them into the menu. And the menu on the display simplifies finding and using all the instrument's available capabilities.

Expanded capabilities

And, in an effort to help processors do more with less, vendors are indeed providing more and more capabilities on their pressure transmitters. ABB is working to broaden the spectrum of capabilities of its pressure devices. For example, options within the company's 2600T pressure transmitters range include a multivariable transmitter offering a three-in-one solution for the measurement of flows of liquids, steam or gas with absolute pressure and temperature compensation. Also available is an absolute pressure sensor for measuring process pressure and a differential pressure sensor for flow measurement; and the multivariable version can also be fitted with an optional, external temperature sensor. The combination of these different measurements enables users to select appropriate accuracies for their applications including 0.04%, 0.075% and 0.15%.

Incorporating three different forms of measurement into one unit can also significantly reduce installation costs, save on installation through the need for fewer devices and reduce the

PRESSURE TRANSMITTER VENDORS AND SERVICE PROVIDERS:

ABB	www.abb.com	KOBOLD Instruments	www.koboldusa.com
Brooks Instrument	www.brooksinstrument.com	Omegadyne	www.omegadyne.com
E Instruments Group	www.einstrumentsgroup.com	Emerson Process Management	www.emerson.com
Fluke Process Tools	www.fluke.com	Siemens Energy & Automation	www.sea.siemens.com
Gems Sensors	www.gemssensors.com	WIKA Instrument Corp.	www.wika.com
JUMO	www.jumo.net	Yokogawa	www.yokogawa.com

amount of cabling and I/O devices required. With a nominal operating pressure of up to 400 bar and a differential-pressure measuring range of 0.5 mbar to 100 bar, the 2600T multivariable transmitter is suitable for high-end process automation applications.

Yokogawa, too, has a transmitter loaded with capabilities. The EJX series of pressure transmitters incorporates an improved digital harp sensor and improved capsule design. The transmitters are smaller, more responsive (90 ms response time) and offer additional intelligence and self-diagnostics. Other features include an additional set of contacts that can be used as an assignable alarm (open collector).

A recent addition to the EJX family is the Multivariable transmitter, EJX910A, which allows a number of flow elements (orifice plates, venturi, averaging pitot, and so on) to be used with the device. It can be configured to measure mass or volumetric flow and references all the appropriate industry standards for compressibility and density compensation. The EJX910A also contains an additional set of parameter-assignable contacts. Along with having the ability to assign the contact closure to an alarm event, they can be used for a frequency output to match the transmitter's measured flowrate, or be used for providing a scaled pulse output equal to a specified flow amount.

However, unlike the HMI interface that would be provided with Emerson/Rosemount and ABB's high-capability pressure transmitters, Yokogawa's product would have interface and configuration accomplished via FieldMate PC-based software.

This software tool simplifies commissioning and maintenance of HART, Foundation Fieldbus and Yokogawa's BRAIN devices. Complete configurations, which can be stored within its database along with maintenance and system information, can be retrieved and downloaded to replacement instruments in the field or at any point within the loop itself. "FieldMate speeds the device configuration and commissioning of smart instrumentation," says David Matherly, product manager, Advanced Product Solutions, Yokogawa. This advance creates, yet another labor savings.

Whether a transmitter is reference class, intelligent or loaded with capabilities, and whether an HMI or software tool helps simplify setup, enhanced pressure transmitter devices are helping to reduce some of the pressure felt by chemical processing end users. ■

Joy LePree

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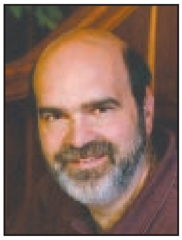
WHO'S WHO


Hester


Koch


Shankland


Ragosta


Blinn

Swagelok Company (Solon, Ohio) names *David Hester* general manager of Swagelok Ltd. (Isle of Man, U.K.).

Joseph Acker retires as president and CEO of the **Society of Chemical Manufacturers & Affiliates (SOCMA;** Washington, D.C.), effective December 2009.

Juergen Gunther, head of global marketing for the technical rubber products unit of specialty chemical company **Lanxess AG** (Leverkusen, Germany) is now the new management board chairman of Deutsche Kautschuk Gesellschaft, the German Rubber Soc.

Wilhelm Sittenthaler becomes president and CEO of **Siltronic AG** (Munich, Germany).

Brice Koch joins the group executive committee of **ABB** (Zurich), in the new role of head of marketing and customer solutions.

Robert Dellinger becomes senior vice-president of finance, and CFO for **PPG Industries** (Pittsburgh).

Honeywell Specialty Materials (Morris Township, N.J.) names *Ian Shankland* vice-president and chief technology officer.

Joe Ragosta becomes CEO of equipment manufacturer **Ely Energy** (Tulsa).

Mark Blinn becomes president and CEO. **Flowserve Corp.** (Dallas), succeeding the retiring Lewis Kling, who becomes vice-chairman of the board. ■

Suzanne Shelley

Circle 25 on p. 66 or go to adlinks.che.com/23019-25

Addressing the most critical challenges that chemical engineers face today with practical, results - centered advice

The tracks and sessions being offered are:

Solids Processing

- **Blending and Segregation and Their Effects on Product Quality**
- **Selection of Screws, Belts, and Rotary Valve Feeders for Reliable Flow and Rate Control**
- **Preventing Bulk Solids Caking and Particle Attrition**

Presented by
Eric P. Maynard, Senior Consultant, Jenike & Johanson Inc.

Automation & Control

- **Wireless and Asset Management – Small Investments, Quick Returns**

Presented by
Stephen Lambirght, Vice President of Marketing and Customer Services, Apprion
Andrew Nolan, Wireless Networking Consultant, Honeywell Process Solutions
Rusty Ekness, Director of Global Sales & Marketing for Emerson Process Management's Asset Optimization business

Career

- **How to Find and Secure the Best Job**

Presented by
Jessalyn Cotter, Recruiting Manager, Engineering Resource Group
Allan Berman, Account Executive/Recruiter, Engineering Resource Group

Cost-Effective Conservation

- **Biomass Energy – Practical and Cost-effective Applications in the CPI**

Presented by
Thomas F. McGowan, PE, President and Founder, TMTS Associates Inc.

- **Water Treatment and Reuse**

Presented by
Peter S. Cartwright, PE, Cartwright Consulting Co.

Register now and gain insight and information to help your business today!

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Chemical Resistance of Thermoplastics

Corrosion is estimated to account for a significant portion — 8–10% — of total annual-plant-capital expenditures for the chemical process industries. To avoid it, engineers can consider corrosion-resistant plastics for process piping and storage vessels. Thermoplastics are generally resistant to chemical attack and thus suitable for many process applications. However, plastics must be selected based on process specifics. When chemicals affect plastics, it usually happens as: chemical solvation or permeation, where physical properties may change, but the polymer molecular structure is not chemically altered; and direct chemical attack, where a chemical reaction with the polymer occurs.

References

1. "Perry's Chemical Engineers' Handbook: 8th ed." McGraw Hill, New York, 2008.
2. Nibco Chemical Resistance Guide. Nibco Inc. Elkhart, Ind. 2003.
3. Plastics Pipe Institute. Chemical Resistance of Thermoplastics. Techincal Report 19. 2007.

CHEMICAL RESISTANCE OF SELECTED COMMERCIAL THERMOPLASTICS AND ELASTOMERS

Name	Notes	Recommended Uses	Uses to Avoid
ABS (acrylonitrile butadiene styrene)	Smooth inner surface and resistance to deposit formation Resistant to a wide variety of materials up to 65°C (150°F)	•Commercial sanitary systems •Weak acids	Oxidizing acids
PVC (polyvinyl chloride)	Most frequently specified of all thermoplastic materials	•Chilled water •Deionized water, irrigation •Salt solutions •Acids •Alkalis	Polar solvents, such as ketones
CPVC (chlorinated polyvinyl chloride)	Better chemical resistance than PVC	•Hot corrosive liquids •Hot or cold water	Ultraviolet (UV) radiation
PE (polyethylene)	Lowest-cost commercially available plastic. Pipes generally must be supported	•Ethanol, methanol •Sodium, potassium, calcium hydroxide (30%) •Glycol •Oils, natural gas, gasoline	•Diethylether •Methylene chloride •Ethylene chloride
PP (polypropylene)	Lightweight polyolefin Can be used at higher temperatures than PE	•Organic solvents •Resistance to sulfur-bearing compounds •Salt-water disposal lines •Crude-oil piping •Mixtures and acids, bases, solvents	•Strong oxidizing agents •Chlorinated hydrocarbons •Aromatics
PVDF (polyvinylidene fluoride)	Best combination of strength, chemical resistance and working temperatures	•Wet or dry chlorine, bromine, other halogens •Acids, bases, organic solvents	Fuming sulfuric acid
EPDM (ethylene propylene diene monomer)	Good abrasion and tear resistance	Variety of acids and bases, alcohols, ketones	•Petroleum oils •Strong acids •Strong bases
Chlorosulfonated polyethylene (Hypalon)	Good resistance to ozone, flames	Salt solutions, nitric, sulfuric, hydrofluoric acids	Fuming nitric and sulfuric acids
Neoprene	Among the first synthetic rubbers developed	•Food and beverage applications •Vegetable oils	•Strong oxidizing agents •Chlorinated solvents •Esters •Ketones
Nitrile	Copolymer of butadiene and acrylonitrile	•Solvent •Oil •Water •Hydraulic fluid	•Highly polar solvents •Chlorinated hydrocarbons
Polyamide (Nylon)	Hygroscopic material Good abrasion resistance	•Gasoline •Alkanes •Acetone, methylethyl ketone	•Strong oxidizing agents •Phenols •Mineral acids
Fluorocarbon	Inherently compatible with a wide spectrum of chemicals	•Mineral acids •Salt solutions •Chlorinated hydrocarbons •Petroleum oils	Steam
Polytetrafluoroethylene (PTFE; Teflon)	Most chemically resistant plastic commercially available	Outstanding resistance to most chemicals and solvents	Molten metals
PEEK (polyether etherketone)	Can be used at higher temperatures than PTFE; physical characteristics approaching some metal	•Heat transfer fluids •Steam •Hydrocarbons	Concentrated nitric, hydrochloric, hydrobromic, hydrofluoric and sulfuric acids
Polyethylene teraphthalate (PET)	Shows resistance to ultraviolet radiation	•Hydrocarbon fuels •Water •Ethanol, ethyl ether	•Concentrated sulfuric acid •Phenol •Acetone

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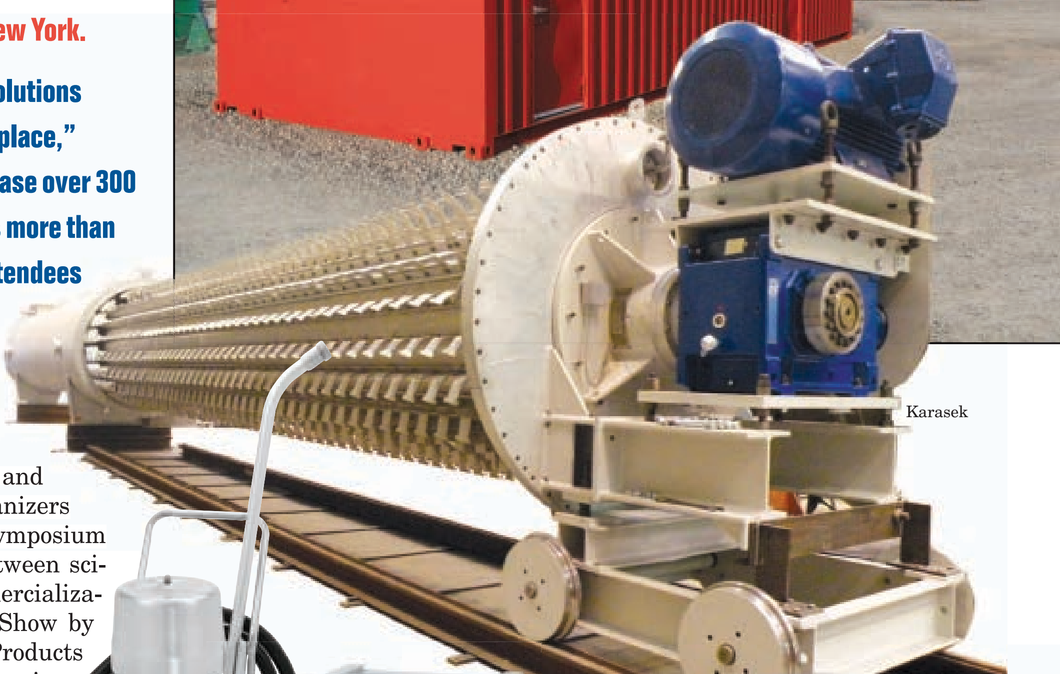
The New CHEMSHOW
Processing Solutions for a Changing Marketplace


A Box 4 U

The 53rd ChemShow exhibition will be held November 17–19 at the Jacob Javits Convention Center in New York.

Themed "Processing Solutions for a Changing Marketplace," ChemShow 2009 will showcase over 300 exhibitors and anticipates more than 10,000 professional attendees


Karasek


Goodway Technologies


Mettler Toledo


Sweco

ChemShow 2009 will feature a technology conference and symposium on nanoscale materials and "green" technology. Organizers say the focal point of the symposium will be bridging the gap between science, technology and commercialization. Created for the ChemShow by Innovative Research and Products (iRAP; Stamford, Conn.; www.innoresearch.net), the "Nano and Green Conference & Symposium" will explore the impact of nanotechnology on environmentally friendly processing. The conference will focus on colloids and surface modifications that benefit nanotechnology applications, nanoparticle synthesis and nano-bio convergence and their emerging technologies and markets.

Aside from the product exhibition and symposium, the show features a host of educational sessions. *Chemical Engineering* will present a two-day educational program (see pp. 30-31). The Valve Manufacturers Association (VMA; Washington, D.C.; www.vma.org) will present sessions on the use of valves and actuators in the chemical process industries (CPI). A number of sessions are offered as part of AIChE Day (American Institute of Chemical Engineers; New York; www.aiche.org) at the Chem Show. Among the offerings is a tutorial session on the fundamentals of powder flow technology, which will seek to provide insight into common flow problems of solids. Other AIChE sessions include mixing basics, troubleshooting pneumatic conveying systems, sustainability practices, process safety and others. Additional information about the show can be found at www.chemshow.com

During the show, look for *Chemical Engineering*'s exclusive coverage of the ChemShow in its daily newspaper. Those attending the show are also encouraged to visit *Chemical Engineering* at Booth 703. Among the ChemShow exhibitors are the following:

This storage unit can survive a 5 psi blast without damage

In testing, this blast-resistant storage unit (photo) remained structurally undamaged following a 5-psi, 500-ms-duration blast generated by a high-explosive, ammonium-nitrate fuel-oil charge at a standoff distance of 110 ft. The module is designed for worker safety in the petrochemical, chemical processing and construction industries. Booth 827 — *A Box 4 U, Wichita, Kan.*
www.abox4u.net

Note: For more information, circle the 3-digit number on p. 66, or use the website designation.


Do you see dolphins?
We also see a challenge to provide solutions that guarantee good quality water.
Veolia Water provides drinking water every day for more than 80 million people. As the world's largest water company, our technologies also benefit industries, commerce and agriculture. Our leadership ensures excellence at the nation's largest water partnership (Indianapolis), largest wastewater partnership (Milwaukee) and the largest design-build-operate project for drinking water (Tampa Bay).
The environment is our universal challenge.
VEOLIA ENVIRONNEMENT
VE LISTED NYSE
Learn more about how the nation's largest, most innovative water partnership delivers exceptional results in Indianapolis.
| veolianorthamerica.com
Circle 34 on p. 66 or go to adlinks.che.com/23019-34

BHS-Filtration

Show Preview

Increase process capacity with this thin-film evaporator

Powerfilm rotor technology can be fabricated into thin-film evaporators (photo, p. 32D-2) with inside diameters of 2,000 mm or more. The design and large size of the evaporator rotors can help increase profit margins by raising process capacity and by improving product purity. Booth 835 — *GIG Karasek GmbH; Stuppach-Gloggnitz, Austria*
www.gigkarasek.at

Microdyn Technologies

Optek

This vacuum filter is certified to 0.12 microns

The VAC-CRV Dry Clean Room Vacuum with ultra-low-particulate air (ULPA) filtration (photo, p. 32D-2) is certified 99.999% efficient for particle sizes down to 0.12 microns. The vacuum, designed for clean-room surface cleaning, has a stainless-steel tank for easy cleaning, a small footprint and multistage filtration system. VAC-CRV features include a 5-gal paper filter collection bag, a change indicator light, and a large-sized ULPA filter. Booth 741 — *Goodway Technologies, Stamford, Conn.*
www.goodway.com

Clean-up and maintenance for this round separator is easy

The MX Separator (photo, p. 32D-2) has an open-base construction to allow cleaning underneath the unit, and eliminates external crevices that can trap product. The separator is also designed to increase safety, with an enclosed weight guard to prevent "reach-in" injuries. Booth 527 — *Sweco, Florence, Ky.*
www.sweco.com

These balances offer redesigned user interface

The redesigned user interface of the NewClassic balances (photo, p. 32D-2) allows for more intuitive operation, with "SmartKeys" that directly access preferred applications, and a high-contrast display for easier reading. NewClassic balances also feature a new metal housing designed to resist chemicals and protect the weighing cell from environmental influences and impacts. The new line of balances retains technology from its predecessor line, including the MonoBloc weighing cell and fully automatic calibration technology. Booth 358 — *Mettler Toledo, Columbus, Ohio*
www.met.com

Get a large filter area with this belt filter

This belt filter (photo) is 3.5 m wide, and offers 73.5 m^2 of filter area for washing and drying of high-value products in alkaline slurry. The belt filter is coupled to a candle filter, which maximizes product recovery by collecting fine particles and recombining them into the process. The belt filter features a continuous-indexing design that eliminates the need for rubber carrier belts and vacuum-pressure-rated hoses. The candle filters provide for thin-cake pressure filtration, cake washing, drying reslurry and automatic discharge. Booth 315 — *BHS-Filtration Inc., Charlotte, N.C.*
www.bhs-filtration.com

Filter viscous media with this ultrafiltration cassette

The Flow-Cel cassette (photo) has a membrane of 10 m^2 and is designed to filter protein-containing liquids with high solids content. The cassette has the ability to be cleaned by backwashing from the permeate side of the filter, a feature that increases cleaning effectiveness and saves resources. Its

Got Leaks?

Corzan® Piping Systems offer the reliability you need, so you don't have to baby your pipes.

Simply dealing with corrosion is an expensive proposition for the plant and for the municipality. You need a piping system that's tough enough to stand up to corrosive chemicals, high temperatures and harsh application conditions.

Corzan piping systems offer an excellent balance of properties improving reliability and confidence while reducing capital and life cycle costs. Made from high performance CPVC, Corzan pipe and fittings are the responsible solution for today's tough water treatment piping challenges.

To learn more, call 888-234-2436 or visit **www.corzancpvc.com**.

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FBC™
Building Solutions

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molecular weight cut-off is 10 kDa (kilodaltons). Flow-Cel is suitable for food processes, as well as other protein-concentration applications with high solids levels, such as biotech fermentation processes. The modular design of the filter allows the system to be modified according to the needs of the operator. Booth 317 — *Microdyn Technologies Inc., Wiesbaden, Germany*
www.microdyntech.com.

Chemglass Life Sciences

Robatel

Increased process control offered with this absorption sensor

The AF26 (photo, p. 32D-4) measures color and concentration at light wavelengths from 380 to 1100 nm. It is designed to automate manual processes and increase control for improved product quality and reduced product loss. The AF26 is constructed of stainless steel 316Ti, and can withstand high temperatures (up to 464°F), high pressures (up to 325 bar) and sanitary clean-in-place applications. It can also be used in applications such as monitoring chemical concentrations in water, water disinfection, trace hydrocarbons in water and turbidity measurements among others. Booth 229 — *Optek Inc.; Carrollton, Tex.*
www.optekinc.com

Design of this gas scrubber allows visual monitoring

This new gas scrubber (photo) features a compact design that allows for visual monitoring of the scrubbing process. The scrubber is designed for use in an array of air and exhaust cleanup tasks, and is available with an optional stationary or mobile support stand. The compact design will fit into any laboratory hood, or can be used in walk-in hoods when assembled on the firm's mobile, bench-top-reactor stands. The maximum air flow is 8 L/min. Booth 932 — *Chemglass Life Sciences Inc., Vineland, N.J.*
www.cglifesciences.com

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Precisive

VTA

This centrifuge combines filtration and solids drying

This laboratory or pilot scale centrifuge (photo, p. 32 D-6) offers centrifugal filtration and solids drying in a single machine. It is equipped with interchangeable rotors to allow its use as a horizontal basket centrifuge, and as a tumble dryer as a "two-for-one" approach to centrifugation and drying. The machine is equipped with interchangeable rotors and casings that allow it to operate as a horizontal peeler centrifuge with automatic cake discharge, or as a basket centrifuge and tumble dryer. This interchangeability allows its use for a wide variety of separation problems. Booth 928 — *Robatel Inc., Annonay, France*
www.robatel.com

A blanket gas regulator for lower-volume processes

The Model 3011/3041 blanket-gas-regulator product line now includes a ½-in. connection for lower volume processes that require smaller flow capacities. The new ½-in. size connection is available with an optional sanitary fitting or quick-disconnect linkages. The regulator is constructed of stainless steel or additional materials by request. Booth 706 — *Groth Corporation, Stafford, Texas*
www.grothcorp.com

This modular system is ANSI manifold compliant

Modular platform components from this company offer a variety of options for a systems approach to process analysis and control. The system, compliant with the Modular Sample and Conditioning System standard (ANSI/ISA 76.00.02), can include substrate and manifold layers with a variety of surface-mounted valves, gages and manifold flow components. The modular platform component (MPC) system features a 38.2-mm (1.5-in.) size and is easy to configure, assemble, and maintain for use within process analyzer, sample-handling and fluid distribution systems. Booth 403 — *Swagelok Co., Solon, Ohio*
www.swagelok.com

This glass film evaporator allows visual image of process

A new film evaporator is constructed in glass (photo) to allow the operator the ability to see the process. With a 70-mm I.D., the evaporator can be configured with a rigid evaporator rotor or a drying rotor. It can be used with small samples, making it ideal for development. Booth 334 — *VTA GmbH, Rock Hill, S.C.*
www.avta-us.com.

These process monitors measure multiple gases to sub-ppm range

The OXS Series Optical Gas Monitors (photo) use tunable filter spectroscopy to measure gas flow components in the ppm to percent range (3100 Series) as well as sub-ppm concentrations (4100 Series). The process monitors are automated, and provide realtime scanning of multiple compounds in gas flows. They are factory calibrated and have the capability to be networked. The optical scanners can monitor trace impurities, such as CO, CO_2, H_2O and hydrocarbons. Booth 335 — *Precisive LLC, Stoneham, Mass.*
www.precisive-instruments.com

This filter housing is compatible with any filter cartridge

FlexFlo filter housings accept filter cartidges from any manufacturer and feature an interchangeable filter basket. Adaptable to inside-out or out-side-in flows, the standard filter housings have diameters ranging from 4 to 36 in. The housings allow process engineers and purchasing managers the potential to reduce downtime for lines during filter changes. Booth 737 — *MorFab Inc., Moravia, N.Y.*
www.morfabinc.com

Get 20 kW of cooling capacity with this cooler

The FL Series recirculating coolers offer 20 kW of cooling capacity with a pump supplying 80 L/min at pressures up to 87 psi. The temperature control instruments feature intuitive operation, wide operating temperature range, rapid cool-down times and a small footprint. The FL Series is capable of interfacing with both digital and analog equipment, and comes with a two-year warranty. Booth 547 — *Julabo Labortechnik GmbH, Black Forest, Germany*
www.julabo.com

Handle highly corrosive chemicals with this surface alloy

A recently introduced technology for manufacturing tantalum surface alloys offers an affordable solution for processes involving hot acids and other highly corrosive materials. The corrosion-resistant alloy can be applied to valves, fittings, instrumentation and other custom products. The process of making the alloy involves heating and reacting pure tantalum metal to produce a gaseous atmosphere of the element. The tantalum vapor creates an alloy bond with the instrument's surface that gives corrosion-resistant properties of tantalum while maintaining the original part's size and shape. Booth 759 — *Tantaline Inc., Waltham, Mass.*
www.tantaline.com ■

Scott Jenkins

OCTOBER New Products

Purafil

BETE

Walther Couplings

Saint-Gobain Performance Plastics

FF-Automation

Scrub more H_2S with this new adsorbent

This firm's Environmental Systems Div. (ESD) has launched its newest dry-scrubbing media, Odorcarb Ultra, which is said to be the first activated alumina media with the ability to remove 0.3 g of hydrogen sulfide per cubic centimeter of media. Odorcarb Ultra replaces Odorcarb II as the primary component of ESD's odor-control applications. Similar to its predecessor, the improved media also contains the patent-pending Media Life Indicating Pellets. These blue pellets (photo) appear white after chemisorption to distinguish new media from spent media. — *Purafil Inc., Doraville, Ga.*
www.purafil.com

Hazmat suits that are certified for safety

The ONESuit Pro hazmat suit (photo) has earned the highest level of certification recognized within the EU and Asia. The British Standards Institute has deemed the suit compliant with the recognized benchmark in fire and hazmat safety for 30 different member countries, EN 943-2 Type 1a standard. Along with EU certification, ONESuit Pro is said to be the only ensemble certified in the U.S. to both NFPA 1991 and 1994 standards. European certification requires testing not only of the fabric, but the entire ensemble — seam type, glove, boot, respirator interfaces and closure systems — to ensure it is an effective barrier against hazardous materials. — *Saint-Gobain Performance Plastics, Merrimack, N.H.*
www.onesuittec.com

Improve vessel cleaning with this new range of spray balls

This new range of rotary spray balls (RSB; photo) is ideal for replacing static spray balls to ensure more efficient cleaning. Available in two sizes (RSB45 and RSB65), they ensure a maximum cleaning radius (depending on pressure and flowrate) from 1.5 to 2.43 m, which makes them suitable for smaller to medium sized tanks with 1.5- to 5-m dia. They can be supplied with 360 deg., 300 deg. up, and 180 deg. down spray patterns, and have a working pressure of 1–3 bar and a maximum working temperature of 95°C. A number of connections are available for easy retrofitting to existing systems. — *BETE Ltd., Lewes, East Sussex, U.K.*
www.beteuk.com

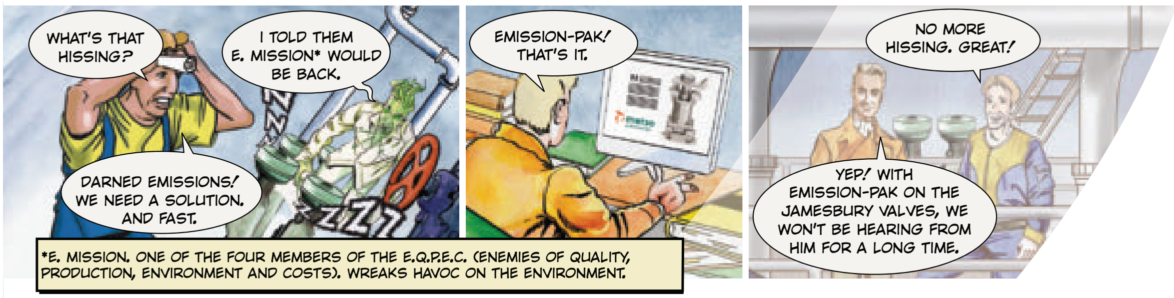
Connect and disconnect fluid lines safely with this coupler

The clean-break, low-pressure couplings of the CT Series (photo) are designed for multipurpose use in chemical and fluid technology, hydraulics, machine and systems engineering, and process engineering. Manufactured from stainless steel, the CT Series is suited for aggressive and toxic substances, in the pressure range from vacuum to 64 bar. The clean-break technology enables the user to connect and disconnect the non-drip, non-squirting coupling safely and quickly. Nominal sizes of this Series (5, 7, 9, 12 and 19 mm) complement the manufacturer's range of couplers with larger sizes (25 to 100 mm). — *Walther Couplings, Tring, U.K.*
www.walther-couplings.com

A wireless modem for gathering data remotely

The AutoLog WSN radio modem series (photo) is suitable for stand-alone

Note: For more information, circle the 3-digit number on p. 66, or use the website designation.



Jamesbury Emission-Pak® valves keep your emissions under control

Many process streams encourage fugitive losses. Metso Automation's Emission-Pak provides a quick, easy way of assuring compliance with emissions standards.

Mounted on Jamesbury® valves, Emission-Pak combines a PTFE/graphite body seal and gasket, which maintains a leak-free joint at the valve bonnet, with a double-packed, live-loaded V-ring steam seal mechanism that maintains a constant packing force without over-compression.

Emission-Pak is available in a wide range of corrosion resistant trim materials, and is suitable for use in extreme pressure and temperature situations.

metso
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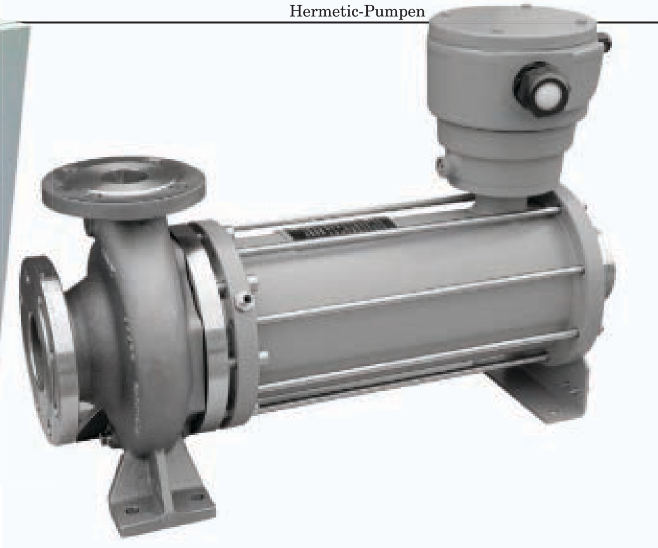
Edwards



Hermetic-Pumpen

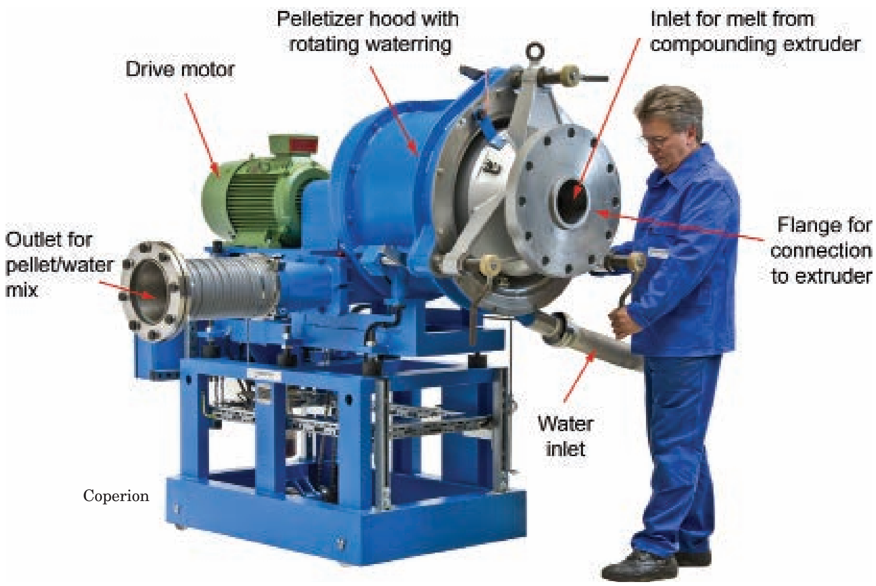
wireless data applications or for integration into OEM products. A discrete component RF stage is used to give better performance than would be possible using the simpler "single chip" solutions found in other low-cost designs, says the manufacturer. VHF (138–225 MHz), UHF (406–512 MHz) and 869MHz (863–870 MHz) versions of the AutoLog WSN are available for simplex or half-duplex operation. The device has been optimized, through the use of advanced digital-signal processing (DSP) technology, for reliability and low current consumption, making it especially suitable for operation on remote sites without main power. — *FF-Automation Py, Vantaa, Finland*
www.ff-automation.com

For high throughputs, consider this dry vacuum pump

The iXL 500 (photo) is the first member of the new iXL line of dry vacuum pumps. The iXL 500 is designed primarily for load-lock applications in solar-cell and flat-panel-display manufacturing where high gas throughputs and fast pump-down times are crucial. Compared to its predecessor, the iXL 500 offers up to 60% improvement in cost of ownership, says the manufacturer. The unit has a pumping speed of 1,600 m^3/h while consuming only 7 kW of power. Its low-inertia booster shortens load-lock evacuation times with faster, more efficient pumping at higher inlet pressures. — *Edwards, Crawley, U.K.*
www.edwardsvacuum.com

This standardized canned-motor pump has built-in protection

The newly developed HCN/HCNF range of canned motor pumps was designed for the most demanding



Coperion

Sensonics

areas of application. The HCN range is designed for aggressive, inflammable, toxic and highly volatile liquids, solvents or other substances. The HCNF range is used for liquid gases, such as ammonia, Freon, propane and carbon dioxide. The most recent development is a single-stage standardized chemical canned motor pump (photo, p. 32I-4) in accordance with EN 22858/ISO 2858. The area of application for liquids covers a temperature range from –120 to 120°C. The pump performance lies between 6 and 41 kW, with a maximum flowrate of 230 m^3/h and a maximum head of 140 m. One special design feature is an integrated monitoring system for the rotation direction, which is firmly molded in the terminal box. A thermistor secured in the winding guarantees efficient protection of the motor. — *Hermetic-Pumpen GmbH, Grundelfingen, Germany*
www.lederle-hermetic.com

A better way to make pellets of PS and POM

The WRG range of waterring pelletizers (photo) for making pellets of polystyrene (PS) and polyoxymethylene (POM) has the advantage that the cooling and conveying medium (water) does not come into direct contact with the die plate. The rotating knives cut the extruded strands of melts into pellets. Centrifugal action of the knives sends the still-hot pellets into the rotating water ring, which cools them and conveys them out of the pelletizer hoods. Favorable operating costs result from: the low energy requirement for the die plate and the rotor drive; the negligible wear on the knives and the die plate; and the simple and rapid startup process. A WRG 320 has been delivering 5,000 kg/h PS pellets for two years, and a 9,000 kg/h unit has recently been delivered. — *Coperion GmbH, Stuttgart, Germany*
www.coperion.com

These transmitters track rotating equipment

The DN8033 thrust and rod drop transmitter (photo) is designed to measure shaft axial or rod position of a range of rotating equipment. The 4–20-mA loop-powered module provides easy integration with either the local machine PLC or a plant-wide DCS since it is powered through the measurement loop. The unit operates in conjunction with the company's

Emerson Process Management

Dietrich Engineering Consultants

Senturian range of 8-mm-dia. proximity probes, offering a maximum measurement range of ±1 mm. The DIN rail-mountable unit provides two miniature multi-turn potentiometers for the setting of the gain and zero point parameters. — *Sensonics Ltd., Berkhamsted, U.K.*
www.sensonics.co.uk

A control valve with faster action

The Fisher Control-Disk valve (photo) offers excellent throttling performance and is ideal for applications that involve fast processes and varying pressure drops. The valve's wide control range is twice that of traditional butterfly valves for better adherence to set point, which allows control closer to the target set point, regardless of process disturbances. When paired with a Fisher spring-and-diaphragm actuator and Fieldvue digital valve controller, the assembly can capture and deliver data to AMS ValveLink software, which provides an accurate picture of the valve, actuator and digital-valve-controller performance. The valve body meets PN 10 through PN 40, CL 150, and CL 300 ratings. Face-to-face and raised-face dimensions meet EN 593, API 609 and MSS-SP68 standards. — *Emerson Process Management, Baar, Switzerland*
www.emersonprocess.eu

Charge more than reactors with this powder-transfer system

Although especially designed for safe reactor charging, the PTS powder-transfer system (photo) has proven itself in many applications of a much wider spectrum than traditional reactor charging. The PTS-System is exempt from ATEX 95, and therefore does not need an ATEX certification or confirmation. The system does not create its own ignition source and therefore is intrinsically safe. By means of active powder transfer, by a combination of vacuum and pressure, the PTS is able to replace risky open manual handling. Powders can be transferred from almost any receptacle, such as sacks, big bags, drums or storage vessels, and be discharged into any type of receiver. The system can be mounted directly on a vessel or is available as a mobile unit. The PTS is fully CIP (cleanable in place) and guarantees hygiene and complete containment. — *Dietrich Engineering Consultants S.A., Ecublens, Switzerland*
www.dec-sa.com

A peristaltic pump with a variety of hose materials available

A compact, double-head hose pump that provides higher flows yet requires less space, is the latest addition to the range of Ponndorf peristaltic pumps. Available from this firm, the PK 40 high-pressure twin unit (photo, p. 32I-7) is capable of providing flowrates of up to 15,000 L/h at pressures up to 15 bar. These self-priming pumps offer advantages of peristaltic pumping that are especially relevant to the food processing and water treatment industries. For example, shear sensitive, delicate liquids, or those containing solids remain unaffected by the pumping process. The pump is fully reversible and is supplied with a wide selection of hose materials, including natural rubber, neoprene, hypalon, food-grade NBR and EPDM. — *Pump Engineering Ltd., Littlehampton, U.K.*
www.pumpeng.co.uk

A stronger magnet delivers improved separation efficiency

The redesigned High Gradient Separator (photo, p. 32I-7) has been developed for the recycling industry and is particularly suitable for operation in a difficult and dirty environment. The magnetic strength of the coils has been increased to 10,000 Gauss, which allows the magnetically weak iron and slightly magnetized particles to be removed from waste and residual streams. The complete system consists of a frame, a vibrating chute, a control unit, the separator and an easily adjustable splitter unit. — *Goudsmitt Magnetic Systems B.V., Waalre, Netherlands*
www.goudsmit-magnetics.nl

Supersonic nozzles keep this spray-dryer filter clean

SaniCIP is a system of CIP bag filters for spray dryers that use reverse-jet pulsing technology to make sure that powder is removed from every part of the bag. Now, the SaniCIP filters have been improved to achieve even higher performance and longer life. Among the new features are the following: the diameter of the cylinders has been enlarged to reduce the wear rate in use due to sand blasting and rubbing; the air inlet has been redesigned tangentially to reduce risk of powder deposits forming; supersonic nozzles are used for reverse-jet pulsing instead of reverse-jet nozzles, which reduces compressed air and maintenance requirements; the clean-air plenum above the nozzles has been redesigned to be easier to clean in place; top covers now weigh less for easier removal; and the system now includes new sanitary explosion vent panels. — *GEA Process Engineering, Søborg, Denmark*
www.niro.com

Integrated software delivers a host of advantages

The LDRA tool suite has been integrated with the IBM Rational Rose RealTime model-driven development

Goudsmitt Magnetic Systems

Pump Engineering

environment. This integration introduces LDRA's powerful code quality analysis and code coverage techniques into the domain of model-driven development using Unified Modeling Language (UML). The LDRA tool suite supports the analysis, instrumentation and testing of both autogenerated and user-created source code both within the Rose RealTime user interface or the LDRA development environment. — *LDRA Software Technology, Wirral, U.K.*
www.ldra.com

This continuous gas analyzer can also monitor CO_2 emissions

Upgrades for the Advance Optima AO2000 Series Continuous Gas Analyzers are now available for expanding the monitoring capability to include carbon dioxide greenhouse gas emissions measurements to address expected U.S. Environmental Protection Agency (EPA) environmental compliance requirements. The regulations will impact reporting requirements for cement kilns, nitric-acid plants, power generation, incinerators, petroleum refineries and petrochemical plants. A full range of upgrade options is available to meet site- and application-specific requirements. Installation and commissioning services for all upgrades can be implemented onsite by this firm's factory-certified service engineers. — *ABB Analytics Services, Houston, Tex.*
www.us.abb.com

Hamilton

New Products

Accurate mass flowrates, even for fluctuating velocity profiles

The new Multi-Trak Model 670S is an advanced, state-of-the-art instrument for measuring mass flowrates in very large ducts or stacks that have non-uniform velocity profiles, high turndown requirements, dirty gas streams, wide temperature ranges and fast velocity and temperature changes. The unit dynamically compensates for changes in the flow profile by using up to four independent mass-flow sensing points to measure the instantaneous, average gas-mass-flow velocity. The device has an accuracy of ±1% of reading and 0.5% of full scale, a one-second response to changes in flowrate, and patented Dry-Sense Technology that eliminates sensor drift. The sensors are FM, CSA and ATEX certified for hazardous areas, and are also CE Approved. — *Sierra Instruments, Inc., Monterey, Calif.*
www.sierrainstruments.com

A pressure transducer for low-pressure applications

The 3300 Series pressure transducer is designed for low-pressure applications that demand small size and low cost along with high accuracy and stability. These transducers are especially suitable for chemical sterilizers, autoclaves, pneumatics, HVAC, pumps and compressors. The devices are available over the pressure range from 1 to 16 bar, and can operate at temperatures from –40 to 125°C, and have voltage, current and ratiometric outputs. — *Gems Sensors & Controls, Plainville, Conn.*
www.gemssensors.com

Ultrasonic flowmeters for drop-by-drop dosing

The PFA SonicLine ultrasonic flowmeters (photo) are now available in a new, low-flow version for quantities from 0.03–6 L/min in DN 3/8 in. Flowrates from 0.5–1 mL/s are achieved, which corresponds to almost one drop at a time and opens up new areas of application in fine dosing of chemicals, says the manufacturer. The SonicLine is suitable for accurate (1%) and fast batch and dosing processes with high reproducibility (0.5% of measured value). All medium-wetted parts are made of corrosion-resistant, high-purity fluoropolymer PFA-HP. — *GEMÜ Gebr. Müller Apparatebau GmbH & Co. KG, Ingelfingen-Criesbach, Germany*
www.gemue.de

Bronkhorst High-Tech

Move lubrication fluids with this smooth-starting pump

The Allfuel Series of screw pumps is designed to move oils and other lubricating liquids with a maximum discharge pressure of 40 bar. Available in six different construction types, the pumps have many new features, including heating elements for the mechanical seal and filter chamber (which provides for smooth starting) and a filter design that simplifies maintenance. The design of the pump casing allows the filter to be changed without having to drain, dispose and refill the oil. — *Allweiler AG, Radolfzell, Germany*
www.allweiler.de

Mass flowmeters for controlling high-purity gas flows

These metal-sealed mass flowmeters/controllers (photo) are designed to meet the requirements of the semiconductor market and other high-purity gas applications. The devices feature high surface quality and are of modular construction with metal-to-metal seals for long-term tightness. Now, as an alternative to traditional face-seal fittings, optional downport connections (c-seal and w-seal) are offered to reduce mounting space and facilitate installation and maintenance. Metal-sealed units are supplied in ranges from 0.1–5 cm^3/min up to 0.6–100 L/min (or higher on request). — *Bronkhorst High-Tech, Ruurlo, Netherlands*
www.bronkhorst.com.

GEMÜ

These sensors do more than measure control variables

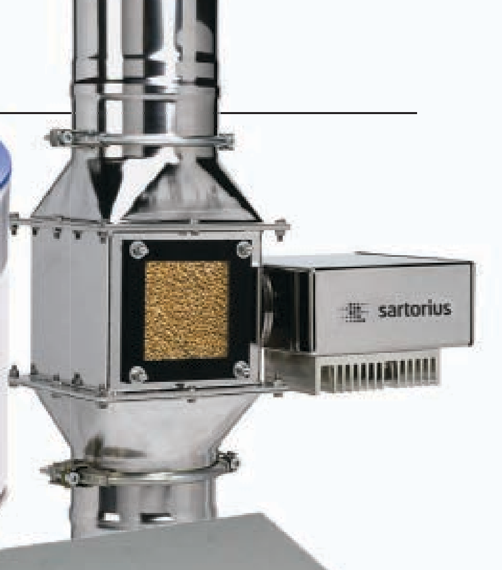
The ARC concept (photo) is a new family of sensors for process control, which includes pH, dissolved oxygen and conductivity measurements. More than just sensors, the devices are complete solutions that include sensors, and direct standard interface to the process-control system. In addition to the analog analytical signal, the units also deliver the power of digital sensor management. ARC Sensors are available with both standard 4–20 mA and digital ModBus interfaces built in and supported directly from the sensor itself. — *Hamilton AG, Bonaduz, Switzerland* ■
www.hamiltoncompany.com

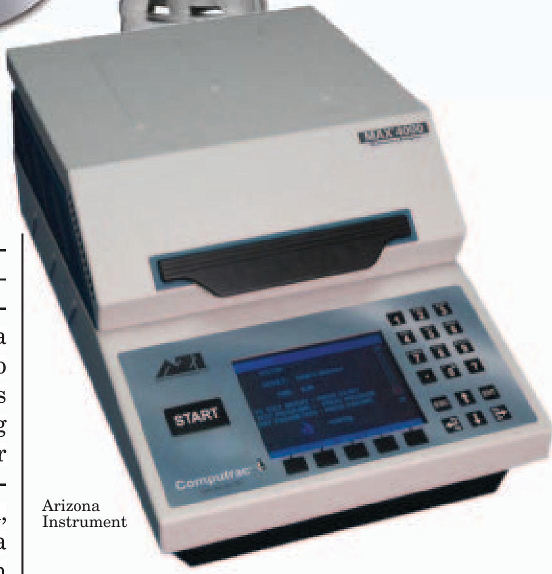
Gerald Ondrey

FOCUS ON

Analyzers

Mettler Toledo





Arizona Instrument

A new line for simply and easily determining melting point

Melting point is one of the most frequently determined thermal values for material characterization. With these new melting point systems (photo), only one click is required to run melting point determination. The units feature an intuitive, color touch-screen interface that makes instrument operation simple. Clever navigation properties, an online screen featuring current measurements, and a unique user-specific home screen with shortcut buttons, provide ease-of-use and security. As a result, the user is quickly acquainted with the instrument. All-three available models, the MP50, MP70 and MP90, are supported with video recordings and the ability to simultaneously measure up to six samples. Color changes, the transparency point, and the decomposition temperature can also be investigated. The underlying measurement principle and norm conformity are said to assure exact and reliable results. — *Mettler Toledo North America, Columbus, Ohio*
www.mt.com

In-process analyzers eliminate need for random sampling

The new PMD 500 Series of online process analyzers (photo) optically determine the moisture content and concentration of other constituents using near infrared (NIR) technology, thereby eliminating the need for testing random samples, which prevents downtime and saves costs. Concentrations of various ingredients, such as water, moisture, fat, protein and solvent can be analyzed online in milliseconds for free-flowing or pourable solids, liquids or pasty media. A particularly useful area of application is end-point determination in a mixing process, which can save considerable time and thus production costs. In fact, the manufacturer claims that in mixing applications PMD500 analyzers will pay for themselves within six months. Qualitative uses include visual characteristics, such as "bad spots" or black specks in product. The analyzers feature a flexible array of detectors for the UV|VIS and NIR spectra in combination with a high-resolution digital camera and a comprehensive software package. The PMD500 system works with a redundant light source and, thanks to the use of a diode array spectrometer, is capable of analyzing even fast-moving samples, such as those on a conveyor belt, and delivering accurate and reproducible values. The modular-design, low-maintenance system features a patented automatic calibration function and is also suitable for use in hazardous areas. — *Sartorius Mechatronics, Goettingen, Germany*
www.sartorius.com

New laser gas analyzer for insitu, cross-stack tests

Designed for insitu cross-stack measurements in extreme or harsh environments, the Servotough Laser gas range is the first of this vendor's product lines to incorporate Tuneable Diode Laser Absorption Spectroscopy (TDLAS) technology from Norsk Elektro Optikk (NEO). Able to detect a wide range of gases including O_2, HCl, HF, NH_3, CO, CO_2, H_2O, H_2S, HCN, NO, N_2O, CH_4 and other hydrocarbons, the laser range offers a fast response time, highly stable performance and minimum sample conditioning requirements with out moving parts or consumables. Typical applications include usage in emission control systems for scrubber and abatement plants, combustion control systems for boilers or waste incinerators and slippage control in deNOx plants. — *Servomex Group Ltd., Crowborough, U.K.*
www.servomex.com

Moisture and solids analyzer cools 25% faster

The Computrac MAX 4000XL moisture and solids analyzer (photo) is said to provide the latest in rapid loss-on-drying technology available today. The instrument facilitates faster throughput via a forced-air cooling system, which allows it to cool from test temperature to idle temperature 25% faster than previous models. It also features a temperature ramp-rate control option, which allows the user to control the rate at which the instrument heats from idle to test temperature. The MAX 4000XL has the ability to measure moisture and solids down to a range of 0.005 to 100%. A color LCD display facilitates review of test results and test graph data. Meanwhile, the Webserver option allows test results to be downloaded, and test parameters to be uploaded via a local Intranet. Test results can also be captured directly from an instrument using an external flash-memory device. — *Arizona Instrument LLC, Chandler, Ariz.*
www.azic.com ■

Rebekkah Marshall

Note: For more information, circle the 3-digit number on p. 66, or use the website designation.

Cover Story

Estimating the Total Cost of Cartridge and Bag Filtration

When changeout and disposal costs are added to the purchase cost of filters, the total cost of disposable filters can more than quadruple. A proven method of reducing total life-cycle cost is larger surface-area filters

Frank Buehner
Filtration Technology Corp.

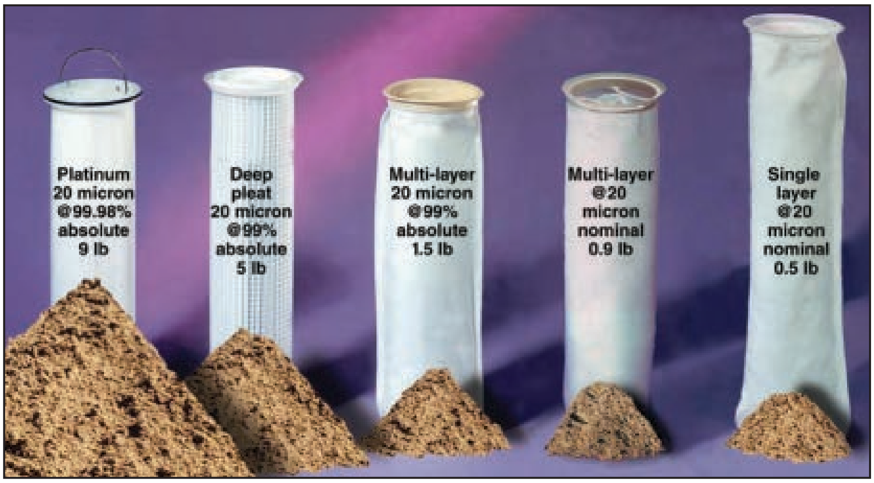


FIGURE 1. The dirt holding capacity of #2 bag filters varies, and is largely dependent on filter surface area

Bag filters for industrial applications have been in existence longer and are considered by some to be easier and simpler to specify than cartridges for a filtration project. And although cartridge filtration is now one of the mostly widely used filtration technologies in the chemical process industries (CPI), it is not always the first choice.

How does one decide which filtration method should be used? Like any other technology choice, this decision is based upon the strengths and weaknesses of the two options.

There are many factors an engineer should consider when choosing a filtration system. So when does one specify a cartridge filter instead of a bag filter? What are the basic differences between the two? How does one determine filter life for either type? Often the lack of a logical approach to liquid filtration design leads engineers down a "what did we do the last time" approach instead of determining critical properties, such as the total dirt-holding capacity, filter life, filter surface area, flowrates, and other factors. Schooling in this unit operation is not a common university practice, and the lack of ASTM standards, for instance, regarding filtration test procedures and specification of filters adds to system under- or over-design.

Besides the capital costs of a filter, there are additional factors that affect overall filtration economics, namely: (a) design considerations and options, (b) process requirements, (c) maintenance requirements, (d) maintenance procedures, (e) mean-time-between-changeout (MTBC) costs, and (f) disposal costs. This article outlines basic design issues, discusses selection considerations, and presents a cradle-to-grave cost analysis of bag and cartridge filtration.

Design factors

Even before selection decisions are made, there is a need to address two important criteria: the chemical and physical compositions of the feedstock stream going into the filter; and the quality and specification of the desired exit liquid.

Other important design considerations include the following:

- Process specifications (metallurgy, temperature, pressure and instrumentation)
- Footprint, weight, clearance
- Filter flux rate
- Filter surface area, length, diameter, design type
- Filter type (bag, cartridge, other)
- Flowrate and pump requirements
- Solids concentration and solids characteristics
- Fluid viscosity, density, specific gravity, pH, volatility, hazards
- Changeout requirements, frequency
- Instrumentation, safety and disposal issues
- Costs of hardware, filters, maintenance, disposal

Important design steps include the following:

- Determine stream composition, flowrate and temperature
- Calculate total solids per day removal, know total suspended solids (TSS) and particle size distribution (PSD)
- Set flux rate (0.5 gal/ft^2/min for pleated cartridges and bags; 60–120 gal/min/bag for regular bags)
- Determine total surface area
- Determine bag or cartridge
- Calculate best fit (number and size of filters required)
- Calculate number of vessels required
- Calculate total pressure drop (clean and fouled)

FIGURE 2. Cartridge filters are available in various lengths and materials of construction

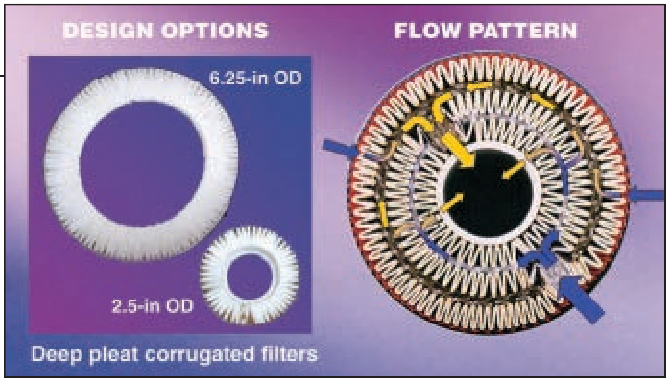


FIGURE 3. Shown here are a deep-pleat corrugated design (left) and the flow channels and chambers of high capacity filters

- Modify design to minimize changeout frequency
- Design vessel layout; then optimize
- Calculate volume and weight of waste

Bag filters

Bag filters come in various configurations and materials of construction. A bag filter usually has inlet flow through the top of the filter and exit flow along the sides and bottom. A metal or plastic perforated basket in the filter vessel keeps the bag from expanding outwards from flow pressure as the filter fills. The typical, maximum fouling pressure for bag filters is 25 psi. With a typical fabric bag filter containing 4.0–4.4 ft^2 of surface area, the dirt holding capacity of a bag filter varies gradually as the construction moves from a mesh or felt, single or multilayer construction, to a pleated bag, which looks similar to a cartridge filter. The reason for the dramatic increase in dirt holding capacity is filter surface area (Figure 1). The surface area of pleated bags jump dramatically from 4.4 ft^2 for standard single or multilayer construction to 30–60 ft^2 for pleated construction.

For bag filters, maximum flowrates, dirt holding capacity, and materials of construction and style (microfiber, mesh, felt, needled felt, binder resins, finish coatings/glazing, seams or seamless, and cap seal) vary widely by manufacturer. The design of the bag and materials of construction control the surface area, dirt holding capacity, and maximum flowrates the filter can withstand. A long used rule of thumb employs an estimate of 100 gal/min per bag for a full-sized 4.4-ft^2, surface area, 9–10 oz., 100-micron nominal-rated felt bag. Vessel inlet velocity is usually limited to an 8–10 ft/s maximum range. As the bag becomes tighter, flowrates drop to 85 gal/min and then to 40 gal/min or less per bag. The manufacturer's production method and materials of construction require the design engineer to consult the vendor's data sheet for specific flowrates and pressure-drop data.

Cartridge filters

Cartridge filters are available in various lengths and materials of construction (Figure 2).

A cartridge filter's flow is in the opposite direction of a bag filter — from the outside in. This requires that the construction of a cartridge filter be strong enough to have a core with a high burst strength and does not rely on the filter vessel itself for compression strength. Filter alignment rods, either temporary or permanent, are usually included with a cartridge vessel to assist with installation and removal. These alignment rods allow the filter to slide and be guided over a rod or shaft and become increasingly important to support the filter and help with changeout if the filter vessel is horizontal or on an angle. Orientation of the cartridge filter vessel can be based upon available plot area or the need to reduce the physical height of long-length cartridge vessels to help with access during removal, replacement, and aid with liquid drainage before filter changeout.

Cartridge filters are available in much larger sizes (length and diameter) than bag filters, and different designs allow filters to have much higher surface areas (and dirt holding capacities). Single 2.5-in. × 40-in. pleated cartridges contain from 5 to 9 ft^2 of surface area per cartridge depending upon the number of pleats the manufacturer uses. In comparison, a 20-in.-dia., 40-in.-long cartridge filter can contain up to 1,100 ft^2 of surface area.

High capacity filter cartridges

Today's more-efficient filter cartridges are often referred to as high capacity filters. They offer improved MTBC and mean time between replacement (MTBR), and, this kind of filter will easily offer economic advantages when run until it reaches its maximum dirt-holding capacity. The high capacity filter pays for itself and, in some critical services (such as amine purification loops in sulfur-removal plants), one high capacity unit can replace as many as 200 standard, 2.5-in. cartridges (see box on p. 39). Traditional single or multilayer bag filters cannot approach the dirt holding capacity of a high-capacity pleated cartridge or bag filter, so we must continue this study examining pleated media filters only.

Available worldwide from a number of vendors, high capacity filters are pleated and are made from several types of filter media and pore sizes in order to maximize dirt-holding capacity. Employing the available options of high surface area, materials of construction, and filter efficiency, the high capacity cartridge can handle a wide variety of fluids at various temperatures. The technology utilizes either an optimized deep-pleat design (Figure 3, left) or a continuous pleat employing a series of segregated flow channels and flow chambers (Figure 3, right) to improve the alpha factor (described below).

A close analysis of the high-capacity, filter-flow channels and flow chambers reveals that improved filterability and particle removal capabilities are directly related to the increased amount of filter-surface-area that is available with these high capacity units. The improvement of dirt holding capacity is shown in Table 1. These results identify the dirt holding capacities of the filters employing seven types of test dust from 1 to 70 microns. The design of a pleated bag is accomplished by reversing the pleat pack as shown in Figure 3, for flow from the inside to the outside of the filter and employing the bag filter basket as a filter expansion control device.

TABLE 1. DIRT HOLDING CAPACITIES-CARTRIDGE FILTERS		
(2.5-in. O.D. x 40-in. length)		
String wound filters	0.3 lb	nominal filter
Spun bonded filters	1.0 lb	nominal filter
Pleated media filters	2.0 lb	absolute filter
(6.25-in. O.D. x 40-in.length)		
Pleated media filter	18 lb	absolute filter
(12.00 -in. O.D. x 40-in. length)		
Pleated media filter	100 lb	absolute filter
(20.00-in. O.D. x 40-in. length)		
Pleated media filter	300 lb	absolute filter

TABLE 2. DESIGN CONSIDERATIONS	
Filter media temperature limitations	
Polypropylene	Max: 180°F
Polyester	Max: 270°F
Fiberglass	Max: 270°F
Cellulose	Max: 385°F
Metal	Max: 550°F
Filter temperature and chemical compatibility considerations	
Not only filter media but also cap, gasket, cores, webbing, netting, and joining materials.	

TABLE 3. MONTHLY OPERATING PARAMETERS AND YEARLY OPERATING COSTS (36-in I.D. vessel, contaminate load = 72 lb/mo)

Monthly operating parameters	String wound	Pleated filter	Platinum, 6.25-in. O.D.	Platinum, 12.75-in. O.D.
Housing depreciation, $	400.00	400.00	400.00	400.00
Filter quantity	120	120	19	5
Filter price, $	7.00	44.00	266.00	1,053.00
Pounds of dirt per filter	0.30	2.0	18.0	100
Change outs per month	2	0.3	0.20	0.15
Change out time, h	4	4	2	1
Labor cost, $/h	30.00	30.00	30.00	30.00
Disposal cost, $/filter	1.00	1.00	15.00	60.00
Yealy operating costs, $				
Depreciation	4,800	4,800	4,800	4,800
Filter cost	20,160	19,000	12,129	9,477
Labor cost	5,760	864	720	360
Disposal cost	2,880	432	684	540
Total cost	**35,600**	**25,096**	**18,333**	**15,177**
Alpha factor ($\AA$)	23.3	22.0	14.8	10.5

Holding vessels

The vessels that hold bag (Figure 4) and cartridge (Figure 5) filters are designed to hold single or multiple bags and cartridges. These vessels can obviously become quite large, and their footprints can take up large parcels of valuable real estate. Weight can also be an issue for offshore platforms and where vessels are elevated in the deck structure.

Design and process engineers must recognize that both the filter housing and the pump size are dictated by the desired flowrates, pressure drop limitations and the required level of filtration (micron size of the particles that must be removed). The recommended flow capacity of the filter element is used to determine the total number of cartridges required.

Housing size must be synergistic with filter size, and if absolutely no downtime can be tolerated, then parallel filters (sized to handle the total flowrate of the processing line or the effluent line) should be considered. In doing so, footprint and overhead spacing are both important — particularly overhead spacing if a mechanical lift is used to remove the element from the vessel. Another approach is to employ horizontal filter vessels with single or multiple filters up to 80-in. long. These vessels can be loaded and unloaded without a mechanical lift.

Bag versus cartridge filters

Now, the question of bag versus cartridge filter is addressed.

Bag filter considerations. An often overlooked consideration is that non-pleated bag filters may extrude into the vessel basket holes making removal time consuming and ripping more likely. Not only can maintenance personnel have a problem but robotic equipment cannot operate efficiently when this situation exists.

Each bag vessel manufacturer has slightly different sealing and seating features that may require that a variety of filters be stocked for each vessel type in a facility, even if the design parameters are the same. Absolute rated, high-efficiency bag filters, are available in multi-layer non-pleated construction. Filter hold-down devices are available to assist with filter sealing, and many vessel manufacturers have devised proprietary locking or snap-in systems. The 7.25–7.5-in. dia. inlet for bag filters require large diameter vessels or multiple vessels for large flowrates. The bag filter tubesheet must be designed to withstand pressure and temperature fluctuations to eliminate warping. Newer fabrics and methods of construction allow the use of single, multilayer, and pleated bag filters up to 385°F (Table 2). Pleated-bag-filter caps cannot always be economically fabricated of metal to fit all bag vessels for high temperature applications. Nylon, fiberglass, acetyl (polyoxymethylene), and other plastics can extend the temperature range beyond polypropylene (PP). For pleated bag filters, the O-ring cap seal or gasket is large in diameter, and that cost must be considered if exotic materials, such as Viton, Cal-Rez, TEV, or Teflon are required.

Maximum dirty pressure drop (ΔP) for pleated bag filters is also 25 psi to avoid extrusion or destruction, or both. In some cases, the dirt can act as a filter cake and allow for longer filter life and dirt holding capacity for both pleated and non-pleated designs.

Cartridge filter considerations. Flow is outside-in requiring strong core cages to handle the pressure drop through the filter without crushing it. Common end-cap designs include 222, 226, 335, and 339 double O-rings and a variety of builtin end-cap compression devices that are used to ensure a 100% seal in the vessel receiver. Cartridge filters can be built with metal end caps and other high-temperature (450°F), solvent-resistant materials. The O-rings employed on a cartridge filter are smaller in diameter than those on bag filters, reducing costs when exotic O-ring materials are required. Cartridge filters can be built with very large surface areas and dirt holding capacities. Maximum dirty ΔP for a cartridge filter is normally 35 psig, but can be increased by designing the core to handle higher pressures. Cartridge filters can incorporate cores of oil absorbent materials and internal flow chambers to offer unique high-volume, oil-absorption features and also improve uniform flow in large diameter filters to ensure that the surface area is "effective".

Employing corrugated media and metal cages, filter lengths of 80 in. and longer with diameters of 20 in. are available. However, original cartridge filter designs, and those in service today are largely based on 2.5-in.-dia. filters. This means that to

FIGURE 4. Shown here is a typical bag-filter housing with a capacity of 150 gal/min

FIGURE 5. This cartridge filter (left) and its housing has a capacity of 150 gal/min

handle large flowrates, vessels containing 50–250 or more cartridges per vessel are employed in petroleum refineries and chemical plants. Cartridge filters can be arranged in series to increase surface area and dirt holding capacity.

Filter changeout

Liquid holdup in the filter itself and in the filter vessel must be considered in design. The vessel will normally be blown-down with nitrogen or air or employ pumps to remove liquid from the vessel prior to filter changeout. The value and type of fluid will determine the most economical method of removing the fluid. Hot fluids and those that might vaporize may require a cool-down time, which adds to the cost of the changeout. Some vessels may require a steam-out or vacuum system to remove hazardous fluids and vapors prior to opening the vessel. In some systems the contaminant may be pyrophoric so additional safety issues regarding handling and disposing of spent filters must be considered.

Filter efficiency

A filter has an optimum flowrate to maximize dirt holding. One can push a filter to higher flowrates, but the dirt holding capacity will decrease as shown in Figure 6. By knowing the filter surface area (in this case, 94–115 ft^2) and varying the media micron size and the recommended flux (usually optimized at 0.50 gal/ft^2/min) for pleated cartridges, the dirt holding capacity of the system can be maximized.

Some filter manufacturers do not wish to disclose dirt holding capacities or filter surface area. This can be due to competitive pressures to keep this information secret or the lack of a full-scale, test flow loop that validates the dirt holding capacity of the filter. Filter data sheets are notorious for their lack of critical information and may require careful inspection and phone calls, examining the fine print or competitors' product data sheets to obtain the information needed.

Beta ratios

The tried and true use of efficiency as a percent is difficult to understand and explain to purchasing or management who wants to know why a 99.98% efficiency filter may be significantly higher in price than a 99% filter. A simple-to-calculate parameter, called the beta ratio (see box on p. 40), is much easier to understand (and explain) and can eliminate a host of uncertainties.

As an example, consider a filter with an absolute efficiency rating of 99.98% at 2 microns. Performing the simple calculation, we find that a 99.98% efficiency equates to a beta ratio of 5,000. In contrast, a 99% efficiency filter has a beta ratio of 100. The engineer can now describe the differences in filters in easy to understand terms: a beta 5,000 filter will only pass 1 particle in 5,000 greater than 2 microns. A beta 100 filter will pass 1 in 100 particles greater than 2 microns. So, while percent efficiency is typically what is published in the literature or on a data sheet, the beta ratio better describes what is happening.

Nominal versus absolute rating

The absolute rating of a filter is the diameter (in µm) of the largest particle that will pass through the filter (roughly, the pore size). In contrast, the nominal rating of a filter is an arbitrary value determined by the manufacturer, and is expressed in terms of percentage retention (normally 90, 95 or 98 wt.%) of a specific contaminant of a given size.

Most nominal-rated filters are found in single-layer bag filters and cartridge filters employing coiled string or media that does not have a uniform pore size, a large average pore size, or if the media can move during filtration (not-fixed in location by binders or of uniform pore size), so its efficiency rating is not uniform from filter to filter or within the same filter or is low in the ability to reproduce uniform tests of efficiency and must be averaged to report a result. Nominal rated filters are used extensively in water and wastewater-treatment applications.

A nominal filter cannot have a beta-ratio rating because the tests of nominal rated filters are not reproducible under tests that include changes in flowrate and pressure, including pressure surges that can move the media or dislodge bridged particles that would change the actual pore size. There are attempts to relate a nominal rated filter to an absolute, but the designs and materials of construction of the two different ratings do not allow a true comparison. Figure 7 shows that even though this filter is rated at 5 microns, reductions in filtered versus unfiltered particles do not become significant until after 19 microns.

Filter testing and sizing

The typical material used to challenge test filters is ISO test dust, formally SAE test dust, which comes in ultrafine, fine, medium, and coarse varieties. Test dust is certainly not a common contaminant, so why use it for filter testing? The answer is that although dust itself is not normally a fluid contaminant, it does have properties of two commonly occurring contaminants: particulate matter and turbidity; dust can be a source of both. However, the main purpose of test dust, in terms of liquid filter testing, is to provide a source of clogging to test mechanical reduction properties of filter systems. These mechanical filtration properties are most stringently tested when pressure drop is high and flowrate is decreased due to clogging, so the purpose of the dust is to eventually blind-off the pores of the filters.

Certainly, the engineer needs to know a filter's dirt holding capacity for various micron ranges to design any filter system. Vendors' data sheets should contain this information. The data must be reliable and reproducible. Most manufacturers have flow loops and in-house laboratories to test their own and competing filters. These laboratories can also be of help to the engineer by measuring PSDs and TSSs from samples from pilot plants or similar operations at other locations. For field work, the engineer can employ a portable filter-test kit and turbidity meter to zero in on a filter of choice. Knowing the flowrate of the stream in question along with the PSS and TSS, one can calculate the pounds of dirt per day by size. In turn, a filter meeting the required dirt holding capacity, while considering changeout frequency, is then selected.

Since no ASTM standards exist for filter or media testing (ASTM F-795 was withdrawn), the engineer must trust the data supplied by the vendor. Test results and procedures for a supplier's filter claiming to be nominal or absolute and of a removal percent or specific beta ratio should be made available to the engineer.

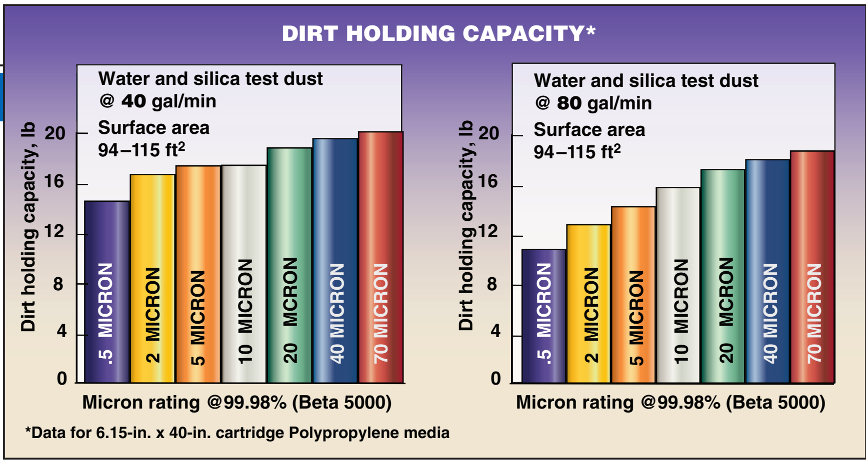


FIGURE 6. A filter has an optimal flowrate to maximize the dirt holding capacity. Doubling the flowrate (right) reduces the dirt holding capacity (left)

Costly shutdowns

Filters used in refineries and petrochemical plants handle very large volumes of product or processing fluids on a continuous basis. Other plant operations found throughout the CPI are batch. Regardless of whether the process is batch or continuous, online time is extremely critical to optimize profitability. Shutting down due to a filtration problem (or any problem) affects bottom line production income by as much as $10,000/h or more. While batch operations have more flexibility, the choice of the filter is still a major concern. Potential product sitting in holding tanks that cannot be shipped because the filtrate does not meet quality control specifications can halt production just as in a continuous process.

Up to 70% of a firm's products may be in a suspension during processing, and filtration is often used for recovery of an expensive end-product rather than to remove an unwanted contaminant. In these cases, filtration becomes the most important of all processes utilized by many chemical giants.

Consequently, higher efficiency and higher product-holding capacity (in lieu of dirt-holding capacity) is essential to assure profitable operations. And, time online becomes even more critical in these situations. It is not unusual for a return-on-investment (ROI) analysis to include considerations for a duplexed system (two parallel filters) to service a process line so that there is never downtime due to changeout requirements.

Even in light of the above, most plant managers and many engineers do not realize that the filtration operation can be the most expensive process that takes place within the production unit, especially when the filter is handling toxic or hazardous (or lethal) materials, and especially when the employees have to "suit up" in order to perform filter maintenance or replacement.

Consequently, remaining online is imperative, and that means improving MTBC and MTBR are critical issues in filtration. The subtle difference between MTBR and MTBC is that changeout sometimes occurs before a cartridge is totally full, while replacement optimally occurs when a filter

DIFFERENT DEPARTMENTS´ NEEDS

At the heart of a plant design are the needs and wants of the decision makers in the flow chain from raw materials in, to finished product out. There are usually conflicting interests that can challenge the filter choice.

For example, the maintenance department wishes to minimize overall costs including number of filter changeouts, time to changeout, number of filters requiring changeout, individual filter cost, disposal cost, loss of product due to filter changeouts, and also to meet plant safety requirements.

The process department requires the quality of the product to meet customer specifications (specs) or intermediates to meet specs, which ultimately produce a finished product that meets customer specs. The intermediate streams must be clean as not to foul heat exchangers, process equipment, and instrument probes. The process engineers usually have selected several products that meet their specs.

The purchasing department desires a minimum number of vendors that they deal with and also to minimize the costs of the filters and number of different filters they purchase. The budget is always tight and purchasing wishes to find alternatives that meet constantly changing pricing requirements, without intentionally disregarding process specs. The filter spec may now be secondary or just moved further down the line in importance.

When the maintenance shift begins a changeout, does the process group know what filter was purchased and if it meets their specs? Were they informed of any changes in the selection process? Who actually controls what filter ends up in the process stream?

Given different needs and desires within a process plant's internal structure, what happens later may not be immediately obvious. Let's consider a real-life example: an amine system in a petroleum refinery.

An amine system

The main purpose of an amine system is to remove H_2S from the process stream and, as part of the sulfur unit's source, carries one of the dirtiest streams in the refinery. This example amine system is similar to many found around the world. Filtration is limited to 10–15% of the circulation stream. Why? The total amine flow circuit can be greater than 3,500 gal/min. The vessels and equipment to handle 100% of that stream did not exist in an economical size or cost range 15 years ago. So in this case, we are filtering a dirty stream with several filter systems; usually the lean and rich streams, before and after the carbon bed, and those protecting coalescers. What happens when a filter that is less expensive and not very efficient at removing particulate matter is is introduced into this system?

From outward appearances, all is fine initially and can be for months. Maintenance is happy because they change filters less often, purchasing is happy because the filters are less expensive. But, because the filters are not removing the particles they should, these build up in the towers, vessels, piping, low points and any other hiding place they can. All gas plants have surges or an increase in capacity that will fluidize the particles that have now accumulated in the hundreds of pounds throughout the system and create a full system upset. When an upset occurs, the filters are quickly fouled and may require changeouts every 30 min for days or weeks before the system settles down. The finger pointing begins and consultants are called in, the filter distributor or vendor is called in, production has halted and the plant manager wants to know what happened? Even if the plant manager is given the answer, the same situation can happen over and over again.

In truth, a filter that lasts long may be bypassing solids or releasing solids at its capacity but not performing the job it was intended to do. It looks good on paper but costs in the long run. Particulate matter helps create stable foams, and when active corrosion loops form when pipe passivity is upset by high acid from heavy crudes, filters can quickly foul from iron carbonate (Siderite). Heat exchangers are fouled requiring increased energy to the regenerator reboiler, velocities in the towers increase, amine carryover occurs and trays foul. The system becomes unstable and the sulfur plant upsets.

Fortunately, many plants are replacing or upgrading their amine filtration systems to handle flows up to 100% of full circulation flowrates. These systems are more stable, and upsets are shorter in duration. Stable systems still require filters that keep the system clean.

What micron range is best for amine systems? Micron ranges for filters range from 10 to 48 microns are in the field with an average at 20 microns for most systems at beta 100 efficiency (99%). ❑

has completely reached its capacity to remove particulate matter, that is, it has reached its maximum dirt- (or product-) holding capacity. But it is important to recognize that cost-savings associated with improved dirt- (or product-) holding capacity should begin with an economic analysis tied to the original filter specification.

Filtration costs

The goal of the filtering process is to obtain the lowest total cost of removing one pound of solids from the system.

FILTER EFFICIENCY (ABSOLUTE RATED FILTERS)

$$\text{Beta ratio} = \frac{\text{Upstream particle count at specified size and larger}}{\text{Downstream particle count at specified size and larger}}$$

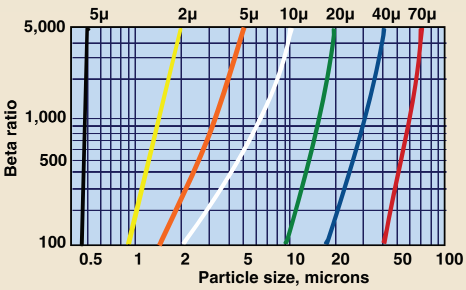
The beta ratio (β) at a given particle size can be correlated to the filter efficiency at that particle size according to the following formula:

Filter efficiency (%) = [(β-1)/β] x 100%

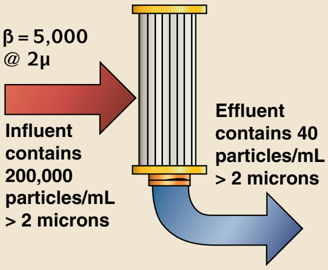
Beta ratio (β)	Filter efficiency (%)
100	99.00
1,000	99.90
5,000	99.98

Each filter element will have a different beta ratio for every specified particle size. The determination of a variety of beta values for the same filter provides a filter efficiency profile commonly referred to as a beta curve.

BETA CURVES



BETA EXPLANATION



If we disregard equipment depreciation, we can express filtration cost efficiency, E, as the total costs (direct and indirect) that are associated with removing one pound of solids from a processing stream. Direct cost is the filter price, P, and indirect costs include labor, L, and disposal, D. These latter two items can dramatically affect total-filtration cost calculations.

Filter price and dirt holding capacity are the dominant components in operating costs, and the ratio of these two items defines the alpha factor, $\AA$ ($\AA = P/H$). With the expression for filtration cost efficiency,

TABLE 4. TYPICAL DATA 20 micron (Absolute) Beta 5,000-rated polypropylene cartridges

Filter type	Dirt-holding capacity, lb	Typical cost, dollars	Alpha factor
2.5-in. O.D., pleated	2.0	44.00	22.0
6.25-in. O.D., pleated	18.0	266.00	14.8
12.75-in. O.D., pleated	100.0	1,053.00	10.5
20.0-in. O.D., pleated	300.0	2,829.00	9.43

$$E = \AA + (L + D)/H$$

we see that indirect costs are reduced as the dirt-holding capacity (H) of the filter increases. Therefore, the alpha factor becomes the dominant number in the equation and overall cost as shown in Tables 3 and 4.

MTBC and dirt-holding costs

Both operations and maintenance engineers recognize that having more on-line time, extended MTBC or MTBR, higher efficiency and higher dirt holding (or product-holding) capacity are essential to lower overall

TABLE 5. COMPARING FILTER CHANGEOUT COSTS FOR A FILTER USING STANDARD 2.5-IN. O.D. CARTRIDGES

Item	Non-hazardous service		Hazardous or toxic service	
	Basis	Cartridge	Basis	Cartridge
Purchase price of filter(s)	Same	Same	Same	Same
Disposal cost	$60/drum per changeout	$240	$800/drum per changeout	$3,200
Changeout time, h	1 h	-	8 h	-
Changeout labor (cost per hour for one person)	$30/man, two men needed	$60	$100/man, three men needed	$2,400
Protective clothing	Tyvek throw-away	$30	$10/h See note #1	$240
Respiratory equipment	None	-	$100/man	$300
Oxygen costs	None	-	$100 per man	$300
Decontamination expense	None	-	$100 per man	$300
Training expense per changeout	-	$100	$4,500	$4,500
Cost subtotal	-	$430	-	$11,240
Number of changeouts	Four change-outs per year	$1,720 Total annual cost (non-hazard-ous)		$44,960 Total annual cost (hazardous)

NOTE #1: Protective clothing is as much as $500/h in lethal service
NOTE #2: All dollars are U.S. (2008)

filtration costs. This is especially true when the filter is handling toxic or hazardous (or lethal) materials.

This article cannot discuss all of the requirements of regulating bodies, but, when filter changeout must include suiting up and breathing protection tied to opening a vessel and handling the filters, filter changeout costs can skyrocket. As shown in Table 5, these costs can go far beyond the simple purchase price of the filter itself.

Some hazardous chemicals (for example, bromine compounds that release Br_2 fumes) can require a team of three people to work the changeout, and each of these personnel may have to undergo annual training (40 h) at a cost to the company (or cost to service companies who may be called in to handle a hazardous work project). Training is estimated at a minimum of $6,000/yr per person.

Assuming a typical MTBC of three months (that is, changing out the filters four times a year), one might select a filter that will reduce the number of changeouts down to one per year, which would result is a savings of $33,720/yr. There can also be a saving in the actual costs of the filters.

One can compare filters using only the basic, actual, annualized costs (no training or other costs) comparing non-hazardous versus hazardous operation. The saving when using high-surface-area filters for toxic, hazard or lethal service is very significant.

Disposal costs

Let's consider the saving discussed above in light of what is happening in the real world with a discussion of filter disposal.

Case 1. First consider a specialty chemical manufacturer that is located on the Houston Ship Channel. This company handles various petrochemicals starting with C_4 compounds and higher with almost all filtration operations considered hazardous (flammable). The filter most commonly used in the plant is a standard cartridge (2.5-in. O.D.). In the disposal effort, about 60 of these filters fit into a standard 55-gal drum.

To avoid having to send these filters to incineration or to a hazardous waste disposal site, management chose to neutralize the used filters by a process known as fixation. That way, the filters can leave the plant classified as a non-hazardous waste. The disposal cost of a drum of these used filters is $60. So, the disposal cost can be considered as $1.00 per filter.

If one considers the total cost of filter disposal, the company must also address the time and economics of fixation. In this case, the fixation agent is flyash. Some companies following a similar disposal ethic, use lime or other agents that can effectively tie up the hazardous materials via oxidation or neutralization, and the filters may have to be cut up or shredded in order to attain the desired level of fixation.

Fixation itself can be a concern; one environmental engineer suggests

TABLE 6: DISPOSAL COST FOR A TYPICAL U.S. GULF COAST REFINERY	
Waste classification	**Comments and costs**
Non-hazardous	Class 2 or 3 Industrial waste (Texas) NA due to high TPH Must be less than 1,500 ppm
Non-hazardous	Class 1 Industrial waste (Texas) $180/drum
Hazardous	Debris that meets LDR for direct burial into landfill $2,000
Hazardous	Debris that must be treated using an immobilization technology prior to landfill $3,200 to $4,200 per drum

Codes and Acronyms: NA Not applicable LDR Land disposal restrictions
TPH Total petroleum hydrocarbons in parts per million (ppm)

that the process can become so hot that one might actually see a blue flame emitted from fixated drums. (The drums used are usually open-top drums that allow for easy entry of the used filters).

In light of the above, consulting engineers have addressed the cost issues by suggesting the following:

- It takes one man-day to remove the filters from their vessel and to gather the filters into a location in order to cut into pieces or shred them
- There is a cost for receiving and handling the flyash
- There is a footprint cost for the processing area as well as a storage cost for flyash (or whatever is used to fixate)
- Protective clothing must be worn, and if the filters contain benzene, one must suit up to avoid exposure
- There is processing time to cut up or shred the filter, add the flyash, assure neutralization and load the spent filters into the filter drum
- There are handling costs (and handling time) for the drum
- There are transportation costs, which are separate from the $60 disposal cost

In total, the fixation for a single drum can utilize two or more man-days, actual flyash material costs of $30/drum, warehousing and storage costs for the ash that has a footprint of (say) 200 ft^2, which amounts to $400/mo. Movement and material handling and transportation adds another $50. Tyvek clothing can cost $40/mo (this assumes that there is no suiting up with breathing apparatus).

In total, the above cost components add $520 to the $60 drum disposal cost for a total cost of $580/drum.

If the plant produces 1 drum/wk of spent filters, the monthly cost reaches $2,320, enough for the plant to consider a high-surface-area filter, which may last for three months thereby freeing personnel for operations and reducing overall disposal costs.

Case 2. Next consider some real numbers from a U.S. Gulf Coast petroleum refinery making (mainly) gasoline and diesel fuel. Filter disposal costs can fluctuate widely depending on volume, density, state taxes, transportation costs and fuel surcharges. The rates (below) are based on approximately 20 yd^3 (one rolloff container) and are for the disposal cost only. Other change-out costs are similar to the numbers found in Table 6.

Land Disposal Restrictions are set by the U.S. Environmental Protection Agency (EPA) and are usually part of a State Implementation Plan (SIP). These restrictions (sometimes published as guidelines) must be met in order to place a hazardous waste into a hazardous waste landfill. If the waste does not meet that standard or cannot be treated to meet the standards, then an alternative must be used, such as incineration or thermal desorption. These latter options are often much more expensive than using a landfill.

Transportation costs are becoming more and more significant. In 2007 one could estimate that a rolloff dumpster could travel at $3.50 per mile, but that cost is quickly reaching $5.00/mi because transporters tack on added fuel charges. Typically, a refinery in Texas experiences a 75-mi haul (one way) and the size of the load is a 20-yd^3 rolloff.

In a refinery, cartridge filters that are typically used (and disposed of) include the following:

- Amine pleated-paper cartridges
- Reformer naphtha feed filters
- Fuel gas filters
- Lube oil filters for big compressors
- Wastewater treatment filters
- Filters that handle gases or liquids from the coking operation
- Fuel filters (both gasoline, diesel and jet fuel filters)

The latter are often metal filters that must handle high temperatures. These are sent out for chemical and physical cleaning — an additional cost not covered here.

Case 3. As a final example, consider costs related to having an outside contractor to handle filters used in hazardous or toxic chemical service. It is common for outside contractor to charge $250/drum to dispose of spent filters — and this does not necessarily include pickup at the plant or delivery to the disposal site.

A full service provider must be strict in respect to the MSDS (Material Safety Data Sheet) taking a close look at flammability, toxicity and heavy metals. Personal protective equipment will be utilized to be on the safe side. Levels of safety (for example, either A, B, C or D will be dictated by either NIOSH, OSHA or the EPA). Level "A" personnel will cost $850 per shift per person. Tyvek clothing will be worn (then thrown away) — a typical cost for that uniform can be $50. Even simple jobs that are non-hazardous are billed at $70–90/h per individual. It is not unusual that safety or risk assessment managers will be required to sign off on a plant's filter disposal procedures.

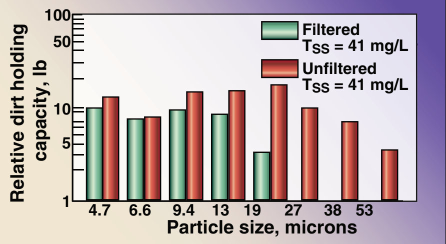
A service provider is expensive. Even non-emergency fee schedules can be exorbitant, both for personnel and expendables, such as: $14 for a 5-gal pail; $20 for a broom; $288 for an 85-gal polymer drum; $70 for a roll of polyethylene.

The point is, operating companies often do not know the true cost of their filtration operations and especially have room for improving their analyses of disposal costs.

It would be unfair not to mention large volumes of waste that are toxic and hazardous, but have energy value, are used in cement kilns for between $1,000 and 1,500/ton. Cement kilns are dramatically short of low-cost fuel but some can still charge for waste disposal.

The kilns are accepting some used filters (if they do not contain vinyl chloride polymers) at $65/drum. This is based on four layers of upright, standard cartridge filters and twenty, 12-in. filters per layer, or about 80 filters per drum.

On the plus side, (from the standpoint of filter disposal) the incineration business (in the U.S.) has been so bad that companies are charging as little as $0.60/lb of waste — even those containing heavy metals or chloride ions because incineration fixates the solids going though the furnace with the ash suitable to go into a regular landfill.



Cartridge filter, 2-5 μm nominal. 9.6 lb.gal NaCl.

Note the distribution of filtered particles greater than the cartridge's nominal micron rating.

(after McLeod & Crawford, copyright 1982 SPE-AIME)

FIGURE 7. Even though this filter is rated at 5 micron, reductions in filtered versus unfiltered do not become significant until after 19 micron

Conclusions

In summary, we can conclude that:

- It is much more expensive to changeout and dispose of filters that have been used in hazardous or toxic service
- Overall performance and cost reductions occurs when a plant can utilize high-surface-area cartridge filters
- By comparison, a high-surface-area filter may only have to be changed out two or three times a year compared to as many as 18 changeouts when using standard cartridges
- By improving MTBC or MTBR, high-surface-area cartridge filters used in toxic or hazardous service gives less exposure to operating and maintenance personnel
- The total cost of ownership should address MTBC and MTBR
- High-surface-area filters offer an increase in effective surface area and in dirt-holding capacity leading to longer filter life
- A filter element's alpha factor is easy to calculate; the lowest alpha factor offers the lowest filter cost

It is not surprising that ROI is dramatically affected by filter selection and filter costs (including replacement and disposal). Yet, this unit operation is often ignored by many companies that heavily depend on fluid-particle separation to assure plant profitability. ■

Edited by Gerald Ondrey

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Feature Report

ENERGY EFFICIENCY: Tracking Natural Gas With Flowmeters

Thermal mass flowmeters provide advantages over other options for metering the consumption of natural gas by individual combustion units throughout the facility

Wayne Shannon, Magnetrol International

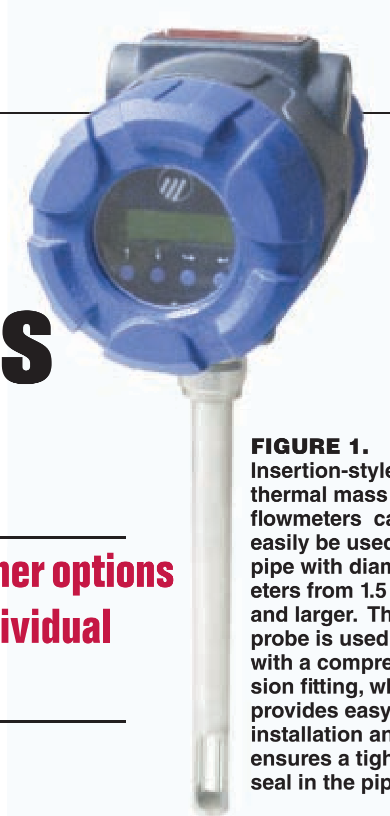


FIGURE 1. Insertion-style thermal mass flowmeters can easily be used in pipe with diameters from 1.5 in. and larger. The probe is used with a compression fitting, which provides easy installation and ensures a tight seal in the pipe

With today's increased emphasis on strategic energy management, many throughout the chemical process industries (CPI) and elsewhere are attempting to obtain better information on the natural gas consumption in their facilities. While custody-transfer flowmeters are typically in place at the property line (to track total gas consumption throughout the facility), the flow to individual combustion sources, such as heaters, furnaces, boilers and so on, generally remains unknown. When armed with better information on actual natural gas utilization, users can optimize the combustion performance by operating combustion processes at peak efficiency.

Similarly, when users measure actual natural gas flow, they are able to determine which of their units is the most efficient. The operating efficiency of furnaces or dryers will vary. Knowing which process unit is the most efficient can result in significant cost savings. For instance, if more than one furnace, dryer or other type of gas-consuming unit is available, the user will be able to choose the combustion unit that provides the highest efficiency.

The first step to energy management and reducing the energy usage is to obtain good measurements of the flowrates of each individual combustion source. In addition to providing tools for improving energy management, the measurement of the natural gas utilized by individual combustion sources may also permit users to meet the regulatory requirements for determining emissions by reporting actual (rather than estimated) natural gas usage for each individual combustion source within the facility.

In general, the pipe size for natural gas flow to individual combustion sources typically ranges from 1 to 6 in. The temperature of natural gas is typically at ambient conditions; rarely will you find natural gas at elevated temperatures.

However, the pressure varies with the application. Because of this, flowmeters are generally located downstream of a pressure regulator. Line pressures typically range from 5 to 10 psig, and occasionally are as low as 1 to 2 psig. Even though the flowmeter is downstream of a pressure regulator, the actual pressure of the natural gas in the pipe may vary depending on the gas consumption. As the consumption increases, the line pressure may decrease.

Flowmeter options

There are many different ways to measure the flow of gases. A brief description of the leading options follows (see also Evaluating Industrial Flowmeters and Advances in Industrial Flowmetering, *CE*, April 2007, pp. 54–64). The difficulty in obtaining good, gas-flow measurements is the simple fact that gases are compressible, and thus the volume of the gas is dependent upon the pressure and temperature at the point of measurement. Chemical engineers will recall the basic concepts of the Ideal Gas Law, whereby gas volume is proportional to the temperature and inversely proportional to the pressure. This complicates gas flow measurement because, with the exception of thermal mass and Coriolis flowmeters, many gas-flow-measurement technologies measure the flow at the actual operating pressure and temperature. These units of measurement are typically expressed as either actual cubic feet per minute (acfm) or cubic meters per hour (m^3/h).

When comparing natural gas usage at various combustion sources for energy-management systems, on the other hand, the desired goal is to measure the flow relative to a defined pressure and temperature — at standard conditions (standard temperature and pressure; STP). While the definition of standard conditions will vary with different industries and in different geographic areas, when the flow is referenced to standard conditions, a mass flow measurement is obtained with units of measurement that are expressed as standard cubic feet per minute (scfm), standard cubic feet per hour (scfh), or normal cubic meters per hour (Nm^3/h).

Flow measurement via orifice plate. This is the traditional method of flow measurement for both gas and liquids. In simplest terms, an orifice is a plate with a hole that is smaller in diameter than the pipe diameter.

FIGURE 2. In this thermal mass flowmeter, the sensors are an integral part of the body construction. This design can be used in pipe sizes from 0.5 to 4 in., and may be used with an optional, built-in flow-conditioning element

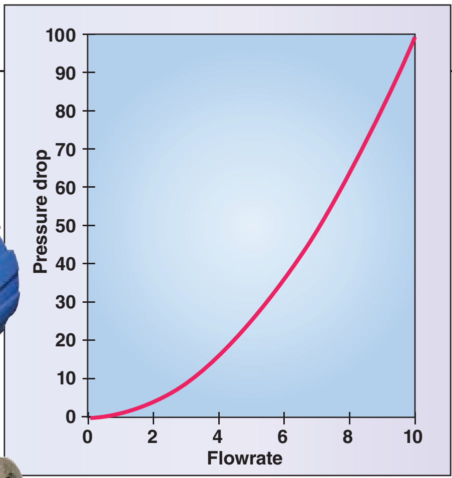


FIGURE 3. Shown here is a typical curve showing the square root relationship between pressure drop and flow for differential-pressure-type flowmeters. At very low flowrates, there is little signal, which limits the ability to accurately measure low flowrates. Similarly, pressure drop increases with the square of the flowrate, and this may limit the turndown or range of this particular type of flowmeter for certain applications

The orifice plate is positioned between two flanges. As the gas is accelerated through the smaller orifice, the pressure decreases, creating a lower pressure on the downstream side of the orifice plate. The flowrate is proportional to the square root of the pressure drop. Flow is therefore determined by measuring the pressure drop across the orifice plate.

The important thing to consider is that the pressure drop is based on the flowrate at the gas density at the actual operating conditions. In order to get a mass flow measurement whereby the temperature and pressure are referenced to standard conditions, it is necessary to also have a temperature transmitter, a pressure transmitter, and a flow computer or multi-variable transmitter. As a result, while the cost of the orifice plate itself is relatively inexpensive, the installed price of the complete system becomes substantially more expensive when one considers the additional instrumentation that is required to obtain an accurate mass flow measurement.

Another factor with orifice plates is their range and turndown. With the orifice plate or any flow measurement based on differential pressure, the signal (pressure drop) is at zero at no flow and then increases with the square of the flow as shown in Figure 3. Thus, if the user has an application requiring a 5-to-1 turndown in flow, a differential pressure transmitter with a turndown of 25-to-1 is required. This issue of turndown can create limitations with the application of orifice flowmeters. Similarly, when sizing an orifice to handle the maximum flowrate, it may not be possible to also measure the flow at the lower end of the range, due to loss of signal.

The pressure drop across a flow element may be a consideration when looking at competing flow-measurement devices for natural gas. Generally, the flowmeter is installed downstream of the pressure regulator with line pressures potentially as low as 1 psig. Under these situations there may not be adequate pressure in the pipe to provide sufficient pressure drop to ensure accurate flow measurement.

Vortex flowmeters. In a vortex flowmeter, a bluff object or shedder bar is placed in the flow path. As gas flows around this shedder bar, vortices are cyclically generated from opposite sides of the bar. This principle is seen every day when looking at a flag fluttering in a breeze. The flag pole is the bluff object and the fluttering of the flag is a visual indication of the vortices as they move across the surface of the flag.

The frequency of vortex generation is a function of the gas velocity. Various methods, frequently relying on piezoelectric crystals, are used to detect and count the number of vortices.

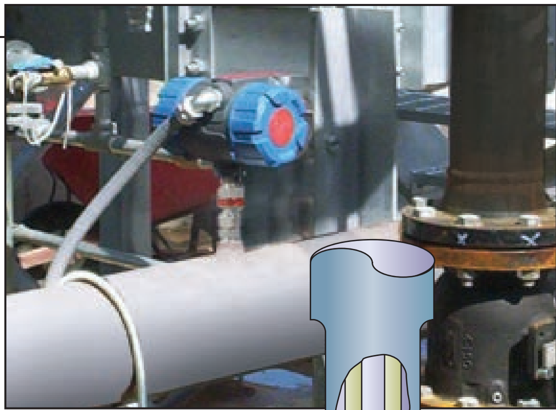
The relationship between the number of vortices shed from the bluff object with the flow is considered to be linear after some minimum flowrate has been reached, as determined by the Reynolds number. It is also important to realize that the measured flow is based on the actual gas density at the operating pressure and temperature. Thus, to convert the flowrate measured by a vortex meter to mass flow, the pressure and temperature must be measured (to adjust for changing gas density).

When applying vortex flowmeters to applications involving natural gas flow, it is important to get complete process information including the minimum and maximum flowrate, the gas pressure and gas temperature. Because of the Reynolds number influence, when sizing a vortex meter to measure the minimum flowrate, it is often necessary to reduce the pipe size in order to increase the velocity to a range that ensures that vortices will be generated. This may complicate the installation of a vortex flowmeter in existing installations and may also increase the pressure drop.

Turbine flowmeters. Turbine flowmeters have wide application for natural gas flow measurement. The operation of a turbine is based on a free-spinning rotor. As the fluid flows past the rotor, the rotor is turned with each revolution that corresponds to a given quantity of gas. There is a magnet in the rotor. The number of rotations are counted using an external pickup that provides a series of electronic pulses with each pulse equivalent to one rotation. The pulses are then sent to the transmitter.

The manufacturer provides a K factor to relate each rotation to a given gas volume. The number of pulses that are counted over a given time period provide both the flowrate and the totalized flow.

Turbine meters have relatively high turndown capabilities with corresponding high measurement accuracy. Like the previously mentioned flowmeter types, the turbine flowmeter is a volumetric device that measures the actual flow at the operating conditions and thus requires pressure and temperature correction to obtain accurate mass flow. Considerations when applying turbine meters include the cleanliness of the gas and the fact that there are moving parts in the gas stream.



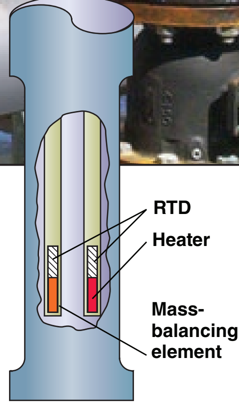


FIGURE 4 (top). **In this installation of a thermal mass flowmeter in a 6-in. pipe, the device measures and totalizes the flow of natural gas to a combustion source such as a boiler, heater, furnace or other combustion unit**

FIGURE 5 (bottom). **Thermal mass flowmeters include a sensor such as the one shown here. It consists of two pins. Each has an RTD. One has a heater and the other has a mass-balancing element to ensure equal thermal mass between the two pins. A small temperature difference is maintained between the two RTDs. The amount of power applied to the heater to maintain this temperature difference is then used to obtain a mass flow measurement**

Ultrasonic flowmeters. This technology measures the difference in transit time of pulses that travel from a downstream transducer to the upstream transducer, compared to the time from the upstream transducer back to the downstream transducer. While this technology is accurate and accepted by AGA (American Gas Assn.) for the custody transfer of natural gas, the suitability of this technology for measuring the flow of natural gas to individual combustion sources within a facility becomes questionable, considering the relatively low velocities, and more importantly, the high cost of this device compared to other technology options. (Note that AGA also accepts orifice plate, turbine and Coriolis flowmeters.) Flowrate is measured at the actual operating conditions, requiring pressure and temperature to obtain mass flow. Some ultrasonic flowmeters will require a higher pressure (for instance, some units require a minimum of 150 psi operating pressure).

Coriolis mass flowmeters. Coriolis flowmeters provide a direct mass -flow measurement by measuring the deflection of a vibrating tube. This is a true mass flowmeter, as it is insensitive to changes in pressure, temperature, density or gas composition. The Coriolis flowmeter is very accurate, with high turndown capabilities.

Coriolis flowmeters often require the pipe size to be reduced in order to obtain the desired range measurement. While suitable for measuring flow to individual combustion sources, this approach becomes rather expensive and is rarely used for the in-plant measurement of natural gas.

Thermal mass flowmeters. Thermal mass flowmeters (Figures 1, 2 and 4) provide an inferred measurement of the mass flow of the gases passing through them. Specifically, thermal mass flowmeters measure heat transfer that is caused as the molecules (hence, the mass) of gas flow past a heated surface. The relationship between heat transfer and mass flow is obtained during the calibration of the instrument.

In addition to providing a mass flow measurement without the need for additional devices to correct for pressure and temperature (as is required with the other flowmeters, with exception of Coriolis devices), thermal flowmeters also provide the following advantages:

- *Lower flow sensitivity*. A thermal mass flowmeter will easily measure flowrates that are much lower than those that can be measured using orifice plates or vortex flowmeters. This permits a thermal flowmeter to be retrofitted into existing natural gas pipes using a simple NPT (national pipe thread) thread or flange connection on the pipe. This simplifies installation compared to other flowmeters, which may require a reduction in the pipe size in order to obtain the desired rangeability
- *Higher turndown capabilities*. A range of 100-to-1 is easily obtained with a thermal mass flowmeter. Some combustion systems may have a high natural-gas firing rate during initial warm-up operation and then, once the desired temperature has been obtained, the flowrate of the gas is typically reduced to maintain the desired operating temperature. A thermal mass flowmeter can easily handle this range, which may be difficult to obtain with other technologies
- *Simplified installation*. An insertion device permits simplicity of installing the flowmeter using NPT connection, flange, compression fitting or even a complete retractable probe assembly. Using a "hot tap" permits the user to install the flowmeter without having to shut down the operation. The insertion design also permits the use of the same instrument in different pipe sizes. Some use the insertion probe as a semi-portable instrument and reconfigure the transmitter for the different pipe sizes
- *Lower pressure drop*. There is virtually no pressure drop when using a thermal mass flowmeter. This is advantageous in low-pressure applications where other technologies would consume operating pressure

Today, thermal mass flowmeters from different manufacturers rely on different methods of operation and sensor designs. All methods accomplish the same thing, which is to provide a mass flow measurement.

A cutaway of a typical sensor is shown in Figure 5. The sensor consists of two elements, one providing a temperature measurement of the gas, with the other element heated to maintain a desired temperature difference between the two RTDs (resistance temperature detectors). Some manufacturers use self-heated RTDs, while others use a separate heater.

Because there is a heated element in contact with the natural gas, the user should ensure that the temperature rise of the sensor is less than the autoignition temperature of natural gas, and that the instrument has all appropriate agency approvals for use in hazardous areas.

With this design, the electronics maintain a desired temperature difference between the two pins. At no flow, there is little heat loss and it takes little energy to maintain the desired temperature difference.

As flow increases, heat is transferred from the heated sensor into

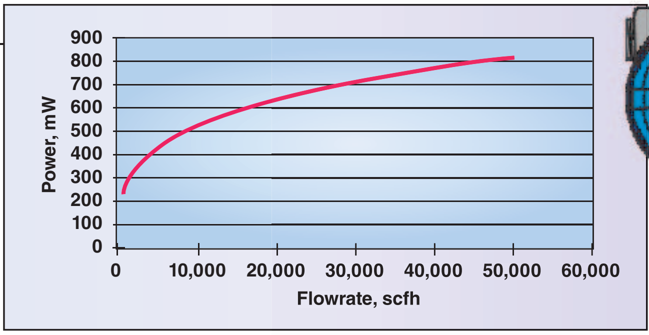


FIGURE 6 (top left). This curve shows the relationship between the power and the mass flowrate for a thermal mass flowmeter in a 4-in. pipe. Such a curve is developed during the calibration of the instrument

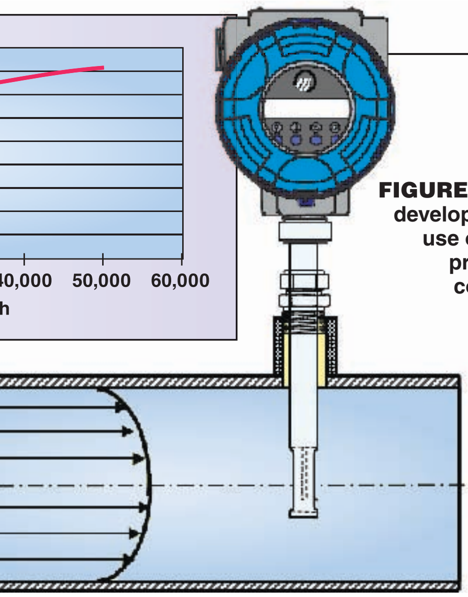


FIGURE 7 (bottom right). This figure shows a fully developed flow profile in a pipe. It also shows the use of a compression fitting for positioning the probe in the pipe. This installation provides considerable flexibility and easy installation

the gas stream, the electronics detect the reduction in the temperature difference and apply more power to the heater to maintain the desired temperature difference. The typical relationship between mass flow and power is shown in Figure 6.

The shape of this curve is very different from the comparable curve that was previously discussed for an orifice plate flowmeter (Figure 3). For instance, with a thermal mass flowmeter, there is a signal at low flow, and that signal increases rapidly, providing a great deal of sensitivity at low flowrates. This is why the thermal mass flowmeter is able to reliably measure much lower flowrates compared to competing flow-measurement technologies.

Meanwhile, as the flowrate continues to increase, the amount of power required to maintain the desired temperature difference continues to increase — but not as rapidly — thus providing the higher turndown capabilities mentioned earlier. However, as the flowrate continues to increase, the sensor will eventually reach a state where it becomes saturated and unable to transfer any more heat into the gas.

Calibration of the thermal mass flowmeter is required to establish this relationship between mass flow and heat transfer. Calibration involves placing the flowmeter in a test bench, flowing a known amount of gas past the sensor, measuring the signal, and repeating the process at different flowrates. At least ten calibration points should be obtained over the calibration range of the instrument for best results. These data are analyzed and the calibration data are then loaded into the instrument. After calibration, the flowmeter will provide a linear output signal over the calibration range.

Because of the heat-transfer characteristics of the sensors, each individual sensor must be calibrated. Once calibrated, the user can reconfigure the instrument for a lower flow range to accommodate those situations where the initial flow may be low, and then increase over time as production in the facility increases.

We have previously shown that thermal mass flowmeters provide a mass flow measurement based on the thermal properties of the gas, and thus, temperature correction for density adjustments are not required when going from actual operating conditions to standard conditions. However, it is recognized that the thermal properties of the gas will change with gas temperature. Thus it is important that the thermal flowmeter have realtime temperature compensation, to continually adjust the flow measurement for variations in the process gas temperature.

Various manufacturers deal with the issue of temperature compensation differently, with some manufacturers providing temperature compensation as a standard offering; with these designs, the instrument also measures the gas temperature and adjusts the flow measurement for variations in the thermal properties of the gas with temperature.

Thermal flowmeters will provide a 4–20-mA output signal that is linear with the flowrate. A built-in software totalizer is also available, with the totalized flow shown on the display for those users who want to obtain the total consumption of the natural gas over a given time period. Those designs that also measure the gas temperature as part of the realtime temperature compensation also have the ability show the temperature on display of the flowmeter. Units with HART communication have the ability to transmit the mass flow, temperature and totalized flow as part of the HART data stream. Other units may also provide a pulse output and a milliamp signal of the temperature.

Changing gas composition will affect the heat transfer characteristics of the gas and potentially create an error in flow measurement. This is most prevalent when a significant change is made in the type of gas that is flowing through the unit — for instance, using a thermal mass flowmeter that was originally calibrated for air in natural gas service.

Fortunately, minor changes in the composition of natural gas, such as a reduction of methane content with a corresponding increase in the ethane content, will have very minor changes on the overall flow measurement that is produced by a thermal mass flowmeter. Using this example, the density of methane and ethane are considerably different, which will have a significant effect on other flowmeter technologies (such as those based on the measurement of differential pressure) where the gas density is directly used in the flow measurement.

With thermal mass flowmeters, the gas density is only one of the factors that affect convective heat transfer. Variations in methane and ethane content of the natural gas can create a change in the heat transfer characteristics of the natural gas (and slightly affect the flow measurement). However, the relative change in heat transfer is comparatively less than the change in gas density, which is directly used by other flowmeters.

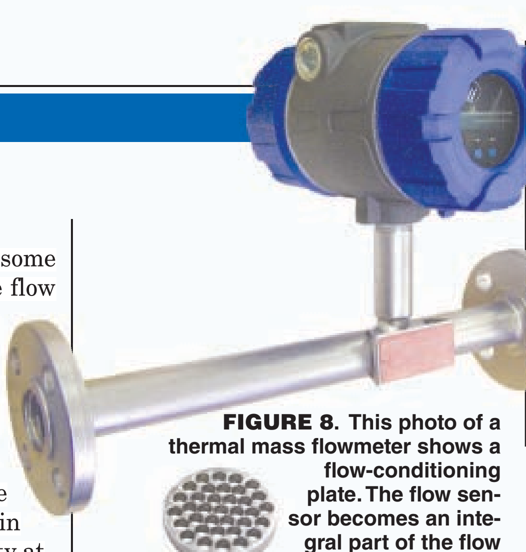


FIGURE 8. This photo of a thermal mass flowmeter shows a flow-conditioning plate. The flow sensor becomes an integral part of the flow body. This design can be used in pipes as small as 0.5 in. and up to 4 in. The optional flow conditioning is used for those applications where there is insufficient straight run to obtain the expected flow profile

FIGURE 9. A thermal mass flowmeter with remote electronics is used to measure the biogas flow from an anaerobic digester. The probe is located roughly 3 ft from the floor, and the remote head permits the operator to view the display. A retractable probe assembly is used to permit the removal of the probe from the pipe to ease maintenance while minimizing leakage of a combustible gas

Installation considerations

Nearly all flowmeters require some straight run of pipe ahead of the flow sensor. Thermal mass flowmeters follow the same basic guidelines. The flow calculations used with an insertion-type flowmeter assume the presence of this fully developed flow profile and the placement of the sensor on the centerline of the pipe as shown in Figure 7. Theoretically the velocity at the wall is zero and the velocity on the centerline of the pipe is 20% higher than the average velocity.

This illustration also shows the use of a compression fitting that is commonly used for inserting the probe into the pipe. Because the flow profile at the centerline is relatively flat, minor variations in the insertion depth of the sensor will not have any impact on the flow measurement.

Theoretically, this desired flow profile occurs with a straight run of pipe whose length is the equivalent of approximately 20 pipe diameters. This is the general guideline for the amount of straight run following a single elbow, while longer lengths are required following a double elbow.

In many cases, this amount of straight run may not be available. When this is the case, options that are available include the use of a flow body with a flow conditioner as shown in Figure 8. This design ensures that the desired flow profile at the sensor is obtained. The use of a flow conditioner reduces the straight-run requirements. Or, the user may accept a reduction in the absolute accuracy due to the presence of the non-uniform flow profile, realizing that the flow measurement will continue to be repeatable.

If using an insertion probe, another installation effect that is not frequently realized is the correctness in pipe size. The inner diameter (ID) of the pipe or the pipe area is entered into the transmitter. Users will frequently specify pipe size such as 4-in. Schedule 40 in which case the manufacturer utilizes the pipe dimensions from the standard pipe tables. What many users may not realize is that the dimensions in the pipe tables are nominal dimensions, and in reality, the wall thickness of the pipes may vary, resulting in corresponding variations in the pipe ID. Since the pipe area is a critical factor in calculating the mass flow, any deviation between actual pipe size and the nominal dimensions will cause errors in the flow measurement.

It is generally possible to enter correction factors in the transmitter to adjust for non-uniformity of the flow profile, pipe size or other installation effects. However, this requires that the user have a valid basis for comparing the measured mass flow with the expected flow.

Biogas measurement

Considerations related to the measurement of biogas using thermal mass flowmeters are very similar to those for natural-gas flow measurement. The primary difference is that biogas composition is typically a mixture of methane and carbon dioxide, with the potential trace concentration of other gases depending upon the application. Typically, this ratio is 65% methane and 35% carbon dioxide. Biogas can come from a number of sources including anaerobic digesters, landfill operations, and organic-industrial-waste processing. Other distinguishing issues with biogas is that the gas is often wet and may also be dirty.

Biogas measurement systems frequently operate at relatively low pressures and low flowrates. The combination of low flow, low pressure, and a wet and dirty gas rules out most other technologies, due to lack of sensitivity at low flowrates and difficulties with the potential buildup of particulate matter on the flow element. By comparison, thermal mass flowmeters (Figure 9) are particularly well-suited for biogas/digester gas-flow measurement, due to the low flow sensitivity and low pressure drops. The use of an insertion probe with a retractable probe assembly eases the periodic removal of the probe for cleaning.

There are many flow-measurement technologies that can be used for the measurement of natural gas and biogas. However, thermal mass flowmeters provide certain advantages in terms of mass flow measurement, turndown, flow sensitivity, low pressure drop and ease in installation. In fact, thermal mass flowmeters tend to allow for very economical installations, thereby providing the lowest installed cost compared to other technologies that require pressure and temperature compensation. ■

Edited by Suzanne Shelley

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Preventing Dust Explosions

Risk management programs are critical for safe handling and processing of combustible dust as well as for OSHA regulatory compliance

FIGURE 1. This photo shows the effects of pneumatic transport of powder to a silo through a hose not designed to conduct away static electricity. The friction caused by static electricity has created enough heat to cause a hole to form. Code compliance with OSHA requires continuous monitoring of potential ignition hazards, including the control of static electricity and process equipment hot spots, similar to the pictured example

Geof Brazier and Mitch Rooker
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Household items, such as breakfast cereal, flour, corn starch and sugar are so common that many were left surprised after the 2008 combustible-dust explosion at a sugar refinery in Georgia. Heard in much of the early media coverage was the question "How could sugar explode?"

Plant explosions are, thankfully, not routine occurrences. However, when they do occur, it is the unusual event — often a combination of abnormal events — that is typically the trigger. This article outlines some of the guidelines that are available to help prevent dust explosions. It also offers a list of factors to consider when choosing explosion vent technology to minimize combustible-dust-explosion hazards.

The facts are that in the U.S. and elsewhere, the chemical process industries (CPI) are working to minimize the risk of combustible dust explosions by following a revised suite of National Fire Protection Association (NFPA) standards, that are recognized by the U.S. Occupational Safety and Health Administration (OSHA). A documented combustible-dust, risk-management program that is regularly updated, forms the cornerstone of a plant's owner/operator responsibility to provide a safe workplace. Identification of areas of risk, along with implementation of prevention and protection strategies, achieves compliance with these safety standards.

OSHA's Combustible Dust National Emphasis Program (NEP) and the NFPA's current standards define best engineering practices and are designed to protect both personnel and plant from combustible dust explosions. These standards are typically adopted by state fire marshals, insurance companies, consultants and their legal representatives and are referenced by the OSHA NEP. OSHA can and does issue safety citations in relation to combustible dust risks. Its citations are based on the General Duty Clause whereby the owner/operator of a facility shall provide a safe workplace, as well as by reference to specific NFPA standards including 61, 68, 69, 86, 484, 499, 654, and 664.

OSHA's NEP

OSHA introduced the Combustible Dust National Emphasis Program in October 2007 issued by the Directorate of Enforcement Programs and revised it on March 11, 2008 with directive number CPL 03-00-008*. This document describes OSHA's policies and procedures regarding inspection of facilities that handle combustible dust as well as their expectations regarding owner/operator compliance with U.S. safety standards. The scope is national and administered by national, regional and area offices of OSHA or the officials of participating state programs. Its focus includes the following three technical areas of risk management:

1) Dust control
2) Ignition control
3) Injury and damage control

Dust control. To summarize, dust control is achieved by the implementation of appropriate combinations of housekeeping and dust collection-and-filtration measures. These measures are combined with inspection to ensure that they remain effective. A layer of dust that is only 1/32-in. thick is a concern when it covers 5% or more of a workplace floor area that has dust-laden structural members, such as joists and I-beams. Successful dust control reduces fugitive emissions of combustible dusts, which in turn cuts the dust explosion risk.

Quantification of a combustible dust risk requires that the characteristics of the material be identified by test. Key parameters include the maximum explosion pressure (*Pmax*), the deflagration index (*Kst*) and the minimum ignition energy (MIE) of the dust. Prevention and protection strategies must also be based on knowledge of process conditions, such as dust concentration, airflow velocity, operating pressure, temperature and humidity.

The higher the *Kst* value, the faster the rate of pressure rise due to combustion. *Kst* values above 600 are considered extremely explosive. Most common plant dusts have *Kst* values between 100 to 150. Even if a plant owner/operator knows the characteristics of a particular dust, a sample must be tested under NFPA 68. Particle size can profoundly affect explosive properties, as the finer the dust, the higher the *Kst* value. For example, sugar has a recorded *Kst* value of about 138. Of more concern with regard to the potential damage to process equipment is the fact that a fine-sugar-dust explosion will generate a pressure in excess of 100 psi within an enclosed volume in less than 100 milliseconds. Other key

* Available for review on www.bsbipd.com

parameters include particle size, with smaller particles equating to more rapid combustion and easier ignition. The reason is that more surface area is freely accessible by the surrounding air to support combustion.

Ignition control. Understanding and monitoring for potential ignition hazards at a plant provides a first layer of protection to the facility. Essential measures include proper grounding and bonding of equipment and ducting, appropriate wiring of electrical equipment, the control of static electricity (see Avoiding Static Sparks in Hazardous Atmospheres, *CE*, June 2009, pp. 44–49) and monitoring of process equipment hot spots (Figure 1). Preventive maintenance programs ensure that such design safety measures remain effective.

Review of dust-explosion loss history proves that it is important to consider "normal" and potential "abnormal" circumstances while evaluating processes within a facility. Many times a dust explosion is the result of an abnormal event, such as when an automated process fails and it is replaced by a temporary, manual activity. Other times it could be a consequence of a change in product packaging. For example, an operator at a manual bag-emptying station receives a shrink wrapped pallet of bags. Instinctively, he walks toward the pallet, across a concrete floor, while wearing appropriately specified conducting shoes. The surrounding metal equipment is grounded. The operator stands on shrink-wrap-packaging material (an insulator) as it is unwrapped, tears open a bag of material and empties it into an adjacent hopper. As the dry powder flows, static charge builds on the now insulated operator until there is sufficient electrical potential to release a spark having sufficient energy to ignite the dust present in the emptying station.

Injury and damage control. The OSHA NEP anticipates the deployment of specialty technology to mitigate the effects of a dust explosion. Referenced techniques fall into the following four areas:

- Prevention: Detection of sparks and embers traveling through a dust collection system can lead to their quenching before reaching an area of high dust-explosion risk, such as a filtration unit
- Isolation: Introducing a barrier to flame propagation can prevent a primary dust explosion in one piece of equipment from amplifying into a typically more-severe secondary event in a connected item of equipment. Solutions include chemical isolation (particularly well-suited to large or irregular-shaped ducting) and mechanical isolation barriers (Figure 2), such as pinch valves, knife gate valves and rotary airlocks
- Venting: Pressure relief is provided to process equipment and to building structures by releasing the products of combustion to the atmosphere in a safe trajectory. Flameless venting provides for over-pressure protection without the release of flame or particulates to the atmosphere when following the requirements of NFPA68-2007
- Suppression: Explosion effects can be minimized by injecting a flame quenching agent into process equipment to arrest the combustion process — explosion suppression equipment responds rapidly to prevent the full development of a dust explosion, preventing a destructive overpressure from developing (Figure 3)

FIGURE 2. Isolation introduces a barrier to flame propagation that can prevent a primary dust explosion from amplifying into a secondary fire and explosion in an interconnected piece of equipment. This example shows chemical barrier isolation on a 36-in.-dia. duct

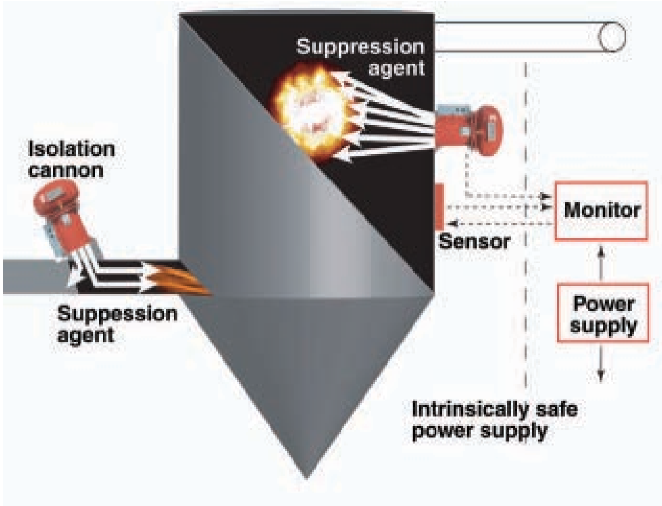

FIGURE 3. In this illustration, the explosion suppression system extinguishes the fireball as it occurs, rapidly injecting a heat-quenching agent into the tanks and duct to extinguish the fireball. The outside world does not hear or see the fireball. The readings from the sensor and monitor are the only indication that an explosion has occurred

In addition, an emergency action plan with properly maintained exit routes ensures the right safety response for protection of personnel.

Understanding the risks

The course of action to minimize combustible-dust-explosion hazards begins, preferably, in the planning stages of a process by identifying the risks, determining the explosive reactivity of the combustible process dust, and implementing a combination of both prevention and protection measures.

Economic considerations favor the use of explosion vent technology in terms of cost of equipment and installation. However, many factors must be considered before choosing explosion vents. Consider the following application factors:

Can the flame ball that is ejected from an open vent be accepted? It will usually extend 30 to about 100 ft in length and about half this in diameter. An 1,800-ft^3 vessel venting from a single position will produce a flame ball over 100 ft in length and 50 ft in diameter. Simple free venting must be directed to a safe location where personnel will not be present and other equipment cannot be damaged (Figure 4).

If venting equipment is installed

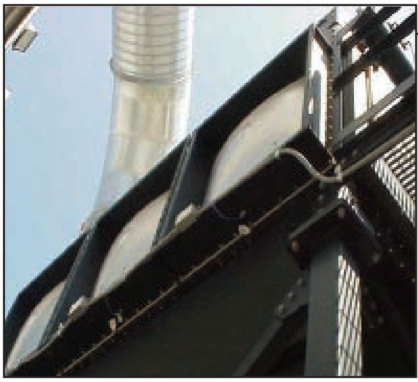

FIGURE 4. **The photo shows explosion venting of a dust collector. A vented flameball is a mass of dust and combustion gases over 2,000°F that may extend 30–100 ft from the point of exit. Simple free venting must be to a safe location where personnel will not be present and other equipment cannot be damaged**

indoors, can a vent duct to a safe outdoor location be provided? Vent ducts will always increase the required vent area, and their use may not allow smaller process volumes at higher *Kst* values to be protected by venting at all.

Can the required vent area be accommodated? As well as requiring the space for vent installation, can the reaction forces during venting be sustained and, for tall equipment, can a near-thrust, neutral vent arrangement (top-sidewall-mounted vents) be achieved to prevent collapse during relief?

If there are process inlets and outlets to the protected equipment, are these protected to prevent propagation of the dust explosion to other equipment or work areas? Standards are now very clear in requiring isolation of vented equipment to prevent secondary explosions. Secondary explosion risks are typically much greater in their potential for damage and destruction.

Can the clean up of a vented explosion be accepted? Depending upon the design basis adopted, a vented explosion may require replacement of capital equipment components that have become damaged by the pressure wave, resulting in loss of production while delivery is awaited. Most vented equipment is designed with a pressure relief area that prevents failure of the equipment structure. A higher vent area is always required to protect equipment within its design pressure.

What will the neighbors think? A vented explosion is a spectacular event that will draw considerable community attention.

What if the process material is toxic or hazardous? A vented release must simply be avoided for certain materials.

As illustrated by the previous series of questions posed for a vented-dust-explosion application, each process needs to be considered both alone and as a component of a production facility to ensure that the right explosion protection and prevention technology is implemented. There are always options for dust-explosion-risk management. The technical solutions adopted must take proper account of the practical needs of each process and the consequences of safety system operation.

Some final rules of thumb include: plan for the abnormal; and maintain a strict management of change policy that will catch the potential consequences of product material changes, hardware changes, and procedural changes. Dust-explosion-risk management requires periodic detailed review, even at the best-protected facility. ■

Edited by Dorothy Lozowski

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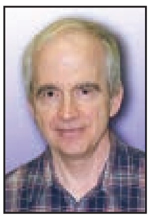


Mitch Rooker is a senior development engineer at BS&B Safety Systems LLC and along with his co-author, serves as a member of the NFPA Committee on Explosion Protection Systems. He has more than 30 years of experience in research, design and development of industrial products and many patents in the area of overpressure protection. He holds a degree in Mechanical Engineering from the University of Oklahoma.

COMPRESSED GASES: Managing Cylinders Safely

Richard Palluzi
ExxonMobil Research & Engineering

Follow these recommendations to ensure the safe handling, storage and use of gas cylinders

Compressed gas cylinders are widely used in research, pilot plant, laboratory and small-scale manufacturing and processing operations as a way to provide a convenient, economical and safe source of high-pressure gases for various applications. These gases can be inert, flammable, toxic or oxidizing (or mixtures of any or all), and are typically supplied at pressures from 800 to 6,000 psig, with 2,250 psig being common. A compressed gas is defined by the U.S. Department of Transportation (DOT) as any materials or mixtures in containers having an absolute pressure in excess of 40 psi at 70°F, or in excess of 104 psi at 130°F.

Cylinder basics

Gas cylinders have several major components, including the cylinder body, a steel or aluminum cylinder with a strengthened, threaded neck, a flat bottom rim for standing level, the valve assembly to control the gas flow, and a protective cap. Each cylinder is stamped with its design information, as shown in Figure 1. Items of particular interest include the cylinder size (which is required for calculating the content volume), the cylinder maximum design pressure, and the cylinder test date.

If it is past the test date indicated on the cylinder, the cylinder can be transported and the contents can still be used, but the unit cannot be refilled. Nearly all manufacturers label their cylinders with a stick-on label that provides the type of information shown in Figure 2.

Different manufacturers refer to their cylinders by a variety of different terms, and not all manufacturers provide all sizes. The most common sizes are shown in Table 1.

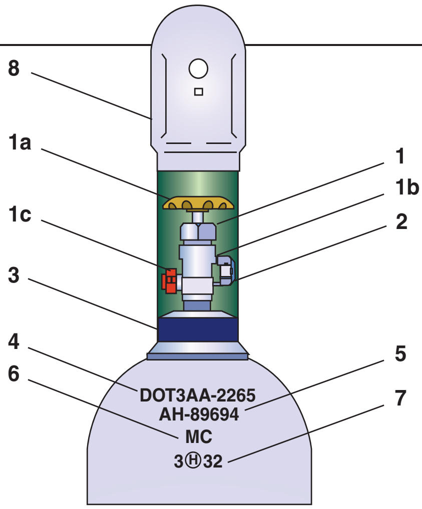
In the U.S., gas cylinder design and construction is governed by DOT codes. Rarely does a user need to worry about how a given cylinder is designed. One exception, however, is when the user is asking for a specialty cylinder for a non-standard application, such as a specialty gas made specifically for a one-time application, a sample of a new mixture, or similar one-of-a-kind uses. Specialty cylinders that are significantly past their date (by two years or more), should not be used; rather, they should returned to the supplier as soon as this fact has been discovered. Cylinders provided by specialty suppliers for non-standard sources should be confirmed to be adequately designed before being accepted.

Gas cylinders are designed to be transportation vessels — not pressure vessels. As such, they are not usually intended to replace a well-designed pressure vessel. In particular, DOT design standards are not intended to adequately cover pressure cycling. Most DOT vessels will only be rated for ~60% of the comparable American Society of Mechanical Engineers (ASME) rating. Hence, before using any gas cylinder as a pressure vessel (such as an accumulator), the design should be reviewed by both a pressure vessel expert and the vessel manufacturer. In most cases, using the cylinder will not prove to be the best course. For these applications, a properly designed and constructed ASME-code vessel is the proper choice.

Pressure relief

Gas cylinders are protected from overpressure in several ways. A pressure-relief device is always installed in the neck of the cylinder (Figure 1). A variety of such devices may be used, depending on the supplier and the gas:

- ***A rupture disk (CGA code CG-1).*** This device consists of a thin piece of metal that is designed to burst and release the cylinder contents to the atmosphere. The rupture disk setting may not exceed the minimum-DOT-required test pressure of the cylinder, which is usually 167% (5/3) of the cylinder service pressure. It may not exceed 4,500 psig for the DOT-3E or CTC-3E specification cylinders, nor be less than 105% of the cylinder test pressure, or greater than 80% of the minimum burst pressure for DOT-39 cylinders.
- ***A fusible link (CGA code CG2 or 3).*** This device relies on a metal link that is designed to melt at a given temperature and release the cylinder contents to the atmosphere. Fusible links are generally set between 165 and 220°F.
- ***A combination rupture disk and fusible link (CGA code CG 4 or 5).*** In this design, a fusible plug is provided on the atmospheric side of the rupture disk. The burst pressure of the disk may not exceed the minimum DOT-required test pressure of the cylinder, and the fusible link must melt or extrude between 157 and 220°F. Such an assembly is designed to prevent a release in the event of a small external fire (in which case the fusible link may fail but the pressure not rise sufficiently to burst the rupture disk), or a premature failure of the rupture disk (in which case the fusible link will remain intact).
- ***A spring-loaded relief device (CGA code CG7).*** This device is designed to open when the pressure exceeds a set value and to close again once the excess pressure is relieved. These are relatively uncommon in most gas cylinders due



1 Cylinder shut-off valve packing nut
1a Cylinder shut-off valve
1b CGA outlet connection
1c Cylinder pressure-relief device (relief valve, rupture disk or fusible link)
2 CGA outlet cap to protect threads and keep clean
3 Threaded cylinder collar to accept protective metal cap
4 DOT specification (3AA) and service pressure (2,265 psig)
5 Manufacturer's serial number
6 Manufacturer's symbol (MC)
7 Test date (3/89)
8 Cylinder cap

FIGURE 1. Key components of an appropriately appointed compressed-gas cylinder are shown here

to their larger size, higher cost and greater complexity. The relief device setting must be greater than 75% and less than 100% of the cylinder's minimum test pressure with a reseating pressure greater than the pressure in a normally charged cylinder at 130°F. The relief device on DOT-39 cylinders must not exceed 80% of the minimum burst pressure of the cylinder nor be less than 105% of the cylinder test pressure.

Meanwhile, heating is often required for calibration gases (to prevent condensation) and liquefied petroleum gases (to vaporize the liquid or increase the delivery pressure). No matter which type of device is used, the potential for cylinder overheating remains a concern. In all cases, gas cylinder heating should be carried out by indirect methods using steam, hot water, hot air enclosures or similar heated enclosures.

While some manufacturers supply electric heating blankets, these should be considered a higher-risk alternative. The electric heating elements often operate well above the fusible-

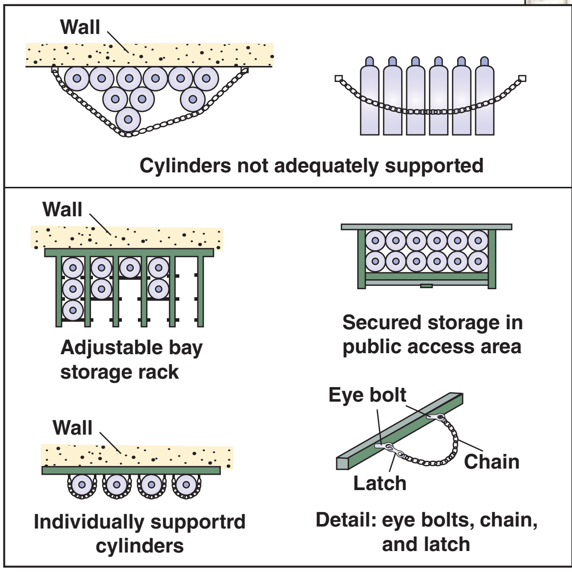
FIGURE 2. The manufacturer's label provides critical information to assist the end user

TABLE 1. COMMON CYLINDER DIMENSIONS AND CAPACITIES

Size	DOT specifications	Nominal dimensions* (Excluding valve & cap), in.	Average tare weight, lb	Average internal volume, ft^3
High pressure				
A	3AA2400	9 x 55	137	1.76
B	3AA2265	9 x 51	119	1.55
C	3A2015	7 x 33	57	0.56
D-1	3A2015	7 x 19	26	0.26
D	3AA2015	4 x 17	9	0.10
4X	3AA2015	4 x 13	6.6	0.075
L.B.I.	3E1800	2 x 12	2	0.015
L.B.	3E1800	2 x 12	2	0.015
Medical E	3AA2015	4 x 26	14	0.16
BX	3AA6000	10 x 51	300	1.49
BY	3AA3500	9 x 51	187	1.53
Low pressure				
A	3A480	10 x 49	85	1.93
B	3A480	10 x 36	90	1.28
C	3A480	8 x 22	33	0.53
AA	4AA480	15 x 52	160	4.46
A1	4BW240	16 x 50	75	3.83
A-2	4BW240	22 x 48	167	7.64
C_2H_2				
A	8/8AL	12 x 41	185	2.36
HCl and bulk electronic gases				
Y	3A1800	24 x 90	1,108	15.83
H_2S				
T	106A800X	30 x 82	2,254	25.82
SO_2, C_2H_5Cl, Cl_2, CH_3Cl				
T	106A500X	30 x 82	1,400	25.64
Aluminum				
A(Al)	3AL2216	10 x 52	90	1.64
B(Al)	3AL2015	8 x 48	48	1.04
C(Al)	3AL2216	7 x 33	32	0.56
D-1(Al)	3AL2216	7 x 16	15	0.21
4X(Al)	3AL1800	4 x 10	3.3	0.057
Nickel				
B	3BN400	7 x 45	88	0.65
D-1	3BN400	7 x 22	48	0.28
D-2	3BN400	5 x 15	10	0.10
Stainless steel				
55 gal	UN1A1	24 x 45	175	7.35
10 gal	UN1A1	14 x 29	50	1.34
5 gal	UN1A1	9 x 24	25	0.67

*These dimensions are not exact. They should not be used for engineering drawings or equipment specifications.

link, relief-valve or rupture-disk setting (800–1,100°F is common) even when operating at lower temperatures. Hence the heating elements rely on the control system (whether automatic or manual) to limit the cylinder temperature to a value below that required to initiate the relief device. The Box on p. 58 shares some simple guidelines for safe hot-box design.



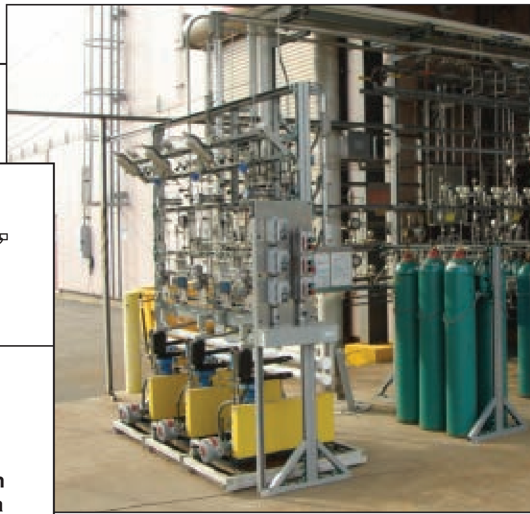


FIGURE 3. Unless they are properly secured, compressed-gas cylinders can fall and present a hazard in the workplace. Examples of proper procedures for securing gas cylinders are shown here

Regulations and codes

In the U.S., specific requirements from the Occupational Safety and Health Administration (OSHA) for gas cylinders are rather minimal:

- OSHA 1910.101 (a) requires routine inspections per DOT regulations [49CFR parts 171–179, and 14CFR part 103]
- OSHA 1910.101 (b) requires that in-plant handling, storage and utilization shall be per Compressed Gas Association CGA P-1-1965
- OSHA 1910.101 (c) requires all cylinders to have safety-relief devices

Similarly, in several other parts, OSHA 29CFR provides some more-specific requirements for larger-size installations that are typical of full-scale industrial plants:

- 1910.253 Oxygen-Fuel Gas Welding and Cutting
- 1910.102 (Acetylene)
- 1910.103 (Hydrogen)
- 1910.104 (Oxygen)
- 1910.105 (Nitrous Oxide)

These are generally for larger site-wide or plant-wide installations.

Meanwhile, DOT addresses cylinders in depth in several regulations (namely, 49CFR parts 171–179 and 14CFR part 103), but these are generally restricted to the transportation aspects and do not affect laboratory research or other end-use applications except with regard to receiving cylinders or shipping out materials in cylinders. DOT regulations do prohibit refilling of any cylinder without the manufacturer's permission (although obtaining the manufacturer's permission in this litigious age can prove to be challenging). Fortunately, such applications, while rare, may need additional time and effort to be addressed.

Meanwhile, the National Fire Protection Association (NFPA) addresses gas cylinder usage in several codes. The the two most prominent are NFPA-55: Storage, Use and Handling of Compressed and Liquefied Gases in Portable Cylinders, and NFPA-45: Fire Protection for Laboratories Using Chemicals. NFPA-55 is intended more for industrial applications, focusing on larger volumes and manufacturing applications. In fact, NFPA-55 specifically excludes laboratory applications and storage in 1.1.2 (0) from the scope of the standard. NFPA-45 addresses cylinders in detail in Chapter 11 but explicitly excludes pilot plants in 1.1.2 (2). Where pilot plants are covered remains somewhat uncertain. Some organizations apply NFPA-45 (despite the specific exclusion), others apply NFPA-55 despite what seems to not be the intent, and some apply neither.

Proper storage

Storage areas should be located away from sources of excessive heat and potential ignition. Care is required to ensure that all cylinders are protected against heating above 52°C (125°F). Storage areas should also be secured against unauthorized personnel and must be properly ventilated. They should be located at least 30 ft from any air intakes at the facility.

Exterior storage areas should always have a roof to keep cylinders out of direct sunlight. Even cooler climates can result in cylinders reaching 52˚C (125˚F) or above on hot summer days.

Exterior storage areas should be kept clear of weeds, grass and similar combustible vegetation for at least 15 ft around the perimeter of the cylinder storage area. Flash ground fires can easily span this distance in a matter of minutes — far too fast for emergency responders to intervene effectively.

All storage areas should also be clearly marked as "No Smoking" areas. Protection against vehicular collision is also necessary. Remember that the delivery vehicle may well be the most likely source of the collision so facilities should plan accordingly for positive protection that is designed to withstand the strongest anticipated collision.

Regardless of where the gas cylinders are stored, they should all be properly secured from falling (Figure 3). Except when stored in a properly designed central storage facility with their metal protective caps on, gas cylinders should not be secured in large groupings. When the chain or rope is removed, it is possible for a group of cylinders to fall, creating a hazard. Cylinders should be secured in smaller groups of not more than 4–6 cylinders, as an added precaution.

When installed for use, all gas cylinders should be individually secured at 1/2 to 3/4 of their height to a fixed support. Movable benches, rolling tables and similar objects should never be used as supports. A cylinder-transport cart, while very useful for transporting cylinders safely, should never be used

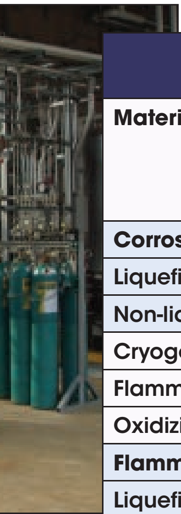


TABLE 2. NFPA-55 MAXIMUM ALLOWABLE QUANTITY OF GASES PER CONTROL AREA (QUANTITY THRESHOLDS FOR GASES REQUIRING SPECIAL PROVISIONS)

Material	Unsprinklered areas		Sprinklered areas	
	No gas cabinet, gas room, or exhausted enclosure	Gas cabinet, gas room, or exhausted enclosure	No gas cabinet, gas room, or exhausted enclosure	Gas cabinet, gas room, or exhausted enclosure
Corrosive gas				
Liquefied	68 kg (150 lb)	136 kg (300 lb)	136 kg (300 lb)	272 kg (600 lb)
Non-liquefied	23 m^3 (810 ft^3)	46 m^3 (1,620 ft^3)	46 m^3 (1,620 ft^3)	92 m^3 (3,240 ft^3)
Cryogenic fluid				
Flammable	0 L (0 gal)	170 L (45 gal)	170 L (45 gal)	170 L (45 gal)*
Oxidizing	170 L (45 gal)	340 L (90 gal)	340 L (90 gal)	681 L (180 gal)
Flammable gas				
Liquefied	114 L (30 gal)	227 L (60 gal)	227 L (60 gal)	454 L (120 gal)
Non-liquefied	28 m^3 (1,000 ft^3)	56 m3 (2,000 ft^3)	56 m^3 (2,000 ft^3)	112 m^3 (4,000 ft^3)
Highly toxic gas				
Liquefied	0 kg (0 lb)	2.3 kg (5 lb	0 kg (0 lb)	4.5 kg (10 lb)
Non-liquefied	0 m^3 (0 ft^3)	0.6 m^3 (20 ft^3)	0 m^3 (0 ft^3)	1.1 m^3 (40 ft^3)
Nonflammable gas				
Liquefied	No limit	No limit	No limit	No limit
Non-liquefied	No limit	No limit	No limit	No limit
Oxidizing gas				
Liquefied	57 L (15 gal)	114 L (30 gal)	114 L (30 gal)	227 L (60 gal)
Non-liquefied	43 m^3 (1,500 ft^3)	85 m^3 (3,000 ft^3)	85 m^3 (3,000 ft^3)	170 m^3 (6,000 ft^3)
Pyrophoric gas				
Liquefied	0 kg (0 lb)	0 kg (0 lb)	1.8 kg (4 lb)	3.6 kg (8 lb)
Non-liquefied	0 m^3 (0 ft^3)	0 m^3 (0 ft^3)	1.4 m^3 (50 ft^3)	2.8 m^3 (100 ft^3)
Toxic gas				
Liquefied	68 kg (150 lb)	136 kg (300 lb)	136 kg (300 lb)	272 kg (600 lb)
Non-liquefied	23 m^3 (810 ft^3)	46 m^3 (1,620 ft^3)	46 m^3 (1,620 ft^3)	92 m^3 (3,240 ft^3)
Unstable reactive (Detonable) gas, Class 3 or Class 4				
Liquefied	0 kg (0 lb)	0 kg (0 lb)	0.5 kg (1 lb)	1 kg (2 lb)
Non-liquefied	0 m^3 (0 ft^3)	0 m^3 (0 ft^3)	0.3 m^3 (10 ft^3)	0.6 m^3 (20 ft^3)
Unstable reactive (Non-detonable) gas, Class 3				
Liquefied	1 kg (2 lb)	2 kg (4 lb)	2 kg (4 lb)	4 kg (8 lb)
Non-liquefied	1.4 m^3 (50 ft^3)	3 m^3 (100 ft3)	3 m^3 (100 ft^3)	6 m^3 (200 ft^3)
Unstable reactive gas, Class 2				
Liquefied	114 L (30 gal)	227 L (60 gal)	227 L (60 gal)	454 L (120 gal)
Non-liquefied	21 m^3 (750 ft^3)	43 m^3 (1,500 ft^3)	43 m^3 (1,500 ft^3)	85 m^3 (3,000 ft^3)
Unstable reactive gas, Class 1				
Liquefied	No limit	No limit	No limit	No limit
Non-liquefied	No limit	No limit	No limit	No limit

Note: The maximum quantity indicated is the aggregate quantity of materials in storage and use combined.
*A gas cabinet or exhausted enclosure is required. Pressure-relief devices or stationary or portable containers shall be vented directly outdoors or to an exhaust hood.

as a support for a cylinder without its protective cap in place.

All storage areas should also be well-ventilated. While laboratories usually have high exhaust rates that are capable of handling routine leaks from gas cylinders, some may be inadequate to handle significant releases, particularly for toxic or liquefied gases. Enclosed interior storage spaces are a particular concern as the modest exhaust capacity provided is often overwhelmed by even a small leakage (and would be unable to safely evacuate a full cylinder release). Accidental releases, while rare in properly designed systems, do occur. As such, exterior storage areas should not be overly enclosed. The best designs are open on all four sides. When this is not practical, then no more than two sides should be enclosed, or special provisions for cross-ventilation should be provided, as shown in Figure 4.

The area electrical classification of cylinder storage areas is a function of the gases stored and the ventilation

TABLE 3. NFPA-45 GAS CYLINDER LIMITATIONS		
Gas	For a laboratory work area of 500 ft^2 or less internal cylinder volume	For a laboratory work area > 500 ft^2 internal cylinder volume per ft^2 area
Flammable	6 scf	0.012 ft^3
Oxidizing	6 scf	0.012 ft^3
Liquefied flammable gas	1.2 scf	0.0018 ft^3
NFPA health hazard 3 or 4 gas	0.3 scf	0.0006 ft^3
Lecture bottles	25 total	

rate. If the flammable gas storage is significant or the ventilation rate low, it may be prudent to classify the area as Class I Division 2. If only a small quantity of flammable materials is involved, if the ventilation rate is high or in an unenclosed exterior location then General Purpose (ordinary) classification is usually adequate. Note that in many cases, cylinder storage areas have only minimal electrical equipment and fixtures, typically lighting. Hence, electrically classifying the area as Class I Division 2, while conservative, may be an appropriate and very low-cost solution.

All storage areas should also have easy access that is free of extended ramps and enclosed spaces. Consider that a release of even an inert gas in an elevator, for example, could be enough to cause asphyxiation.

Cylinder placement

How many cylinders can be used in a laboratory? Table 2 provides the NFPA-55 requirements. Table 3 provides NFPA-45 requirements. Local building codes may mandate even more stringent levels.

NFPA-45 provides some additional guidance. For instance, it specifies that cylinders "not required for current operations" shall be stored outside the laboratory work area. High-hazard gases shall be kept in a hood or other continuously ventilated enclosure. (A high-hazard gas is one that has an NFPA health hazard rating of 3 or 4 or 2 with no physiological warning properties.)

So what is the best location for gas cylinders used in laboratory and research applications? While it has been common practice for years to place cylinders directly in labs, this may not necessarily be the best approach. For instance, it is difficult to maintain the required separation of flammable and oxidizing materials required in a standard laboratory. Hazardous gas cylinders are often placed outside hoods. All cylinders have a tendency to end up in escape paths or along major traffic corridors. Gas cabinets are expensive, and are both space- and exhaust-intensive. They also are not foolproof in preventing a fire or explosion in the (admittedly unlikely) event of a major cylinder leak.

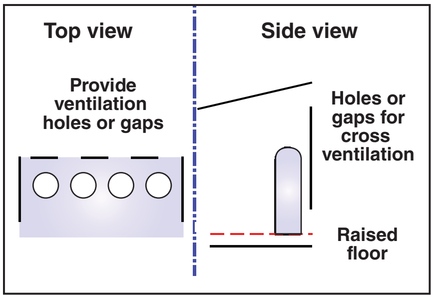


FIGURE 4. Proper ventilation is an important design consideration when storing gas cylinders, even in exterior storage areas

Even worse, cylinders are often moved around to obscure corners, alcoves, cabinets and closets with minimal ventilation or inadequately designed and constructed, ventilated cabinets and boxes that do not meet the safety requirements of a bona fide gas cabinet.

The preferred placement for cylinders used in a research or laboratory setting should be as follows:

- Outside the laboratory or pilot plant area with the gas piped to its final use location
- In a specially designed, gas-cylinder-storage area in the facility, with the gas piped in to its final use. This may be adjacent to the area served, or some distance away, depending on what makes most sense safety wise and economically
- Inside a specially designed gas cabinet that meets the requirements of NFPA-55

Inert gas cylinders, while posing significantly fewer dangers than those containing flammables, toxics or oxidizing agents still pose some risks and should follow these same guidelines. The argument that a lone cylinder of helium for a gas chromatograph poses a trivial or acceptable risk may be valid, but even a single cylinder improperly piped or secured can pose a hazard. And, since this lone cylinder often tends to accumulate additional, more-hazardous brothers and sisters over time, sound engineering design precedent should be established and maintained from the beginning.

Gas cabinets are commonly used for those desiring to keep their cylinders in the laboratory. NFPA-55 provides prudent requirements for such a setup:

- Such cabinets must be at negative pressure with respect to the laboratory, and have an average face velocity across the open doors of 200 ft/min, with a 150 ft/min minimum at any point
- Self-closing access doors and non-combustible windows are required
- The interior must be equipped with sprinkler systems
- The cabinet must be labeled as to its contents

NFPA-55 requires that toxic gases shall be treated to neutralize or dilute the effluent to below toxic levels that are considered to be life-threatening. Many organizations rely on the dilution effect of the exhaust and dispersion from the exhaust stack well above grade to achieve this effect. However, this may not be possible with very toxic gases or larger cylinder volumes.

Cylinder piping

Cylinders need to be properly piped to their final use location to ensure safe operation. A suggested minimum piping schematic is shown in Figure 5. No system should ever be supplied from a gas cylinder without a regulator to set the feed pressure. However, it is not safe to rely on a regulator alone to prevent a system from overpressure. Operator error and regulator failure can lead to a failure of the downstream equipment — with dangerous or even fatal consequences.

Instead, a relief device of some type should be used. It may be a spring-loaded device (Figure 5) or a rupture disk (for higher-purity or lower-maintenance applications), or a similar relief device. The relief device needs to be properly sized to handle a regulator failure, which produces flows as much

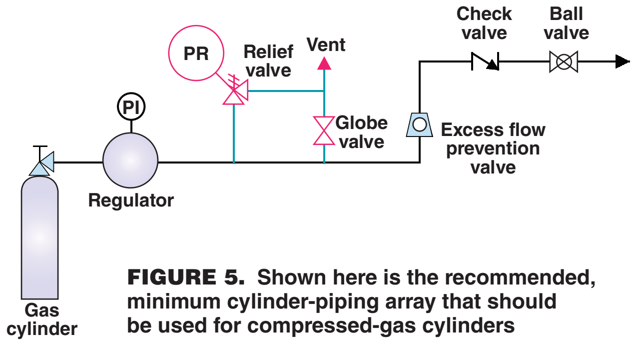


FIGURE 5. Shown here is the recommended, minimum cylinder-piping array that should be used for compressed-gas cylinders

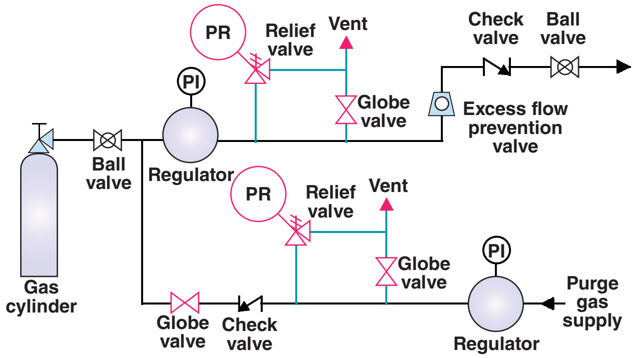


FIGURE 6. The recommended, minimum cylinder-piping array with purge capabilities is provided here

as an order-of-magnitude higher than the maximum regulator-design flow. The relief device vent should be piped to a safe location, typically an exhaust duct or vent stack. Both will need to have their sizing confirmed as adequate.

The purpose of a manual globe valve around the relief device (as shown in Figure 5) is to allow manual venting and purging during cylinder changes and system maintenance. It also allows the system pressure to be lowered through venting, in the event that the supply pressures are inadvertently set too high. This valve should always be a slow-opening, multiple-turn globe type to prevent a sudden depressurization.

The excess-flow-prevention valve should be mandatory on all piping systems involving flammable and toxic systems. It is intended to shut off (or at least limit the flow to an acceptable smaller rate) in the event of a system or component failure. Some facilities allow a manual bypass around this device, to allow initial filling at a higher rate without tripping the device, or to allow the excess-flow-prevention valve to be reset if tripped.

However, this is not the most appropriate approach. Too often, the manual bypass is left open, defeating the capabilities and intent of the excess-flow-prevention valve. If a bypass is required, it should be of the deadman type (requiring the operator to hold it open), or be on a timer that closes the bypass automatically after a minute or two.

The check valve is intended to prevent backflow into the gas cylinder from a source of higher pressure. If such a source is not present, then one might naturally consider eliminating the check valve; however, it should be a standard part of all gas cylinder installations, as higher-pressure sources often appear down the road and create problems if the check valve is not installed.

The manual ball valve is intended to provide a fast means to shut off the gas cylinder in an emergency situation, and also allows the system to be easily locked out and tagged for maintenance. In this case, both the gas cylinder shutoff valve and the ball valve should be closed, and the manual vent valve should be opened to vent the system, completing the double block-and-bleed setup.

Many organizations like to add a second block valve immediately downstream of the gas cylinder and before the regulator, to enable the isolation of the system for change out and maintenance. In this case, the valve must be rated for the full cylinder pressure.

Purge streams are also common on higher-purity systems (Figure 6). Since purge systems are usually lower-pressure gas supplies, it is important to provide the back flow and relief protection shown. The purge-system vent should also be treated as a potentially hazardous stream and piped to the same vent location as the purged hazardous gas.

Piping should be run in areas where it is to be expected. Routing pipe above offices, personnel corridors and supply rooms can lead to unfortunate incidents later, in the event that the piping is assumed to be something innocuous. At best it can lead to service interruptions; at worst to accidents. Similarly, piping should not be run above suspended ceilings unless the space is ventilated as part of the laboratory. Small leaks can develop into very hazardous situations over extended periods in unventilated areas. Even if ventilated, all welded systems should be strongly considered above suspended ceilings particularly for flammable or toxic gases. All valves above the ceiling should be of the packless or bellow-type seal. Better yet, no valve should be allowed in these areas.

Open all cylinder valves slowly. Pressurizing a system, particularly for the first time or following maintenance always presents a high potential risk. If the valve does not open by hand or with the manufacturer-supplied wrench, do not attempt to force it with a pipe wrench or similar tool that might be capable of transmitting too much force. Such efforts can result in unscrewing — or at least loosening — the entire valve assembly, with results ranging from leaks to catastrophic failure.

Stand clear of all outlet piping while opening the cylinder until the pressure has equalized. If there is going to be a failure, it usually happens in the first moments of pressurizing. While such an occurrence is extremely rare, this is still a prudent and essentially no-cost safety measure.

Cylinder connections

All cylinders come with special threads on the outlet. In the U.S., these threads follow standards that are developed by the Compressed Gas Association (CGA), and are often called CGA fittings. CGA fittings should never be modified or changed, as they are designed to minimize the chance of unsafe connections.

CGA fittings should never be forced if they do not fit properly. They are very effective for pure gases, but are less foolproof with mixtures since different vendors have different practices for assigning thread types to a particular gas mixture. Care must be taken before connecting a new cylinder to ensure compatibility.

Adaptors are available to ensure a proper fit between a CGA fitting and the existing pipe thread. However, these must be used with extreme care as they essentially allow the bypassing of safeguards.

Labeling

Gas cylinder piping should be clearly labeled as to its contents. The location of the feed cylinder should be posted at the point of final use to allow emergency responders to know where to go in order to shut off the cylinder. Similarly, the location should be posted at the cylinder unless it is obvious (for instance, strapped to the device), so the user knows what impact the shut-off of a specific cylinder may have.

Never rely on the vendor's color coding as it typically vary between vendors. Make sure each gas cylinder is carefully checked to confirm its contents from the label affixed to the cylinder before placing it in service.

Empty cylinders

Empty cylinders should be kept separately from full cylinders. Mark empty cylinders as soon as possible; as a rule-of-thumb (until the situation can be verified), always assume a cylinder is full and act accordingly to ensure safety, even when it is marked empty.

Cylinders should not be used at pressures below ~25 psi, to prevent gases from being drawn from the system into the cylinder and creating an inadvertent hazard for the vendor when refilling the cylinder. The remaining useable volume in a cylinder can be found from the following formula:

Actual volume = [(*Actual pressure*) (*Initial volume*)]/*Initial pressure*

Emergency response

All organizations using gas cylinders should have procedures in place for how to deal with leaking cylinders. The type of gas (inert, flammable or toxic) will obviously be a major factor, as will the cylinder location, rate of leakage, ventilation and numerous other incident-specific factors. Waiting to develop a plan once a leaking cylinder has been found, with no basis from which to work, is a recipe for a very poor and usually ill-conceived, response.

GUIDELINES FOR SAFE HOT-BOX DESIGN

These tips will ensure safe hot-box design for gas cylinders that require heating.

Ensure the enclosure has adequate over-temperature protection that is independent of the control system. A separate sensor, alarm and shutoff are the minimum required. The alarm should be latching (for instance, requiring a person to manually reset it), and should require someone to deliberately reset the alarm before heating can resume. Ensure that the temperature control and alarm systems are interconnected and enabled to allow the hot box to heat.

Confirm the placement of the over-temperature sensor carefully to ensure it monitors the hottest area. All too frequently, the device can be placed out of the way in a significantly cooler corner. Confirm the enclosure does not have such substantial temperature differentials to create a problem.

Provide adequate audible and visual alarms to signal a problem to the operating personnel. Take immediate automatic action to shut down all heat sources in the event of a high temperature.

Ensure the enclosure has adequate ventilation to prevent small leaks from building up to become a major hazard. Typical ventilation rates are 1 ft^3/min per square foot of floor area, with 150 ft^3/min as a suggested minimum. In general, exhaust ventilation should be provided at floor level. In larger installations (over 100 ft^2), both high- and low-point exhaust should be provided.

Make sure all heating elements are protected against direct impingement on the cylinder. Particular care should be paid to ensuring that a heavy cylinder cannot be pushed against a heater. Many mechanical guards to prevent this accident are clearly inadequate when compared to the forces they need to withstand when struck by a 300-lb cylinder in motion.

Ensure the hot box is completely constructed of non-combustible materials. Fire-retardant materials are not adequate. This includes doors, ramps and racks. ❑

Managing the inventory

All organizations should inventory their cylinders at least annually. This allows the user to identify unused cylinders, spot potential problems with older cylinders, and reduce demurrage charges (the rental fee the supplier charges on the cylinders). Return any damaged, suspect or unneeded cylinders immediately to the supplier.

Consider establishing retention times on cylinders with corrosive gases. Six to twelve months are common but each case needs to be individually evaluated. In general, no cylinder should be kept for more than 36 months. If it has not been used in that time, either it is not required or the amount of gas has been oversized.

Develop procedures to force individuals to dispose of cylinders before personnel transfer to other sites, to avoid accumulating un-owned cylinders around the facility. Failure to do so is not only costly in terms of continued demurrage charges, but is potentially very dangerous. Most organizations have their own horror stories of aged gas cylinders that were found in unexpected locations.

Cylinders cannot be tossed in the garbage, but must be returned to the supplier. Note, however, that some new small calibration-gas and mixed-gas cylinders are designed for single use, and are intended to be disposed of when empty.

Gas cylinders are common and very safe if installed and operated properly. However, despite their widespread use in research, they always hold the potential for accidents and injuries if not properly handled. ■

Edited by Suzanne Shelley

Author

Richard Palluzi is a distinguished engineering associate at ExxonMobil Research & Engineering Co. (1545 Route 22 East, Annandale, NJ 08801; Phone: 908-730-2323), responsible for the design, construction and support of pilot plants and laboratories for the firm's research site in Clinton, N.J., and consulting on pilot-plant issues throughout ExxonMobil worldwide. The author of two books, 30 articles and 40 presentations on all phases of pilot plant and laboratory safety and operations, he is a member of AIChE, ISA, the American Soc. of Safety Engineers and the National Fire Protection Assn., and was recently elected to the last-named organization's committee on NFPA-45 Fire Protection for Laboratories Using Chemicals. He teaches three pilot-plant training courses for AIChE, and is a past chair of the AIChE Pilot Plant Committee, as well as of the Clinton site's Safe Operations Team. Also, he currently chairs ExxonMobil's Pilot Plant and Laboratory Safety Standards Committee. Palluzi has consulted for both the U.S. Dept. of Energy and Dept. of Defense on research-related issues. He holds B.S.Ch.E. (1974) and an M.S.Ch.E. (1976) from Stevens Institute of Technology.

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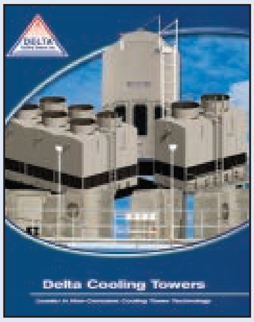

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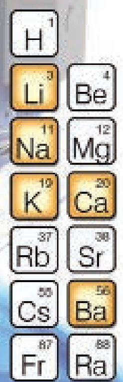

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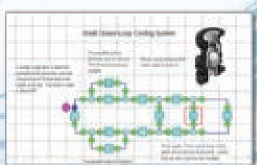

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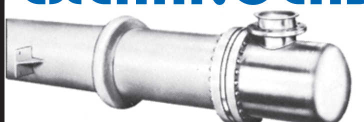

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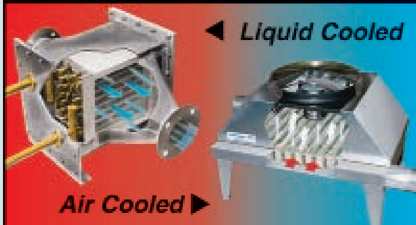

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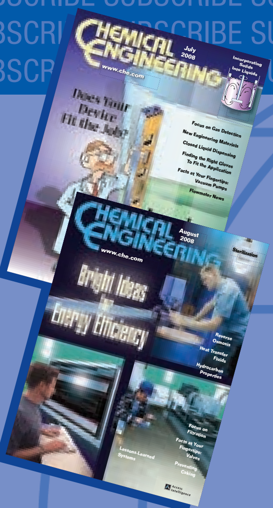

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BUSINESS NEWS

PLANT WATCH

Veolia Water is awarded new contract for water treatment and reuse in Brazil

September 15, 2009 — Under a 50/50 joint venture with Enfil, a Brazilian, water-treatment engineering company, the Brazilian oil company Petrobras (Rio de Janeiro; www.petrobras.com) has awarded Veolia Water's (Paris; www.veoliawater.com) subsidiary, Veolia Water Solutions & Technologies, the complete supply and construction contract for a water-treatment and reuse station at the Abreu e Lima Refinery. Currently under construction, the new refinery will produce primarily diesel fuel and will process heavy oil from Brazil and Venezuela. The water-treatment and reuse station will provide 2,100 m^3/h of filtered water and 580 m^3/h of recycled water for industrial use. The water-treatment plant will also reuse approximately one third of the water consumed by the refinery.

Clariant plans new ethoxylation plant in China

September 15, 2009 — Specialty chemical company, Clariant (Muttenz, Switzerland; www.clariant.com) has announced its plans to build an ethoxylation plant in Dayabay, situated south of Guangzhou. The plant will be operational in early 2011 and will have a capacity of close to 50,000 metric tons per year (m.t./yr). The production site in Dayabay will be Clariant's first ethoxylation plant in Asia. The construction of this new facility is part of a $100-million-investment program in China, which Clariant has been committed to over the last 18 months. This program includes a plant in Hangzhou for specialty organic pigments, a phosphorus pentoxide plant in Kunming, as well as a new masterbatches plant and a center for textiles in Guangzhou. Clariant's new surfactants production facility, which was inaugurated in Zhenjiang, Eastern China in September, is another milestone in the program.

LyondellBasell to close LDPE unit in Carrington

September 15, 2009 — LyondellBasell Industries (Rotterdam, the Netherlands; www.lyondellbassell.com) has announced that it will close the low-density polyethylene (LDPE) plant located at its Carrington, U.K., site by the end of this year. LyondellBasell will focus its LDPE production activities in Europe at Wesseling, Germany and in Berre, France. With a nameplate capacity of 185,000 ton/yr, the Carrington plant is one of the company's smallest LDPE manufacturing sites. The 210,000 ton/yr polypropylene plant located at the Carrington site is not affected by this business decision.

Aker Solutions awarded contract for Staatsolie refinery expansion project

September 9, 2009 — Aker Solutions (Lysaker, Norway; www.akersolutions.com) has been awarded the project management consultant (PMC) contract for Staatsolie Maatschappi Suriname N.V.'s refinery expansion project in Suriname. Once completed, the project will double the refinery's processing capacity to 15,000 bbl/d, producing diesel, gasoline, fuel oil, bitumen and sulfuric acid.

Air Products buys H_2-production facility in Texas

September 2, 2009 — Air Products, Inc. (Lehigh Valley, Pa.; www.airproducts.com) has purchased a new steam-methane-reformer (SMR) hydrogen facility under construction in Corpus Christi, Tex., from MarkWest Energy Partners, L.P. The facility, which will produce over 30 million scfd, will be owned and operated by Air Products and is expected to be on-stream in March 2010.

Toyo awarded polycarbonate resin project in China

September 2, 2009 — Toyo Engineering Corp. (Chiba, Japan; www.toyo-eng.co.jp) has been awarded a project for an 80,000-ton/yr polycarbonate-resin production facility that will be built by Mitsubishi Gas Chemical Co., Inc. (www.mgc.co.jp) and Mitsubishi Engineering-Plastics Corp. (both Tokyo, Japan; www.m-ep.co.jp) in Shanghai Chemical Industry Park. Construction of the plant is scheduled to commence in the spring of 2010, and the production will begin in 2012. The total investment is expected to be approximately ¥30 billion.

MERGERS AND ACQUISITIONS

BASF divests Brazilian polystyrene business

September 15, 2009 — BASF SE (Ludwigshafen, Germany; www.basf.com) is progressing with steps to restructure its styrenics business and has made another divestiture in its styrene value chain. BASF has signed an agreement to sell its Brazilian polystyrene business, including a production plant, to the petrochemical company Companhia Brasileira de Estireno (CBE), a Unigel subsidiary. The parties have agreed not to disclose financial details of the transaction.

AkzoNobel realigns coatings and chemicals portfolios

September 10, 2009 — AkzoNobel (Amsterdam, the Netherlands; www.akzonobel.com) is realigning its Performance Coatings and Specialty Chemicals portfolios, which will result in the launch of two new business units and the merger of two others. Due to come into effect on January 1, 2010, the planned changes include the creation of standalone Wood Finishes and Adhesives businesses and a restyled Industrial Coatings business, while the company's Polymer Chemicals activities will be merged into the Functional Chemicals organization. The new structure will see Bob Taylor become managing director of Marine and Protective Coatings; John Wolff will become managing director of the new Wood Finishes and Adhesives business; and Conrad Keijzer will be managing director of the new Industrial Coatings business. Bob Margevich will continue as managing director of Functional Chemicals and will lead the new combined business when it is merged with Polymer Chemicals. Alan Kwek will remain managing director of Polymer Chemicals until the end of 2009.

Merck acquires Chinese effect-pigments producer

September 9, 2009 — Merck KGaA (Darmstadt, Germany; www.merck.de) has acquired Suzhou Taizhu Technology Development Co. (Taizhu; Taicang, China). With total revenues of more than €14 million in 2008, Taizhu is one of the biggest effect pigments companies in the Chinese market. Within the scope of this transaction, Merck has acquired the production site of Taizhu in Taicang, as well as the entire sales-and-marketing organization in China and abroad for a total consideration of €28 million.

Clariant sells specialty silicones business

September 1, 2009 — Clariant (Muttenz, Switzerland; www.clariant.com) has sold its specialty silicones business, including its Gainesville, Fla. facility, to SiVance LLC, an affiliate of New York-based, private-equity firm GenNx360 Capital Partners. Financial terms of the transaction were not disclosed. ■

Dorothy Lozowski

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

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FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

Economic Indicators

2009 2008

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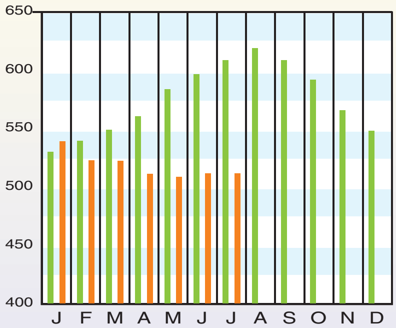
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Jul.'09 Prelim.	Jun.'09 Final	Jul.'08 Final
***CE* Index**	512.1	512.0	608.8
Equipment	601.2	601.5	746.4
Heat exchangers & tanks	542.8	538.0	760.1
Process machinery	589.7	584.9	669.5
Pipe, valves & fittings	732.1	749.0	875.5
Process instruments	387.8	391.8	459.0
Pumps & compressors	898.5	898.9	869.9
Electrical equipment	459.1	459.8	468.2
Structural supports & misc	615.9	610.0	815.8
Construction labor	327.3	325.6	322.1
Buildings	486.9	485.7	521.5
Engineering & supervision	346.5	347.2	352.9

Annual Index:
2001 = 394.3
2002 = 395.6
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4

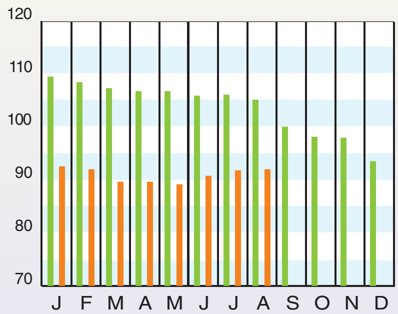


Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics

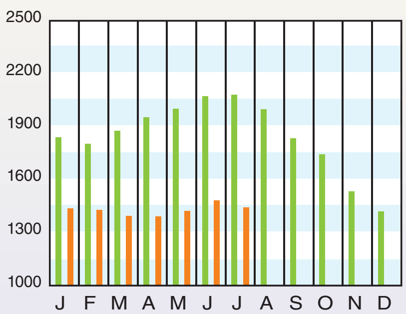
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS				YEAR AGO	
CPI output index (2000 = 100)	Aug.'09 =	92.0	Jul.'09 =	91.8	Jun.'09 =	90.7	Aug.'08 =	105.1
CPI value of output, $ billions	Jul.'09 =	1,444.2	Jun.'09 =	1,482.4	May.'09 =	1,424.8	Jul.'08 =	2,082.0
CPI operating rate, %	Aug.'09 =	67.7	Jul.'09 =	67.4	Jun.'09 =	66.4	Aug.'08 =	76.9
Producer prices, industrial chemicals (1982 = 100)	Aug.'09 =	236.9	Jul.'09 =	234.6	Jun.'09 =	229.8	Aug.'08 =	309.1
Industrial Production in Manufacturing (2002=100)*	Aug.'09 =	96.3	Jul.'09 =	95.7	Jun.'09 =	94.4	Aug.'08 =	109.7
Hourly earnings index, chemical & allied products (1992 = 100)	Aug.'09 =	147.7	Jul.'09 =	148.5	Jun.'09 =	147.3	Aug.'08 =	142.6
Productivity index, chemicals & allied products (1992 = 100)	Aug.'09 =	131.6	Jul.'09 =	131.3	Jun.'09 =	132.0	Aug.'08 =	131.8

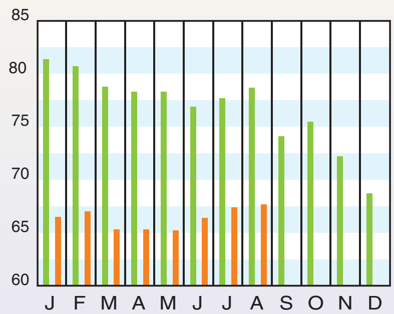
CPI OUTPUT INDEX (2000 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



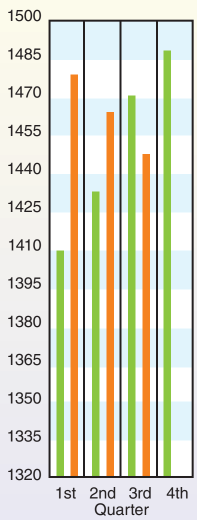
*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
Current business indicators provided by Global insight, Inc., Lexington, Mass.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	3rd Q 2009	2nd Q 2009	1st Q 2009	4th Q 2008	3rd Q 2008
M & S INDEX	1,446.4	1,462.9	1,477.7	1,487.2	1,469.5
Process industries, average	1,515.1	1,534.2	1,553.2	1,561.2	1,538.2
Cement	1,509.7	1,532.5	1,551.1	1,553.4	1,522.2
Chemicals	1,485.8	1,504.8	1,523.8	1,533.7	1,511.5
Clay products	1,495.8	1,512.9	1,526.4	1,524.4	1,495.6
Glass	1,400.4	1,420.1	1,439.8	1,448.1	1,432.4
Paint	1,515.1	1,535.9	1,554.1	1,564.2	1,543.9
Paper	1,416.3	1,435.6	1,453.3	1,462.9	1,443.1
Petroleum products	1,625.2	1,643.5	1,663.6	1,668.9	1,644.4
Rubber	1,560.7	1,581.1	1,600.3	1,604.6	1,575.6
Related industries					
Electrical power	1,370.8	1,394.7	1,425.0	1,454.2	1,454.4
Mining, milling	1,547.6	1,562.9	1,573.0	1,567.5	1,546.2
Refrigeration	1,767.3	1,789.0	1,807.3	1,818.1	1,793.1
Steam power	1,471.4	1,490.8	1,509.3	1,521.9	1,499.3

Annual Index:

2001 = 1,093.9	2003 = 1,123.6	2005 = 1,244.5	2007 = 1,373.3
2002 = 1,104.2	2004 = 1,178.5	2006 = 1,302.3	2008 = 1,449.3



CURRENT TRENDS

Although preliminary estimates for the June CEPCI showed a very slight decrease in equipment prices from month to month, when the final numbers came in, there was actually more than a 3 point increase (from 508.9 to 512.1). Meanwhile, the operating rate continues to climb slowly but surely.

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