CHEMICAL ENGINEERING

February 2005

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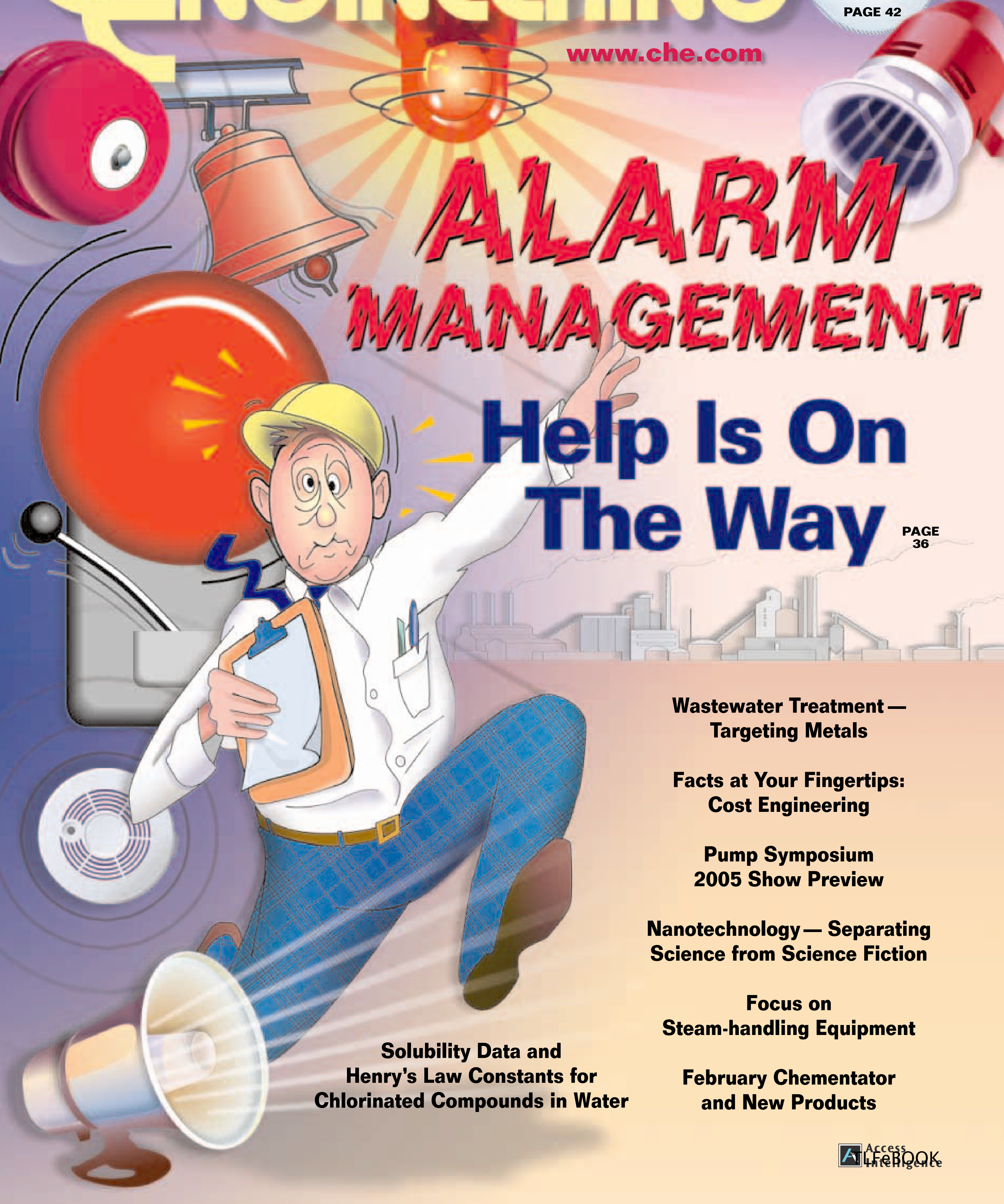


Removing Particulates From Gas Streams
PAGE 42

ALARM MANAGEMENT

Help Is On The Way

PAGE 36

Wastewater Treatment — Targeting Metals

Facts at Your Fingertips: Cost Engineering

Pump Symposium 2005 Show Preview

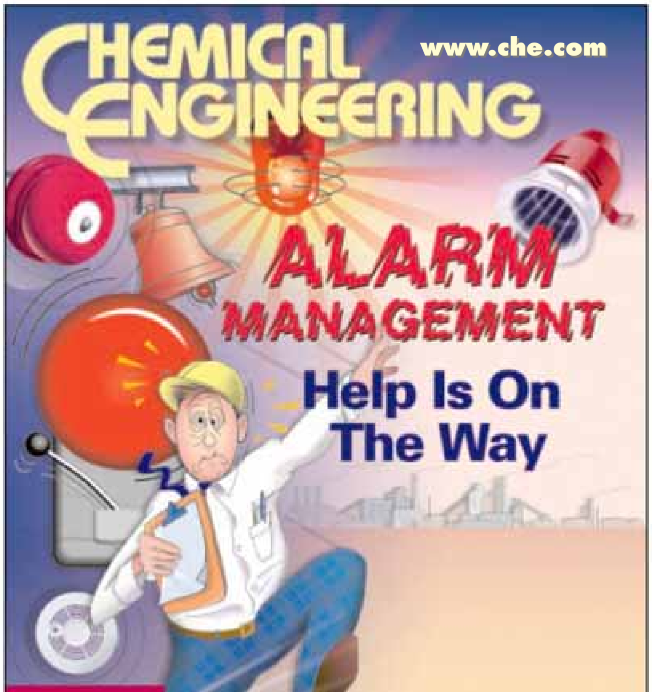
Nanotechnology — Separating Science from Science Fiction

Focus on Steam-handling Equipment

February Chementator and New Products

Solubility Data and Henry's Law Constants for Chlorinated Compounds in Water

TLFeBOOK

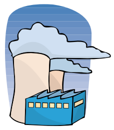


Cover Story

IN THIS ISSUE

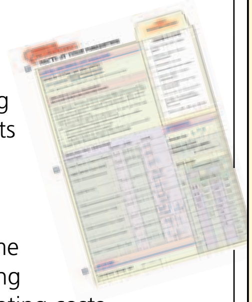
IN THIS ISSUE

Economic Indicators



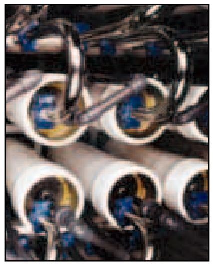
In the news: Saudi Aramco/Snamprogetti S.p.A. and USFilter are adding 2.5-million-bbl/d seawater-treatment capacity in Saudi Arabia; Johns Mansville is building a $100-million facility to make pipe insulation materials in Ohio; Great Lakes Chemical has voluntarily ceased production of certain chemicals in Indianapolis, in favor of "greener" alternatives; MerckKgaA is undertaking a $10-million expansion of a mixed-liquid crystal unit in Korea; Shin-Etsu Handotai is building a plant to produce 200,000 silicon wafers/month in Vancouver, Wash.; and more

Facts at Your Fingertips



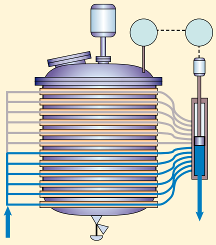
It may have been a while since you learned all of those basic cost engineering equations —such as how to estimate costs using scaling factors, how to calculate inflation and depreciation, present worth analysis, and internal rate of return. This handy reference card brings together some of the key equations needed for estimating capital equipment costs and annual operating costs

Newsfront



Wastewater treatment varies widely from plant to plant. Despite the site-specific makeup of the specific treatment train, many process operators are focusing on a common theme — how to use more recycled water in the plant to cope with shortages in fresh-water supplies (and attendant cost increases)

Chementator



These technology advances are profiled in Chementator this month: Using fullerenes to optimize anti-wear properties; Halide injection shows promise for reducing mercury emissions; Extremophile bacteria that thrive on radioactive waste discovered; A solid-phase-extraction sorbent selectively removes riboflavin, but not other desirable vitamins; A new process-monitoring tool passes field tests; A VOC-destruction process that combines zeolite absorption with electric discharge decomposition; Energy-efficient desalination; and more

EQUIPMENT & SERVICES

26 **Focus:** **Steam handling**
Discussed here are products ranging from steam traps and devices for managing and monitoring steam temperature, to improved insulation, materials of construction, and clean-in-place options

EQUIPMENT & SERVICES

34D-1 **Show Preview:** **Pump Symposium 2005** The 22nd International Pump Users Symposium will return to Houston February 28–March 3. The technical program and short courses offered are described here, as are a sampling of the pump-related products that will be on display . Note that this Show Preview appears only in Domestic issues of *CE*

34I-1 **February New Products:**
Among the new products profiled in this article — which appears only in International issues of CE — are a controller for both simple and complex heating tasks, new simulation software, a machine that fills vials with powder accurately, a new datalogging system for IR thermometer data, a more-flexible polyurethane foam insulation material; and more

BUSINESS

69 **Mergers and acquisitions; Business deals; Construction spotlight**

COMMENTARY

7 **Editor's Letter:** **Nanotechnology — Don't let science fiction trump science** While the ability to synthesize and manipulate matter in nanometer-scale dimensions has heralded many impressive discoveries already, cautious observers fear potentially diabolical consquences, should this new technological paradigm be abused or misappropriated. If the possibilities of nanotechnology are ever to be fully exploited, its potential consequences mitigated, opponents and proponents are going to have to work together

DEPARTMENTS

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Cover art: David Whitcher

Editor's note 1: *Chemical Engineering's* CE Plant Cost Index (CEPCI) can now be downloaded from our website. While regular *CE* subscribers will retain access to the latest data in our printed version (or pdf files on www.che.com/ei), upgraded CEPCI users will have the ability to access, query and print both current and historical databases. ***NOTE: A special introductory price of $295/yr — a $200 savings off of the regular $495 price — is available for a limited time.*** This service is entirely separate from subscriptions to *CE*'s print and online magazines, and will provide realtime access to the following:

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Editor's note 2: *Chemical Engineering* invites you to check out its **"Build Your Engineering Library" Book Series**. The detailed Table of Contents for each of the 12 titles can be viewed, and orders can be placed, at **www.che.com** (*Click on the* ***CE Book Series icon*** *on the left margin of the home page*). These books include more than 3,500 pages of practical, "how to" engineering articles," written by engineers, for engineers" from the pages of *Chemical Engineering*, and can be purchased as spiral-bound books, perfect-bound books, or CD-ROMs. ***Place your order now to lock in Frequency discounts!***

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Access Intelligence

Editor's Page

Nanotechnology – Don't Let Science Fiction Trump Science

While nanotechnology — which pertains to the ability to manipulate matter at particle sizes of 100 nanometers (nm) or less[1] — is still in its infancy, awareness of it is no longer confined to research circles. Rather, ongoing publicity about many promising breakthroughs has, in recent years, thrust nanotechnology into the public eye.

At infinitesimally small particle sizes, metals, metal oxides, ceramics, polymers and novel carbon derivatives (carbon nanotubes and buckyballs) attain extraordinary ratios of surface area to diameter, advantageous particle geometries, and notable improvements in various material properties. Nanoscaled additives already figure prominently in today's precision semiconductor-polishing slurries, advanced composites that have increased conductivity, catalytic activity, hardness, self-cleaning capabilities, and anti-microbial properties, and many consumer products. Nanoscaled materials and manufacturing techniques also show promise for making better batteries, fuel cells, catalysts, and gas sensors, and for helping potent drugs reach their intended targets in the body more effectively and with fewer toxic side effects (*CE*, Dec. 2002, p. 23ff; Jan. 2003, p. 27ff). Some even envision Lilliputian devices that could be programmed to repair clogged arteries and kill cancer cells, or dramatically improve the detection of chemical, biological, radiological and nuclear hazards.

Cautious observers, however, see nanoscientists as dabbling with dangerous forces they cannot control, and note that many key questions remain unanswered — such as how might the absorption, ingestion or inhalation of nanoparticles affect human and animal health and the environment? Such critics also argue that nanotechnology's thorny ethical and societal implications are not being explored or debated meaningfully enough. For instance, what menacing or diabolical consequences might arise should this powerful new technology ever be co-opted or misappropriated by terrorists, criminals or dictators and used for evil purposes? One could imagine, for instance, the production of ultra-effective nanoscaled devices to deliver chemical and biological agents, and remote assassination devices that would be difficult to detect or avoid.

Ardent opponents have called for everything from legislative restrictions to a complete moratorium on all nano-related R&D. Others argue that such actions would be unethical or even immoral, because the potential gains, especially in medicine, energy management, material science and national security, are so great. Such a ban would also push the research underground — as happened to some extent when efforts were mobilized to restrict R&D on cloning, stem-cell use and genetically modified foods. This could lead to espionage and the theft of intellectual property, and a black market that would no longer be within the reach of regulators.

Suzanne Shelley

The scientific and engineering community must address the backlash, rather than ignoring these dissenting voices. Only by modeling and analyzing potential problems, debating the issues, and implementing meaningful regulatory controls can we close the gap between science and science fiction. And only then can we effectively mitigate any harmful consequences of nanotechnology, and still fully realize its potential.[2]

1. To lend perspective: There are one billion nm in one meter (3.28 ft); one thousand nm in one micrometer.

2. This editorial was adapted from a chapter, written by this author, entitled Nanotechnology — Turning Basic Science into Reality, that appears in the forthcoming book: "Nanotechnology: Environmental Implications and Solutions," Theodore, L., and Kunz, R., John Wiley, March 2005 (ISBN: 0-471-69976-4).

Postscripts, corrections

December 2004, Flashpoints Are Affected by Process Pressure, pp. 50–53: The address and telephone number for the author are now as follows: Chilworth Technology, Inc., 250 Plainsboro Rd., Bldg. #7, Plainsboro, NJ 08536; Phone: 609-799-4449.

Calendar

NORTH AMERICA

Paper Chemicals. Chemical Week (New York, N.Y.). Phone: 212-621-4978; Fax: 212-621-4970; Email: reg@chemweek.com
New Orleans, La. **Feb. 24–25**

Clean Air Technologies & Strategies. Institute of Clean Air Companies (Washington, D.C.). Phone: 202-457-0911; Fax: 202-331-1388; Email: CATS@icac.com
Baltimore, Md. **Mar. 8–10**

NPRA Annual Meeting. National Petrochemical & Refiners Assn. (Washington, D.C.). Phone: 202-457-0480; Fax: 202-457-0486; Web: npra.org
San Francisco, Calif. **Mar. 13–15**

30th World Petrochemical Review. Dewitt & Company, Inc. (Houston, Tex.). Phone: 281-878-7299; Fax: 281-878-7210; Web: dewittworld.com
Houston, Tex. **Mar. 29–31**

20th Annual World Petrochemical Conference. CMAI (Houston, Tex.). Phone: 281-531-4660; Fax: 281-531-9966; Web: cmaiglobal.com
Houston, Tex. **Mar. 29–31**

The 8th Annual Chemical Industry Information Technology Forum. Chemical Week (New York, N.Y.). Phone: 212-621-4978; Fax: 212-621-4970; Email: reg@chemweek.com
Philadelphia, Pa. **Mar. 30–31**

International Petrochemical Conference. National Petrochemical & Refiners Assn. (Washington, D.C.). Phone: 202-457-0480; Fax: 202-457-0486; Web: npra.org
San Antonio, Tex. **Apr. 3–5**

Corrosion 2005. National Assn. of Corrosion Engineers (Houston, Tex.). Phone: 281-228-6200; Fax: 281-228-6300; Web: nace.org
Houston, Tex. **Apr. 3–7**

2005 AFS Annual Conference & Exposition. American Filtration & Separations Society (Richfield, Minn.). Phone: 612-861-1277; Fax: 612-861-7659; Web: afssociety.org
Atlanta, Ga. **Apr. 10-13**

AIChE 2005 Spring Meeting. American Institute of Chemical Engineers (New York, N.Y.). Phone: 212-591-7338; Fax: 212-591-8894; Web: aiche.org
Atlanta, Ga. **Apr. 10–14**

AchemAmerica 2005. Dechema e.V. (Frankfurt, Germany). Phone: +49-69-7564-0; Fax: +49-69-7564-201; Email: achemamerica@dechema.de
Mexico City, Mexico **Apr. 12–15**

(Continues on p. 12)

Calendar

Interphex 2005. Reed Exhibitions (Norwalk, Conn.). Phone: 203-840-5427; Fax: 203-840-9427; Web: reedexpo.com
New York, N.Y. **Apr. 26–28**

EUROPE

StocExpo 2005: European Bulk Liquid Storage Terminal Operations Conference and Exhibition. StocExpo (Surrey, U.K.). Phone: +44-20-8648-7078; Fax: +44-208-687-4130; Web: stocexpo.com
Rotterdam, The Netherlands **Mar. 1–3**

The 3rd Annual European Senior Financial Officer Meeting. Chemical Week (New York, N.Y.). Phone: 212-621-4978; Fax: 212-621-4970; Email: reg@chemweek.com
Frankfurt, Germany **Apr. 6–7**

Hannover Fair 2005. Deutsche Messe AG (Hannover, Germany). Phone: +49-511-89-31615; Fax: +49-511-89-32693; Web: messe.de
Hannover, Germany **Apr. 11–15**

Global Petrochemicals Conference and Technology Showcase. World Refining Assn. (London, U.K.). Phone: +44-207-067-1800; Fax: +44-207-242-2673; Web: wraconferences.com
Cologne, Germany **April 26–27**

12th International Trade Fair for Sensorics, Measuring and Testing Technologies. AMA Service GmbH (Wunstorf, Germany). Phone: +49-5033-9839-0; Fax: +49-5033-1056; Web: sensor-test.com
Nuremberg, Germany **May 10–12**

ASIA & ELSEWHERE

6th Annual Refining & Petrochemicals in the Middle East Conference. World Refining Assn. (London, U.K.). Phone: +44-207-067-1800; Fax: +44-207-242-2673; Web: wraconferences.com
Dubai, UAE **Feb. 20–21**

The 10th Annual Asia Pacific Chemical Industry Meeting. Chemical Week (New York, N.Y.). Phone: 212-621-4978; Fax: 212-621-4970; Email: reg@chemweek.com
Bangkok, Thailand **Mar. 1–2**

Win 2005 – World of Industry. Hannover-Messe International (Istanbul, Turkey). Phone: +90-212-3346900; Fax: +90-212-3346934; Web: win-fair.com
Istanbul, Turkey **Mar. 17–20**

2005 China (Shanghai) International Chemical Equipment and New Technology Exhibition. Shanghai Maidawei Exhibition Service Co. (Shanghai). Phone: +86-21-52040691; Fax: +86-21-52040691; Web: sohu.com
Shanghai **May 30–June 1** ■

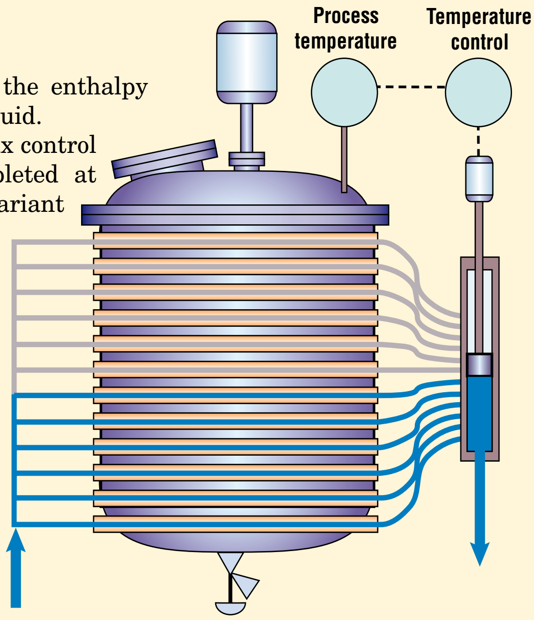
Joan Schweikart


She doesn’t need
to understand
biocatalysis.
She needs to feel better.

CHEMENTATOR

Edited by Gerald Ondrey February 2005

A new process-monitoring tool passes field tests

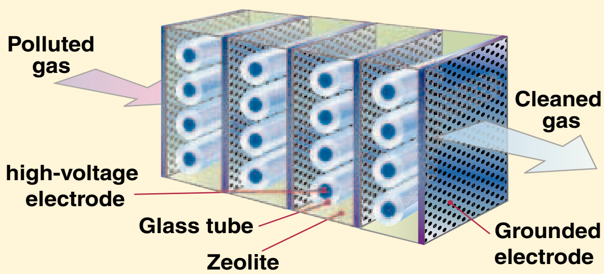


Most online monitors (such as one employing infrared [IR], near IR, ultraviolet, or Raman, spectroscopy) can only be applied to monitoring those species with clear optical absorption characteristics. Because most process changes have an identifiable thermal fingerprint, calorimetry has potential as an alternative for online monitoring, not only of chemical but also of physical and biological processes. However, poor accuracy, slow response and complex procedures of traditional heat-flow calorimetry make it unsuitable for routine process monitoring, says Robert Ashe, chairman and technical director of Ashe Morris Ltd. (Hertfordshire, U.K.; edlinks.che.com/4517-**531**). Now, with Ashe Morris' patented constant-flux control (Coflux) technology, very fast and accurate (±0.1%) measurements are possible with virtually no precalibration, he says.

Coflux is based on the constant-flux reactor (*CE*, November 2003, p. 25), which varies the heating or cooling power by regulating the heat-transfer area (diagram) rather than the temperature of the heat-transfer fluid. When the device is used as a calorimeter, the heat entering or leaving the vessel is determined by measuring the enthalpy changes in the heat-transfer fluid.

The first field trials of Coflux control have been successfully completed at the Horsforth, U.K. site of Clariant Chemicals (Basel, Switzerland). There, a 10-L constant-flux reaction calorimeter, made of Hastelloy, was used to continuously monitor two different unit operations — powder dissolution and a chemical reaction — without interruption, says Ashe. Further trials are currently being performed at other operating companies, including AstraZeneca Plc. (Macclesfield, U.K.). The Coflux technology has been licensed to Syrris (Hertfordshire, U.K.; edlinks.che.com/4517-**532**) to develop laboratory-scale reaction calorimeters, which will be supplied to Radleys (Essex, U.K.; edlinks.che.com/4517-**533**) as modules for Radleys' LARA Controlled-Laboratory Reactor. The LARA modules are expected to be commercially available in mid 2005.

Electric discharge zaps VOCs, without additional fuel



Mitsubishi Electric Corp. (Tokyo; edlinks.che.com/4517-**534**) has developed a process that combines zeolite absorption with electric-discharge decomposition to destroy volatile organic compounds (VOCs) from gas streams. Normally, absorption is used for gas streams with low VOC concentrations, and incineration is required for very high VOC loads. Because the new process requires no additional fuel, the operating costs are about half those of incineration. Emissions of CO_2 are one-half to one-tenth those of incineration, says the firm, and those of NOx are one-half.

The system (diagram) consists of four parallel units, each packed with a hydrophobic zeolite. Glass insulating tubes containing high-voltage (20 kV) electrodes pass through the zeolite bed, and the ground electrodes (perforated plates) are at both sides of the units. Contaminated gas is blown through the units. When a sufficient amount of VOCs has become absorbed on the zeolite in one of the units, the high voltage is applied and an electric discharge completely decomposes hydrocarbon VOCs into CO_2 and water. During this time, the other three units continue to absorb VOCs. The switching from adsorption to discharge operation is repeated periodically. The system is said to be most effective for gas streams with a VOC concentration of 20 to 200 ppm.

A unit capable of treating 10,000 m^3/h of gas is expected to cost less than, and occupy one-fourth the space of, that required for combustion processes, says the firm. Patents have been applied for for the new technology, which is expected to be commercially available in late 2006.

Spinning internals

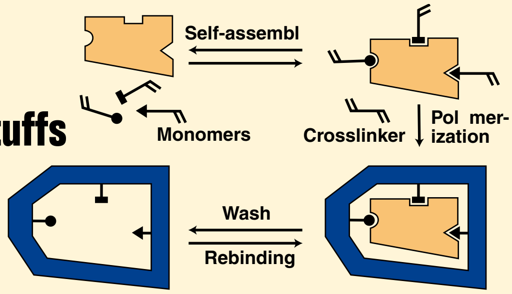
HAT International Ltd. (Nelson, U.K.; edlinks.che.com/4517-**549**) has become the exclusive global licensee for the range of high-capacity mass-transfer internals known as Highspeed vortex jet flow elements and trays. Highspeed systems, developed at the University of Berlin and commercialized by Gesip GmbH (Berlin, Germany; edlinks.che.com/4517-**550**), are based on axial cyclone technology using a swirler (static mixer) to both mix and separate gas and liquid streams with high efficiency (*CE*, July 2000, p. 27, 29). Applications to date include natural gas dehydration with glycol, distillation systems, and gas-oil separation at both high and low pressures. Highspeed systems are said to outperform the latest random and structured packings as well as alternative cyclone-technology products.

Fieldbus

This month, BP Chemicals, Inc. (Lima, Ohio; edlinks.che.com/4517-**551**) is hosting a field demonstration of Foundation fieldbus (FF) high-speed ethernet (HSE) and flexible-function block (FFB) technology at its

(*Continues on p. 16*)

A molecular-designer sorbent removes riboflavin from foodstuffs



Riboflavin (vitamin B_2) is very sensitive to light; its decomposition products can alter the flavor and reduce the nutrients in beer, wine and dairy products. Last month, MIP Technologies AB (Lund, Sweden; edlinks.che.com/4517-**535**) launched a new solid-phase-extraction (SPE) sorbent that selectively removes riboflavin without removing other desirable vitamins. The new sorbent promises to be a simpler way to remove riboflavin compared to the current extraction processes (such as chromatography), which are time-consuming and complex, says chief operating officer Christine Widstrand.

The new sorbent is a molecularly imprinted polymer (MIP) called MIP4SPE^{Riboflavin}. MIPs are stable polymers in which artificial receptor sites have been created to bind components; in this case, riboflavin. They are made (diagram) in the presence of a template molecule, which interacts with functional monomers, via a spontaneous self-assembly process, prior to and during polymerization. The latter takes place in the presence of a cross linker. After polymerization, the template is washed away, leaving behind a polymer network with functional groups in the correct locations, thus providing a binding site that mimics the template.

The new MIP is suitable for analytical applications, and is amenable to scaleup for large-scale extraction of riboflavin from food products, says Widstrand. Last month, the firm also signed a research and development agreement with FeF Chemicals A/S (Køge, Denmark; edlinks.che.com/4517-**536**), a subsidiary of Novo Nordisk A/S (Copenhagen), to develop separation media with potential for use in large-scale purification of proteins.

Halide injection shows promise for reducing Hg emissions from coal-fired plants

Initial testing of a low-cost technology aimed at reducing mercury emissions from coal-fired power generation plants has been completed by the Electric Power Research Institute (EPRI; Palo Alto, Calif.; edlinks.che.com/4517-**537**), Texas Genco LP (Houston, Tex; edlinks.che.com/4517-**538**), and URS Corp. (San Francisco, Calif.; edlinks.che.com/4517-**539**). The tests – the first full-scale application of the method — were conducted on an 890-MW boiler at Texas Genco's Limestone Station in Jewett, Tex.

Limestone's existing electrostatic precipitator and wet scrubber (for particulate and SO_2 control) captures virtually all of the soluble oxidized mercury, which accounts for 50–65% of the total mercury in the power plant's fluegas. The new concept involves oxidizing elemental mercury with small amounts of a halogen compound — a liquid stream of calcium chloride or bromide — injected into the boiler, so that the mercury can be rendered soluble for capture in the SO_2 scrubber.

The preliminary results show that the halogen injection increases the mercury removal to around 75%, says URS. Work will continue through 2006 to determine if higher removal efficiencies can be achieved with increased halogen injection, and to study the corrosive effects that may be caused by the halogen additives.

Making sabotage visible

Lanxess AG (Leverkusen, Germany; edlinks.che.com/4517-**540**) has developed a luminescent indicator that, when used with a new surveillance system, can reliably detect small changes of ground surfaces from the air. The weather-resistant chemical is sprayed over the area beneath. When applied, the substance is invisible to the human eye. However, when exposed by radiation from a pulsed laser, the substance's luminescence can be easily detected.

Surveillance can be performed day or night from a helicopter, for example, using a fully automatic imaging software application. The self-teaching software compares, in real time, images that were made just after spraying with those taken after flyover. Ground changes the size of a postcard can be detected from a height of 100 meters, says the firm.

The new system has been demonstrated to be technically feasible, and major field-testing is being planned. Potential applications include the surveillance along railway tracks and pipelines, around power and chemical plants, and at airports.

(Continued from p. 15)

1,4-butanediol plant. Developed specifically for the FF HSE (100 Mbits/s) technology, FFBs are key components of the open, integrated FF architecture for plantwide information integration. FFBs, which are application-specific, reside at the fieldbus user layer along with standard function blocks, and enable control strategies, such as supervisory data acquisition, batch control, programmable-logic-control sequencing, burner management, coordination-drive control and I/O interfacing, according to the Fieldbus Foundation (Austin, Tex.; edlinks.che.com/4517-**552**). A live demonstration of the combined HSE/FFB architecture is planned for May 19.

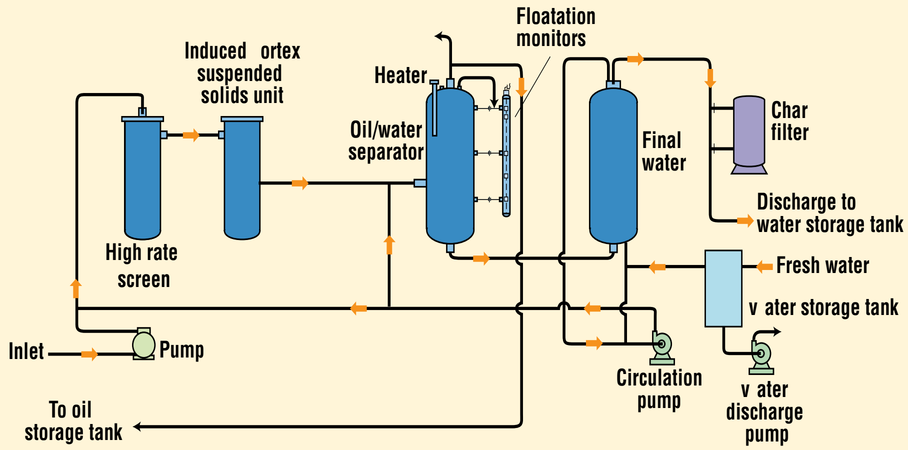
Extremophiles

Microorganisms that thrive in the hostile environment of a high-level radioactive waste tank have been discovered by researchers at the U.S. Department of Energy's Savannah River National Laboratory (SRNL; Aiken, S.C.; edlinks.che.com/4517-**553**). The bacterium, *Kineococcus radiotolerans*, is able to withstand radiation doses thousands of times the dose that is lethal to humans, as well as exposure to ultraviolet radiation and toxic chemicals, and prolonged desiccation. The microorganism is currently undergoing genome sequencing at the DOE Joint Genome Institute (Walnut Creek,Calif.). Learning about its self-repair mechanism may prove useful in such areas as environmental cleanup, space exploration and medicine, says SRNL.

H_2 sensors

Air Products and Chemicals (Lehigh Valley, Penn.; edlinks.che.com/4517-**554**) and H2scan Corp. (Valencia, Calif.; edlinks.che.com/4517-**555**) are developing solid-state chemical sensors for uses in hydrogen plants, petroleum refineries and other process facilities. The aim is to produce sensors to operate inside process lines or vessels of Air Products' production units, providing realtime H_2-concentration data from the process gas flow. H2scan has commercialized H_2 sensors based on proprietary technology of Sandia National Laboratories (Albuqerque, N.M.).

A more efficient way to separate oil and water



A system that achieves greater than 97% efficiency for separating oil and water has been developed by Nu-Corp International Technologies, Inc. (Byhalia, Miss.; edlinks.che.com/4517-**541**). The high efficiency of NuCorp's XpaK system, measured by researchers at Mississippi State University's Diagnostic Instrumentation and Analysis Laboratory (DIAL; Starkville; edlinks.che.com/4517-**542**), is significantly higher than the 75% efficiency typically achieved by conventional gravity separators, says the firm.

XpaK takes advantage of the difference in densities of immiscible fluids. As such, it can be applied to any mixture of immiscible liquids of different buoyancy. In the separation process (flowsheet), solids are first screened and recovered in an induced-vortex, suspended-solids unit. The oil-water mix is then pumped to a high-rate separator. The high-rate separator is a curvilinear compound separator made up of XpaK internals. The mixture circulates through this column, from bottom to top, along a controlled flow pathway (multiple channels), under controlled temperature and pressure. The combination of the fluid's kinetic energy, thermal gradient and nucleation causes the oil and water particles to separate — the oil moving towards the walls and the water towards the center, of the column.

Nu-Corp states that the capital cost for the system is about one-quarter that required for conventional equipment. The operating costs are also lower because no chemicals are required to enhance the separation; the return on investment can be weeks to months, depending on the application. A large-scale demonstration is being planned, pending federal funding, at an oilfield site in Mississippi.

Using fullerenes to optimize surfaces for anti-wear applications

Next month, a consortium of 31 companies and institutions from 13 countries will begin a three-year research project called Foremost: fullerene-based opportunities for robust engineering — making optimized surfaces for tribology. The project will be based on inorganic fullerenes, such as molybdenum bisulfate and bisulfate of wolframite. These new allotropic states of established solid lubricants have the property of forming nanospheres and layers (analogous to onion skins), which act as "nano ball bearings" between contact surfaces.

The project is being coordinated by the Tekniker Technological Center (Eibar Guipúzcoa, Spain; edlinks.che.com/4517-**543**), and includes companies such as Ion Bond, Ltd. (Consett, U.K.), Microcoat Ltd. (Dunstable, U.K.), Fuchs Petrolub, AG (Mannheim, Germany), Spolchemie (Ústí nad Labem, Czech Republic), and Nanomaterials Ltd. (Rehovot, Israel). Three different product families will be developed: hard layers (where the fullerenes exhibit a greater thermal stability than the bisulfates in their natural state); polymeric layers and paints (where the addition of fullerenes will increase the wettability); and lubricants (where fullerene addition will reduce the coefficient of friction and increase the load-resistance capacity).

A consortium bets on sonic fusion

Impulse Devices Inc. (IDI; Grass Valley, Calif.; edlinks.che.com/4517-**544**) has commercialized a reactor for conducting research on acoustic inertial confinement fusion (AICF). An emerging field, AICF was discovered in 1989 by IDI's chief scientist, Felipe Gaitan, and fusion reactions occurring in an AIFC reactor have been documented twice by multi-institution teams (in *Science* [2002] and *Physical Review E* [2004]).

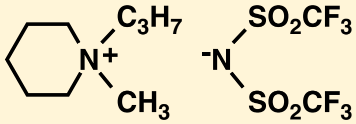
The proprietary reactor is a stainless steel sphere filled with heavy water and has a "bubble" of deuterium in the center. Acoustic transducers focus sound waves (kilohertz) onto the core, causing the bubble to rapidly expand and collapse, and the cavitation leads to high localized temperatures. When the temperature is sufficiently high, the deuterium is fused into helium, releasing heat that could some day be used to drive a steam turbine. IDI's reactor has a 1-ft diameter and costs $250,000.

Last month, a consortium was established to further AICF research. The consortium is made up of researcher from IDI, Boston University, Purdue University, the University of Mississippi and the Washington Center for Industrial and Medical Ultrasound at Washington University. IDI believes the AICF technology can produce energy on a break-even basis within five years, and produce enough net energy for making electricity within ten years.

Ionic liquids show promise as an electrolyte in the next generation of Li-ion batteries

Researchers of Kansai Center of National Institute of Advanced Industrial Science & Technology (AIST; Ikeda, Japan; edlinks.che.com/4517-**545**) have developed a new flame-resistant electrolyte, based on ionic liquids, for secondary lithium ion batteries that use metallic Li as the negative electrode. Although such batteries offer twice the energy density compared to conventional Li-ion batteries, they are prone to short circuiting due to the formation of dendrites after frequent charge-discharge cycles. As a result, the improved battery has eluded commercialization because of the safety risk associated with the the flammable solvents used in existing electrolytes.

With the support of New Energy & Industrial Technology Development Organization (Kawasaki, Japan), AIST researchers developed New Electrolyte, which is composed of the a salt of asymmetric, cyclic, tertiary ammonium-imides, such as N-methyl-N-propylpiperidinium bis(trifluorometharsulfonyl) imide (picture). Unlike alternative ionic



liquids that have been tried by other researchers, New Electrolyte is able to withstand the electromotive voltages involved without forming dendrites. And the material shows no ignition or weight reduction during flammability tests at 300°C, says AIST.

A battery with electrodes made of lithium metal (negative) and $LiCoO_2$ (positive), and New Electrolyte as its electrolyte, showed a charge-discharge efficiency of 97%. Intended to further the progress towards commercialization, the research is currently aimed at improving the purity and composition of New Electrolyte to increase the battery's efficient.

New use for starch

A technique for changing the water repellency of plastic films using coatings of steam-jet-cooked starch has been developed by scientists at the Agricultural Research Service (ARS; edlinks.com/4517-**546**) of the U.S. Dept. of Agriculture (Washington, D.C.). The technique was developed to improve plastic's retention of water-based dyes and printing inks (used on food labels) as well as to reduce buildup of static charge. Normally, chemical treatment is required to impart hydrophilic properties to commercial polymers, such as polyethylene; ARS believes that the starch-based method is a cheaper and safer alternative. The scientists have shown that the starch, in 1-µm-thick coatings, has the ability to hold water in place. The process has been patented and ARS is seeking a company to license the technology.

Using waste heat to lower desalination costs

Researchers at the University of Florida (Gainesville; edlinks.che.com/4517-**547**) have developed a process that can utilize waste heat from power plants as the main source of energy in desalination plants. The process, which is based on mass diffusion rather than heat to evaporate salt water, has been tested in a laboratory prototype unit that produces approximately 500 gal/d of fresh water. Calculations based on these tests show that the waste heat from a 100-MW power plant could generate 1.5 million gal/d of fresh water using the process, says James Klausner, professor of mechanical and aerospace engineering. The production cost per thousand gallons of water are estimated to be $2.50 for the process, compared to $10 for conventional distillation and $3 for reverse osmosis, he says.

The desalination process uses a packed-bed, falling-film evaporator; but evaporation in it is driven by diffusion rather heat, says Klausner. Salt water is preheated (by the waste heat of a power plant) to 40 to 60°C and sprayed into the top of a diffusion tower. The column is packed with polypropylene packing [(HD Q-Pac) manufactured by Lantec Products, Inc. (Agoura Hills, Calif.; edlinks.che.com/4517-**548**)]. As the water falls down the column, a countercurrent flow of air evaporates the water. The air enters at 25 to 30°C and is gradually heated as it is driven through the diffusion tower. The saturated air is then blown to a direct-contact condenser to condense the vapor out of the air-vapor stream. This feature allows for a compact and inexpensive condenser, he says.

The fraction of feed water converted to fresh water is low (5 to 10%), so mineral-scale buildup is not a major problem, explains Klausner. Biological fouling is more of a concern, but this can be prevented by chlorination or ozonation, he says. "Should the packing become fouled, it is easily replaced at low cost since it is an inexpensive thermoplastic." ■

LDPE

Last month, ExxonMobil Chemical Technology Licensing LLC (Houston, Tex.; edlinks.che.com/4517-**556**) signed an agreement with Huntsman Petrochemical (UK) Ltd. whereby Huntsman will license ExxonMobil's tubular process technology for Huntsman's 400,000-m.t./yr low-density-polyethylene (LDPE) plant, to be built in Teeside, England (*CE*, October, 2004, p. 14). The plant will be the world's largest LDPE facility.

New sweetener

Palatinit GmbH (Mannheim, German; edlinks.che.com/4517-**557**) has launched a new artificial sweetener that is friendlier to teeth and is digested slower than sucrose, which leads to a low glycemic response in the human body. The new sweetener, a derivative of sucrose (6-O-α-D-glucopyranosyl-D-fructofuranose, or isomaltulose), is a natural constituent of honey and sugar cane. The synthetic compound (tradernamed Palatinose) is made by a biotransformation of sucrose by enzymatic rearrangement of the glycosidic linkage from (1,2)-fructoside to (1,6)-fructoside using immobilized cells of *Protaminbacter rubrum*. After the reaction, the sweetener is purified by crystallization. Palatinose is being produced on a commercial scale at the Offstein, Germany, site of Südzucker AG (Mannheim), the parent company of Palatinit. ❑

WRINGING MORE OUT OF WATER

As water inexorably becomes scarcer, recycling it for process use makes more and more sense

Ionics

Reverse osmosis, long used for water desalting, is meeting new challenges in industrial-water recycling

Overtaxed by population growth and increasing industrial demand, supplies of fresh water are becoming scarcer and more expensive in many parts of the world. At the same time, chemical process plants are being required to meet ever-stricter restrictions on the discharge of effluent. In response to these pressures, more and more companies are resorting to their waste-treatment plants as a source of fresh water.

Municipal wastewater treatment plants are also growing in popularity as a source of feedwater in various parts of the world (see box, p. 22). The recycle of effluent from these plants is increasing at a rate of about 15%/year in the U.S. alone, according to the WaterReuse Assn. (Alexandria, Va.). The growth of recycling within industrial plants is more difficult to gauge, given the fragmented nature of the market, but equipment suppliers estimate the worldwide annual growth at around 15 to 20%.

The problem of growing water scarcity is particularly acute in some areas that are rapidly adding large industrial plants, such as petrochemical and steel plants, says Colin Sabol, chief marketing officer for General Electric Infrastructure (Trevose, Pa.). One such region is northern China, he says, "where the price of water was doubled about four months ago."

Waste treatment varies widely from plant to plant, even for those that make similar products. However, the basic, common elements are typically the separation of valuable chemicals that are recycled to the process and of hazardous materials that cannot be discharged, followed by treatment of the resultant aqueous waste stream to meet discharge requirements. Methods used include mechanical filtration and separation, chemical and biological treatment, clarification, flotation, and evaporation.

Adding membranes

Since most plants already have many of these elements in place, the further cleanup of water for recycling is most likely to involve the addition of microfiltration (MF) or ultrafiltration (UF) membranes, followed by reverse osmosis (RO) at the end of the treatment process. Companies that require water of higher purity, such as pharmaceutical and semiconductor operations, may add ion exchange. "On average, RO will remove a good 90% of the dissolved solids, but ion exchange will reduce the solids content to a couple of ppm or less," says Glen Sundstrom, industrial market manager for USFilter's Memcor, Microfloc and General Filter Products operations (Rockford, Ill.).

As an indication of the growing demand, in the past five years USFilter has installed more than a dozen large-scale membrane systems in industrial plants to recycle wastewater, says Sundstrom, versus only a handful in the previous decade. The company has also installed more than 40 smaller-scale units for such businesses as printed circuit board manufacturers and metal-plating operations. "Given the current interest of customers, we could make another dozen large-scale installations in the next two years," he says. Meanwhile, Koch Membrane Systems, Inc. (Wilmington, Mass.) reports that the interest in UF and RO for new projects has increased dramatically. "Five years ago, about 10% of our pilot studies were for UF/RO," says Fran Brady, a Koch process technology leader. "Today, 90% of our pilot work is for the evaluation of UF/RO to recycle water and eliminate discharge to publicly owned treatment plants."

GE, a relative newcomer to water

treatment, decided to enter the market about three years ago after an extensive study showed a huge potential for water-recycling. Since then, GE has made a number of acquisitions, including water-treatment company Betz Dearborn, and Osmonics, which makes spiral-wound membranes. By the end of this month, the company expects to complete the acquisition of Ionics, Inc. (Watertown, Mass.), which has expertise in the construction of very large desalination plants.

Profiting from recycling

Water-recycling can be a profitable endeavor, says GE's Sabol. He cites the case of an Australian mining company that uses about 400 gal/min of water to recover metal from ore. "They were putting the wastewater into settling ponds and getting into trouble with the environmental authorities because heavy metals were leaching into the groundwater," he says.

GE installed a water-recycling system that included clarification, filtration, chemical treatment and nanofiltration that cost about $500,000, plus $75,000/year in operating costs. However, the project paid for itself in less than a year, says Sabol, because the recycling plant recovers about $500,000-worth of metals per year and saves some $200,000/year by avoiding the purchase of fresh water.

The increased interest in membrane-based separation has been prompted not just by a need to recycle water, but also by a significant decrease in the cost of membranes. The capital cost of membrane systems has dropped by around 50% since 1995 because of advances in manufacturing methods and higher-volume production, says Sundstrom. Brady adds that the cost of treating industrial wastewater, using a UF/RO combination, is now less than 2¢/gal, down from close to 4¢/gal five years ago.

Membrane improvements

Improvements in membranes, to reduce energy consumption and obtain better rejection of dissolved solids, have been achieved in incremental steps over the years, says Lance Johnson, global manager for large membrane projects with Dow Chemical Co. Johnson is located in Minneapolis, Minn., where Dow subsidiary FilmTech Corp. makes spiral-wound membranes. "Our RO membranes can now operate below 100 psi for brackish water, compared to 100-150 psi about five years ago," says Johnson.

Dow's latest innovation is a new method of interconnecting spiral-wound membrane modules, which are installed in series in groups of six or eight inside a pressure vessel. Normally, the modules are connected by plastic pipe with O-rings, but the seals tend to get rolled or pinched, resulting in leaks, says Johnson. Dow's

MUNICIPAL WASTEWATER FEEDS THIRSTY PROCESS PLANTS

For many chemical process plants, the most convenient source of water may be that which is recycled from a local sewage treatment plant. This water is often less expensive than the industrial plant's own wastewater, says Glen Sundstrom, of USFilter. This is because municipal wastewater generally has a narrower range of pollutants than industrial wastewater, so it is less expensive to treat for re-use.

One of the larger ventures involving the recycling of municipal wastewater for industrial use is operated by the West Basin Municipal Water District (Carson, Calif.). The district processes 30 million gal/d of wastewater at a plant in nearby El Segundo and sells approximately 20 million gal/d to three local petroleum refineries, operated by BP p.l.c., ChevronTexaco and ExxonMobil. The recycling plant is undergoing an expansion which will increase production to 45 million gal/d in 2006.

West Basin buys secondary-treated wastewater from a Los Angeles wastewater-treatment facility and puts it through tertiary treatment (coagulation, flocculation, filtration and disinfection), followed by denitrification to remove ammonia, then microfiltration and reverse osmosis (RO). Some water destined for the refineries is subjected to double-pass RO. The refineries use the water for boiler feed, cooling, and other uses. West Basin also produces single-pass RO water for injection into aquifers to form a barrier against the intrusion of seawater from the nearby Pacific Ocean. Tertiary-treated water is used for landscape irrigation.

innovation, an interlocking end cap, is an axial compression seal that is said to eliminate this problem.

Koch has a new spiral-wound membrane module that was developed to reduce costs. Called MegaMagnum, it measures 18 in. dia by 61 in. long, versus 8 by 40 in. for standard modules. The benefits, says the company, are lower installation time, lower labor cost and reduced seal and piping complexity; furthermore, the unit takes up only one-third to one-half the floorspace of conventional membranes. On installations made so far, the capital savings have been as much as 14%, compared with standard modules, says Brady.

While RO has been used for decades to produce potable water from seawater and brackish water, and in municipal water-treatment plants (see CE, November 2004, pp. 27–30, for a recent update on desalination), treating plant waste streams presents some special challenges. "Municipal wastewater is well understood and doesn't vary much," says Sundstrom, "but for an industrial waste stream, you need to run a pilot plant to prove that the system works and that the membranes will stand up."

Common materials used in membranes are polyacrylonitrile (PAN) and polyvinylidene fluoride (PVDF), which are popular choices for oily waste streams; and polysulfone, which is not suitable for hydrocarbons. For a fuller list of membrane materials, see the table. RO membranes are typically composites. Sundstrom notes that while PVDF is resistant to such oxidants as chlorine, "there are some aromatic solvents that could dissolve it." In such cases, he says, probably the best course is the removal of the solvents upstream from the membrane.

GE has recently introduced some new membranes that can tolerate pH conditions below 2 and above 12, whereas conventional membranes are limited to pH levels of around 4 and 10, says Sabol. Also new from GE are membranes that can operate up to 90°C, versus about 60°C for standard membranes. The higher temperature allows water to be recovered from hot condensate, so that it does not have to be reheated for boiler or process use, says Sabol.

Other treatment methods

Membranes aside, there are innovations in other treatment technologies that may improve a plant's current waste-treatment system. Electrocoagulation, for instance, is a hoary process that is experiencing a revival.

An electrocoagulation system is offered by World Environmental Technologies, Inc. (WET; Lafayette, La.), a subsidiary of Ecoloclean Industries, Inc. In the first stage of the unit, the waste stream is pumped between horizontal steel plates, which ionize the water, precipitating heavy metals and organics. The stream then passes between aluminum plates, where the contaminants are flocculated. Heavy solids sink to the bottom and lighter material is floated, leaving a waste stream that can be discharged to a sewer or recycled as washwater, says Michael Richardson, president of WET. In some cases the water may need no

THE CLEANUP ARTISTS

Dow Chemical — dow.com	edlinks.che.com/4517-561
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Ionics - ionics.com	edlinks.che.com/4517-564
Koch Membrane Systems — kochmembrane.com	edlinks.che.com/4517-565
Lanxess AG — lanxess.com	edlinks.che.com/4517-566
Severn Trent Services — severn-trent.com	edlinks.che.com/4517-567
Solucorp Industries — solucorpltd.com	edlinks.che.com/4517-568
USFilter — usfilter.com	edlinks.che.com/4517-569
West Basin MWD — westbasin.org	edlinks.che.com/4517-570
World Environmental Technologies — ecoloclean.com	edlinks.che.com/4517-571

TABLE 1 – MEMBRANE FILTER TYPES AND CHARACTERISTICS			
Material	**Abbr.**	**Advantages**	**Disadvantages**
Polypropylene	PP	Low cost High pH range tolerance	No chlorine tolerance Expensive cleaning chemicals required
Polyvinylidene fluoride	PVDF	High chlorine tolerance Simple cleaning chemicals	Cannot sustain pH > 10
Polyether sulfone & polysulfone	PES/PS	Chlorine tolerance Reasonable cost	Brittle material requires support or flow inside to outside
Polyacrylonitrile	PAN	Low cost, typically used for UF membranes	Less chemically resistant than PVDF.
Cellulose acetate	CA	Low cost	Narrow pH range Biologically active

further treatment, and in others it may require sand or charcoal filtration.

The process can treat 100 gal/min, versus 15–20 gal/min for conventional electrocoagulation, says Richardson, and the power requirement is 50 amps or less (220V, single- or 3-phase), compared with 300–400 amps for "most other processes." He adds that the treatment cost is roughly one-third those of standard chemical and biological methods.

WET has four trailer-mounted units, which so far have been used to treat petroleum wastes in oilfields. Richardson says the company is now working toward permanent installations in process plants.

An electrocoagulation process that can treat up to 250 gal/min of wastewater is available from Solucorp Industries, Ltd. (Ft. Lauderdale, Fla.). Solucorp acquired the technology last year through the purchase of WITS, Inc. (Orlando, Fla.), which has tested the process on a variety of wastewaters over the past two years. The first commercial installation is being made in Keysville, Va., for removal of copper in the city's wastewater treatment plant.

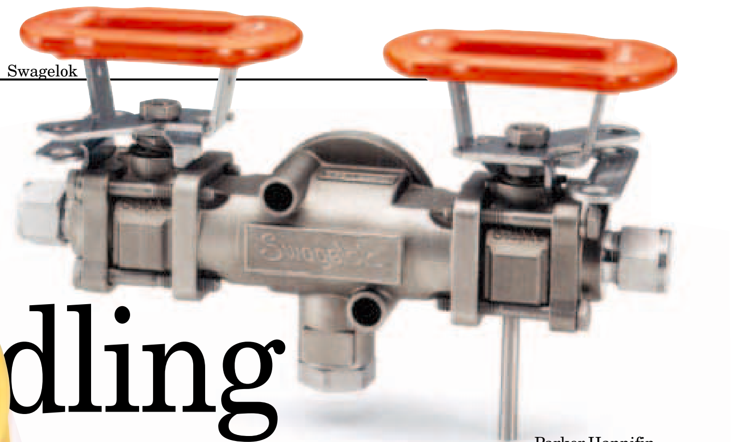
The higher throughput was achieved by using vertical plates, like a plate-and-frame filter, says William Seagraves, president of WITS. The vertical design is said to facilitate scaleup, as well as operation and maintenance. In tests, the process has removed well over 90% of both metal and organic contaminants, says Seagraves. He adds that the capital and operating costs are 20–40% lower than those for chemical treatment methods.

Adsorbents for the removal of arsenic and other heavy metals from water are available from a number of companies. Under a new agreement with Lanxess AG (formerly the chemical arm of Bayer AG; Leverkusen, Germany), Severn Trent Services (Birmingham, England) offers an adsorption system for removing metals from industrial wastewater that uses a fixed bed of Lanxess's synthetic alpha iron hydroxide-oxide (Fe[OH]O) granules (*CE*, May 2002, p. 15). Graver Technologies (Glasgow, Del.) has acquired HydroGlobe (Hoboken, N.J.), which has a process that uses titanium dioxide granules to adsorb arsenic, lead and other heavy metals. However, the principal market for these processes is the removal of arsenic from drinking water (in this connection, the U.S. standard for arsenic in drinking water will drop from 50 ppb to 10 ppb next January).

Returning to the topic of membranes, USFilter offers a membrane bioreactor, the MemJet MBR Express, that combines activated sludge and microfiltration membranes in one package. The bioreactor is a tank that has an inlet for wastewater at the front end and hollow-fiber membranes at the outlet end. As the wastewater flows through the tank, air is injected to promote biological activity. Air is also injected through the membranes, serving the dual purpose of preventing membrane fouling and adding oxygen to the process.

Solids rejected by the membranes are recycled to the tank inlet. This allows the solids concentration to be maintained between 10,000 and 15,000 mg/L, versus 3,000–5,000 mg/L for a conventional activated sludge process, says Sundstrom. The bacteria work much more efficiently at the higher solids concentration, he says. Most of the initial installations were in municipal treatment plants, but more recent installations have been in petroleum refineries and petrochemical and steel plants. ■

Gerald Parkinson



Swagelok

FOCUS ON

Steam Handling

Armstrong

Parker Hannifin

Hose station provides safety for point-of-use steam

The Steamix VE Hose Station (photo, left) is recommended for use with steam/water heaters in various vessel filling, container top-off barrel washing and other applications. In the event of either a complete failure of the inlet cold water supply or a reduction in cold water pressure below 20 psi, Steamix VE will respond with a complete shutdown of outlet flow. In the event of a structural failure of the primary operating component (diaphragm), Steamix VE will fail safe to cold water. To prevent overtemperature selection by the user and the potential for overheated water and flash steam that is common with other types of hose stations, Steamix VE comes standard with a single temperature lockout feature. A maximum temperature limiting option is also available. Operating pressures of 20–150 psi and temperatures up to 180°F can be accommodated. — *Armstrong Hot Water Group, Three Rivers, Mich.*
edlinks.che.com/4517-481

A high-temperature valve gives a warm welcome to steam

The SC-2000 series of piston-operated check valves (photo, bottom right) is designed to withstand pressures of up to 500 psi with virtually no cracking pressure. They can handle steam, hot and cold liquids, inert gases of temperatures from –40 to 450°F. The simple, three-piece valve is constructed of 17-4-grade stainless steel. The valves, available in two- and three-way models, are clearly marked with a cast arrow on the body to indicate flow direction. In addition, the valves offer multiple port sizes ranging from 1/2 to 1 in. — *Parker Hannifin Corp., Parker Fluid Control Division, Twinsburg, Ohio*
edlinks.che.com/4517-482

Keep an eye on steam systems, and stop sweating the efficiency

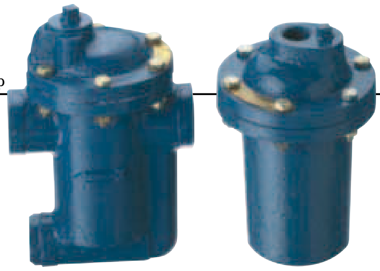
With this integrated test valve assembly (photo, top right), one can visually observe condensate removal and monitor steam trap performance wherever steam heating systems and steam traps are used. Monitoring steam trap performance can help reduce costs related to steam and energy losses, reduced heat capacity and equipment damage. The integrated test valve assembly comprises two of this manufacturer's Series-63 general purpose ball valves, for isolation and testing, and a sturdy CF3M two-bolt universal mount that eases steam trap installation. Valves feature oval quarter-turn handles that are available in locking, non-locking and latch-locking models and a wide variety of end connections, including tube fitting, female NPT and female ISO-7/1. Choose from three test-valve vent locations: facing toward the steam trap, away from the steam trap, or downward. — *Swagelok Co., Solon, Ohio*
edlinks.che.com/4517-483

A mobile system for cleaning in place

The 300L portable cleaning-in-place (CIP) skid can be configured as a one-tank or two-tank system. It is suitable for use on standalone equipment in a pilot plant, or in a small production facility. Controls are either manual or automatic, depending on the level of cleaning requirement. The CIP tank is heated by injecting clean steam directly into the tank or by installing an in-line heat exchanger. Mobile systems offer an economic alternative to a centralized CIP system by eliminating the need for CIP supply and return piping. The manufacturer also offers standard and custom-designed systems, including single-use to drain, single-use circulation and multi-use recovery designs. These systems not only reduce cleaning time and improve productivity, but they eliminate exposure to chemical and biological hazards. If further cGMP design and consulting services are required, the firm can assist with them, as well. Capabilities in this area include cleanability audits, debottlenecking, studies, systems design, equipment installation, commissioning, and validation. — *Alfa Laval Biokinetics Inc., Philadelphia, Pa.*
edlinks.che.com/4517-484

This rigid PU foam insulation can take the heat

With long-term exposure to temperatures of 150°C or more (as occurs in steam pipelines), conventional insulation made of rigid polyurethane (PU) foam materials can become brittle and lose their shape over time. A new high-temperature rigid foam has



Nicholson Steam Trap

been developed to prevent cracking and thermal bridge formation in the insulation. The new product has the same thermal insulation as standard rigid PU foams, but can withstand long-term temperatures of up to 200°C (250°C for short periods). The heat-resistant PU is made by using excess isocyanate; when the foam hardens, the excess isocyanate molecules react to form a more densely cross-linked polyisocyanurate, says the firm. — *Bayer MaterialScience, Leverkusen, Germany*
edlinks.che.com/4517-485

Kit helps this trap and others accommodate wider pressures

Rugged, inexpensive and in-line repairable, Dura-Flo Inverted Bucket Steam Traps (photo) are made from durable/heavy walled cast iron bodies for use on steam lines, process equipment, laundry equipment, steam cookers, steam heated vats, pressing machinery, unit heaters, oil preheaters, converters, coils and rotating drums. The hardened stainless-steel valve and seat are said to provide maximum corrosion resistance, thereby extending the steam trap's service life. The rugged stainless steel bucket is also designed to minimize the effects of water hammer. Another convenient feature of the Dura-Flo Inverted Bucket Steam Trap is its easy-to-install PCA (Pressure Change Assembly) kit, which allows the user to change the steam trap's pressure to accommodate a wider range of applications. PCA kits can also be installed in other brands of inverted bucket steam traps. Dura-Flo Inverted Bucket Steam Traps are available for pressures to 250 psig (17.2 barg) and temperatures to 450°F (232°C), in both horizontal and vertical configurations. — *Nicholson Steam Trap, Walden, N.Y.*
edlinks.che.com/4517-486

Reduce pressure but not space

For use where cost or space limitations are the primary concern, the D50 Direct-Acting Pressure Reducing Regulator is a rugged and economical choice for steam irons, autoclaves, laundry mangles, single radiators, steam tables, vulcanizers, steam, water or gas applications. Available in cast iron, bronze and stainless steel, the D50 Direct-Acting Pressure Reducing Valve is rated to 300 PSIG at 420°F and reduces pressures from 3 to 140 psi. Other notable features of the D50 Pressure Reducing Valve include: a spherical seating surface on a floating stainless steel disc for tight shutoff, five spring ranges, integral stainless steel strainer, and the availability of a Teflon disc for liquid and gas dead-end service. — *Spence Engineering Company, Inc., Walden, N.Y.*
edlinks.che.com/4517-487

Clayton Industries

Equip steam generators with a low-NOx package

At 650 and 700 bhp, Models E-654 and E-704 are this vendor's most high-powered steam generators (photo) to date. The units produce steam for high-capacity operations and offer the convenience of fast starts. The controlled circulation and counterflow heat exchanger technology brings fuel savings and size advantages, says the firm. When stringent air quality (single-digit NOx thresholds) is necessary, low-NOx burners are available. In this case, the burner system achieves emissions reduction through a combination of air/fuel mixing, ultra-lean flame design and low-flame residence. Units offer precise PLC control of pressure and automatic or unattended operation. Natural gas, propane, light oil, or combination of the three fuels is possible. — *Clayton Industries, Inc., El Monte, Calif.*
edlinks.che.com/4517-488

A different alloy resists high temperatures and corrosives

Monel grease fittings provide corrosion and temperature resistance, while maintaining a structural strength greater than traditional steel. These properties make the fittings ideal for use in severe operating conditions that are found in chemical process plants. Monel fittings are more corrosion resistant than 316 stainless when exposed to seawater, brackish water or high-temperature steam, and they are ideal for use in harsh chemical environments involving exposure to substances such as ultrapure water, organic acids, chlorine gas, calcium chloride and vinegar. In addition to corrosion resistance, Monel fittings are stronger than traditional steel and withstand extreme temperatures ranging from sub-zero to approximately 480°C (896°F). — *Alemite Corp., Charlotte, N.C.*
edlinks.che.com/4517-489

Heater is a foe to bacteria breeding grounds

Now available in both single- and double-wall versions, the Constantemp Heater destroys *Legionella* bacteria that can grow in hot water systems. Constantemp Steam Water Heaters Feed-Forward system heats water to 200°F and then blends fresh cold water

to achieve set temperature. Accuracy is ±3°F. Constantemp Heaters instantly deliver up to 120 gal/min and never fail hot, says the firm. Large storage tanks that can breed *Legionella* are easily replaced by the compact Constantemp, which fits through a standard doorway. Skid-mount systems are also available. Setup simply requires connection of the water inlet and outlet, steam inlet and condensate drain. — *Leslie Controls, Inc., Tampa, Fla.*
edlinks.che.com/4517-490

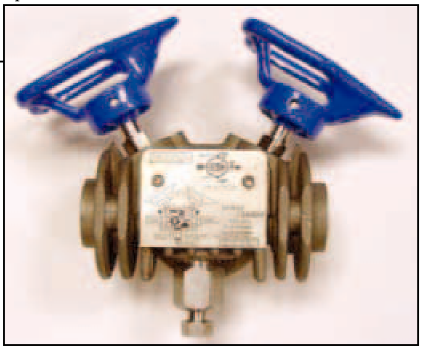
Conquer superheat on high-pressure process applications
Designed specifically for the difficult tasks of draining condensate from


TLV

high-pressure superheated steam mains and turbines, SS5NH (horizontal) and SS5VH (vertical) steam traps (photo) provide seal-tight shutoff and high reliability for extended performance. Constant water seal and novel rotational seating design eliminate concentrated valve wear to ensure long life, while a three-point seating ensures a steam-tight seal even under no-load superheat conditions. For resistance to water hammer, the SS5 Series boasts up to 1720 psig hydraulic shock rating and 0.004 diameters sphericity of the float. The SS5NH operates for pressures up to 659 psig, and is available in screwed, socket weld and flanged connections. — *TLV Corp., Charlotte, N.C.*
edlinks.che.com/4517-491

Transmitter for measuring level in saturated steam applications
The MT2000 uses guided-wave radar to make measurements, which means no moving parts and, therefore, virtually no maintenance. A waveguide directs the microwave pulses, eliminating the beam divergence problems common to conventional non-contact radar transmitters. The new C9P81 Waveguide is designed specifically for saturated steam applications, such as those found in industrial heat processes. The C9P81 Waveguide features an alumina ceramic insulator that allows accurate and reliable measurements up to 2,000 psi (138 bar) at 635°F (335°C). Unlike traditional contact devices, such as displacers, the C9P81 Waveguide does not depend on fluid density to make measurements. As a result, readings do not fluctuate with shifts in the specific gravity of the fluid and are not subject to variations in dielectric constants. This allows for significantly tighter control throughout the steam cycle, from boilers to feedwater heaters to de-aerators. The MT2000 level transmitter is offered in a large selection of probe materials, including 316 Stainless Steel, 304 stainless steel, hastelloy, monel, and

Spirax Sarco



titanium. Accuracy is ±0.20 in. — *K-tek, Prairieville, La.*
edlinks.che.com/4517-492

Steam trap station eases service and changeout
The Universal Steam Trap Station (USTS) enables rapid and easy testing, isolation and changeout of steam traps. When combined with the steam trap technology of choice, the USTS comprises a complete steam main drip or tracer steam-trap station in a compact package. The USTS combines an inlet isolation/blowdown valve and an outlet isolation/test valve. The inlet valve, when set to the blowdown position, isolates the trap for service. The discharge valve, when set to test position, isolates the discharge side of the trap, blocking its outlet port, so that trap function can be checked and downstream depressurization can be done. The standard model has a maximum operating pressure rating of 300 psig (21 barg), with a maximum operating temperature rating of 421°F (198°C). The USTS-HP (high pressure) model is rated at 650 psig (45 barg) and 750°F (399°C). In addition to the manufacturer's brand, the station will support third-party universal connector-type steam traps. — *Spirax Sarco, Inc., Blythewood, S.C.*
edlinks.che.com/4517-493

Produce steam without local byproducts of combustion
Series MBA Electric-Fired Steam Generators are designed to produce efficient steam up to 80 psig in a range from 3 to 20kW. They can be located virtually anywhere and are very quiet, says the vendor. No flue, fuel lines, tanks or onsite products of combustion are required. Each unit is compatible for use with standard tap water. Since the units are small in size, little heat is lost to the surrounding environment. — *Sussman-Automatic Corp., Long Island City, N.Y.*
edlinks.che.com/4517-494 ■

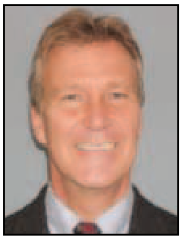
Rebekkah Marshall

WHO'S WHO


Woelfel


Prevost


Chaturvedi


Horgan


Ciemniecki

Basell North America, Inc. (Elkton, Md.) appoints *Randy Woelfel* president of Polyolefins North America. *Ian Dunn* is named president of Polyolefins International, succeeding Woelfel.

Patrick Prevost is elected president of the chemicals, plastics and performance products segments in North America for **BASF** (Florham Park, N.J.). *Hans Engel* is appointed president of the agricultural products and fine chemicals segments in North America.

Black & Veatch Corp. (Overland Park, Kan.) appoints *Robert Wlodek* sales and marketing manager of its Nuclear Group.

Anis Sherali joins **EarthSearch Communications** (Atlanta, Ga.) as vice chairman and member of the board.

Neil Gibbons is named operations director for **Excelsyn's** (Durham, U.K.) engineering technology business.

KGK Synergize, Inc. (London, Ont.) names *Pratibha Chaturvedi* senior scientist.

Louis Peters retires as executive director of **The Polyurethane Foam Assn**. (Knoxville, Tenn.). He is succeeded by *Robert Luedeka*.

Jim Horgan is promoted to vice-president of technology for **Sartomer Co**. (Exton, Pa.).

Siemens Energy & Automation (Alpharetta, Ga.) names *Edward Ciemniecki* international account manager for Johnson & Johnson. ■

Joan Schweikart

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS

COST ENGINEERING

CAPITAL AND ANNUAL COST ESCALATION

Using the *CE* Plant Cost Index (CEPCI)*:

$$\textit{Current cost} = \text{Cost in past period} \cdot \frac{\textit{CEPCI}\text{ for current time perioc}}{\textit{CEPCI}\text{ for past time period}}$$

* Other appropriate cost indexes can be used with this formula as well

CEPCI data can now be downloaded two weeks before your print copy arrives

While regular *CE* subscribers will retain access to the latest numbers in our printed version (or pdf files on *www.che.com/ei*), upgraded CEPCI users will have the ability to access, query and print both current and historical databases. NOTE: A special introductory rate of $295/yr — a $200 savings off of the regular $495 price — is available for a limited time only.

This service is entirely separate from subscriptions to *CE*'s print and online magazines, and will provide realtime access to the following:

- All annual data archives (1947 to present)
- Monthly data archives (1970 to present)
- Electronic notification of monthly updates as soon as they are available
- A selection of helpful cost-estimation articles that have run in past issues of *CE*

To sign up for this service, visit *www.che.com/pindex*

Using time-value relationships

Factor Name	Converts	Symbol	Formula
Single Payment Compound Amount	P to F	(F/P, i%, n)	$(1+i)^n$
Single Payment Present Worth	F to P	(P/F, i%, n)	$(1+i)^{-n}$
Uniform Series Sinking Fund	F to A	(A/F, i%, n)	$\frac{i}{(1+i)^n-1}$
Capital Recovery	P to A	(A/P, i%, n)	$\frac{i\cdot(1+i)^n}{(1+i)^n-1}$
Uniform Series Compound Amount	A to F	(F/A, i%, n)	$\frac{(1+i)^n-1}{i}$
Uniform Series Present Worth	A to P	(P/A, i%, n)	$\frac{(1+i)^n-1}{i\cdot(1+i)^n}$
Uniform Gradient Present Worth	G to P	(P/G, i%, n)	$\frac{(1+i)^n-1}{i^2\cdot(1+i)^n}-\frac{n}{i\cdot(1+i)^n}$
Uniform Gradient Future Worth	G to F	(F/G, i%, n)	$\frac{(1+i)^n-1}{i^2}-\frac{n}{i}$
Uniform Gradient Uniform Series	G to A	(A/G, i%, n)	$\frac{1}{i}-\frac{n}{(1+i)^n-1}$

INFLATION

Combined interest rate $d = i + f + (i \cdot f)$

NOMENCLATURE

- A Uniform amount per interest period
- C Cost
- d Combined interest rate per interest period
- D_j Depreciation in year j
- F Future worth, value or amount
- f General inflation rate per interest period
- G Uniform gradient amount per interest period
- i Interest rate per interest period
- n Number of compounding periods; or the expected life of an asset
- P Present worth, value or amount
- S_n Expected salvage value in year n

DEPRECIATION

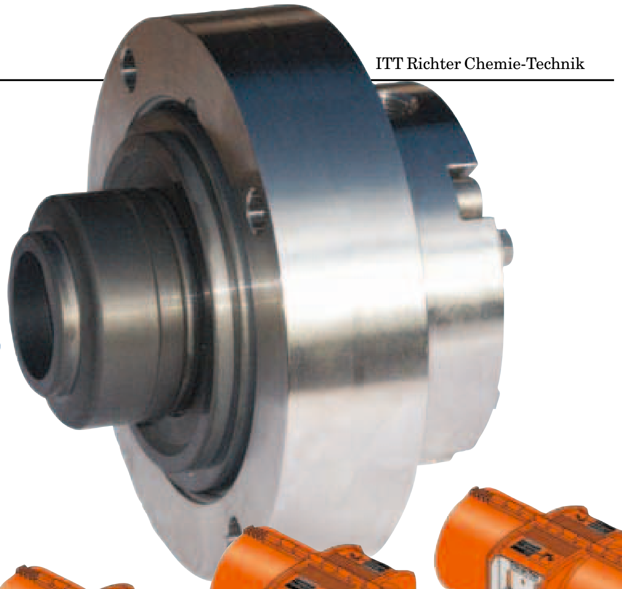
Straight line $D_j = \frac{C - S_n}{n}$

Accelerated Cost Recovery System (ACRS)

D_j = (ACRS factor) · C

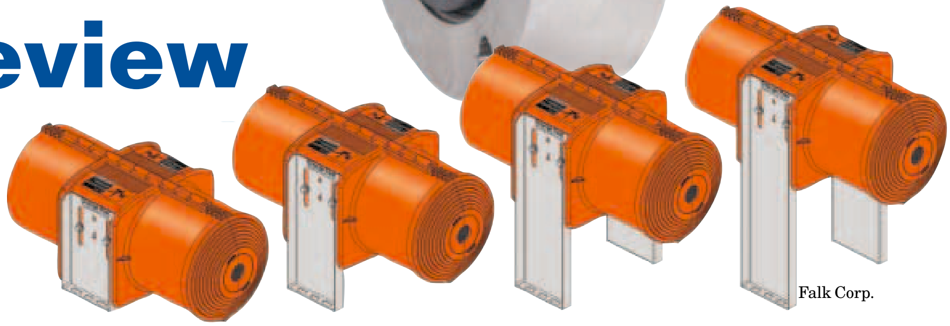
ACRS factors

	Recovery period, years			
	3	5	7	10
Year	Recovery rate, %			
1	33.3	20.0	14.3	10.0
2	44.5	32.0	24.5	18.0
3	14.8	19.2	17.5	14.4
4	7.4	11.5	12.5	11.5
5		11.5	8.9	9.2
6		5.8	8.9	7.4
7			8.9	6.6
8			4.5	6.6
9				6.5
10				6.5
11				3.3



ITT Richter Chemie-Technik

PUMP 22 Houston Show Preview



Falk Corp.

The 22nd International Pump Users Symposium will return this year (February 28–March 3) to Houston's George R. Brown Convention Center. Organized by pump users for pump users, the conference and exposition provides a forum for users concerned with maintenance, performance, troubleshooting, operation and procurement. The technical sessions provide an opportunity for attendees to select those lectures, tutorials, and case studies that best meet their personal and professional needs and interests.

For attendees who are registered for short courses, Monday, February 28th will offer topics ranging from vibration in centrifugal pumps, to designing, operating and troubleshoooting mechanical seals. The main educational program will commence at 8:00 a.m. on Tuesday, however, with a welcoming address by Paul Allaire, Mac Wade Professor of Engineering at the University of Virginia, entitled "Implantable Human Artificial Heart Pumps—Design, Development, and Testing."

Tuesday and Wednesday will be divided into two morning sessions and an afternoon session, each offering the choice of sitting in on a lecture, tutorial or discussion group. New this year, Thursday will be devoted solely to case studies. No other technical sessions will be offered on Thursday, and case studies will not be presented on any other day.

If it is pump-related products you seek, more than 150 exhibitors will be showcasing their newest innovations. Discussed below are some highlights of the products and services that will be on display. For more information about this event, visit turbolab.tamu.edu/pumpshow/pump.html.

Install these spacer coupling guards in no time

Orange Peel Type PCG guards (photo, bottom) offer safety compliance, simplified installation, and reduced maintenance wherever spacer couplings are needed. They are an affordable solution for new and existing installations of pumps, fans, blowers and gear drives. Type PCG Guards are simply trimmed to length and attached to the foundation with four fasteners. An optional end cap is supplied to enclose the extension opening when required. Metal powder-coated leg kits are supplied to meet the base to centerline requirement; and stainless steel leg kits are available as an option. Type PCG Guards feature symmetrical halves, injection molded from maintenance free polyethylene, and joined by a hinge assembly at the top. One size accommodates many ANSI/ ISO pump configurations. They are available from stock in ANSI Safety Orange and ISO Safety Yellow for indoor or outdoor use. Booth 341 & 343 — *The Falk Corp., Milwaukee, Wisc.*
edlinks.che.com/4517-331

A seal of approval for solids-containing fluids

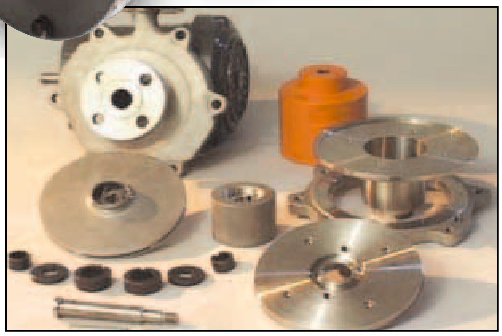
The RG-5 stationary mechanical seal (photo, top) has been specially developed for operation with corrosion-resistant plastic-lined process pumps when a secure sealing of solid-containing or crystallizing liquids is necessary. On the wetted side the RG-5 is metal-free. Silicon carbide sealing elements make it resistant against chemicals and wear and tear. It's sealing chamber is permanently flushed, thanks to a specifically designed housing back plate with wide open distance around the sealing surface. Solids cannot clog, says the manufacturer. Booth 837 — *ITT Richter Chemie-Technik GmbH, Kempen, Germany*
edlinks.che.com/4517-332

Lubricated bearing design lets seals operate in the cool

This manufacturer of American Petroleum Institute (API) radial-split pumps has introduced an oil-lubricated "thrust-pod" bearing design that offers benefits for vertical inline pumps. Problems with over-greasing or under-greasing the bearing are eliminated, and oil level is easily confirmed with a visual inspection of the constant-level oiler. Oil lubrication also allows the use of larger thrust bearings that have higher thrust capacities at all rotational speeds. When combined with a product lubricated radial bearing, the thrust pod carries all pump generated radial and axial loads. Higher thrust capacity of the thrust-pod allows the mechanical seals to operate near suction pressure and at lower temperatures, reducing seal-pressure-velocity values substantially. In many applications, the need for magnetic drives or wet-stator mo-


Junty Industries


Emerson Power Transmission


Magnatex Pumps


Ludeca

tors is eliminated. The manufacturer will design the thrust-pod configuration to suit the seal, which in high-pressure applications, should be the first consideration. Booth 216 & 218 — *CPC/Pumps International, Mississauga, Ont.*
edlinks.che.com/4517-333

A better grade of composite for seals nozzles and more
This supplier of sealing products now offers various kinds of wear parts made in Sintered Pure Silicon Carbide (SSIC; photo, bottom right). SSIC is a better grade of material than SiC RB (reaction-bonded Silicon Carbide), says the vendor, and can be made into seal faces, bushes, thrust washers, nozzles, and so on. SSIC is a very hard material and resists wear and corrosive attack from nearly all chemicals, making it widely applicable for use in pumps and mechanical seals. Booth 724 — *Junty Industries, Ltd., Beijing, China*
edlinks.che.com/4517-334

Elastomer couplings ease stress on the pump
Kop-Flex Odyssey elastomer resilient couplings (photo, top left) feature a patented design that provides a dual flex-point diaphragm, which provides greater parallel offset capacity and reduced reaction forces on the equipment, and is thereby particularly effective for pump applications. The design bonds urethane to steel hubs and a composite center. These high-performance materials minimize corrosion to critical surfaces, thereby reducing both maintenance and life cycle costs. Other product features include: reduced center weight for better balance; less load on bearings and seals; and high strength self-locking fasteners designed to minimize over tightening. Booth 440–442 — *Emerson Power Transmission, Baltimore, Md.*
edlinks.che.com/4517-335

Shaft alignment that is easy to see
The Rotalign Ultra shaft-coupling alignment system features a large scratchproof backlit color screen (photo, top middle) and backlit keyboard that accommodates many working conditions, day or night, indoors or out. Intuitive navigation guides the user through any alignment task from simple pump/motor through complex machine trains of up to 14 machines. The system uses patented single beam technology with a 5-axis, 2-plane sensor and built-in electronic position detector. Accurate data for shimming and horizontal correction are obtained from the patented continuous "SWEEP" measure mode, even at very small angle rotation. The ULTRA offers USB and Bluetooth connectivity for interface with printers and PCs, allowing alignment reports to be produced in full color. Life-like machine graphics are used for both screen display and printed reports. The lightweight computer is powered by a rechargeable battery and is water, shock and dustproof to IP65. Booth 315 & 317 — *Ludeca, Inc.*
edlinks.che.com/4517-336

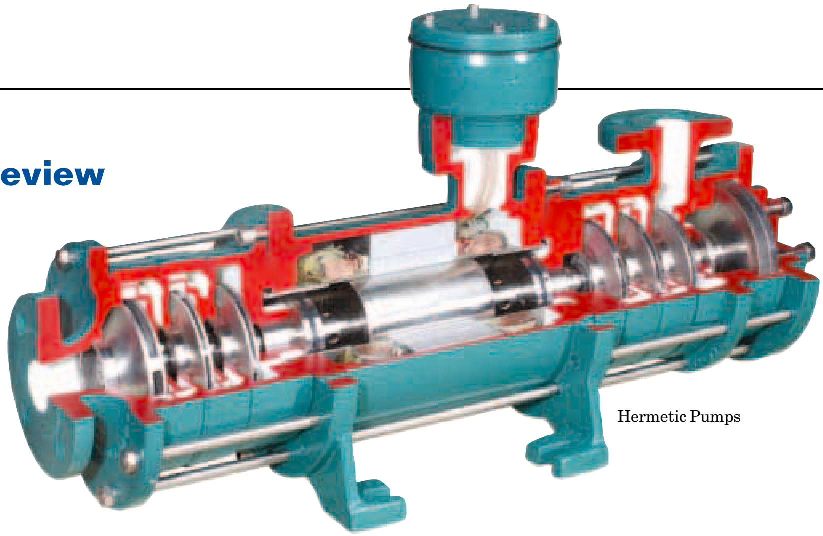
Tap these dry-run bearings to extend service life
This manufacturer is now offering as standard new silicon carbide dry-run (SiC-D) bearings (photo, top right) in its MP, MMP, MPT and MPH pumps to enhance performance and extend run life. A proprietary treatment strengthens the surface of the bearings and provides a significantly reduced friction coefficient for superior performance during dry-run startups. The dry-run bearings diminish the harmful effect of heat shock that other magnetic-drive pumps experience during dry-run conditions, preventing bearing breaks and cracks that impact operation and increase maintenance costs. Booth 718 — *Magnatex Pumps, Inc., Houston, Tex.*
edlinks.che.com/4517-337

Lubricant is well-suited for delivery by mist
Specifically for use in centralized air-mist lubrication systems, Synmist high-film-strength, synthetic lubricant is designed to readily atomize to eliminate large, unwanted, wet oil droplets that can accumulate in mist systems. It also exhibits good reclassification properties, which ensure that oil is delivered onto the bearing surface where it is needed. Synmist rapidly and completely demulsifies from water and displaces moisture from bearing surfaces. Its performance advantages come from a novel blend of synthetic oils and the manufacturer's proprietary Synerlec additive technology, which forms a tenacious, ionic, protective film on bearing surfaces. Synmist is wax free; so, it does not cause a wax buildup nor does it congeal at low temperatures. Overall, the lubricant reduces bearing vibrations, remains fluid at low temperatures, and is compatible with most synthetic and all mineral air-mist oils. Good oxidation stability and synthetic solvency keep bearings free of harmful oil de-

TLFeBOOK

posits. Booth 822–824 — *Royal Purple Ltd., Porter, Tex.*
edlinks.che.com/4517-338

Sealless pumps keep track of cooling fluid temperatures
Most modern sealless pumps offer a method to monitor their bearings and motor temperatures. Monitoring fluid temperatures should also be considered. Thus, this manufacturer has redesigned its CAM Line of multistage canned motor pumps (photo) to separate the flow required for motor cooling from the thrust balance flow. The CAM line is designed to handle flows up to 1,000 gal/min and can produce over 3,000 ft of head. System pressures of to 15,000 psi can be accommodated. The pumps can be manufactured in many different alloys for pumping toxic, hard to seal, expensive fluids. Booth 333 & 335 — *Hermetic Pumps Inc., Humble, Tex.*
edlinks.che.com/4517-339


Hermetic Pumps

Electric actuator boasts strength and durability
The Limitorque SMB multi-turn electric actuator's strength and durability make it useful for a wide range of applications, including oil and gas wells, platforms and pipelines; petroleum refining; hydrocarbon and chemical processing; power generation; water treatment and distribution; and steam distribution. Now available with a 10-year standard warranty on commercial applications, the Limitorque SMB features an solid construction and cast-iron housings. The SMB actuator series covers a broad scope of capabilities, producing torque ranging from 15 ft-lb (20 Nm) to 60,000 ft-lb (81,349 Nm), and handling stem thrusts up to 500,000 lb. (2,224 kN), thereby making valve control easier wherever the application demands maximum durability. Booth 401 — *Flowserve Flow Control, Irving, Tex.*
edlinks.che.com/4517-340 ■

Rebekkah Marshall

FEBRUARY
New Products

Pump Engineering

Siemens Automation & Drives

Solartron Mobrey

ARCA-Regler

Robert Bosch

Double the length of your AS-i with this extension plug

The AS-i (actuator-sensor interface) Extension Plug and the new AS-i Extension Plug Plus (photo, top left) double the cable length of an AS-i segment from 100 to 200 meters. Both components are suitable for any network topologies such as line, tree, or star, and only one plug per segment is required. To monitor the AS-Interface voltage and the supply voltage of all connected stations, the Extension Plug is equipped with an integrated undervoltage detection circuit. A flashing green LED indicates when the voltage level has fallen below the minimum requirement, and a message is sent to the higher-level controller. — *Siemens Automation & Drives, Nuremberg, Germany*
edlinks.che.com/4517-341

This smart positioner features FDT/DTM technology

Besides the possibility to integrate field devices via electronic device description (EDD) into engineering and control systems, the FDT/DTM technology makes a new interface available, which is independent of themanufacturer. The intelligent positioner of the second generation Arcapro Type 827A (photo, bottom left) now offers this possibility as an alternative to the DDL (device description language) concept. The DTM (device type manager), which is developed on the basis of the FDT specification 1.2, facilitates the use of enhanced diagnostics for preventive maintenance. — *ARCA-Regler GmbH, Tönisvorst, Germany*
edlinks.che.com/4517-342

This machine accurately fills vials with powder

The AFG 3000 Series of powder filling machines (photo, bottom right) has been developed to cover mid-range capacities: the 3010 fills up to 160 vials per minute and the 3020, with two dosing aggregates, fills 320 per minute. Powders are vacuum conveyed into the dosing chamber. Sterile compressed air (or inert gas) is then used to transport the powder into the vial. Powder in the supply chamber is constantly in motion by means of an agitator. A dosing accuracy of up to 1.5% is achieved, which is a factor of two above the accuracy of other dosing systems, claims the firm. The systems control software is programmed according to GAMP guidelines (good automated manufacturing practice) and the requirements of U.S. 21 CFR Part 11. — *Robert Bosch GmbH, Stuttgart, Germany*
edlinks.che.com/4517-343

Pocket-sized pumps for corrosive liquids

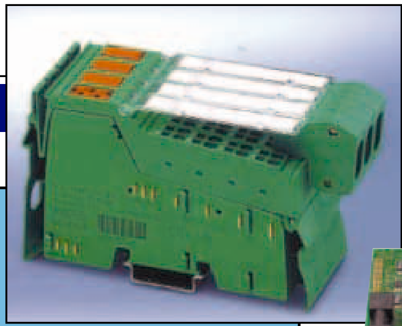
The Pageboy SFD15 self-priming diaphragm pump (photo, top right) is suitable for pumping aggressive liquids such as solvents, strong acids or alkalis. The pocket-sized, air-driven pump has only three moving parts. A venturi is used to create a vacuum behind the diaphragm. At the end of the suction stroke, a control rod, attached to the diaphragm, blocks the outlet on the venturi and diverts air onto the back of the diaphragm creating the discharge stroke. This "stress-free-diaphragm" design improves the pump reliability compared to conventional diaphragm designs, where the return stroke is a mechanical process, says the firm. The pump has a maximum output of 3 L/min and operates at a maximum pressure of 6 bars. — *Pump Engineering Ltd., Littlehampton, U.K.*
edlinks.che.com/4517-344

A flowmeter with ATEX approval for hazardous areas

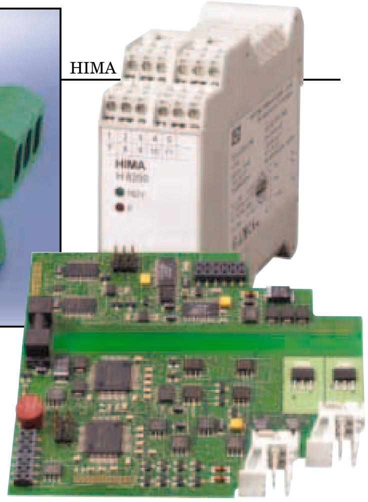
The Rotameter 250 Series flowmeter (photo, middle right) is now available

with a built-in, explosion-proof 4–20-mA transmitter, making it possible to measure the flow of gases and liquids in a range of hazardous applications. The metal-tube design is ideal for use in corrosive and aggressive environments, such as those in petroleum refineries, chemical processing plants, and nuclear power plants. The ATEX EExd-approved unit provides reliable indication of flow, within 2% of full scale reading, in applications at high temperature (150°C) and pressures (50 bars). — *Solartron Mobrey, Slough, U.K.*
edlinks.che.com/4517-345

Phoenix Contact



HIMA



Vega Grieshaber

Collect data via phone or internet with this device

Vegascan 693 (photo, left) is a new data-collection system for recording and transmitting measured values of up to 15 HART sensors. The device also supplies power to the connected sensors. The unit is available with either an RS 232 interface (for connection to an analog, ISDN or GSM modem with serial port), or an Ethernet connection, which enables control and SCADA systems to retrieve measured data via the Modbus TCP/IP protocol. Both versions enable easy visualization of the measured values as a chart using a web browser. — *Vega Grieshaber KG, Schiltach, Germany*
edlinks.che.com/4517-346

A controller for both simple and complex heating tasks

The Tempcon 300 controller system (photo, middle top) can be adapted to a wide range of applications, ranging from simple ones, such as controlling baking ovens, to very complex tasks, such as controlling multi-zone heating systems in plastic-injection or blow-molding machines. The system uses the firm's modular Inline automation system, which allows users to configure compact controller units for 4–30 control zones. The required components, including bus couplers, control units and I/O modules, are simply plugged together. The bus coupler modules are available for operating the modular temperature and process controllers on industrial fieldbus systems, including Interbus, Ethernet, Profibus, CANopen, DeviceNet and Modbus. — *Phoenix Contact, Blomberg, Germany*
edlinks.che.com/4517-347

Handle HART signals without feedback using this separator

The SIL3-certified Ex separator H6200 (photo, far right) converts an analog Ex input signal into two independent, standard analog output signals, while simultaneously extracting transmitted HART signals. The firm's safety technology guarantees the lack of feedback from the HART signal on the analog signal. Also available now is the HART multiplexer H6210, which collects the data from up to eight H6200 units and forwards it to a HART server via the integrated RS 485 interface. Thanks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process

Christ Water Technology

Land Instruments

to the safety related HART filter function, this device claims to be the world's first multiplexer that is able to guarantee zero feedback from the HART diagnostic data on the reparameterization of HART transmitters. — *HIMA Paul Hildebrandt GmbH + Co. KG, Brühl, Germany*
edlinks.che.com/4517-348

Keep an eye on IR thermometer data

With the introduction of the Cyclops DL-1000 Data Logging System (photo, right), the task of downloading and analyzing temperature measurements of reheat and reformer tube furnaces has been simplified. The system combines the company's own software with a Pocket PC on which readings can be stored and then transferred to a PC (as a .txt file) for display and analysis. A choice of options is offered at the start of each measurement logging session, including thermometer type, temperature units and text identifiers. A timed acquisition function can be set to record temperature data at predetermined intervals from 1 to 3,600 seconds. — *Land Instruments International, Dronfield, England*
edlinks.che.com/4517-349

Plants for ultrapure water, and more

The newest version of this firm's water-purification plant, Osmotron 2 (photo, left), has a new external design and offers a more flexible configuration compared to its predecessor. In addition, the Osmotron 2 is fully automated, which means there are no analog meters or indicators such as for pressure and flowrate. Instead, such measured values are connected directly to the controller and can be displayed on the monitor. The water plant can easily be extended from, for example, a system for making purified water, to one that produces water for injection in accordance with USP 26, or one that produces highly purified water in accordance with EP 5. Such an upgrade does not require any additional space. — *Christ Water Technology Group, Aesch, Switzerland*
edlinks.che.com/4517-350 ■

Gerald Ondrey and Rebekkah Marshall

Dear Colleagues,

A leading analyst reported that chemical companies planned to increase their IT budgets by approximately 8.8% in 2005, 2.2% of their total revenue, despite stagnate growth in 2004. This investment in IT reflects the recent trend among chemical companies to maximize IT strategies in order to differentiate products and services, lower fulfillment costs, and improve overall competitive position. (*CW*, September 2004)

Today's information technology leaders are faced with the daunting task of managing increased responsibilities and new priorities while cutting infrastructure costs and demonstrating a high return on investment. The recent industry growth has increased budgets and heightened expectations.

How will IT executives meet the challenges and demands of this recent upcycle?

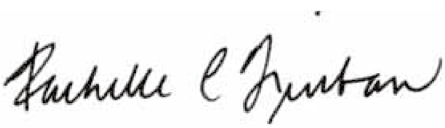
At *Chemical Week's* 8th Annual Chemical Industry IT Forum, chemical executives and other industry leaders will present best practices across the industry. Join these industry leaders as they converge in Philadelphia in search of solutions to today's most pressing challenges.

During the conference you will get powerful insight into an array of topics, including:

- IT & the Chemical Industry: The Increasing Complexity of IT and the Industry's Growing Independence on it
- Real Savings from Supply Chain Optimization
- Cutting Edge Technologies – What's Next?
- Improvements to Cyber Infrastructure to Enable R&D

Mark your calendar for March 30 – 31. I look forward to meeting you in Philadelphia.

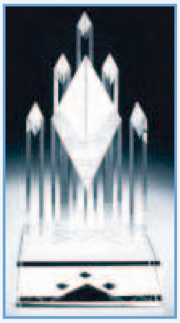
Sincerely,



Rachelle C. Quiban
Conference Program Manager

CHEMICAL WEEK'S 2nd ANNUAL

CIO EXCELLENCE AWARD



Chemical Week will announce the winner of its 2005 CIO Excellence Award at the 8th Annual Chemical Industry Information Technology Forum. The CIO Excellence Award recognizes chief information officers for: innovative and creative planning and deployment of their enterprise systems; exemplary leadership and management; and service to his/her organization and the industry.

Conference attendees are invited to attend the CIO Excellence Award Presentation on Wednesday, March 30. Join us for a spectacular reception featuring great food and drinks and the rare opportunity to network with the true industry leaders. Finalists will be announced on March 2nd with the winner announced LIVE at the Reception. Attendance to this reception is limited to attendees and speakers of the 8th Annual Chemical Industry Information Technology Forum–Register Today!

For additional information including the nomination form, please contact:

Rachelle C. Quiban p: 212.621.4643
Conference Program Manager e: rquiban@chemweek.com

WHO SHOULD ATTEND

The 8th Annual Chemical Industry IT Forum is for the decision maker involved with technology for the chemical industry.

PREVIOUS TITLES INCLUDE:

- Chief Information Officer
- Chief Technology Officer
- Vice President of Information Technology
- Director of Information Systems
- Head of Networking
- Director of E-Business
- CRM Manager
- Director of Technology Business

Wednesday, March 30,2005

8:15 AM **Registration / Continental Breakfast / Showcase Exhibits**

8:50 AM **Introduction by Moderator**

Esther D'Amico, Managing Senior Editor, *Chemical Week*

9:00 AM **Keynote Presentation**

IT & the Chemical Industry: The Increasing Complexity of IT and the Industry's Growing Independence on it

Karl Wachs, Chief Information Officer, *Celanese*

9:45 AM **Update on Sarbanes-Oxley Legislation Compliance: Strategies to Meet the Deadline**

With companies facing Sarbanes-Oxley Legislation Compliace deadlines in 2005, Syminis will source his experience leading FMC's Sarbanes-Oxley compliance project and discuss strategies to effectively and efficiently meet these deadlines. Also, as chemical companies whose deadlines have passed are still faced with managing the impact of ongoing compliance, this presentation will uncover strategies to minimize the impact of these requirements.

Terry Syminis, Director IT Security, *FMC Corpora ion*

10:30 AM **Networking Refreshments / Showcase Exhibits**

11:00AM **The Collaboration Imperative - How leading companies are driving collaboration strategies to impact their business**

Microsoft's session examines technology trends in collaboration. How companies are leveraging new collaboration strategies to drive everything from new product introduction to global visibility in their manufacturing operations will be discussed.

Chris Colyer, Worldwide Industry Director, Process Manufacturing, *Microsof Corpora ion*

11:30 AM **Global Sourcing - Experiences and Lessons**

The current stampede toward offshore outsourcing should come as no surprise. There are savings associated with outsourcing but it takes years of effort and a huge up-front investment, or does it? In this session, a leading executive will discuss the challenges and rewards of offshoring and we will find out the total cost of outsourcing.

12:15 PM **Networking Luncheon**

1:15 PM **How do you do it? - Strategies for Balancing IT goals with the Company's Business Strategy**

Hanna Lukosavich, Chief Information Officer, *Hercules*

2:00 PM **The Changing Faces of ERP and the Impact on ERP Integration Goals**

2:30 PM **Networking Refreshments / Showcase Exhibits**

3:00 PM **Outlook on Cybersecurity Trends & Issues**

IT Security remains one of the most serious system challenges of 2005 and beyond. How do you know which external threats to prepare for? Where do the internal weak spots lie? This session will assess the best practicies in acquiring, implementing, managing and measuring information security without compromising corporate prosperity.

Christine Adams, Director, Chemical Sector Cyber Security Program, *Dow Chemical Company*

3:45 PM **Document Management Solutions**

4:15 PM **Closing Keynote**

Redefining the I" in IT

While IT is often viewed as a way to reduce costs and manpower requirements, Dow Corning has used its Information Technology platform to support the transformation of the company from a product-focused supplier to a solutions company. This session will share Dow Corning's commitment to IT as a powerful tool for growth and differentiation.

- Aligning IT with Dow Corning's commitment to innovation.
- Transforming a corporate culture and "back office" information technology to provide a competitive edge.
- Leveraging IT to give customers choices in the ways they want to be served.

Abbe Mulders, Chief Information Officer, *Dow Corning*

5:30 PM to 7:30 PM

Chemical Week's 2005 CIO Excellence Award Reception

The award will be presented by last year's winner, Abbe Mulders Chief Information Officer of Dow Corning. *Attendance to this reception is open to conference attendees only.

Thursday, March 31,2005

8:15 AM **Continental Breakfast / Showcase Exhibits**

8:50 AM **Day Two Opening Remarks**

Esther D'Amico, Managing Senior Editor, *Chemical Week*

9:00 AM **Developing IT Strategy: Business Orchestration at Quaker Chemical**

Quaker Chemical will serve as a case study on developing IT strategy and a specific process Tyler calls "business orchestration." Quaker's practical efforts will be used to demonstrate the successes and lessons learned through the process to those interested in implementing the business orchestration process at their firms.

Irving Tyler, Chief Information Officer, *t uaker Chemical*

10:00 AM **Cutting Edge Technologies – What's Next?**

10:30 AM **Networking Refreshments / Showcase Exhibits**

11:00 AM **Managing Increased Electronic Communications**

11:45 AM **Wireless Technologies beyond the Plant Floor**

12:15 PM **Building Customer Relations Electronically**

Mature industries, like the chemical industry, can too benefit from the fiscal and operational efficiency of electronically based business. Electronically based relationships offer revolutionary changes to the traditional manner and speed by which people in the organization - from logistics and manufacturing, to sales - obtain the necessary information to make critical decisions and to deliver key information to customers. The session will discuss strategies to best develop customer relations electronically.

1:00 PM **Networking Luncheon**

2:00 PM **Measuring the Impact of IT Strategies - Maximizing ROI**

2:45 PM **Closing Keynote Presentation**

Emerging Industry Trends and Challenges in the Chemical Industry

Chemical manufacturers are facing a myriad of challenges today. The session will discuss the future technology developments and the next wave of innovation in the chemical value chain.

3:30 PM **Conference Concludes**

Alarm Management

Process and system alarms are intended to assure efficient process-plant operations and even, occasionally, save lives. But in too many plants, the alarm system has paradoxically evolved into a nuisance. A five-step procedure can put a degenerate alarm system aright

Peter Jofriet
Honeywell

How many alarms are currently configured in the system or process you manage or that you are designing? 25? 100? 1,000? How many of those alarms would go off in the first minute of a process disruption or system shutdown? Would your facility's operators know which alarms to address first?

Now consider the finding that a typical operator can effectively deal with only one alarm per minute during an upset. In light of this fact-of-life, it becomes easier to recognize the value of alarm management in strengthening operational efficiency and averting costly disruptions and incidents, often referred to as "abnormal situations." It has been estimated that the inability to diagnose and control abnormal situations has an economic impact of at least $10 billion annually in the U.S. petrochemical industry alone.

A recent related example involving the electric utility industry comes from the Eastern North America blackout that occurred in August 2003. Authorities are still reviewing records of the thousands of alarms and events that occurred up and down the power grid to determine exactly what caused the outage. But whatever the cause, it is already clear that non-functioning alarm systems, alarm floods and ineffective operator responses exacerbated the situation.

On the one hand, high alarm rates can promote a culture of "operate by alarm," whereby the alarm system drives the operators and, therefore, the plant. But there is also a converse risk: when alarms proliferate, their collective value as a tool for diagnosing and preventing problems declines. The alarms become a nuisance to operators, who eventually will ignore or turn them off if the chattering (repeated activation) continues. During normal operation, it is not uncommon to have one alarm activated every one to two minutes, with some alarms chattering throughout a shift. When incidents occur, there can easily be 30 to 50 alarms per minute – 600 alarms per minute in extreme cases.

Why so many alarms?

Alarms have proliferated as manufacturing processes and equipment have become more complex, demanding and dangerous. In recent years, the evolution of controls technology pushed the process industries from single, independent mechanical components toward an interdependent, command-and-control electronic system. In a modern distributed control system (DCS), for example, almost every configured point can have multiple alarms. PID loops can have up to 15—20 alarms per point, including loop integrity alarms, high-range alarms, setpoint-deviation alarms and

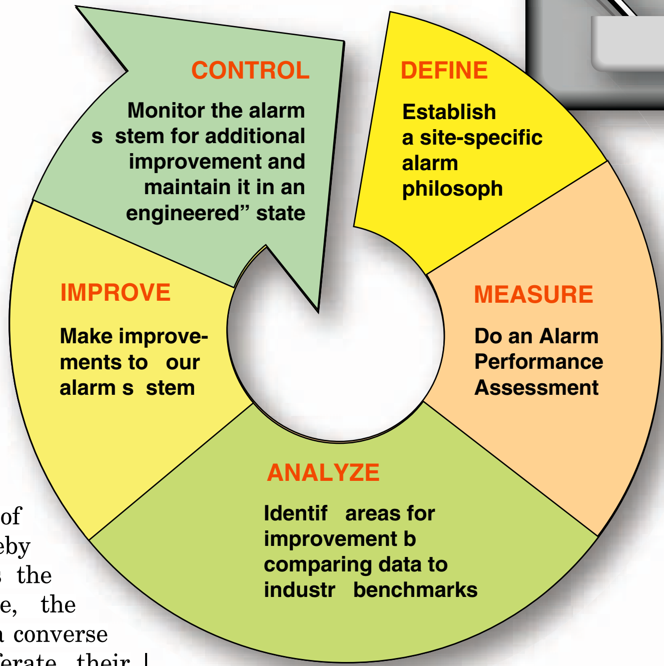
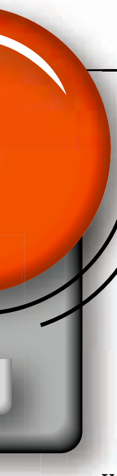


FIGURE 1. The Six Sigma sequence lends itself well to improving a process plant's alarm system

many more. It is also possible to have a large number of overall-system alarms – so many that these alarms are sometimes more intrusive than individual-process alarms, and arguably of lesser value to operators.

Over time, it has become easier and easier to set alarms for system and process changes; and, simply put, engineering and plant management have gotten carried away. The philosophies of "more is better" and "alarms are free" have guided their decisions.

One specific cause of the problem is "alarm creep" in which the easiest solution to a problem is often to add another alarm, with the result over time that the overall effectiveness of the alarm system suffers [1]. It has been noted [2] that alarm systems have grown from "a few hundred alarms to many hundreds or thousands of alarms on most plants during the past 20 years." Among the consequences are redundant alarms, chattering alarms, standing alarms (alarms that have been continuously in the acti-



Phase	Alarm Improvement Activity
Define	Document your alarm philosophy.
Measure	Conduct an alarm system performance assessment and current practices assessment.
Analyze	Compare the data to industry benchmarks, review best practices and identify areas for improvement.
Improve	Make improvements to the alarm system through a combination of repairing nuisance alarms, rationalization and application of advanced alarm processing techniques.
Control	Monitor the system to identify the need for additional improvements and implement the tools/procedures to maintain the alarm system in its "engineered" state.

vated state for some period of time), and the inability of a given alarm setting to track the state of the plant.

These problems become all the more bothersome in light of today's widespread tendency to push petroleum refineries and other process plants to their maximum capacity. For such plants, it is particularly desirable that alarm systems not only perform well but also communicate succinctly and effectively with the plant operators.

A well-managed alarm system can provide operators with the appropriate information in a timely manner that is crucial to identifying the cause of an abnormal situation and restoring the plant to normal operation. But such a system is possible only through consistent and proper management. For a given process plant, the first step is to fix the existing alarm system. How to do so is the main focus of this article.

HARNESS SIX SIGMA

A suitable framework for improving alarm effectiveness can be found in the well-known Design for Six Sigma philosophy (see, for instance, Putting Six Sigma Processes to Work, *CE*, November 2003, pp. 62–67): define, measure, analyze, improve and control. These five phases, known in Six Sigma circles as the "DMAIC process," can be applied to alarm improvement as shown in Table 1.

Alarm improvement projects are most successful when operators and engineers work together. Start by forming a cross-functional team that will be the steering committee for the project. Sites that have successfully implemented alarm improvement projects typically have included representatives from the operations, process engineering, and safety departments, as well as control engineering and instrumentation personnel, on their teams.

As a preliminary, consider having the newly formed team participate in a workshop or presentation on the alarm improvement process, led by an internal or third-party expert. This ensures that all members understand the importance of alarm management and of the improvement process that will be employed.

Since the possibilities for alarm improvements come, in part, from software solutions, it is prudent to have your solutions provider take part in this preparatory step. In addition to providing insight into industrywide best practices, he or she can introduce the software available for alarm analysis, rationalization and management, and educate the team about optimal use of these tools.

Phase 1: Define – Establish your desired alarm philosophy

An alarm philosophy is a written document that governs how a given alarm system is designed and implemented. It defines how alarms will be managed at a particular site or within an organization, and provides structure and consistency in configuring alarms. It will not only provide long-term guidance but, for the present, also constitute the basis for the rest of the alarm improvement program.

The philosophy must be written in such a way that paths of action are consistent and clear, and so that the alarming process can be implemented with reasonable effort and resources both now and in the future. The members of the alarm improvement team, as well as anyone else whose job will be impacted by this philosophy, must buy into it.

To determine the content of the alarm philosophy, the cross-functional team must collectively answer the following questions:

- What is the purpose of our alarm system?
- Under what circumstances should an alarm be used?
- How is an alarm priority set?
- How are critical alarms handled?
- How should individual alarms be configured?
- Who is responsible for our alarm system?
- What are the criteria to suppress an alarm, and what tools or procedures will be used to do so?
- How will nuisance alarms be controlled?
- How will ongoing performance of the alarming system be monitored and improved?
- How should changes to that system be controlled?

It is likely that in answering these questions, the team will grapple with some basic philosophical and operational issues. But once the philosophy has been completed, it will lay the groundwork for more-consistent and more-relevant alarming practices.

Although these ideas are captured in an official site document, that document should not be regarded as immutable. A correctly prepared alarm philosophy is a living document that needs to be refreshed, updated and changed as processes, technologies and business objectives evolve.

Phase 2: Measure – Assess the performance of the existing alarm system

Once the team reaches consensus on an alarm philosophy, it's time to measure how well the alarm system already in place is functioning. During this measurement phase, perceived problems are identified that will form the basis for Phases 3 and 4, the analysis and improvement phases.

The sequence of activities during this measurement phase is as follows:

- Assemble the alarm-activation data typically available in the plant's DCS (distributed control system) alarm and event journals. Such data assembly is often is a challenge, because many sites do not have DCS-based diagnostic tools that can delve into the data files of the process servers and retrieve necessary event information. However, some vendors of control systems or of software do offer tools and services that make

this task less arduous. Spreadsheet or database programs may be used as rudimentary substitutes.
- Applying diagnostic tools to the assembled data, calculate alarm-performance statistics on dynamic alarm activity or events, and summarize the alarm configuration in order to uncover any anomalies. These statistics might include the rate of alarm activations, the patterns (if any) in these activations, and the priority of the activations
- Review the history of plant upsets, and annotate any significant events for future reference
- Gather design and implementation documents, procedure and practice documents, and any HAZOP information available. This documentation will become invaluable in the next phases of this process.

Phase 3: Analyze – Alarm Performance Benchmarks

The tasks associated with Phase 2 and Phase 3 are not mutually exclusive. The data produced and tabulated in Phase 2 only become useful when analyzed. Analysis, done in Phase 3, consists of comparing the calculated, plant-relevant statistics against industry standards or benchmarks. The goal is to identify problems with the way the plant is utilizing its alarm system. In this step, the problems are quantified and the seriousness of issues is realized.

In general, industry benchmarks define how many alarms operators should be able to handle and whether or not they can discern the important ones. One recommended document for this purpose is Reference [*3*], the Engineering Equipment and Materials Users Assn. (EEMUA; London, U.K.) Publication No. 191, "Alarm Systems - A Guide to Design, Management and Procurement," published in 1999. Also useful for making the benchmark comparisons is a tool, available via the author's employer, known as an alarm performance benchmark report (Figure 2).

The analysis in this phase supports the reengineering that is subsequently done in Phase 4, because it gives a baseline of performance and configuration to which the post-rationalization system can be compared. In addition, Phase 3 becomes the basis for removing nuisance alarms, and it can aid decisionmaking regarding advanced alarming techniques. With all this said, perhaps the most compelling reason to make a thorough analysis of your alarm performance data is to gain some insight into what level of performance may be possible for your site.

There are many ways to analyze the data collected in Phase 2, and space limitations do not allow a discussion here. But whichever is employed, three aspects of performance are critical and should certainly be analyzed.

The first is the frequency of alarm activations on a daily basis. Calculating the average number of alarms that are received per day provides the engineer with a good indication of system usability during normal operation. According to the aforementioned EEMUA Publication 191, a manageable condition consists of 288 alarms or less during any 24-hour period – any more and the situation will be too much for the operator to handle.

While analyzing the frequency of activations, consider also the priority distribution of the alarms that are being received. For example, if several vessels are becoming overheated at the same time, does that overheating pose more of a risk in some of the vessels than in others? A correctly established alarm priority can play a big role in helping the operator to distinguish one alarm from another.

The second must-do step consists of employing that same sort of frequency analysis and priority-distribution analysis to determine how an alarm system performs during an upset-condition. Consider, for instance, the first 10 minutes after an upset occurs. How many alarms are received during that first period, and how many during subsequent 10-minute ones? What percentage of them are HIGH-priority or LOW-priority alarms? The EEMUA guideline states that having fewer than 10 alarms during the first 10 minutes "should be manageable"—whereas 20 to 100 alarms during the first 10 minutes is "hard to cope with." Arguably, alarm flooding during an upset-condition is perhaps the most common problem exhibited by poorly designed alarm systems. This type of analysis will indicate whether that problem exists on your site.

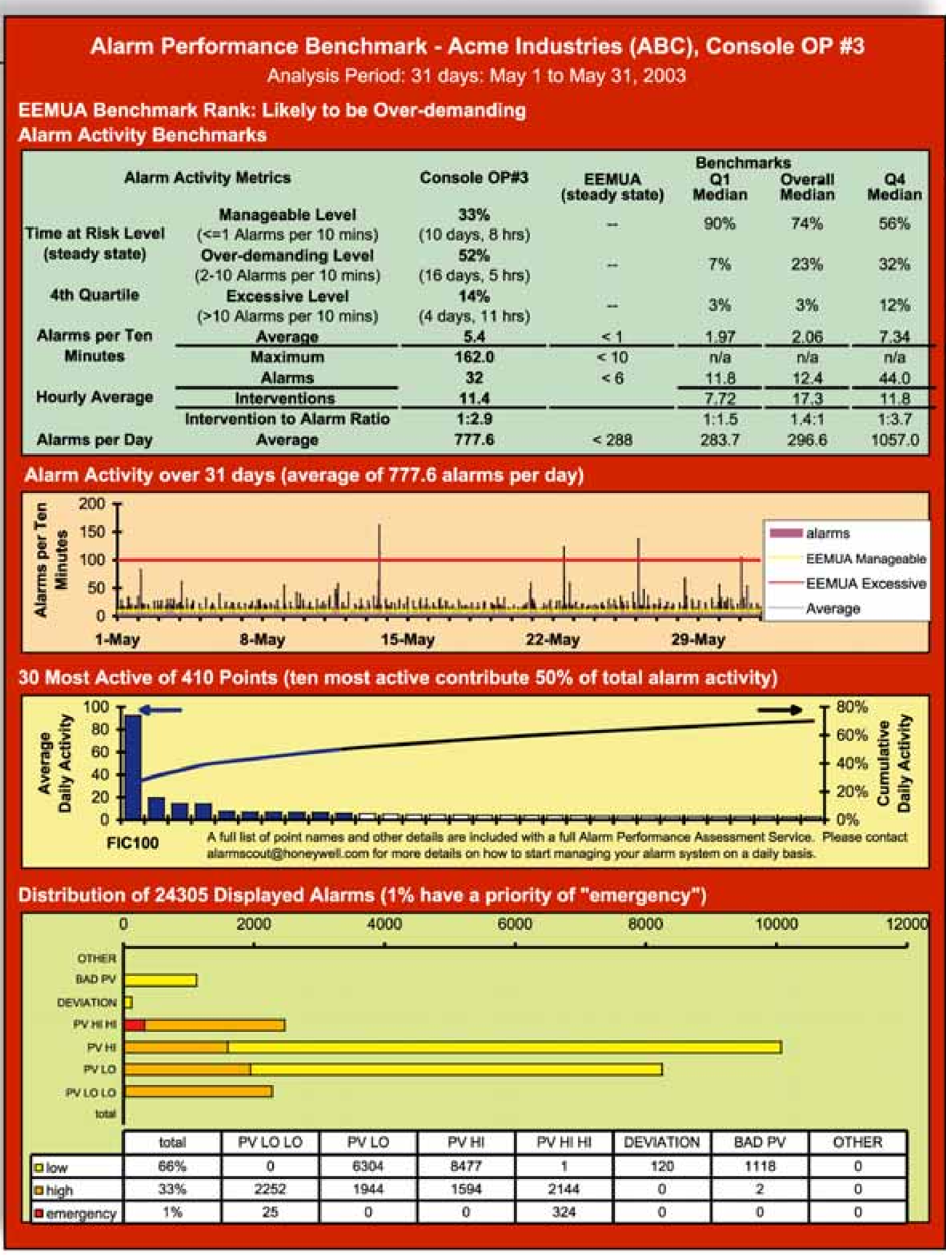
Finally, the third piece of analysis that is considered a "must do" is the bad-actor analysis. Are all of your alarm activations and problems coming from two or three alarm points, for example, or do you instead have a lot of activations from a lot of different points? A bad-actor analysis will help to identify points that are contributing to the "background noise level" of your alarm system. It will also help to identify process areas that are particularly poor in terms of the way that alarms have been configured.

Beyond these three critical areas of analysis, further investigation may be required to determine such things as the following:
- What is the risk of an operator missing an alarm?
- What is the relative contribution of each problem area to the overall alarm activity?
- What are the possible causes of peaks in alarm activity? Possibilities include nuisance alarms, or alarms that chatter, or alarms that activate in unison with a group of others (consequential alarms). One can quickly attribute such conditions to a lack of priority management, or to poor configuration of deadbands and trip points.

Phase 4: Improve – Rationalize the existing alarms

In this improvement phase, every configured alarm is scrutinized. Advanced techniques that may reduce overall alarm activations are identified and implemented. For example, one can identify equipment groups that could incur multiple alarm activations while the equipment is shut down. Wherever that situation exists, mode-based alarming could be implemented to disable or suppress alarms while the equipment is not operating. Otherwise, these alarms will annoy the operator or, worse, cause her or him to miss a more serious situation.

This process of alarm rationalization is the core activity of many alarm management projects. It reduces the number of configured alarms significantly, while at the same time ensuring that the remaining alarm param-



Alarm Performance Benchmark - Acme Industries (ABC), Console OP #3

Analysis Period: 31 days: May 1 to May 31, 2003

EEMUA Benchmark Rank: Likely to be Over-demanding

Alarm Activity Benchmarks

Alarm Activity Metrics		Console OP#3	EEMUA (steady state)	Benchmarks Q1 Median	Overall Median	Q4 Median
Time at Risk Level (steady state)	Manageable Level (<=1 Alarms per 10 mins)	33% (10 days, 8 hrs)	--	90%	74%	56%
	Over-demanding Level (2-10 Alarms per 10 mins)	52% (16 days, 5 hrs)	--	7%	23%	32%
4th Quartile	Excessive Level (>10 Alarms per 10 mins)	14% (4 days, 11 hrs)	--	3%	3%	12%
Alarms per Ten Minutes	Average	5.4	< 1	1.97	2.06	7.34
	Maximum	162.0	< 10	n/a	n/a	n/a
Hourly Average	Alarms	32	< 6	11.8	12.4	44.0
	Interventions	11.4		7.72	17.3	11.8
	Intervention to Alarm Ratio	1:2.9		1:1.5	1.4:1	1:3.7
Alarms per Day	Average	777.6	< 288	283.7	296.6	1057.0

Alarm Activity over 31 days (average of 777.6 alarms per day)

30 Most Active of 410 Points (ten most active contribute 50% of total alarm activity)

Distribution of 24305 Displayed Alarms (1% have a priority of "emergency")

	total	PV LO LO	PV LO	PV HI	PV HI HI	DEVIATION	BAD PV	OTHER
low	66%	0	6304	8477	1	120	1118	0
high	33%	2252	1944	1594	2144	0	2	0
emergency	1%	25	0	0	324	0	0	0

FIGURE 2. An alarm performance benchmark report can provide a detailed picture of how one given plant's alarm system measures up against the norms

Honeywell

eters are correctly specified. The net result is fewer activations.

Success in alarm rationalization hinges on keeping four basic aims in mind:

- Once the alarm system has been rationalized, the alarms and alerts will meet production management's requirements for process performance and economics
- Each alarm and alert will be justified and properly designed
- Causes of alarms and alerts will be identified.
- Consequences of not acting will be determined.

As pointed out in the EEMUA Publication 191, the rationalized alarms and alerts should be designed or engineered to "direct the operator's attention to a plant condition that requires timely assessment and action". Accordingly "each alarm or alert should alert, inform and guide," and should be useful, relevant and have a predefined response.

The rationalization process encompasses four basic steps:

1. Identify existing alarms that should be changed to "alerts."
2. Identify existing alarms that need to be eliminated.
3. Determine the appropriate priorities and trip points for alarm response.
4. Identify hazards for which there are no appropriate alarms.

These simple steps can result in dramatic reductions in alarms. For example, one chemical-process unit that underwent the scrutiny of this process started with 154 configured alarms and ended up with dramatically fewer. Here is a summary of the rationalization activities that achieved that result:

- 62 alarms were deleted
- 59 documentation corrections were made
- 52 alarms were changed to alerts
- 50 configuration corrections were made
- 26 priorities were changed
- 19 alarms were consolidated into 7 alarms
- 7 alerts were consolidated into 1
- 3 alarm settings were changed
- 2 new alarms were added
- 1 new alert was added

The results of rationalization are not always so spectacular, but even small improvements can have a big impact in terms of operator effectiveness.

As part of the improvement phase, consideration must also be given to matters such as final sign-off or approval of the rationalization results, as well as to bi-directional cut-over plans and scheduling (bi-directional in the sense that if a defect in the rationalization scheme is not detected until after the switchover has been made, the system can nevertheless be returned to its previous state while the defect is remedied). Validation and testing of the new configuration may also be required.

Software is available to support rationalization that can greatly reduce the work to actually implement the results. These tools permanently record how the rationalized alarm system was implemented, and can tie the alarms to the equipment's basic constraints. Also, software and control-system-based tools that support mode-based or state-based alarming can reduce the work required.

Do not forget to evaluate operator graphics during this rationalization phase. How alarms appear on the operator's console plays a big part in the operator's ability to recognize an alarm, determine the priority of the alarm, evaluate the reason for the alarm and decide how to respond. Consider how the alarm information is presented to the operator. Pay attention to such things as color usage, indicator shape and size, and the general ability of the operator to navigate alarm-correction screens. One can go a long way toward improving operational effectiveness by taking the operator interface into account.

Phase 5: Control – Maintain the improved alarm system

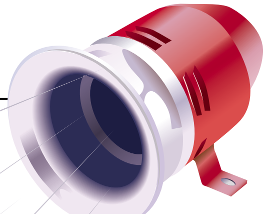
Without control, the improvements made through rationalization will not be sustained or further improved. In this phase of the alarm improvement process, the implemented redesigned alarm system is monitored for improvement in the subsequent months or years of its operation.

The results of the alarm improvement process are tested and maintained, and areas for additional improvements might be explored. Follow-up studies, upset investigation and alarm system enforcement will help ensure that the alarm system not only remains in its newly engineered state, but continues to promote maximum operator effectiveness.

To be successful, alarm management must be more than a one-time activity. The improvement process for a plant or facility has to be accompanied with a change in thinking about how alarms are perceived. Three basic activities can help promote and maintain good alarm management through the alarm system's life:

Conduct follow-up studies: Continue to gather new alarm performance statistics to track dynamic alarm activity, unit upsets and maintenance costs. Compare these findings to your earlier assessments of the alarm system's performance and measure them against the established design guidelines and best practice benchmarks. Make additional changes as necessary, on an ongoing basis.

Investigate upsets: Establish a "high-water mark" for alarm-activation frequency, above which you will declare the alarm system to be in "flooded" condition. When alarm floods occur, evaluate the actions of operators and the state of the process – what was going on, what happened, what didn't happen that should have? Establish a daily reporting and/or monthly benchmarking regime to analyze dynamic data, to provide additional clues to needed improvements for both normal oper-



ating and process-upset conditions.

Enforce the alarm system philosophy: At regular intervals use a "master alarm database" to compare the engineered alarms (that is, alarms whose presence can be justified, on the basis of sound engineering and of operating experience) to those actually configured in the DCS database at a given moment in time. Making this comparison once a week or during each shift ensures that unauthorized changes are not being made to alarms. You can use this approach to monitor and document any disabled or inhibited alarms, and thus empower operators to defend and enforce the alarm system philosophy.

The beginning of each shift also is a good time to compare alarms to the master database. This choice allows outgoing operators to discuss issues with incoming ones, and ensures that the incoming operators know the state of the alarm system. In this connection, keep in mind that some software systems can be configured to automatically reset alarms based on a particular process variable or change of state.

In a nutshell

In summary, experience tells us that many process-plant alarm systems perform poorly. But by following a systematic approach to alarm management and changing the way you think about alarms, you can turn your alarm system back into a tool that is relevant, useful and trusted by your operators. ■

Edited by Nicholas P. Chopey

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1. Campbell Brown, Donald, Alarm Management: A Problem Worth Taking Seriously, *Control*, August 1999.
2. Androw, Peter, Alarm Performance Improvement During Abnormal Situations, in "Hazards XV: The Process, Its Safety, and the Environment: Getting It Right," Institution of Chemical Engineers, Manchester, U.K., April 2000.
3. "Alarm Systems - A Guide to Design, Management and Procurement," Publication No. 191, Engineering Equipment and Materials Users Assn. (EEMUA), London, U.K.,1999.

Author

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He joined that company three and a half years ago as an industry consultant. He has prepared more than 17 papers and presentations about process control, and has worked on alarm management improvement programs with Syncrude, Petro-Canada, Encana, Oxy Chem, Glaxo, Irving Oil, Devon Gas and Weyerhaeuser. He started his career as a Production Supervisor in Northern Ontario. As a control engineer in the Niagara region, he worked on supervisory control, advanced control, performance monitoring issues and systems operator console upgrade projects. He also worked in a corporate technology group as a senior process engineer implementing MPC control on various applications. He holds a master's degree in process control, in the area of model-based fault diagnosis, expert systems and neural networks from Queen's University, Kingston, Ont.

DESIGN GUIDE FOR DUST COLLECTORS

Consider these factors when selecting, specifying and operating dust collectors to remove unwanted particulate matter from gaseous process and exhaust streams

Amrit T. Agarwal
Pneumatic Conveying
Consulting Services

Dust collectors are used widely in most manufacturing operations to remove dust and other airborne particulate matter from process gases before releasing them to the atmosphere or to downstream processes. Several different types of dust collectors are widely in use today, and they vary in terms of nomenclature, design and operation (for more, see the box at right).

For instance, in pneumatic conveying systems, dust collectors are routinely used for removing dust from the conveying gas before the gas is released to the atmosphere. They are also often installed at the end of the conveying line on bins and silos, as bin vent filters or as filter-receivers. When used with systems that convey fine solid particles, dust collectors not only recover these fine particles from the conveying gas, but they also clean the gas before it is discharged to the atmosphere or recycled.

In most dust-collection devices, the filtration mechanism combines both depth filtration and surface or surface-cake filtration. Typically, the dust-laden air enters the dust collector and is forced to enter the filtering medium. Only the gas passes through, while any entrained particulate matter is trapped inside the filter pores or is deposited as a cake on the surface of the filter medium. The dust cake buildup is periodically removed from the filter surface by any of several methods; or, in the case of guard or cartridge filters, the dirty filter medium is generally thrown away and replaced by a clean, pre-packaged filter medium.

GETTING THE TERMINOLOGY STRAIGHT

The term dust collector is very broad. Listed below are some of specific types of dust collectors that are widely used today:

Bin vent filters. Bin vent filters are installed on the tops of bins and silos to capture entrained particulates before the conveying gas or other process gases are vented to the atmosphere or to other downstream process equipment.

Filter-receivers. Dust collectors are called filter-receivers when, in addition to filtering the incoming gas, they also receive the incoming solids, and then, by gravity, they feed or pneumatically convey these solids to the downstream process. Filter-receivers have three components: a dust filter, a hopper, and a feeding device, such as a rotary valve, which also functions as an isolation device (also called an airlock) to prevent gases from blowing back into the upstream process through the bottom of the receiver or vice-versa (For more on rotary valves used in pneumatic conveying systems, watch for an article by this author, which is scheduled to appear in the Solids Processing Dept. in *CE*'s March issue).

Filter-receivers are generally installed on the tops of bins or silos to receive the conveying gas and solids when isolation of the pneumatic conveying system from the bin or silo is required. They are also used in combination-type vacuum-pressure pneumatic conveying systems, or as a dropout station when two pneumatic conveying systems are used in series. In this case, the solids enter the filter-receiver and are then reconveyed to a bin or silo.

Dust collectors. As stated above, dust collector is a broad, generic term. However, this term, in many cases, refers specifically to a filter that is used for dust collection service, such as in a central dust collection system. These dust collectors are not installed on the tops of bins or silos or in pneumatic conveying systems, but operate at a remote location so that the dust can ultimately be discharged by gravity into a disposable container.

Guard filters. Guard filters refer to devices that are installed in the vent line from the bin vent filters, filter-receivers, or dust collectors. These often serve as a backup to the main or primary filters, to provide additional protection in preventing dust emissions from escaping to the atmosphere or reaching any downstream processes. Unless two guard filters are installed in parallel, these filters require process shutdown to periodically clean or replace the dirty filter elements.

Cartridge filters. Cartridge filters typically are disposable devices. In recent years however, the design of these filters has improved so that many of today's cartridge filter designs can be cleaned online and reused. ❑

Types of dust collectors

Aside from the guard filter, dust collectors are generally classified by the type of cleaning method that is used to remove the particulate matter from the surface of the filter medium. Typical classifications and their brief descriptions are given below:

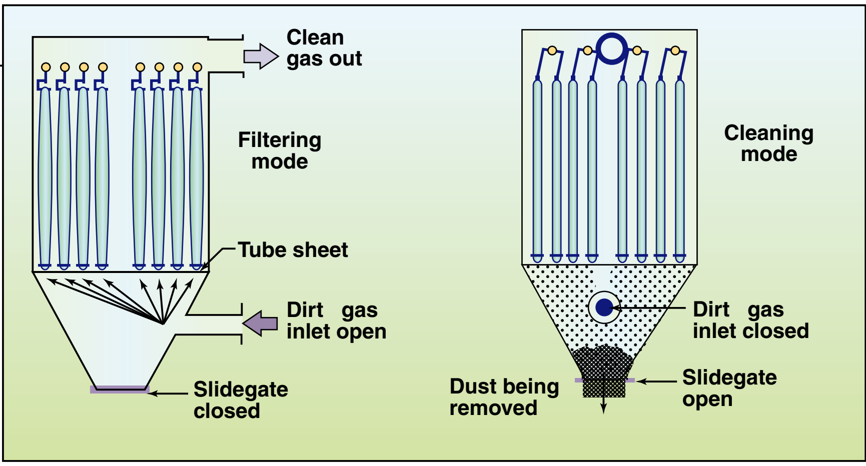


FIGURE 1. A typical design of a dust collector is shown here. As shown, the operation of the filters alternates between filtering mode and cleaning mode

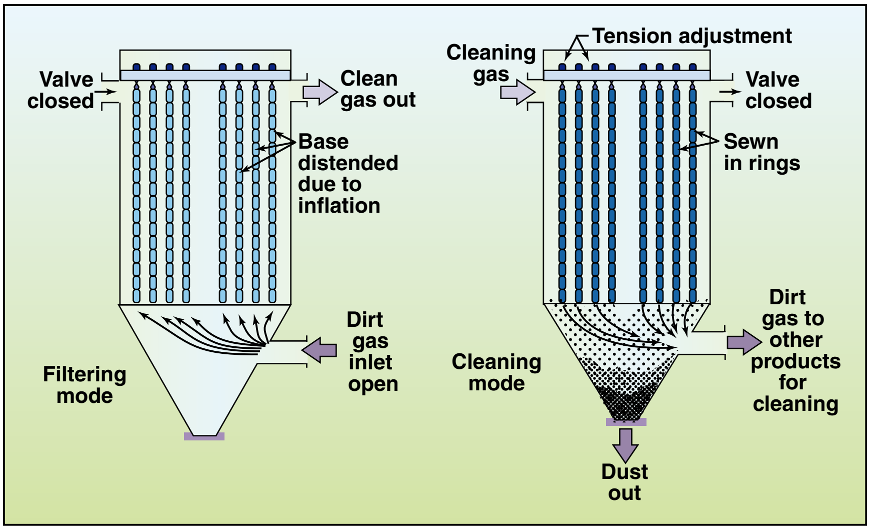


FIGURE 2. The typical design for a reverse airflow filter is shown here

Shaker type filters. With this design, the filter medium is shaken manually or mechanically to remove the dust particles (Figure 1). These dust collectors are generally not as efficient for dust removal as the pulse-jet type described below. They tend to plug more quickly because the shaking action does not release the dust cake completely or easily. Consequently, the use of shaker-type dust collectors tends to be reserved for certain unique or special applications. One example is a process where the blow-back gas used in a pulse-jet type of duct collector creates excessive pressure in the upstream or downstream process, or where high pressure blow-back gas is unavailable.

When using shaker type filters, the flow of incoming air must be stopped or diverted to another filter during the cleaning cycle. As shown in Figure 1, these filters operate batchwise in their filtering and cleaning modes. These days, very few dust collector vendors offer this type of dust collector, as the market preference has turned more strongly toward the more effective pulse-jet design.

Reverse airflow filters. With these filters, the flow of the incoming gas is periodically reversed from inside of the filter element to its outside, and the same gas flows across the filter elements (Figure 2). Just as with shaker type filters, reverse airflow filters are also not as efficient as the pulse-jet filters, because they do not generate sufficiently high gas velocities throughout the filter element to fully dislodge the filter cake.

Pulse-jet filters. With this design, a separate source of high-pressure gas is used to generate short-duration pulses of very high velocities inside the filter medium, propagating from the filter's top to its bottom. High-pressure, high-velocity jets of gas are created using a venturi that is installed at the inlet of each filter element. These high-energy pulses result in fast, momentary inflation of the filter medium, and flow of the incoming gas from the inside to the outside of the filter element, across its entire length. These two actions effectively loosen and dislodge the dust cake that has formed on the external surface of the filter medium. Presently, pulse-jet dust collectors are used almost universally by all types of manufacturing plants, because of their excellent cleaning efficiency.

Design aspects

The basic design of a pulse-jet dust collector is shown in Figure 3. These dust collectors have the following main mechanical components and characteristics:

1. The filter elements are installed inside the main body or housing. The vessel generally has a conical or pyramidal hopper bottom that is sloped at an angle of at least 60 deg from the horizontal.
2. Filter elements are generally of cylindrical or rectangular panel type construction, although the cylindrical type is more commonly used. These elements have internal wire cages to help them retain their shape. Pleated filter elements without a wire cage are also used sometimes in special applications.
3. A horizontal tube sheet supports the filter elements and separates the clean side of the dust collector from the dirty side.
4. A clean-air plenum chamber is located above the tube sheet, with an outlet to discharge the clean gas.
5. A system is provided to supply high-pressure gas to the dust collector to clean the filter elements. This system has high-pressure gas manifolds located inside the plenum chamber above each row of filter elements These manifolds (also called blow pipes) are connected to the gas supply source via shutoff valves. Nozzles or orifices in the blow pipes, located directly above and concentric with those elements, are provided to control the gas flow into each of the filter elements. Each filter element also has a venturi at its inlet, located exactly below the hole or nozzle in the blow pipe above.

A control system with timers for pulse duration and time interval between the pulses controls the flow and duration of the cleaning gas to each filter element or to a bank of filter elements. A typical design of this blow-back system is shown in Figure 4. Figure 5 shows how the blow-pipes are located above each row of filter elements.

6. The body of the dust collector is generally cylindrical for high pressures and square or rectangular for low pressures. Low pressures are typically in the range of one psig or less.
7. The size of the dust collectors can vary from very small to very large. Small sizes may be only a few square feet of filter surface area. Very large units may have more than 50,000 square feet of filter area.
8. The standard lengths of the filter elements, often called filter bags, are 2, 3, 4, 6, 8, 10, and 12 ft. The longer the element, the lower is the cleaning efficiency because of the energy decay in the pressure pulse from the top to the bottom of the filter element. As a result, based on performance data, the optimal bag length is generally limited from 6 to 8 ft.
9. The outside diameter of the bags may vary from 2 in. up to 8 in. Smaller-diameter bags are more easily and more thoroughly cleaned than larger-diameter bags because of the higher-pressure pulse that is generated in them Because of this, the maximum diameter of the bags is generally limited to 5 or 6 in. Thus, for most applications, the preferred size of the bags is 5 or 6 in. diameter and 6 or 8 ft length.
10. Pulse-jet dust collectors have two options for removal of the bags. The bags can be removed from the bottom of the tube sheet, or from the top of the tube sheet through its plenum chamber. The top removal method is preferred if the dust collector is installed on the top of very tall bins or silos or if bags could fall into process equipment. Top-removal type construction tends to be about 10% more expensive overall than the bottom-removal type. Top-removal type bags should have easily removable or rotatable top head, with flexible connections and removable spool pieces in all piping. For very large dust collectors, walk-in type plenum chambers can also be used to eliminate the top-head removal equipment and its mechanism.
11. The nozzle for the incoming gas is located below the bottom of the filter bags to avoid direct impingement of the incoming gas-solid mixture on the bags. Generally, the inlet nozzle is located at least one foot below the bottom of the bags.
12. The inlet nozzle is also provided with an internal baffle or impingement plate to deflect the solid particles toward the bottom of the vessel and to dispense them across the entire cross-section of the dust collector. Properly designed inlet nozzles can reduce dust loading on the bags by reducing the solids velocity and thus helping some initial settling of the solids. Tangential inlet nozzles are seldom used because they may result in smearing of the solids on the internal surface of the vessel, especially when handling soft or sticky materials, and because the high tangential velocity could cause erosion of the dust collector walls.
13. Complete baghouse assemblies without a shell or body are also sometimes used for direct mounting on the top of a storage bin or other vessel. In this case, the bags extend into the "free space" that exists between the top of the bin and the highest level of solids in the bin.

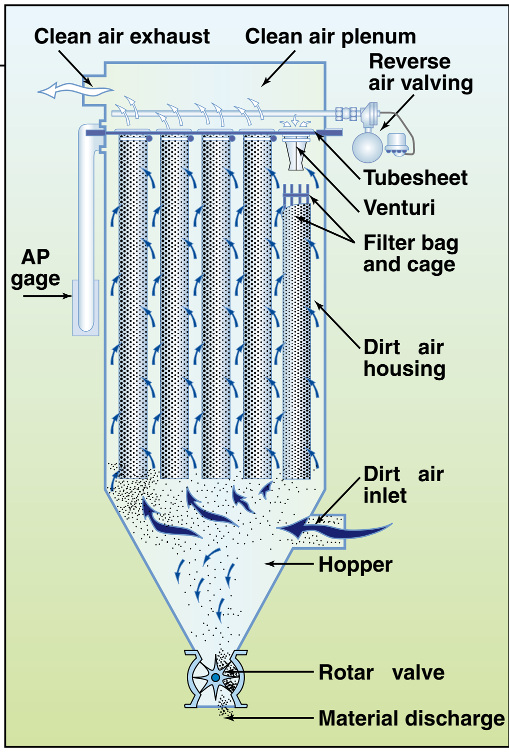


FIGURE 3. Pulse-jet dust collectors have emerged as a favored design among CPI plant operators. The basic design elements are shown here

Operating principles

During operation, the dust-laden air enters the dust collector from the bottom, flows vertically upward into the filter area, and then flows across and into the bags. The entrained particulates in the dirty stream enter the filter element or are deposited on the outside surface of the bags. The cleaned air passes through the bags, flows upward inside the bag, and then flows into the plenum chamber through the venturi of the bags. From the plenum chamber, it then flows to the atmosphere or to other process equipment.

As mentioned above, dust that is deposited on the bags is removed by a pulsed-air system. The pulses of air are injected into the bag — over short durations and intermittently — through an orifice located directly and concentrically above the bag and then through a venturi. The short durations last just a fraction of a second. The venturi converts the high pressure of the incoming air into high discharge velocity. Depending upon the pressure, this velocity can be as high as sonic velocity. The sudden flow of this high- velocity gas creates a shock wave that causes the bag to swell over most of its entire length. As the bag swells, the dust cake that is deposited on the surface of the bag becomes loosened, falls off the filter medium surface, and drops to the bottom of the dust collector.

A side effect of the venturi is generation of a slight vacuum at its inlet resulting in induced airflow (see Figure 4) into the filter bags. If the dust collector is vented to the atmosphere, atmospheric air will be induced into the venturi and flow into the bags. The amount of this induced airflow depends upon the pulse air pressure and can be significant. This induced flow can have adverse effect on bag cleaning if this flow sucks in humid air that could condense on the internal surface of the bags.

The bags are typically cleaned one by one, or bank by bank. This allows continuous operation of the dust collector because when one bag or one bank of bags is being cleaned, the

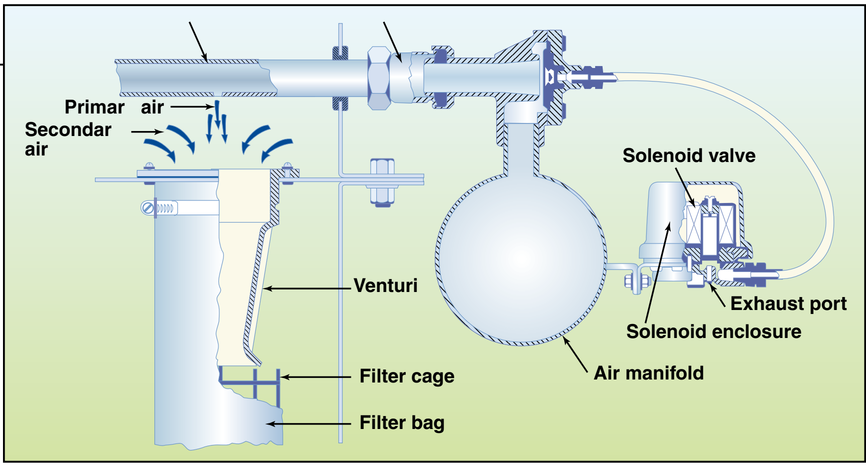


FIGURE 4. This figures shows the design of a typical blow-back system, which is used to introduce pulsed air into the system to periodically dislodge the collected particulate matter

other bags or banks are still in operation. Therefore, pulse-jet dust collectors operate continuously.

To improve cleaning efficiency of the filter bags, set the pulse-air cleaning sequence for each row of bags so that it does not clean the adjacent rows of bags but alternates between the rows located away from each other as shown in Figure 6.

The consumption of air required to clean the bags can be obtained from the dust collector vendors.

Design issues to consider

Basic design considerations for dust collectors are described below:

Gas-to-cloth ratios. One of the universally used measures to define the size of the dust collector is called "air-to-cloth ratio". This is the ratio of the volumetric flow of air (or gas) into the dust collector divided by the total external surface area of the dust collector's filter elements:

Air flow (acfm)/Surface area (ft^2)

This ratio expresses the air (or gas) velocity, in ft/min, at the external surface of the filter elements. For depth-type filter elements, this velocity is important because it affects their life as well as their filtration efficiency. High velocities cause the solid particles entrained in the air to penetrate deeper into the filter, eventually resulting in plugging up of all of the passages through which the air can flow out of the filter element. This is especially true if the solid particles are very fine in size. Once the filter element is plugged, it must be thrown away and replaced.

The required size or surface area of the filter medium depends upon the dust loading and the fineness of the dust particles. It also depends upon the type of the filter medium used.

Typical design guidelines for selecting the air-to-cloth ratios for new dust collectors are as follows:

- Fine powders (particle size less than 200 mesh): 1 to 5
- Granular materials: 5 to 7
- Pelleted materials, such as pelleted plastics: 7 to 9

Use the above ranges of values for dust collectors that are in continuous service. One can use higher ratios if the dust collectors are used intermittently, or if the dust loading is light, or if retrofits of existing dust collectors are required. However, do not use air-to-cloth ratios greater than 12, because of the high velocities that they generate and the resulting damage that such velocities can cause to the filter elements.

When retrofitting existing dust collectors or for incremental expansions, relax the above ratios to maximum ratios of 7, 10, and 12, respectively.

For very fine dusts such as talc that has a particle size in the range of 1 to 5 micrometers, use a ratio of 1 with 2 as a maximum.

Superficial gas velocity. In addition to the surface area, the other major requirement for sizing a dust collector is that the dust particles or the dust cake should drop after they leave the surface of the bags and not remain suspended between the bags. If the bags are located too close to each other, the removed dust particles can remain suspended and not fall below the filter elements. To assure that the dust particles fall, the criterion used is called the free space velocity or the superficial upward gas velocity outside adjacent filter elements. This velocity is equal to air or gas flow coming into the dust collector, divided by the cross sectional area of the dust collector's shell, minus the total cross sectional area of the filter elements as viewed from the bottom:

$$\frac{\text{Air or gas flow (acfm)}}{\left[\begin{array}{c}\text{Cross-sectional area of the dust collector}\\ \text{shell(ft}^2\text{)} - \text{Total cross-sectional area of}\\ \text{the bags as viewed from the bottom (ft}^2\text{)}\end{array}\right]}$$

This velocity determines whether the dust particles that are released from the filter surfaces will drop to the bottom of the dust collector, or will remain suspended in the gas space between the filter elements. If this velocity is too high for a given particle size — i.e., higher than the particle terminal velocity — the particles will remain suspended and will not fall.

This problem is worse when the dust particles are 'fines and streamers' that are produced during high-velocity pneumatic conveying of plastic materials, such as polyethylene. In general, when the superficial velocity is too high, these fines and streamers do not fall but remain suspended and form 'bird nests' between the adjacent filter elements, eventually plugging the entire dust collector.

The following guidelines are used to determine the superficial gas velocity:

- Fine powders (less than 200 mesh): 150 ft/min maximum
- Granular materials: 250 ft/min maximum
- Pelleted materials: 300 ft/min maximum

Use a maximum velocity of 75 ft/min for very fine dusts, such as talc and carbon black.

Arrange the layout of the filter elements so that this velocity is not exceeded in any part of the dust collector.

The basis for the above superficial velocities is single-particle terminal velocity in a dust collector at a few inches of water pressure. For example, the terminal velocity of 60-mesh (or about 200-micrometer) granular polyethylene particles in air is 4.2 ft/s or about 250 ft/min. This means that all particles larger than 60 mesh or 200 micrometers will drop from the dust collector's filtration section to the bottom of the dust collector or will not enter the filtration section. The 60-mesh particle size is selected instead of a smaller size because the cake that forms on the filter surface increases the size of the dust particles that are released.

When handling gases other than air, or when operating at pressures higher than atmospheric, the above superficial velocities should be recalculated using Stokes' Law.

Dust loading. Dust loading is also an important criterion for sizing dust collectors. Minimize the incoming dust loading to reduce the size of the dust collector. In general, the incoming dust loading should not exceed 20 grains per acfm of air or gas. If the incoming air or gas has a higher than 20 grains solids loading, reduce this loading by using equipment such as "pre-separators" or impingement separators.

Pulse-air control system. Reducing the pulse air pressure can control the intensity of cleaning of the bags. Typically, the supply pressure is about 90 to 100 psig. This pressure can be reduced to 30 or 40 psig depending upon the dust loading in the incoming gas stream.

In addition, the cleaning frequency can be increased or decreased by adjusting the timer supplied by the dust collector vendor. Normally, this frequency is a gas pulse every 30 seconds to 2 min, but it can be manually changed as required. The duration of the gas pulse is normally about 0.05 to 0.1 seconds but it also can be controlled. These controls are generally located in a control box supplied by the vendor. They should be located so that they have easy access to the operators.

An alternative to manual control of the pulse air system is automatic control. The automatic control system initiates the pulse air cycle when the pressure drop across the filter elements is above about 4 in. of water. It then stops when this pressure drop reduces to about 1 in. A clean filter element typically incurs a pressure drop of about 1 in. The benefit of automatic control is that unnecessary pulsing of the bags is avoided and thus the bag life is increased. Another benefit is that the amount of pulse air needed to clean the bags is reduced.

The pulse-gas manifold, solenoid valves for each row of bags, and inlet piping up to the manifold are usually sized by the vendor. However, these sizes should be checked to assure that they are adequate to provide full gas pressure (80 to 100 psig) at the orifice nozzle above each bag. The high pulse-gas pressure may be required for optimal cleaning of the bags, especially if the dust loading is high or the bags are very long.

The pulse gas manifold contains orifices for each bag. As stated above, these orifices must be perfectly centered above the venturi of each bag. Perfect centering is critical for satisfactory operation of the pulse-air system. Use only those dust collector designs that assure correct positioning of the orifices.

Make sure that the air or gas used to pulse the bags is clean and dry. Do not use moist air because the moisture may condense on the bags.

Handling of sticky dusts. When handling sticky dusts, it is important that these dusts do not stick to the surface of the bags. In such cases, the selection of the filter medium becomes important. Use those filter media that prevent sticking. These can be Teflon or Gore-Tex type membranes.

Moisture in incoming air or gas. Moisture in incoming dirty air or gas will cause rapid fouling of the filter elements because of condensation of the moisture on and inside the filter elements. In such cases, the dust collectors are designed and operated so that the temperature inside is above the gas dew point. In cold climates, the dust collector housing may have to be insulated or even heat traced to prevent condensation.

Location of dust collectors. Locate the dust collectors so that there is easy access to them, and so that the bags can be removed, and replaced easily and safely.

Bin vent filters that are normally installed above bins and silos require special attention. Avoid manual entry inside the bins to remove the bags, because of the safety hazards. In some special cases, gratings are used below the bags to catch a falling bag or to increase manual access to the bags. However, use of such gratings should be avoided because the accumulation of dust particles on their surface can result in product contamination and unsafe working conditions for operators. Instead of using bottom-removal type bags, use top-removal type bags to prevent personnel safety hazards, especially when access to the bin vent filter is poor.

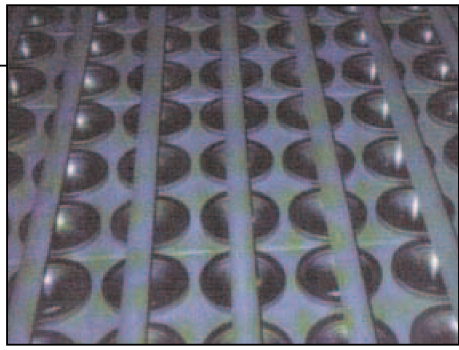


FIGURE 5. This figure illustrates how the blow-back pipes are located above each row of filter elements in a pulse-jet filter

Filter media. Selection of a suitable filter medium is important for successful operation of a dust collector. Filter media are generally cotton or synthetic fabrics, or synthetic membranes. Sometimes, for very high temperatures or for ultrahigh-efficiency filtration requirements, sintered-metal or woven-metal type filter elements are used.

The cotton or synthetic fabrics can be woven or felted. Felted fabrics have a higher surface area, so they are more efficient for a given filter size. As discussed below, felted fabric can have a glazed finish, which is a very smooth surface, or a singed finish, which has a rough texture. The as-produced felted fabric has fibers that protrude from the surface. These fibers are burnt and singed for the singed finish and are further pressed under hot rollers for the smooth or eggshell finish.

For most applications, felted fabrics are preferred over woven fabrics because of the larger surface area, more depth, and smaller pore size. Exceptions are single sock type filters for duties requiring very light dust removal.

Polyester or polypropylene bags are acceptable and interchangeable in most cases, and the choice can be made on the basis of cost and availability. The exceptions are based on the following special considerations:

- Polyester has a significantly higher melting point than polypropylene.
- Polypropylene is limited to process temperatures below 90°C. Polyester is limited to temperatures below 150°C
- Polyester deteriorates quickly in the presence of some chemicals

In applications above 90°C and up to 232°C and where corrosive chemicals

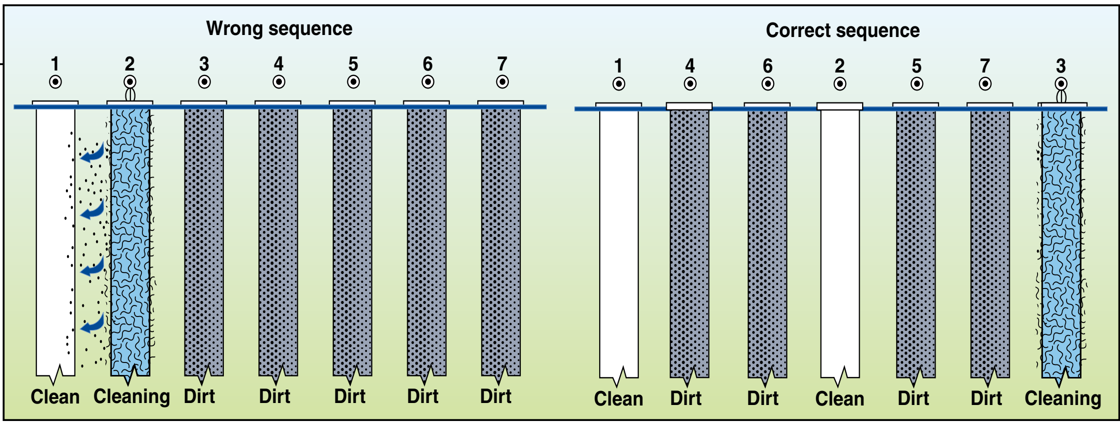


FIGURE 6. When cleaning the filter bags in a pulse-jet system, cleaning efficiency can be improved by cleaning alternate, rather than adjacent, rows, as shown here

are present, bag material, including the thread used to sew the bags, should be Teflon. Do not use Teflon-coated bags because this coating will develop cracks due to the frequent inflation and deflation of the bags used to dislodge the collected particulates.

As mentioned above, surface treatment of one of the following types should be specified for non-coated bags:

- Eggshell or glazed
- Singed

These treatments are available on most materials and are roughly equivalent in performance. Essentially, they remove the loose fibers that may result in product contamination. The eggshell or glazed finishing process presses down the loose fibers of the felted cloth into the fabric by using a hot roller. The singed process burns the loose fibers by using a flame. Therefore, singed bags have a higher permeability than eggshell or glazed finish.

The weight of cloth should be at least 14 oz/yd^2. A weight of 16 oz/yd^2 is preferred for longer bag life.

These filter media are suitable for removal of dust particles larger than 20 micrometers. They have an efficiency of about 99.9% for most of such dusts. In addition to polyester, polypropylene, and Teflon, a number of other less-often-used filter media are commercially available.

Pressure drop across the bags. The dust collector vendor normally supplies a differential pressure indicator connected to the dirty side and to the plenum chamber. Make sure that the dirty side has a filter to prevent dust from migrating into the pressure indicator and affecting its reading. Locate this indicator so that the pressure drop reading is easily visible. If the pulse-air system operates automatically based on pressure drop, provide a pressure differential transmitter in addition to this local indicator so that this reading can be monitored in the control room.

When the bags get dirty, the pressure drop across the baghouse, including at the inlet and outlet connections, should be in the range of 4 to 8 in. of water (As noted earlier, pulse-jet systems with automatic control initiate the pulse-air cycle when the pressure rises to 4 in. of water.) Pressure drop exceeding 10 in. of water indicates that the bags are too dirty and need replacement. On the other hand, if the pressure drop remains below 1 in. of water even when handling dirty air, then the bags may be leaking or ruptured. As a general rule-of-thumb, clean filter bags should have a pressure drop of about 1 in. of water.

Inlet nozzle. Use tangential or "straight-in" nozzles, based on the process needs and the properties of the dust being handled. For some of the plastic materials, avoid tangential nozzles because they may increase streamer formation unless inside surface is rough.

Inlet nozzles must be baffled or arranged to avoid direct impingement of solids on filter cloth. The baffle must be designed to overcome the impact forces caused by the incoming high velocity of solids and gases.

Materials of construction. Use nonrusting materials such as aluminum or stainless steel for applications where the collected solids are returned to the process. Carbon steel is acceptable in an inert or non-corrosive atmosphere, such as closed-loop nitrogen conveying systems or in dust collectors in which the collected dust is discarded.

Steel or epoxy-coated steel is acceptable in applications where the collected solids are considered waste, such as in central dust collection systems.

Mechanical design considerations. Most dust collectors are used in relatively low-pressure applications (such as those with a pressure rating of less than 15 psig). For these applications, it is not imperative that the manufacturers follow any pressure vessel code for the design and construction; hence, all too often, such dust collector vessels are poorly built or have relatively flimsy construction. To guard against such poor construction, specify even low-pressure dust collectors so that they meet the ASME pressure-vessel code requirements, even if they do not have the code stamp.

Safety considerations. Safe design of the dust collectors is very important because of the potential for dust explosions when handling combustible dusts. Dust collectors inherently contain fine dust particles; therefore, the probability of a dust explosion is quite high if there are also sufficient oxygen and an ignition source of sufficient strength inside the dust collector. Friction of the synthetic filter media (for instance, bags) against the internal metallic wire cage can always generate a static charge on the cage. This charge can accumulate and develop sufficient strength to initiate ignition unless the cage is grounded. Therefore, it is imperative that the wire cages are grounded such that the resistance to ground is less than 5 ohms. The bags should have at least one, and preferably two, grounding wires sown into them so that these wires make a positive contact with the cage and with the grounded tube sheet.

For sizing of the explosion vents, their mounting methods, and testing requirements, use the design guidelines given in the NFPA 68 standards.

Locate dust collectors handling combustible dusts and whose volume is larger than 8 ft^3 outside closed buildings. If an inside location is unavoidable, locate the dust collector very close to an outside wall, use the design method explosion venting for designing the explosion vent, and provide a duct between the explosion vent and the outside of the building, all as described in the NFPA standards.

Electrical grounding requirements for dust collectors are as follows:

1. The housing must have grounding lugs for direct grounding to connected equipment, steel structures, or to ground.
2. All internal metal parts, including venturis, wire cages and bag clamps, must be connected to the housing for positive and continuous grounding.
3. Do not use conductive bags or filter elements, because if they rupture, a spark could be generated due to the accumulated charge on their surface. Bags themselves do not need grounding; only the wire cages that support the bags need grounding.

Do not use compressed air to blow-clean the bags while they are still inside a dust collector because of the potential dust explosion hazard.

Wire cages for bags. Wire cages must be designed to withstand the maximum pressure that a bag is exposed to; otherwise, they will deform and may rupture. Instead of carbon steel, which could rust and degrade product quality, use stainless steel or galvanized steel wire cages. Typically, the cages should have at least eight rods made from 10-gage wire with at least eight rings.

Pleated filter elements. Pleated filter elements provide more surface area than cylindrical bags; however, dust can accumulate inside the pleats and not release when the filters are pulsed. This is particularly true for sticky dusts. Certain pleated designs, such as those whose pleats are not folded too close to each other or are not too deep, may be suitable for some dusts.

Dust collectors in feed bins

Dust collectors that are used in feed bins require special care because they can get severely damaged if discharge of the material from the feed bin stops and new material keeps on entering the bin from a pneumatic conveying system or from another source. Because of the rising level of the material bags can get buried under the material, get collapsed, or restrict the flow of the conveying gas. To prevent such incidents, the rotary valve, which is generally used as the feed-out device, is provided with a motion switch installed on its rotor, such that if the rotor stops, the incoming pneumatic conveying system or any other feed stream also stops. Redundant level switches in the bin are also provided to stop the flow of incoming material into the bin.

Dust collector efficiency. Felted polyester bags capture particles up to 20 micrometers. Their efficiency depends upon the size of the dust particles but, in general, it is about 99.95% if the dust collector is correctly sized and operated.

Bags with Gore-Tex membrane (or equivalent membrane) capture particles up to 2 micrometers. Their efficiency can be as high as 99.99%.

Guard filters. As noted earlier, guard filters are often provided as protection against the failure of a primary filter. Their surface area can be much smaller because of their infrequent use. The air-to-cloth ratio can be five times that of the primary filter. However, they should use the same type of filter element as that used in the primary filter so that they can capture the same size particles.

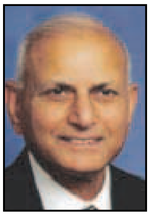
Instrumentation and control systems. Controls for pulse-air systems are discussed above. Aside from that, dust collectors are generally provided with the following instruments and controls as a minimum:

- A local and an optional remote differential pressure indicator to enable monitoring of the pressure drop across the filter elements
- Alarms for both very high pressure and very low pressure drops across the filter elements, as indications for bag replacement
- A high level switch interlocked to stop the incoming material flow located at least one foot below the filter elements to prevent damage to the bags
- For pulse-jet dust collectors, timers to control the duration of the pulse and the frequency of the pulse, and a selector switch to control the sequence of pulsing rows of bags. These are provided by the dust collector vendor but can be locally adjusted.
- For pulse-jet dust collectors, a pressure control valve with a pressure gage to control and monitor the pulse gas pressure

The design of dust collectors is a subject that is generally not included in many engineering curricula, despite the widespread use of dust collectors in many chemical process and manufacturing operations. The information provided here should give design and operating engineers sufficient guidance for the successful selection, specification and operation of dust collectors. ■

Edited by Suzanne Shelley

Author



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Solubility & Henry's Law Constants for Chlorinated Compounds in Water

The new correlation and data presented here are appropriate even for very low concentrations

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Prasad K. Narasimhan
and **Helen H. Lou**
Lamar University

Ralph W. Pike
Louisiana State University

The solubility of chlorinated compounds in water is very important. This importance will increase in the future in view of heath, safety and environmental considerations. Although such compounds are relatively insoluble in water, even very low concentrations (ppm or less) can provide concentrations in air at the air-water interface that exceed the threshold-limit value (TLV) for human exposure and the lower-explosion limit (LEL) for flammability.

Results for water solubility and Henry's Law constants are presented for a wide variety of chlorinated compounds (alkanes, olefins, and aromatics containing chlorine) in water. The results are provided in an easy-to-use tabular format that is especially applicable for rapid engineering usage with the personal computer or hand calculator. A new correlation for solubility is also presented. The new correlation maybe used to provide reliable solubility values down to very low concentrations for monochlorinated alkanes in water. The correlation is based on the boiling point of the compound. Correlation and experimental data are in favorable agreement. The results are useable in health, safety, and environmental studies.

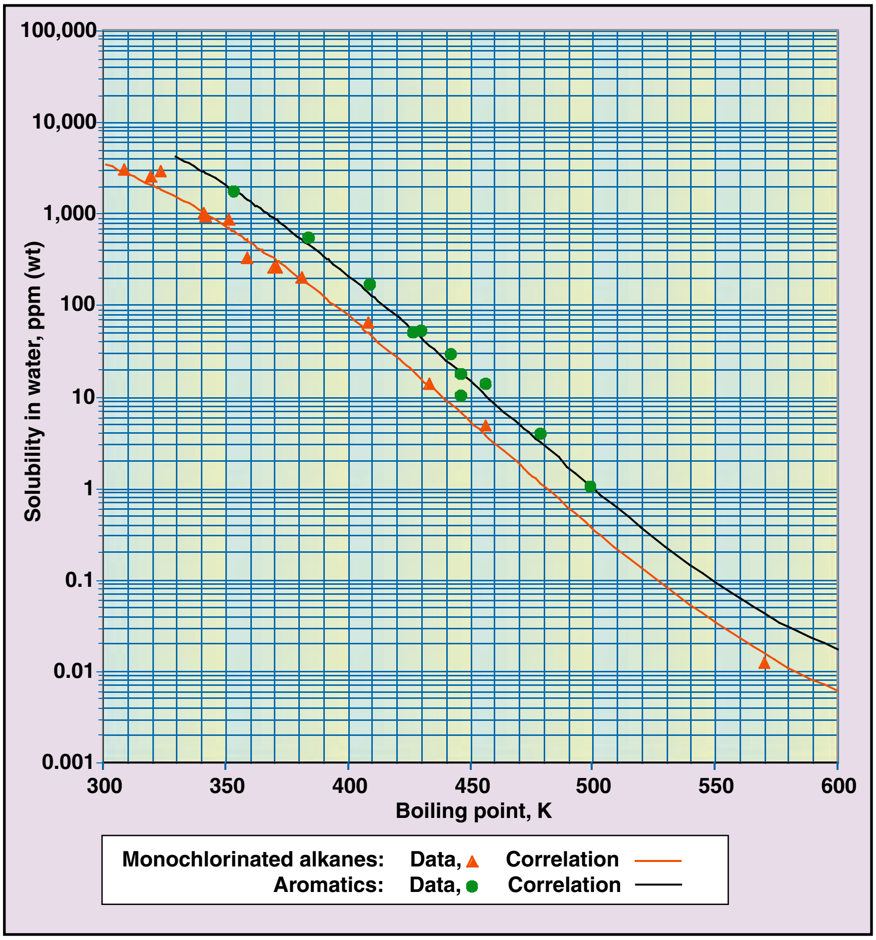

FIGURE 1. As shown by this plot of solubility versus boiling point, monochlorinated alkanes are slightly less soluable in water than aromatic compounds

Consider these examples

The following brief discussion, using dichloromethane as an example, illustrates the importance solubility relationships for chlorinated compounds, even at very low concentrations. A sample calculation is also shown in the box on p. 56.

For human exposure to substances in air, the threshold-limit value (TLV) for dichloromethane in air is given as 50 ppm (parts per million) by volume by the U.S. Occupation Safety and Health Act (OSHA; *10*). A concentra-

SOLUBILITY IN WATER, (*S*), AND HENRY'S LAW CONSTANT (*H*)

No.	Formula	Name	CAS No.	T_B, K	*S* @ 25°C, ppm (wt)	*S* @ 25°C, ppm (mol)	Code	*H*@25°C, atm/mol frac	*H* @ 25°C, atm/mol/m^3	Code
1	CCl_4	carbon tetrachloride	56-23-5	349.79	8.0000E+02	9.3681E+01	1	1589.36	2.8609E–02	1,2
2	$CHCl_3$	chloroform	67-66-3	334.33	7.8400E+03	1.1901E+03	1	211.19	3.8015E–03	1,2
3	CH_2Cl_2	dichloromethane	75-09-2	312.90	1.9400E+04	4.1754E+03	1	137.00	2.4661E–03	1,2
4	CH_3Cl	methyl chloride	74-87-3	248.93	5.3800E+03	1.9264E+03	1	502.93	9.0528E–03	1,2
5	C_2Cl_4	tetrachloroethylene	127-18-4	394.40	1.5000E+02	1.6297E+01	1	1542.31	2.7762E–02	1,2
6	C_2Cl_6	hexachloroethane	67-72-1	460.00	8.0000E+00	6.0878E–01	1	1281.09	2.3060E–02	1,2
7	C_2HCl_3	trichloroethylene	79-01-6	360.10	1.1000E+03	1.5097E+02	1	661.08	1.1900E–02	1,2
8	C_2HCl_5	pentachloroethane	76-01-7	433.03	5.0000E+02	4.4547E+01	1	106.35	1.9143E–03	1,2
9	$C_2H_2Cl_2$	1,1-dichloroethylene	75-35-4	304.71	3.3450E+03	6.2338E+02	1	1253.86	2.2570E–02	1,2
10	$C_2H_2Cl_2$	cis-1,2-dichloroethylene	156-59-2	333.65	3.5000E+03	6.5227E+02	1	395.77	7.1239E–03	1,2
11	$C_2H_2Cl_2$	trans-1,2-dichloroethylene	156-60-5	320.85	6.3000E+03	1.1768E+03	1	360.96	6.4973E–03	1,2
12	$C_2H_2Cl_4$	1,1,1,2-tetrachloroethane	630-20-6	403.65	1.1000E+03	1.1808E+02	1	142.63	2.5674E–03	1,2
13	$C_2H_2Cl_4$	1,1,2,2-tetrachloroethane	79-34-5	418.25	3.0000E+03	3.2258E+02	1	20.52	3.6940E–04	1,2
14	C_2H_2Cl	vinyl chloride	75-01-4	259.78	2.6970E+03	7.7890E+02	1	1243.84	2.2389E–02	1,2
15	$C_2H_3Cl_3$	1,1,1-trichloroethane	71-55-6	347.23	1.0000E+03	1.3505E+02	1	1186.15	2.1351E–02	1,2
16	$C_2H_3Cl_3$	1,1,2-trichloroethane	79-00-5	387.00	4.4200E+03	5.9868E+02	1	53.26	9.5863E–04	1,2
17	$C_2H_4Cl_2$	1,1-dichloroethane	75-34-3	330.45	5.1000E+03	9.3155E+02	1	317.63	5.7173E–03	1,2
18	$C_2H_4Cl_2$	1,2-dichloroethane	107-06-2	356.59	8.7000E+03	1.5938E+03	1	64.14	1.1546E–03	1,2
19	C_2H_5Cl	ethyl chloride	75-00-3	285.42	5.7000E+03	1.6095E+03	1	601.94	1.0835E–02	1,2
20	$C_3H_4Cl_2$	2,3-dichloropropene	78-88-6	365.75	2.1500E+03	3.4966E+02	1	239.53	4.3115E–03	1,2
21	C_3H_5Cl	3-chloro-1-propene	107-05-1	318.11	4.0000E+03	9.4454E+02	1	526.77	9.4820E–03	1,2
22	$C_3H_5Cl_3$	1,1,1-trichloropropane	7789-89-1	379.15	1.9000E+03	2.3236E+02	1	136.73	2.4611E–03	1,2
23	$C_3H_5Cl_3$	1,1,2-trichloropropane	598-77-6	405.15	1.9000E+03	2.3236E+02	1	36.41	6.5530E–04	1,2
24	$C_3H_5Cl_3$	1,2,3-trichloropropane	96-18-4	430.00	1.7500E+03	2.1399E+02	1	23.78	4.2803E–04	1,2
25	$C_3H_6Cl_2$	1,2-dichloropropane	78-87-5	369.52	2.7400E+03	4.3752E+02	1	157.45	2.8341E–03	1,2
26	$C_3H_6Cl_2$	1,3-dichloropropane	142-28-9	393.55	2.8000E+03	4.4713E+02	1	53.66	9.6581E–04	1,2
27	C_3H_7Cl	1-chloropropane	540-54-5	319.67	2.5000E+03	5.7453E+02	1	786.75	1.4162E–02	1,2
28	C_3H_7Cl	2-chloropropane	75-29-6	308.85	3.0400E+03	6.9892E+02	1	956.06	1.7209E–02	1,2
29	$C_4H_8Cl_2$	1,1-dichlorobutane	541-33-3	386.95	5.0100E+02	7.1031E+01	1	423.09	7.6158E–03	1,2
30	$C_4H_8Cl_2$	DL-2,3-dichlorobutane	2211-67-8	392.65	5.6200E+02	7.9684E+01	1	210.90	3.7962E–03	1,2
31	$C_4H_8Cl_2$	meso-2,3-dichlorobutane	4028-56-2	389.15	5.6200E+02	7.9684E+01	1	249.91	4.4983E–03	1,2
32	C_4H_9Cl	1-chlorobutane	109-69-3	351.58	8.7200E+02	1.6982E+02	1	791.61	1.4249E–02	1,2
33	C_4H_9Cl	1-chloro-2-methylpropane	513-36-0	342.00	9.2400E+02	1.7996E+02	1	947.68	1.7058E–02	1,2
34	C_4H_9Cl	2-chlorobutane	78-86-4	341.25	1.0000E+03	1.9477E+02	1	1042.66	1.8768E–02	1,2
35	C_4H_9Cl	2-chloro-2-methylpropane	507-20-0	323.75	2.8700E+03	5.5984E+02	1	715.18	1.2873E–02	1,2
36	C_4H_9Cl	2-chlorobutane	53178-20-4	341.35	1.0218E+03	1.9903E+02	2	995.91	1.7927E–02	1,2
37	$C_5H_{10}Cl_2$	1,2-dichloropentane	1674-33-5	420.15	2.8600E+02	3.6510E+01	1	108.98	1.9616E–03	1,2
38	$C_5H_{10}Cl_2$	2,3-dichloropentane	600-11-3	412.15	2.8600E+02	3.6510E+01	1	173.83	3.1289E–03	1,2

Code: 1 - data, 2 - estimate T_B - boiling point, K   *S* - solubility in water, ppm   *H* - Henry's Law constant

SOLUBILITY IN WATER, (*S*), AND HENRY'S LAW CONSTANT (*H*)										
No.	Formula	Name	CAS No.	T_B, K	*S* @ 25°C, ppm (wt)	*S* @ 25°C, ppm (mol)	Code	*H*@25°C, atm/mol frac	*H* @ 25°C, atm/mol/m^3	Code
39	$C_5H_{10}Cl_2$	2,3-dichloro-2-methylbutane	507-45-9	402.15	2.8600E+02	3.6510E+01	1	190.84	3.4351E–03	1,2
40	$C_5H_{11}Cl$	1-chloropentane	543-59-9	381.54	2.0100E+02	3.3976E+01	1	1226.90	2.2084E–02	1,2
41	$C_5H_{11}Cl$	2-chloropentane	625-29-6	369.67	2.5100E+02	4.2429E+01	1	1568.14	2.8227E–02	1,2
42	$C_5H_{11}Cl$	3-chloropentane	616-20-6	370.94	2.5100E+02	4.2429E+01	1	1117.04	2.0107E–02	1,2
43	$C_5H_{11}Cl$	1-chloro-2-methylbutane	616-13-7	373.69	2.6895E+02	4.5464E+01	2	1265.76	2.2784E–02	1,2
44	$C_5H_{11}Cl$	1-chloro-3-methylbutane	107-84-6	371.66	2.9478E+02	4.9831E+01	2	1409.26	2.5367E–02	1,2
45	$C_5H_{11}Cl$	2-chloro-2-methylbutane	594-36-5	358.76	3.2900E+02	5.5618E+01	1	1825.97	3.2868E–02	1,2
46	$C_5H_{11}Cl$	2-chloro-3-methylbutane	631-65-2	365.95	3.7952E+02	6.4161E+01	2	954.03	1.7173E–02	1,2
47	$C_5H_{11}Cl$	1-chloro-2,2-dimethylpropane	753-89-9	357.45	5.4461E+02	9.2083E+01	2	996.27	1.7933E–02	1,2
48	$C_5H_{11}Cl$	1-chloro-2-methylbutane, (±)	114180-21-1	373.05	2.7687E+02	4.6803E+01	2	1205.32	2.1696E–02	1,2
49	$C_5H_{11}Cl$	2-chloropentane, (+)	29882-57-3	370.15	3.1538E+02	5.3315E+01	2	1152.71	2.0749E–02	1,2
50	C_6Cl_6	hexachlorobenzene	118-74-1	582.55	6.0000E–03	3.7955E–04	1	72.92	1.3126E–03	1,2
51	$C_6H_3Cl_3$	1,2,4-trichlorobenzene	120-82-1	486.15	3.4570E+01	3.4324E+00	1	167.10	3.0078E–03	1,2
52	$C_6H_4Cl_2$	o-dichlorobenzene	95-50-1	453.57	9.2320E+01	1.1315E+01	1	172.15	3.0988E–03	1,2
53	$C_6H_4Cl_2$	m-dichlorobenzene	541-73-1	446.23	1.2300E+02	1.5075E+01	1	198.63	3.5753E–03	1,2
54	$C_6H_4Cl_2$	p-dichlorobenzene	106-46-7	447.21	8.0000E+01	9.8046E+00	1	234.74	4.2255E–03	1,2
55	C_6H_5Cl	chlorobenzene	108-90-7	404.87	3.9070E+02	6.2552E+01	1	270.67	4.8722E–03	1,2
56	$C_6H_{13}Cl$	1-chlorohexane	544-10-5	408.24	6.4300E+01	9.6038E+00	1	1292.58	2.3267E–02	1,2
57	$C_6H_{13}Cl$	2-chlorohexane	638-28-8	397.15	8.7685E+01	1.3097E+01	2	1040.21	1.8724E–02	1,2
58	$C_6H_{13}Cl$	3-chlorohexane	2346-81-8	396.15	9.2165E+01	1.3766E+01	2	1039.15	1.8705E–02	1,2
59	$C_6H_{13}Cl$	1-chloro-2-methylpentane	14753-05-0	393.15	1.0692E+02	1.5970E+01	2	1036.20	1.8652E–02	1,2
60	$C_6H_{13}Cl$	1-chloro-3-methylpentane	62016-93-7	402.15	6.8189E+01	1.0185E+01	2	1045.98	1.8828E–02	1,2
61	$C_6H_{13}Cl$	1-chloro-4-methylpentane	62016-94-8	398.15	8.3410E+01	1.2458E+01	2	1041.31	1.8744E–02	1,2
62	$C_6H_{13}Cl$	2-chloro-2-methylpentane	4325-48-8	384.65	1.6144E+02	2.4115E+01	2	1117.36	2.0113E–02	1,2
63	$C_6H_{13}Cl$	2-chloro-3-methylpentane	24319-09-3	380.00	2.0109E+02	3.0038E+01	2	1067.60	1.9217E–02	2
64	$C_6H_{13}Cl$	2-chloro-4-methylpentane	25346-32-1	386.15	1.5027E+02	2.2445E+01	2	1072.08	1.9298E–02	1,2
65	$C_6H_{13}Cl$	3-chloro-2-methylpentane	38384-05-3	385.00	1.5877E+02	2.3716E+01	2	1071.01	1.9278E–02	2

Code: 1 - data, 2 - estimate T_B - boiling point, K *S* - solubility in water, ppm *H* - Henry's Law constant

tion of only 0.00001 mol fraction of dichloromethane in water will provide 1,370 ppm of dichloromethane in air at air water interface, which far exceeds the TLV of 50 ppm.

Similarly, but in the context of plant safety, the lower-explosion limit (LEL) for dichloromethane in air is given as 15.5% by Yaws [*10*]. A concentration of only 0.0015 mol fraction of dichloromethane in water will provide about 20.6% of dichloromethane in air at the air-water interface, which far exceeds the LEL of 15.5 %.

Finally, consider the following environmental scenario: a spill of dichloromethane in water. The water will become saturated with dichloromethane. At saturation, the solubility of dichloromethane in water is about 0.00417 mol fraction (19,400 ppm by weight) as given by Horvath [*4, 5*]. This saturation concentration will provide about 572,000 ppm or 57.2% of di-

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66	$C_6H_{13}Cl$	3-chloro-3-methylpentane	918-84-3	389.15	1.3001E+02	1.9420E+01	2	1124.62	2.0243E–02	1,2
67	$C_6H_{13}Cl$	1-chloro-2-ethylbutane	4737-41-1	399.15	7.9331E+01	1.1849E+01	2	1042.44	1.8764E–02	1,2
68	$C_6H_{13}Cl$	1-chloro-2,2-dimethylbu-tane	6366-35-4	390.15	1.2384E+02	1.8498E+01	2	1126.43	2.0276E–02	1,2
69	$C_6H_{13}Cl$	1-chloro-2,3-dimethylbu-tane	600-06-6	395.15	9.6857E+01	1.4467E+01	2	1083.45	1.9502E–02	1,2
70	$C_6H_{13}Cl$	1-chloro-3,3-dimethylbu-tane	2855-08-5	390.15	1.2384E+02	1.8498E+01	2	1126.43	2.0276E–02	1,2
71	$C_6H_{13}Cl$	2-chloro-2,3-dimethylbu-tane	594-57-0	385.15	1.5764E+02	2.3546E+01	2	1159.87	2.0878E–02	1,2
72	$C_6H_{13}Cl$	2-chloro-3,3-dimethylbu-tane	5750-00-5	384.15	1.6534E+02	2.4697E+01	2	1157.91	2.0843E–02	1,2
73	C_7H_7Cl	p-chlorotoluene	106-43-4	435.65	1.0630E+02	1.5130E+01	1	240.57	4.3302E–03	1,2
74	$C_7H_{15}Cl$	1-chloroheptane	629-06-1	433.59	1.3600E+01	1.8196E+00	1	2130.28	3.8345E–02	1,2
75	$C_7H_{15}Cl$	2-chloro-2,3-dimethylpen-tane	59889-45-1	413.42	3.8197E+01	5.1106E+00	2	1326.50	2.3877E–02	2
76	$C_7H_{15}Cl$	2-chloro-2,4-dimethylpen-tane	35951-33-8	401.15	7.1728E+01	9.5973E+00	2	1024.73	1.8445E–02	1,2
77	$C_7H_{15}Cl$	3-chloro-2,3-dimethylpen-tane	595-38-0	401.15	7.1728E+01	9.5973E+00	2	1024.73	1.8445E–02	2
78	$C_7H_{15}Cl$	4-chloro-2,2-dimethylpen-tane	33429-72-0	401.15	7.1728E+01	9.5973E+00	2	1024.73	1.8445E–02	1,2
79	$C_7H_{15}Cl$	3-chloro-3-ethylpentane	994-25-2	416.65	3.2253E+01	4.3153E+00	2	1430.30	2.5746E–02	1,2
80	$C_7H_{15}Cl$	2-chloroheptane	1001-89-4	413.42	3.8197E+01	5.1106E+00	2	1326.50	2.3877E–02	2
81	$C_7H_{15}Cl$	3-chloroheptane	999-52-0	417.15	3.1417E+01	4.2035E+00	2	1447.43	2.6054E–02	1,2
82	$C_7H_{15}Cl$	4-chloroheptane	998-95-8	417.15	3.1417E+01	4.2035E+00	2	1447.43	2.6054E–02	1,2
83	$C_7H_{15}Cl$	1-chloro-3-methylhexane	1 0 1 2 5 7 - 63-0	424.15	2.1695E+01	2.9027E+00	2	1721.46	3.0987E–02	1,2
84	$C_7H_{15}Cl$	2-chloro-2-methylhexane	4398-65-6	408.15	5.0186E+01	6.7148E+00	2	1180.70	2.1253E–02	2
85	$C_7H_{15}Cl$	2-chloro-5-methylhexane	58766-17-9	411.15	4.2977E+01	5.7503E+00	2	1260.41	2.2688E–02	2
86	$C_7H_{15}Cl$	3-chloro-3-methylhexane	43197-78-0	408.15	5.0186E+01	6.7148E+00	2	1180.70	2.1253E–02	1,2
87	$C_7H_{15}Cl$	2-chloro-2,3,3-trimethylbu-tane	918-07-0	413.42	3.8197E+01	5.1106E+00	2	1326.50	2.3877E–02	2
88	$C_8H_{17}Cl$	1-chlorooctane	111-85-3	456.62	4.8900E+00	5.9252E–01	1	2031.78	3.6572E–02	1,2
89	$C_8H_{17}Cl$	2-chloro-2,5-dimethylhex-ane	29342-44-7	442.45	8.0968E+00	9.8110E–01	2	1778.64	3.2016E–02	2
90	$C_8H_{17}Cl$	3-chloro-2,3-dimethylhex-ane	1 0 1 6 5 4 - 30-2	442.45	8.0968E+00	9.8110E–01	2	1778.64	3.2016E–02	2
91	$C_8H_{17}Cl$	2-chloro-2-methylheptane	4325-49-9	442.45	8.0968E+00	9.8110E–01	2	1778.64	3.2016E–02	2
92	$C_8H_{17}Cl$	2-chloro-6-methylheptane	2350-19-8	442.45	8.0968E+00	9.8110E–01	2	1778.64	3.2016E–02	2
93	$C_8H_{17}Cl$	3-chloro-3-methylheptane	5272-02-6	442.45	8.0968E+00	9.8110E–01	2	1778.64	3.2016E–02	2
94	$C_8H_{17}Cl$	4-chloro-4-methylheptane	61764-94-1	442.45	8.0968E+00	9.8110E–01	2	1778.64	3.2016E–02	2

Code: 1 - data, 2 - estimate T_B - boiling point, K *S* - solubility in water, ppm *H* - Henry's Law constant

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No.	Formula	Name	CAS No.	T_B, K	*S* @ 25°C, ppm (wt)	*S* @ 25°C, ppm (mol)	Code	*H*@25°C, atm/mol frac	*H* @ 25°C, atm/mol/m^3	Code
95	$C_8H_{17}Cl$	3-(chloromethyl)heptane	123-04-6	445.15	6.9930E+00	8.4735E–01	2	1914.84	3.4467E–02	1,2
96	$C_8H_{17}Cl$	2-chlorooctane	628-61-5	445.15	6.9930E+00	8.4735E–01	2	1914.84	3.4467E–02	1,2
97	$C_8H_{17}Cl$	2-chloro-2,4,4-trimethyl-pentane	6111-88-2	445.15	6.9930E+00	8.4735E–01	2	1914.84	3.4467E–02	2
98	$C_8H_{17}Cl$	(S)-2-chlorooctane	16844-08-9	442.45	8.0968E+00	9.8110E–01	2	1778.64	3.2016E–02	2
99	$C_8H_{17}Cl$	(<+->)-2-chlorooctane	51261-14-4	445.20	6.9740E+00	8.4504E–01	2	1917.48	3.4515E–02	1,2
100	$C_8H_{17}Cl$	2-ethylhexyl-6-chloride	2350-24-5	442.45	8.0968E+00	9.8110E–01	2	1778.64	3.2016E–02	2
101	$C_8H_{19}Cl$	1-chlorononane	2473-01-0	478.37	1.1495E+00	1.2728E–01	2	2989.86	5.3818E–02	1,2
102	$C_9H_{19}Cl$	3-chloro-3-ethyl-2,2-dimethylpentane	86661-53-2	470.76	1.7339E+00	1.9198E–01	2	2395.21	4.3114E–02	2
103	$C_9H_{19}Cl$	3-chloro-3-ethylheptane	28320-89-0	470.76	1.7339E+00	1.9198E–01	2	2395.21	4.3114E–02	2
104	$C_9H_{19}Cl$	3-chloro-3-methyloctane	28320-88-9	470.76	1.7339E+00	1.9198E–01	2	2395.21	4.3114E–02	2
105	$C_9H_{19}Cl$	4-chloro-4-methyloctane	36903-89-6	470.76	1.7339E+00	1.9198E–01	2	2395.21	4.3114E–02	2
106	$C_9H_{19}Cl$	2-chlorononane	2216-36-6	463.15	2.6218E+00	2.9030E–01	2	1928.10	3.4706E–02	1,2
107	$C_9H_{19}Cl$	5-chlorononane	28123-70-8	470.76	1.7339E+00	1.9198E–01	2	2395.21	4.3114E–02	2
108	$C_9H_{19}Cl$	3-chloro-2,2,3-trimethyl-hexane	102449-95-6	470.76	1.7339E+00	1.9198E–01	2	2395.21	4.3114E–02	2
109	$C_{10}H_7Cl$	1-chloronaphthalene	90-13-1	532.45	2.2400E+01	2.4815E+00	1	10.96	1.9737E–04	1,2
110	$C_{10}H_{21}Cl$	1-chlorodecane	1002-69-3	499.02	3.8530E-01	3.9276E–02	2	3241.51	5.8348E–02	1,2
111	$C_{10}H_{21}Cl$	decyl chloride (mixed isomers)	28519-06-4	499.02	3.8530E-01	3.9276E–02	2	3241.51	5.8348E–02	2
112	$C_{11}H_{23}Cl$	1-chloroundecane	2473-03-2	518.49	1.4408E-01	1.3607E–02	2	3021.06	5.4380E–02	1,2
113	$C_{12}H_{25}Cl$	1-chlorododecane	112-52-7	536.33	6.1982E-02	5.4526E–03	2	2330.48	4.1949E–02	1,2
114	$C_{13}H_{27}Cl$	1-chlorotridecane	822-13-9	553.15	2.9864E-02	2.4587E–03	2	1766.40	3.1796E–02	1,2
115	$C_{14}H_{29}Cl$	1-chlorotetradecane	2425-54-9	569.99	1.2200E-02	9.4394E–04	1	1352.95	2.4353E–02	1,2
116	$C_{15}H_{31}Cl$	1-chloropentadecane	4862-03-1	585.15	9.2984E-03	6.7855E–04	2	527.69	9.4985E–03	1,2
117	$C_{16}H_{33}Cl$	1-chlorohexadecane	4860-03-1	599.75	6.1362E-03	4.2372E–04	2	209.19	3.7655E–03	1,2

Code: 1 - data, 2 - estimate T_B - boiling point, K *S* - solubility in water, ppm *H* - Henry's Law constant

chloromethane in air at the air-water interface. This concentration greatly exceeds both the TLV of 50 ppm and the LEL of 15.6%.

Correlation for water solubility

In earlier work by Yaws and coworkers [*10*], water solubility for hydrocarbons and other chemical types was correlated as a function of the boiling point of the compound. In this present work, it was determined that the boiling point method was also applicable for correlation of water solubility of monochlorinated alkanes:

$$\log_{10}(S) = A + BT_B + CT_B^2 + DT_B^3 \quad (1)$$

where

S = solubility in water at 25°C, ppm by weight, ppm (wt)

T_B = boiling point temperature of compound, K

A = –7.4500

B = +1.0050 E–01

C = –2.7288 E–04

D = +1.9987 E–07

The correlation applies to a range for boiling point temperature of about 280 to 590K.

The coefficients (A, B, C, D) for the correlation were determined through regression of the available data. In preparing the correlation, we conducted a literature search to identify relevant data-source publications [*1–11*]. The excellent compilations by Howard and Meylan [*6*]; Mackay, Shiu, and Ma [*7*]; Verschueren [*8*]; Yalkowsky [*9*]; and Yaws [*10, 11*] were utilized to a great extent. The publications were screened, and copies of appropriate data were made. These data were then keyed-in to the computer, to provide

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SAMPLE CALCULATIONS

Example 1. A chemical spill of 2-chlorobutane (C_4H_9Cl) occurs into a body of water at ambient conditions (25°C, 1 atm). Estimate the concentration of 2-chlorobutane in the water at saturation.

Substitution of the coefficients and boiling point temperature into the correlation equation yields:

$\log_{10}(S) = A + BT_B + CT_B^2 + DT_B^3$
$= -7.4500 + (1.0050\text{E}{-01})\cdot(341.25) + (-2.7288\text{E}{-04})\cdot(341.25)^2 + (1.9987\text{E}{-07})\cdot(341.25)^3 = 3.01097$

Solubility = $10^{3.1097}$ = 1,025.6 ppm (wt)

Example 2. A chemical spill of 2-chlorobutane (C_4H_9Cl) occurs into a body of water at ambient conditions (25°C, 1 atm). The concentration in the liquid at the surface of the water is 0.0001 mol fraction (x_i = 0.0001). Estimate the concentration of 2-chlorobutane in the air at the surface of the water.

From thermodynamics at low pressure, the vapor concentration is given by:

$y_i = (H_i/P_t)\cdot x_i$

Substitution of Henry's law constant from the table, total pressure (P_t = 1 atm) and liquid concentration into the above equation provides:

$y_i = (1{,}042.66/1)\cdot(0.0001) = 0.1043$

Percent (mol) = $100y_i$ = 10.43 % (mol)

a database for which experimental data are available. The database also served as a basis for checking the accuracy of the correlation.

The solubility in water versus the boiling-point temperature is presented in Figure 1 for monochlorinated alkanes and aromatic compounds. Inspection of this figure indicates that the water solubility of monochlorinated alkanes is lower than that of aromatics, and that the curve for the monochlorinated alkanes is approximately parallel to the curve for the aromatics. The graph also demonstrates that there is a favorable agreement between the correlation and the experimental data.

Henry's law constants

The results for water solubility and Henry's law constant are presented in Table 1. In that tabulation, the results for the Henry's law constant are based upon the water solubility and vapor pressure at ambient conditions, using the appropriate thermodynamic relationships. The presented values are applicable to a broad variety of chlorinated organic compounds (alkanes, olefins, and aromatics containing chlorine) in water.

The results are presented in an easy-to-use tabular format, which is especially applicable for rapid engineering usage with the personal computer or hand calculator. The tabulation is arranged by carbon number (C1, C2, C3, and so on). This arrangement provides ease of use — the engineer can quickly locate the desired data by use of the chemical formula. ■

Edited by Gerald Ondrey

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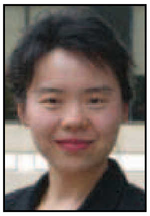

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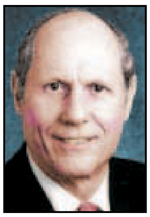

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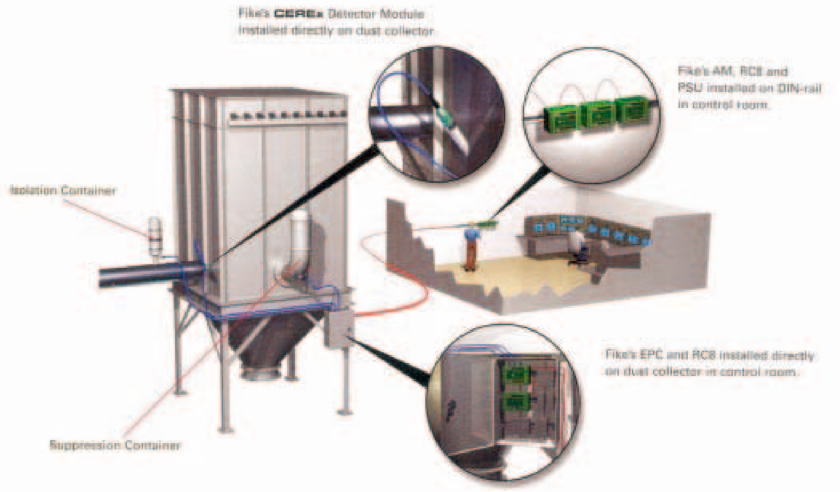

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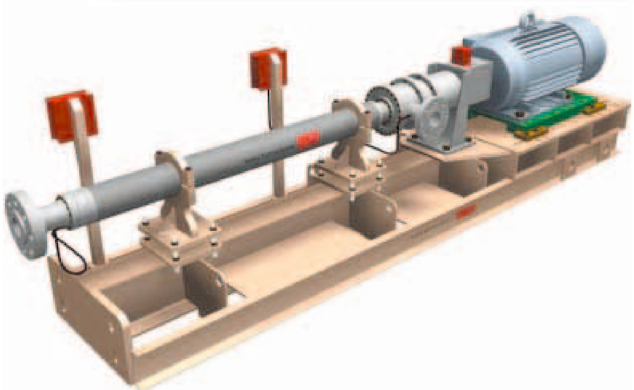

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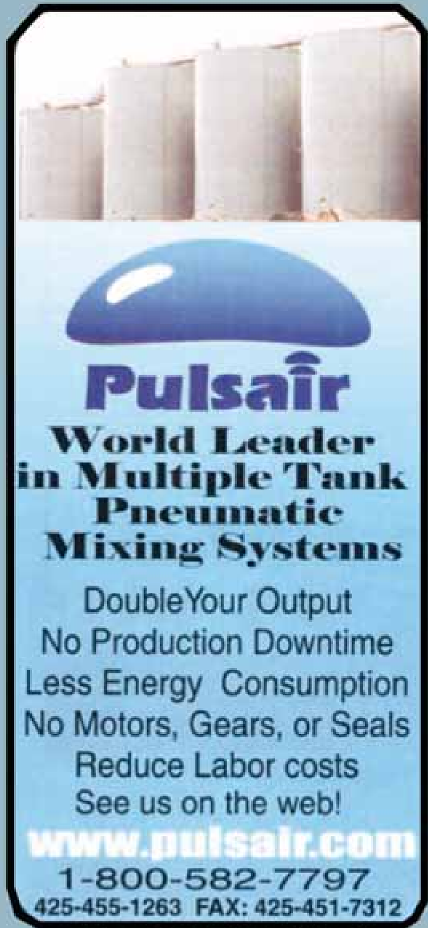
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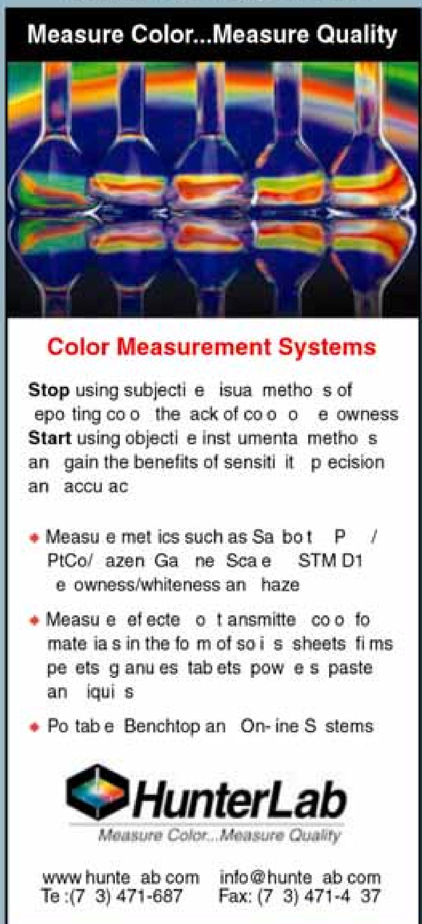
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ORYX GTL Limited (Q.S.C.) / Technip Italy, S.p.A. / USFilter	Ras Laffan Industrial City, Qatar	Liquefied petroleum gas Diesel Naphtha (via gas to liquids)	$900 million; 1,000 bbl/day 24,000 bbl/day 9,000 bbl/day	Late 2005
Johns Manville	Defiance, Ohio	Pipe insulation materials	$100 million	Mid 2006
Basell	Suzhou Industrial Park, China	Polypropylene resins	60,000 tons/yr	Jan. 2005
Great Lakes Chemical Corp.	Indianapolis, Ind.	Penta- and octa-polybrominated diphenyl ether	Voluntairly ceased production in lieu of "greener" alternatives	End of 2004
Shintech, a div. of Shin-Etsu Chemical	U.S. Gulf Coast	Chlorine Caustic soda Vinyl chloride monomer (VCM) Polyvinyl chloride (PVC)	$ 1 billion; 500,000 tons/yr 550,000 tons/yr 1.65 billion lbs/yr 1.3 billion lbs/yr	End 2007
Indian Oil Corp. / Shell Global Solutions / Engineers India	Paradeep, India	Ethylene, ethylene glycol, para-xylene, polyethylene, polypropylene and styrene	$3.5 billion; 1 million m.t./yr	2009
Fujian Petrochemical, ExxonMobil and Saudi Aramco / ABB Lummus Global, Novolen and Sinopec Tech	Quangang, China	Ethylene	570,000 tons/yr	2009
Merck KGaA	Poseung, Korea	Mixed liquid crystals	$10-million expansion	2010
Sitara Peroxide	Faisalabad, Pakistan	Hydrogen peroxide	PRs1 billion ($17 million); 30,000 m.t./yr	1st half or 2006
Shin-Etsu Handotai	Vancouver, Wash.	300-mm-dia. silicon wafers	200,000 wafers/month	2007
Air Liquide / Chicago Bridge & Iron Co.	Bayport, Tex.	Hydrogen	100 million ft^3/day	Summer 2006
M&G Group	Ipojuca, Brazil	Polyethylene terephthalate bottle resins	$150 million; 450,000 m.t./yr	End 2006

MERGERS, ACQUISITIONS AND DEALS			
Buyer	**Other party**	**Date**	**Details**
JPMorgan Partners (New York)	**PQ Corp.** (Valley Forge, Pa.)	Dec. 17	JPMorgan Partners, has reached a deal to acquire privately held PQ Corp. PQ has a leading 25%-30% share of the 1.2-million m.t./year sodium silicate market in the U.S., and has a silicates presence in Europe. It has previously announced plans to build a 40,000-m.t./year sodium silicate plant at Tianjin, China, to start up in first-quarter 2005. Terms of the deal, which is subject to approval by PQ's shareholders, were not disclosed
Sigma Aldrich Fine Chemicals (SAFC) (St. Louis, Mo.)	**CSL Ltd.** (Parkville, Australia) and **JRH Biosciences** (Lenexa, Kan.)	Jan. 18	Sigma Aldrich Fine Chemicals says it has signed a deal to acquire JRH Biosciences, a division of human plasma products, pharmaceuticals, and vaccines company CSL Ltd. (Parkville, Australia), for $370 million in cash. JRH manufactures therapeutic proteins and serum products for the biopharmaceuticals sector
Solvay Pharmaceuticals (Brussels)	**Neopharma AB** (Uppsala, Sweden)	Jan. 21	Solvay Pharmaceuticals has acquired Neopharma AB, as shareholders representing 100% of the company's capital accepted the friendly takeover bid launched by Solvay last December. This acquisition, which values Neopharma at SEK 640 million (€71 million), allows Solvay to add the product Duodopa, a new therapy for people suffering from advanced Parkinson's disease, to its product portfolio
Black & Veatch Corp. (Overland Park, Kan.)	**R.J. Rudden Associates, Inc.** (Hauppauge, N.Y.) and **Lukens Energy Group, Inc.** (Houston, Tex.)	Jan. 17	Black & Veatch Corp. has acquired R.J. Rudden Associates, Inc., an economic and management consulting company specializing in the electric utility industry, and Lukens Energy Group, Inc., a management consulting group serving senior management in the oil and gas industry in strategy, risk mitigation, valuation and regulatory matters. Black & Veatch's strategy in acquiring the firms is to strengthen its financial and business solutions toclients in the energy and water industries. Both organizations will be integrated into Black & Veatch's Enterprise Management Solutions organization, which was formerly known as Enterprise Consulting
Petrochem Carless (Leatherhead, U.K.)		Jan. 20	Petrochem Carless, one of the largest independent petrochemical manufacturers in Europe, has been acquired by its management team in a deal that raised £32 million in new funds. Petrochem Carless was formed in December 2000 following the merger of Petrochem UK Ltd and Carless Refining and Marketing Ltd. Petrochem Carless supplies high performance speciality hydrocarbons, advanced automotive fluids and speciality chemicals, including automotive coolants and hydrocarbon solvents
Honeywell Process Solutions, Inc. (Phoenix, Ariz.)	**Yokogawa Corp. of America** (Newnan, Ga.)	Jan. 20	Yokogawa has joined Honeywell's PKS Advantage Program, a collaborative effort allowing third-party vendors to integrate their products with Honeywell's Experion Process Knowledge System (PKS). As part of the program, Yokogawa will include its digital YEWFLO vortex flowmeters, EJX pressure transmitters, YVP valve positioners and ValveNavi software. Product integration will begin in the first quarter of 2005

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Economic Indicators

2003 2004

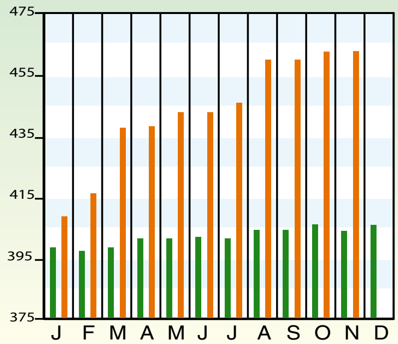
DOWNLOAD THE *CEPCI* TWO WEEKS SOONER AT **WWW.CHE.COM/PINDEX**

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Oct. '04 Final	Nov. '04 Prelim.	Nov. '03 Final
***CE* INDEX**	462.4	462.5	403.8
Equipment	533.8	535.1	447.2
Heat exchangers & tanks	507.9	510.8	372.5
Process machinery	508.9	511.6	439.5
Pipe, valves & fittings	607.7	606.8	576.7
Process instruments	377.0	378.7	339.8
Pumps & compressors	722.5	724.2	708.6
Electrical equipment	355.4	356.1	342.5
Structural supports & misc	584.6	582.5	441.3
Construction labor	311.4	308.4	310.4
Buildings	438.7	437.3	408.5
Engineering & supervision	346.4	345.4	346.0

Annual Index

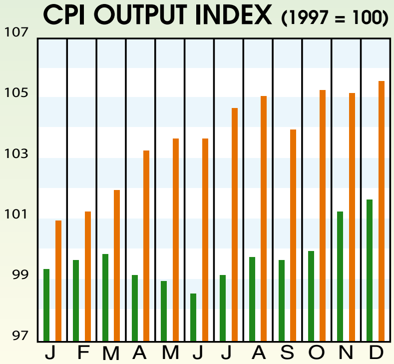
1996 = 381.7
1997 = 386.5
1998 = 389.5
1999 = 390.6
2000 = 394.1
2001 = 394.3
2002 = 395.6
2003 = 402.0



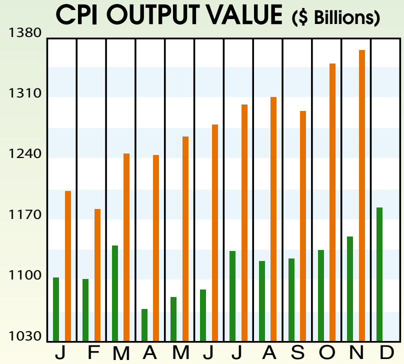
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS				YEAR AGO	
CPI output index (1997 = 100)*	Dec.'04	= 105.6	Nov.'04	= 105.2	Oct.'04	= 105.3	Dec.'03	= 101.7
CPI value of output, $ billions	Nov.'04	= 1,366.7	Oct.'04	= 1,350.9	Sep.'04	= 1,296.5	Nov.'03	= 1,151.7
CPI operating rate, %	Dec.'04	= 81.2	Nov.'04	= 80.8	Oct.'04	= 80.9	Dec.'03	= 78.6
Construction cost index (1967 = 100)	Jan.'05	= 679.3	Dec.'04	= 680.4	Nov.'04	= 680.7	Jan.'04	= 635.4
Producer prices, industrial chemicals (1982 = 100)	Dec.'04	= 177.3	Nov.'04	= 177.9	Oct.'04	= 174.6	Dec.'03	= 143.1
Index of industrial activity (1992 = 100)	Jan. 1,'05	= 238.4	Dec. 25,'04	= 236.6	Dec. 18,'04	= 234.5	Jan. 3,'04	= 213.0
Hourly earnings index, chemical & allied products (1992 = 100	Dec.'04	= 144.2	Nov.'04	= 142.1	Oct.'04	= 142.1	Dec.'03	= 137.2
Productivity index, chemicals & allied products (1992 = 100)	Dec.'04	= 128.3	Nov.'04	= 128.6	Oct.'04	= 127.9	Dec.'03	= 123.9

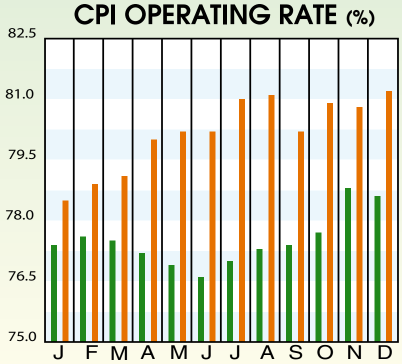
CPI OUTPUT INDEX (1997 = 100)



CPI OUTPUT VALUE ($ Billions)



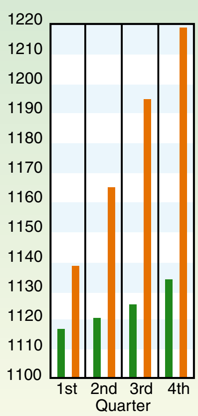
CPI OPERATING RATE (%)



*To convert to 1992, multiply by 1.1514684. To convert to 1987, multiply by 1.2495478. For an explanation and additional information, call 212-621-4612. Current business indicators provided by DRI-WEFA, Lexington, Mass.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	4th Q 2004	3rd Q 2004	4th Q 2003
M & S INDEX	1,218.0	1,194.0	1,133.2
Process industries, average	1,245.4	1,218.9	1,153.6
Cement	1,244.1	1,214.6	1,144.8
Chemicals	1,224.4	1,197.6	1,132.8
Clay products	1228.7	1,202.1	1,141.0
Glass	1,152.6	1,126.9	1,060.6
Paint	1,254.0	1,227.2	1,158.0
Paper	1,195.6	1,169.4	1,103.1
Petroleum products	1,301.8	1,274.8	1,207.6
Rubber	1,312.9	1,289.5	1,230.1
Related industries			
Electrical power	1,118.8	1,091.3	1,018.5
Mining, milling	1,277.0	1,250.1	1,178.3
Refrigeration	1,464.8	1,436.6	1,362.7
Steam power	1,197.2	1,169.8	1,101.3



Annual Index

1998 = 1,061.9	2000 = 1,089.0	2002 = 1,104.2
1999 = 1,068.3	2001 = 1,093.9	2003 = 1,123.6

VATAVUK AIR POLLUTION CONTROL COST INDEXES (VAPCCI)

(1st Quarter 1994 = 100.0)

CONTROL DEVICE[3]	2001 Avg.	2002 Avg.	2003 Avg.[1]	2nd Q 2004	3rd Q 2004[2]	4th Q 2004[2]
Carbon adsorbers	105.9	106.8	113.0	134.3	141.5	145.3
Catalytic incinerators	112.9	114.5	124.0	146.6	151.5	157.8
Electrostatic precipitators	98.5	101.7	102.9	122.5	128.6	133.6
Flares	100.8	101.7	105.2	131.6	142.5	147.7
Gas absorbers	114.4	115.6	117.3	120.9	122.9	124.6
Refrigeration systems	105.8	106.6	108.8	118.7	122.6	124.8
Regenerative thermal oxidizers	110.7	111.9	113.9	123.1	126.4	128.6
Thermal incinerators	107.9	108.6	110.0	121.1	125.2	127.7
Wet scrubbers	111.8	113.2	120.1	141.8	149.7	154.4

1. Effective fourth quarter 2003, the Bureau of Labor Statistics (BLS) converted all of the Producer Price Indexes (PPI's) from the Standard Industrial Classification (SIC) to the North American Industrial Classification System (NAICS). During this conversion, many PPI's were abolished — among them most of the PPI's that had been key inputs to the VAPCCI's. As a consequence, substitute PPI inputs had t be found. The VAPCCI's for fourth quarter 2003 and subsequent quarters reflect these substitutions.
2. All third and fourth quarter 2004 indexes are *preliminary*.
3. Effective second quarter 2001, the BLS abolished the Producer Price Indexes (PPI's) for fabric filters and mechanical collectors. As the VAPCCI's for these two control devices were, essentially, their PPI's, the VAPCCI's can no longer be reported.

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