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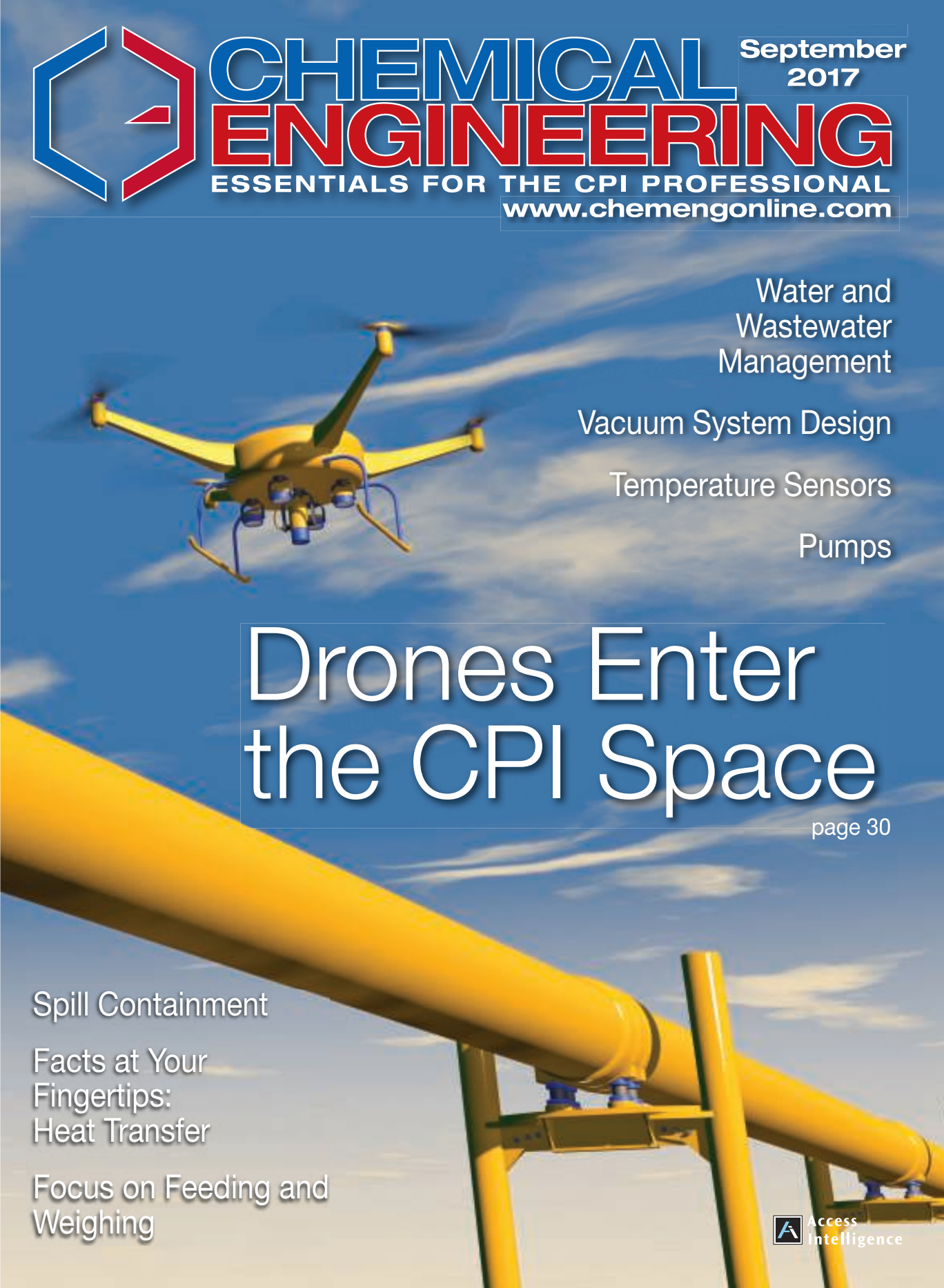

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In the News

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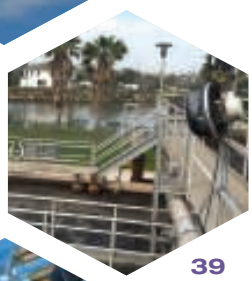

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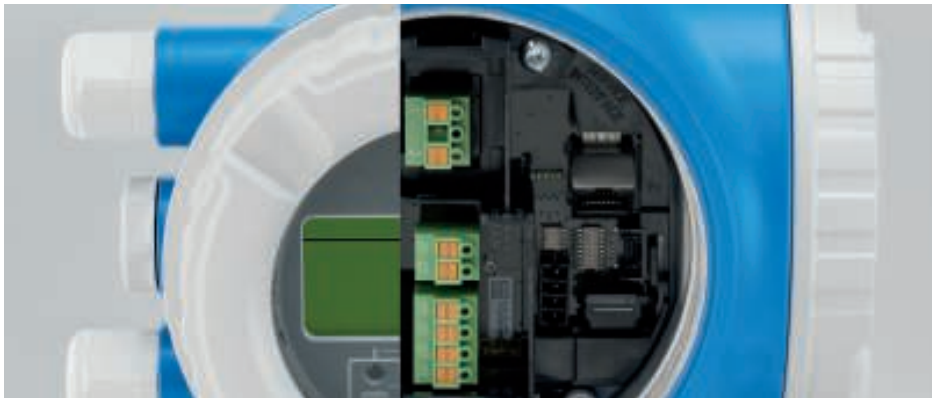

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BPA

Editor's Page

Scientists as celebrities

I recently saw a television commercial that caught my attention and provided "food for thought." The ad begins with a young girl opening a birthday gift, and is delighted when she sees that it is a Millie Dresselhaus doll. A voice asks, "What if we treated great female scientists like they were stars?" and "What if Millie Dresselhaus . . . were as famous as any celebrity?" The commercial thoughtfully places a scientist, Mildred Dresselhaus, in scenes that are common for a celebrity, but quite foreign for a scientist. Images in the ad include a student sending a text that says "Aced physics!!" and includes Millie Dresselhaus emojis; children dressed up as Millie Dresselhaus for Halloween; tourists taking pictures of a Millie Dresselhaus wall mural; the front page of the New York Post featuring a picture of Millie Dresselhaus and a headline of "Physics or Chemistry?"

When I first saw this commercial, I did not know who Mildred Dresselhaus was, and it gave me reason to pause and think about celebrity and where our society places its celebrity emphasis. Most, if not all of us can probably quickly name many famous sports legends, actors and musicians. How many famous scientists can we quickly name? And how many of those would be female scientists? The ad brings attention to scientists, and in particular to women in science. Its sponsor goes on to mention that the company's goal is to have 20,000 women in technical roles by 2020 [*1*]. Such goals and publicity can help to gain more much-needed interest in STEM (science, technology, engineering and math) careers, especially among our youth. I would welcome seeing more ads that put scientists and engineers in the spotlight.

About Mildred Dresselhaus

Mildred Dresselhaus was born in 1930 and grew up in the Bronx, N.Y. She expected to become a school teacher, which she says was one of the three career paths that were open to women at the time (the other two were secretarial and nursing work). In college, however, she was inspired by Rosalyn Yarrow, who encouraged her to study physics. Dresselhaus went on to become the first woman at the Massachusetts Institute of Technology (MIT) to attain the rank of full, tenured professor, and the first woman to win the National Medal of Science in Engineering in 1990. She was a member of the MIT faculty for 50 years and was particularly known for her work on nanomaterials and graphene. She passed away in February of this year, just weeks after the video in the commercial described above was released [*2,3*].

Her mentor, Rosalyn Yarrow, was a nuclear physicist who won the Nobel Prize (one half of the award) in Physiology or Medicine in 1977 for the development of radioimmunoassays of peptide hormones. Her work opened the door to enable the measurement of low levels of various substances, such as insulin, in the body [*4*].

In this issue

This issue covers a wide variety of topics, including our cover story, which highlights the ways that drones are finding new applications in the chemical process industries (CPI); advances in temperature measurement; features on water and wastewater, and on pumps; and much more. We hope you enjoy reading. ■

Dorothy Lozowski, Editorial Director

1.Television commercial by General Electric; www.youtube.com/watch?v=sQ6_fOX7ITQ.
2.www.nationalmedals.org - accessed 8/7/2017.
3.news.mit.edu/2017/institute-professor-emerita-mildred-dresselhaus-dies-86-0221– accessed 8/7/2017.
4. www.nobelprize.org/nobel_prizes/medicine/laureates/1977.

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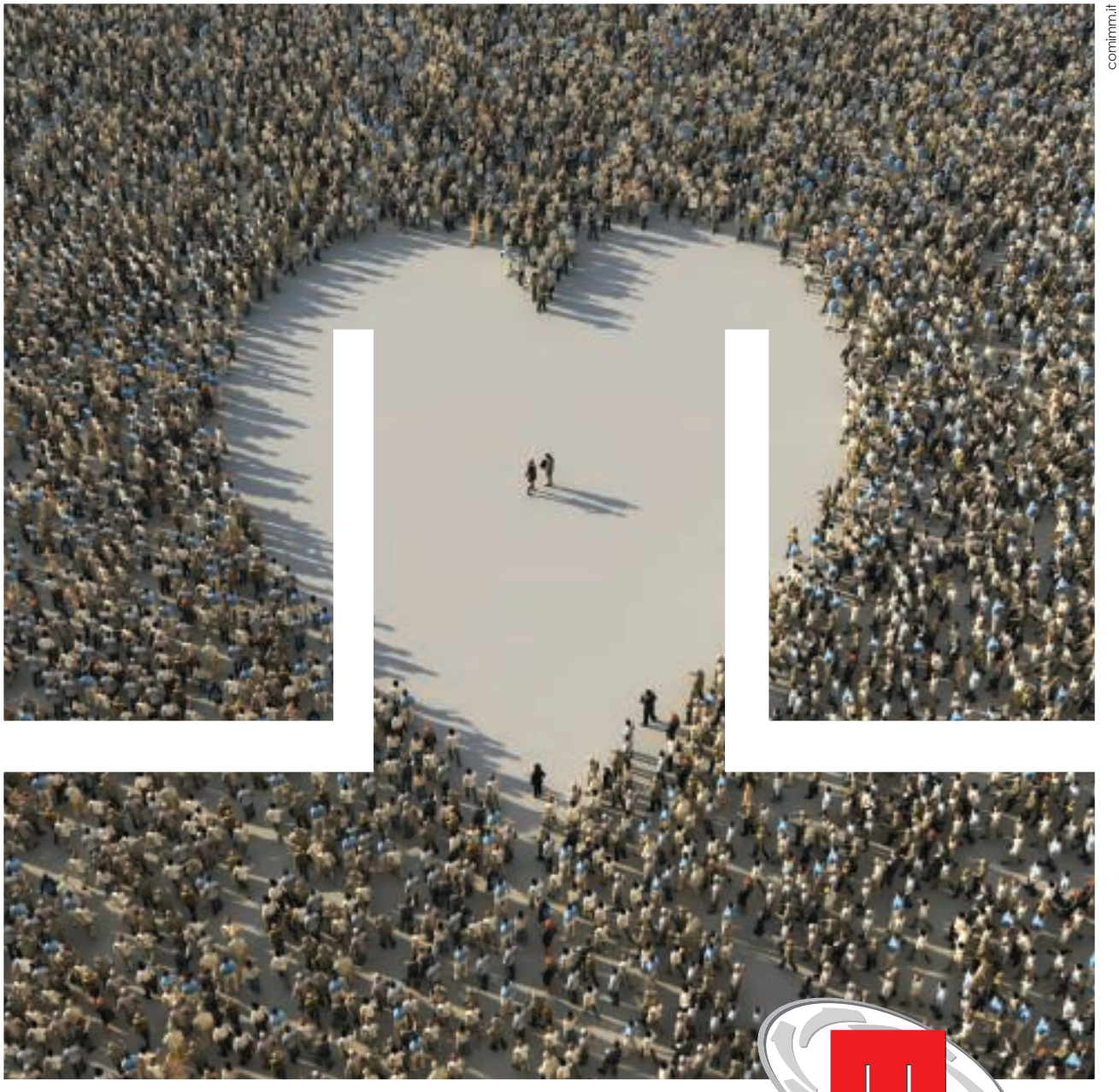

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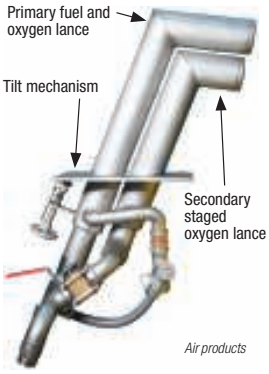
Oxy-fuel burner restores air-fuel regenerative furnaces to full production

Engineers at Air Products (Lehigh Valley, Pa.; www.airproducts.com) have commercialized an improved version of the company's Cleanfire ThruPort oxy-fuel burner for avoiding downtime during repairs and extending the lifetime of air-fuel regenerative furnaces in glass-making plants.



The company's original Cleanfire ThruPort burner was designed to introduce oxy-fuel combustion (using pure oxygen as the oxidant, rather than air) in air-fuel-fired regenerative glass-melting furnaces. The water-cooled ThruPort burners have a unique design (photo) in which two "nested" lances deliver oxy-fuel (top lance) and staged oxygen (bottom lance) are controlled by a mechanism to control the proportion of oxygen between the two.

"By separating (staging) a portion of the oxygen away from the main oxy-fuel flame, we can control the rate of mixing between fuel and oxygen in the flame," says Mark D'Agostini, senior research associate at Air Products. "This leads to flame lengths that can be optimally tailored to the width of the furnace combustion space, and is also a mechanism for reducing NOx emissions."

The recently commercialized ThruPort$_e$ version has design improvements that include a means of adjusting the trajectory of the flame relative to the glass surface and optimal wireless diagnostic sensors that provide realtime status of key burner operating variables, such as oxygen and fuel pressures, burner metal temperature, cooling water flowrate and temperature, and proportion of oxygen delivered to the second (staging) lance.

The ability of the ThruPort$_e$ burner to tailor the flame length and trajectory, remotely monitor key burner performance variables, and be installed rapidly during furnace operation enables glass manufacturers to avoid downtime during repairs and extend the life of aging furnaces. A version of the burner was recently installed at two North American float-glass plants. Air Products reports restoration of full function and improved energy efficiency in both cases.

Magnetized viruses attack challenging bacteria in water-treatment systems

Biofilms in water-treatment systems may harbor problematic bacteria and pathogens since chemical disinfectants typically do not penetrate the biofilm. Now, a new treatment approach developed in the laboratory of Pedro Alvarez at Rice University (Houston; www.rice.edu) could enable the controlled penetration of biofilms to attack harmful, difficult-to-treat bacteria. The Rice team is using bacteriophages (viruses that kill bacteria) that have been attached to specially designed magnetized nanoclusters. In the presence of a weak magnetic field, the nanoclusters can be guided through a biofilm, where the attached phages can infect the targeted bacteria. Variations in strength and duration of the magnetic field can control penetration depth, and horizontal migration is driven by moving the magnet in a particular direction.

The configuration of the phage-nanocluster complex is paramount to ensure its effectiveness in attacking bacteria. First, the orientation of the phage is crucial — the phage must attach to the nanocluster at its head so that the tail fibers that initiate infection are exposed, explains Alvarez. The surface chemistry of the nanoclusters is also quite important. Consisting of iron oxide, sulfur and carbon, the nanoclusters were also affixed with amino groups to form amide bonds with the carboxylic groups of the phage heads. "Accordingly, we wanted to have a high density of amino functional groups on the particle surface to obtain a high loading of phages with the proper orientation," says Alvarez.

Since production of phages and iron oxides is relatively inexpensive, Alvarez sees potential for large-scale application of this technology in such applications as mitigation of microbially induced corrosion, biofilm removal from cooling towers and biofouling control in water-filtration membranes. The concept has been demonstrated at bench-scale, and the team is seeking partnerships with technology developers to accelerate commercialization.

Edited by:
Gerald Ondrey

POLYESTERS

Customizing the macroscale properties of polyesters by using sidechain chemical groups is difficult, and is limited for commercially available polyesters. Now, researchers at Virginia Tech (Blacksburg, Va.; www.vt.edu) have developed a novel method for synthesizing polyesters that may expand the range of available properties for polyesters. The Virginia Tech team's chemistry, known as photoredox ring-opening polymerization, has the potential to synthesize polyesters with highly controlled stereochemistry and narrow molecular weight distributions. Further, a wide range of sidechains can be introduced, allowing the polyesters to be used in applications such as plastic engineering and biomedical drug delivery systems.

The chemistry begins with *O*-carboxyanhydrides, five-membered rings with attached functional groups. Using a photoredox nickel-iridium catalyst combined with a zinc-alkoxide, the carboxyanhydrides undergo a ring-opening polymerization reaction, forming a polymer backbone that contains the desired sidechain.

LITHIUM RECOVERY

Last month, MGX Minerals Inc. (Vancouver, B.C., Canada; www.mgxminerals.com) said its engineering partner, PurLucid Treatment Solutions (www.purlucid.com) started operational testing on the Li-1 lithium-recovery unit at its testing facility in Calgary, Alberta. The Li-1 pilot plant can process 20 m^3/d and will be expanded to increase throughput to 100 m^3/d. The pilot plant separates impurities from oil-and-gas wastewater, allowing for lithium and magnesium extraction, as

(Continues on p. 8)

well as reuse and repurpose of industrial water and brine.

"This system represents the physical and operational templates that move us from bench scale to the field and provide the engineering basis for the large commercial systems (>1,500 m^3/d) we expect to deploy into MGX's property and partner base," says Jared Lazerson CEO of MGX Minerals.

Concurrently with pilot plant testing, fabrication of a commercial-scale system capable of processing 200 m^3/d is underway and is expected to be ready for deployment in fourth quarter 2017. Based on results of pilot plant testing, the company plans to ship commercial-scale systems to sites in the U.S. and Canada beginning in the first quarter of 2018.

URANIUM COMPLEX

Researchers from the École Polytechnique Fédérale de Lausanne (EPFL; Switzerland; www.epfl.ch) have developed a uranium-based complex that can allow nitrogen fixation reactions to take place in ambient conditions. The work, published recently in *Nature*, forms a basis for the development of more efficient catalysts, while it highlights new concepts that can be expanded to metals beyond uranium.

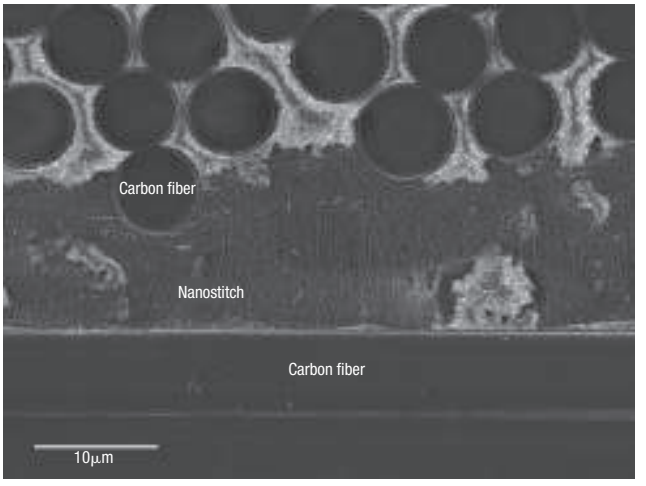
The laboratory of professor Marinella Mazzanti synthesized a complex containing two uranium(III) ions and three potassium centers, held together by a nitride group and a flexible metalloligand framework. This system can bind nitrogen and split it in two under ambient, mild conditions by adding hydrogen or protons (or both) or carbon monoxide to the resulting nitrogen complex. As a result, the molecular nitrogen is cleaved, and bonds naturally with hydrogen and carbon.

The study proves that a molecular uranium complex can transform molecular nitrogen into value-added compounds without the need for the harsh conditions of the Haber-Bosch process, used for over a century to make ammonia. It

(Continues on p. 11)

Carbon nanotube technology toughens carbon-fiber composite materials

N12 Technologies



Under mechanical stress, carbon-reinforced epoxy-resin composite materials can experience cracking and de-lamination at the junctures between layers of material, where the composites are resin-rich. Placing vertically aligned carbon nanotubes (VACNTs) into the inter-laminar regions can toughen the composite and prevent cracking between layers.

N12 Technologies Inc. (Cambridge, Mass.; www.n12technologies.com) has developed the world's first commercially viable manufacturing process for introducing VACNTs into the inter-laminar region of carbon-fiber composites. Known as NanoStitch, the technology transfers VACNTs into the inter-laminar regions of the composites, binding the plies of composite material together and preventing cracking and de-lamination.

The VACNTs look like nanoscale forests, where trillions of precisely aligned nanotubes (photo) are oriented perpendicular to the plane in which the layers of carbon-fiber epoxy composites are being assembled, explains Paul Jarosz, director of science and technology at N12. Introducing VACNTs to the interlaminar region increases shear strength and toughness of the composite material, while adding no weight or thickness. Also, composites with NanoStitch conduct heat and electricity between layers better than conventional composites, allowing functional materials, N12 says.

N12 licensed the NanoStitch technology from the academic laboratory of Brian Wardle at the Massachusetts Institute of Technology (MIT; Cambridge, Mass.; www.mit.edu). N12 has since increased the production rate of the VACNT-strengthened carbon fibers by several orders of magnitude, allowing customers to test the NanoStitch composites. NanoStitch is compatible with industry standard manufacturing methods for composites, the company says.

Now, N12 is working with partners, including the University of Dayton Research Institute (UDRI; Ohio; www.udri.udayton.edu), to further scale up the production process by another "several orders of magnitude," says Jarosz.

Ammonia as a H_2-carrier enabled by a catalytic membrane

A major challenge in using hydrogen to power motor vehicles is the difficulty in transporting H_2 to refueling stations. Researchers at CSIRO Energy (Melbourne, Australia; www.csiro.au/energy) have responded to the challenge by converting H_2 to NH_3 and then using existing transport infrastructure. NH_3 is well suited for use as a H_2 carrier, because it is a liquid at moderate pressures and temperatures and has a volumetric hydrogen density about 45% higher than liquid H_2. The efficiency and cost benefits of using NH_3 as a hydrogen carrier increase with the distance between production and utilization.

CSIRO achieves the conversion of NH_3 back to high-purity H_2 at, or near, the point of use, by means of a catalytic membrane that allows hydrogen to pass through while blocking all other gases. Coupling membranes with a suitable catalyst for NH_3 decomposition allows efficient extraction of pure H_2 from NH_3. The membrane is a vanadium-based alloy, and is said to deliver pure H_2 at a far lower cost than the competing palladium-based membrane technology.

CSIRO is working on a two-year project to demonstrate its H_2-production system, to deliver at least 5 kg/d of H_2, directly from ammonia. The project is being being supported by BOC, Hyundai, Toyota and Renewable Hydrogen Pty Ltd.

This portable device offers a quick check of produce

A micro portable pesticide detector for food analysis, called a Handheld Pesticide Residue Detector, has been developed by the Smart Microsystems Technology Center of the Industrial Technology Research Institute (ITRI, Hsinchu City, Taiwan; www.itri.org.tw).

The detector is based on the absorption spectrum of chemical products, such as agricultural pesticides, and can indicate the level of pesticide residues in fruits and vegetables within a few seconds. The device also features Bluetooth — a wireless technology standard for exchanging data over short distances from fixed and mobile devices — and a wireless charger. Lamps on the wireless charger indicate the testing results. A red light indicates that pesticide levels seriously exceed standards, and that the fruits and vegetables should be vigorously washed before consumption. A yellow light means that there is also a high level of pesticides, but not as high as that shown by a red light. A green light means the amount of pesticide residue is either small or nonexistent and the item is safe to consume.

ITRI says the detector already addresses eight of the ten most widely used water-soluble pesticides in Taiwan. If used in conjunction with specialized fruit and vegetable cleaners, the detector can also be used to detect fat-soluble pesticides at levels up to 0.5 parts per million (ppm), and will indicate when cleansing is complete.

Since pesticide use varies among countries, future versions of the detector will be tailored to the needs of various markets, indicating the level of the pesticides commonly used in any particular country.

Bioethanol from bagasse

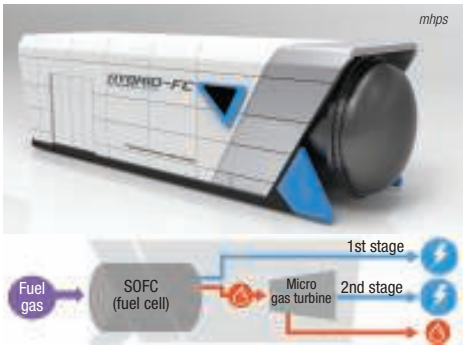
Tsukishima Kikai Co. (www.tsk-g.co.jp) and JFE Engineering Corp. (both Tokyo, Japan; www.jfe-eng.co.jp) have demonstrated a process that produces bioethanol from bagasse, a waste product in the production of sugar from sugarcane. With support from NEDO under a four-year, $10-million project, the companies constructed a plant in Saraburi, Thailand, that is capable of processing 1,300 ton/yr of bagasse into 100,000 L/yr of ethanol. A key feature of the facility is that the enzymes used for breaking down the bagasse into fermentable sugars — *Acremonium cellulolyticus* C-1 — is produced on site, which considerably reduces enzyme costs (by one fifth). Normally, commercial supply of enzymes accounts for 25–50% of the production costs of a cellulosic ethanol plant. Tsukishima Kikai and the National Institute of Advanced Industrial Science and Technology (AIST; Tsukuba City, Japan; www.aist.go.jp) developed the process for producing the enzyme with bacteria cultures.

Although 60–80% of the bagasse supply has been used by sugar plants as boiler fuel, the remaining bagasse has typically been disposed of as excess stock without being used effectively. The NEDO project demonstrates the effectiveness of the on-site enzyme-production technology and simultaneous saccharification and fermentation (SSF) technology to utilize the excess bagasse.

A hybrid power system combines SOFC and a gas turbine . . .

Last month, Mitsubishi Hitachi Power Systems, Ltd. (MHPS; Yokohama, Japan; www.mhps.com) launched a new, pressurized, hybrid power-generation system (photo) that integrates solid-oxide fuel cell (SOFC) stacks with micro gas turbines (MGT). The hybrid system (diagram) has a broad range of commercial and industrial applications, and is especially suitable for distributed or cogeneration power systems, says the company.

SOFCs are ceramic fuel cells that operate at a high temperature of 900°C. In a pressurized hybrid system, power is generated directly by chemical reaction between O_2 in the air and H_2 and CO extracted from reformed city gas; residual fuel is then used to drive an MGT. This two-stage system achieves significantly higher power generation efficiency and, as a result, saves substantial energy. Air pressurized in the MGT's compressor is supplied to the SOFCs for use in generating power, and then high-temperature exhaust is fed to the MGT and the heat and pressure, together with the residual fuel, are used to generate power. The pressurized SOFCs, having substantially increased voltage as a result of pressurization, lead to enhanced power generation efficiency, says the company.



The demonstration system is in the 250-kW class, and delivers generation efficiency of 55%. It is a follow-up to the prototype (Model 15) system that has been undergoing demonstration testing at Kyushu University since spring 2015. The system was developed with support of the New Energy and Industrial Technology Development Organization (NEDO; Kawasaki, Japan; www.nedo.go.jp).

... and a very efficient SOFC

Meanwhile, Hitachi Zosen Corp. (HITZ, Osaka and Tokyo, Japan; www.hitachizosen.co.jp) has installed a solid-oxide fuel cell (SOFC) demonstration unit at Osaka Research Institute of Industrial Science and Technology, Izumi Center (Orist; Osaka, http://orist.jp), and has been performing tests since June. The SOFC has achieved a total efficiency of 90% (50% electrical, 40% thermal), which is said to be the highest level obtained thus far. Researchers say the unit has undergone 4,000 hours of continuous operation under actual load conditions.

The unit is part of a three-year project — supported by the NEDO — that is scheduled for completion in November. HITZ plans to start marketing SOFCs with capacities of 20 to several hundred kilowatts for power generation of stores, office buildings and apartment buildings in the 2017 fiscal year, after surveying the market volumes and economic feasibility. The company says the technology is also suitable for truck-loaded emergency power generation during disasters.

The HITZ SOFC technology also uses H_2 fuel obtained by reforming city gas.

Winning iron and titanium while making vanadium electrolyte

VanadiumCorp Resource Inc. (Vancouver, B.C., Canada; www.vanadiumcorp.com) has achieved direct and consistent recovery of vanadium electrolyte, vanadium oxides and titanium from vanadiferous titanomagnetite (VTM; vanadium-rich $Fe_{3-x}Ti_xO_4$) using hydroelectricity, from the company's Lac Dore Vanadium Project in Quebec. The company has partnered with Electrochem Technologies & Materials (Montreal, Que., Canada; www.electrochem-technologies.com) for the development of technologies to obtain high-performance vanadium electrolyte for energy storage applications.

VanadiumCorp has also successfully recovered high-purity electrolytic iron directly from VTM concentrate from drill core from its La Dore Vanadium Project using conventional milling and magnetic separation.

The company's president and CEO, Adriaan Bakker, says the technology was developed keeping in mind that in addition to vanadium, both iron and titanium also have high value. Currently available technology was not able to recover all three metals while producing high-purity iron.

Conventional pyrometallurgical processes use either direct soda-ash roasting of the magnetite followed by water leaching, or arc smelting and slagging of the magnetite followed by soda ash roasting of the vanadium-rich slag. However, smelting and roasting are capital and energy intensive, and emit greenhouse gases.

Hydrometallurgical processes for extracting vanadium have been proposed, but have failed to be robust. Also, they do not produce iron and do not allow for acid recycling.

The VanadiumCorp-Electrochem technology addresses those issues — it is emissions-free and with low energy consumption — and allows full recovery of vanadium chemicals used for preparing VanadiumCorp electrolyte as well as the concurrent production of a high-quality iron coproduct.

The company initially grinds the feedstock to 40 µm. The material is then placed in a tank with sulfuric acid and dissolved by adding water. The VTM concentrate is converted into copperas crystal ($FeSO_4 \cdot 6H_2O$). The vast majority of impurities drop to the bottom. High-purity iron is then recovered by electrowinning, while vanadium remains in solution and TiO_2 is left as marketable residue. The company plans to expand its process with additional feedstocks to reach one metric ton per month nameplate capacity.

Dual-functioning MOFs maintain a comfortable room humidity

Researchers from the King Abdullah University of Science and Technology (KAUST; Thuwal, Saudi Arabia; www.kaust.edu.sa) have developed a metal-organic framework (MOF) material that can regulate the humidity levels within the "window" established by the American Society of Heating, Refrigeration and Air Conditioning Engineers. The materials may also find applications controlling the humidity in control rooms, aircraft cabins or other enclosed spaces.

Mohamed Eddaoudi and his team in the Advanced Membranes and Porous Materials Center assembled water-stable Y-shp-MOF-5, which is a highly connected MOF in which rare earth-metal-based clusters are connected by 12 organic linkers.

This material was found to selectively adsorb water, depending on the relative humidity (RH). When the RH exceeds 55%, the water adsorption increases dramatically, thereby reducing the humidity in the room. If the RH falls below 45%, the absorbed water is released. As a result, the MOFs can autonomously maintain the RH at the comfortable range of 45–65%, say the researchers. The material was shown to retain this behavior after more than 1,000 adsorption-desorption cycles.

The presence of the high proportion of organic (hydrophobic) linkers are thought to be responsible for the MOFs' low water adsorption at low RH. "Only at higher water-vapor pressure is the hydrophobicity overcome, as water molecules form rapidly growing clusters within the MOF's pores, says Abdul Halim, one of Eddaoudi's doctoral students.

Eddaoudi says the team is pursuing the development of new MOFs with similar adsorption-desorption properties, but with superior water-uptake capacity. The details of the research are reported in a recent issue of the *J. of the Am. Chem. Soc.* ■

also opens the door for the synthesis of nitrogen compounds beyond ammonia, and forms the basis for developing catalytic processes for the production of nitrogen-containing organic molecules from molecular nitrogen.

WIRELESS CHARGING

Blue Inductive GmbH (Freiburg, Germany; www.blue-inductive.de) has recently received Series Seed financing to accelerate the market launch of its wireless power systems to market. The seed investment was led by a consortium, consisting of Phoenix Contact Innovation Ventures, High-Tech Gruenderfonds, MBG Mittelstaendische Beteiligungsgesellschaft Baden-Wuerttemberg and VC Fonds Baden-Wuerttemberg, as well as a Business Angel and the founders.

Founded in 2016 by former scientists of Fraunhofer Institute ISE in Freiburg, the team at Blue Inductive develops wireless charging systems for industrial applications, such as mobile robots, automated guides vehicles or electric forklifts. The technology is based on the principle of magnetic induction and includes several innovations of circuit topology, control strategy and coil design. The so-called etaLink technology allows super-fast charging with high power and efficiency with compact, lightweight and bi-directional hardware. The company is expected to launch its first commercial product in the short-term. ❑

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- WANHUA CHEMICAL
- YOKOGAWA

Plant Watch

$8-billion phosphate megaproject starts up in Saudi Arabia

August 11, 2017 — Fluor Corp. (Irving, Tex.; www.fluor.com) announced that the Ma'aden Wa'ad Al-Shamal Phosphate Co.'s Umm Wu'al Phosphate Project in Saudi Arabia has started production. Fluor is providing overall program-management services for this $8-billion megaproject, which will deliver 3 million metric tons per year (m.t./yr) of diammonium phosphate and nitrogen, as well as phosphorus and potash fertilizers.

Ineos Styrolution to increase compounding capacity in India

August 10, 2017 — Ineos Styrolution (Frankfurt am Main, Germany; www.ineos-styrolution.com) plans to increase its compounding capacity for engineering plastics by an additional 34,000 m.t./yr at its Moxi plant in Gujarat, India. Projected for completion in 2019, this expansion will increase Styrolution's compounding capacity to 100,000 m.t./yr at the site. This project will involve an estimated capital expenditure of $20 million.

Fluor awarded EPCM contract for Petronas isononanol plant

August 8, 2017 — Fluor was awarded an engineering, procurement and construction management (EPCM) contract by Petronas Refinery and Petrochemical Corp. (Kuala Lumpur, Malaysia; www.petronas.com) for an isononanol plant located in Pengerang, Johor, Malaysia. The facility will produce 250,000 m.t./yr of isononanol, and startup is expected in 2019.

Mexichem starts up expanded specialty-PVC facility in Marl

August 4, 2017 — Vestolit GmbH, a 100% subsidiary of Mexichem S.A.B. de C.V. (Tlalnepantla, Mexico; www.mexichemcom), has started up a specialty polyvinyl chloride (PVC) capacity expansion in Marl, Germany. With this expansion, Mexichem has installed a new production line with additional drying capacity of 40,000 m.t. for PVC products.

Linde to construct two ASUs for Wanhua Chemical Group in China

July 28, 2017 — The Linde Group (Munich, Germany; www.the-linde-group.com) signed an agreement with isocyante producer Wanhua Chemical Group to expand the supply of gas to Wanhua's Yantai, China operations. Under the agreement, Linde will invest €108 million to build two additional steam-driven air-separation units (ASUs) which are expected to come onstream in 2019, complementing the two existing ASUs.

Ineos to build world-scale cumene plant in Germany

July 28, 2017 — Ineos' (London, U.K.; www.ineos.com) Phenol division is planning to build a world-scale cumene plant in Germany with startup scheduled in 2020. The construction of a new cumene plant will improve the security of raw material supply to Ineos' phenol and acetone plants located in Gladbeck, Germany and Antwerp, Belgium.

Indorama inaugurates fertilizer plant in Nigeria

July 28, 2017 — Indorama Ventures Public Ltd. (Bangkok, Thailand; www.indorama.net) announced the inauguration of a fertilizer plant located in Nigeria, built by Indorama Eleme Fertilizer and Chemicals Ltd. at a cost of $1.5 billion. The plant has a production capacity of 4,000 m.t./d of nitrogenous fertilizers.

Mitsui Chemicals increases global PP processing capabilities

July 26, 2017 — Mitsui Chemicals, Inc. (Tokyo, Japan; www.mitsuichem.com) announced that augmentation has been completed at three of its global polypropylene (PP) compound hubs in the U.S., Mexico and India. In India, the company started up one new production line, followed by two new lines in the U.S. and one new line in Mexico. Together, the expansions raise global production capacity by 50,000 m.t./yr to a total of 1.05 million m.t./yr.

Indorama completes PTA expansion in Rotterdam

July 26, 2017 — Indorama completed the brownfield expansion of its purified terephthalic acid (PTA) plant in Rotterdam, the Netherlands, resulting in an increase in PTA capacity from 380,000 to 700,000 m.t./yr. The Rotterdam facility's PTA is used as a major feedstock of the site's integrated polyethylene terephthalate (PET) production plant.

Mergers & Acquisitions

Airgas to sell refrigerants business for $220 million

August 11, 2017 — Airgas (Radnor, Pa.; www.airgas.com) has signed an agreement with Hudson Technologies, Inc. (Pearl River, N.Y.; www.hudsontech.com) to sell Airgas-Refrigerants, Inc. (ARI), its subsidiary specializing in the distribution, packaging and reclamation of refrigerant gases. The transaction, which is expected to close before the end of 2017, is said to be valued at around $220 million.

CB&I intends to sell its Technology business

August 10, 2017 — CB&I (The Woodlands, Tex.; www.cbi.com) intends to sell the company's

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Technology business. CB&I is aiming to close the transaction by the end of 2017. CB&I's Technology business provides proprietary process licenses, project-development services and aftermarket support primarily for the petrochemical and petroleum-refining industries. The sale is also intended to include the former Engineered Products business, which specializes in equipment modularization, proprietary equipment and engineering services.

Altana acquires packaging and additive manufacturing assets

August 10, 2017 — Altana AG (Wesel, Germany; www.altana.com) has acquired a technology portfolio and research-and-development platform from U.S.-based NuLabel Technologies, Inc. It comprises technologies for additive manufacturing and resealable packaging that use lower quantities of consumable materials. The acquired technologies will be integrated into Altana's Actega North America division.

Showa Denko to acquire silicon-carbide manufacturing assets

August 7, 2017 — By the end of January 2018, Showa Denko K.K. (SDK; Tokyo, Japan; www.sdk.co.jp) will acquire assets concerning the Sublimation-Recrystallization Method for manufacturing silicon carbide (SiC) wafers from Nippon Steel & Sumitomo Metal Corp. (NSSMC) and Nippon Steel & Sumikin Materials Co. (NSMAT).

Tronox to sell Alkali Chemicals business for $1.3 billion

August 3, 2017 — Tronox Ltd. (Stamford, Conn.; www.tronox.com) announced that it has signed a definitive agreement to sell its Alkali Chemicals business to Genesis Energy, L.P. (Houston; www.genesisenergy.com) for $1.325 billion in cash. The transaction is expected to close in the second half of 2017, subject to customary regulatory approvals and closing conditions. Alkali Chemicals is said to be the world's largest producer of natural soda ash, and has mining and processing facilities in Green River, Wyo.

Jacobs Engineering acquires CH2M Hill

August 2, 2017 — Jacobs Engineering Group Inc. (Dallas, Tex.; www.jacobs.com) will acquire all of the outstanding shares of CH2M Hill Companies Ltd. (Englewood, Colo.; www.ch2m.com) in a cash and stock transaction with an enterprise value of approximately $3.27 billion. CH2M is a leader in key sectors that Jacobs has previously targeted for growth, including water and environmental services.

Yokogawa acquires Norwegian chemical-injection specialist

July 24, 2017 — Yokogawa Electric Corp. (Tokyo, Japan; www.yokogawa.com) announced the acquisition of TechInvent AS, a Norwegian enterprise that holds the rights to FluidCom, a chemical injection metering valve (CIMV) technology. FluidCom prevents blockages and corrosion in pipelines, and employs a patented technology for thermal control. It incorporates the functions of a mass flowmeter, control valve and valve controller. ■

Mary Page Bailey

Modern Temperature Sensors Increase Accuracy

Both new and traditional technologies simplify and improve the temperature-sensing process

IN BRIEF

Temperature is cited as the most frequently measured variable in chemical processing plants. As a result, there is no shortage of instruments available and the offerings run the gamut from traditional thermocouples and resistance temperature detectors (RTDs) to more modern and intelligent versions of these common instruments straight on through to higher technology measurement tools. As a bonus, no matter which of the many options suit your chemical processing needs, most of today's temperature measurement instruments are updated and re-designed to simplify the temperature sensing process, while making it more accurate and reliable.

Siemens Industry

FIGURE 1. The Sitrans TO500 multipoint measuring system evaluates a large number of temperature measuring sensors, which are arranged on a very narrow fiber-optic measuring lance

"As with all measurement instruments, the higher the accuracy and reliability of the sensor, the more valuable it is to the user because tighter, more accurate process control results in better quality and utilization," says Ted Johnson, director of global temperature sales with SOR Controls Group (Lenexa, Kan.; www.sorinc.com). "This is especially true in temperature measurement because temperature is the most measured process variable in the plant. And, when you have the most accurate temperature sensor possible, you have tighter control of the process, which means you are optimizing the amount of energy needed to heat and cool the process. Not only does this save energy, but tighter, more accurate temperature control means improved repeatability and consistency of the process, which is essential in chemical processing."

Challenging applications

For the most challenging applications, which include taking multipoint measurements, continuous measurements or measurements in extremely harsh environments, technologies have been developed to bring simplicity, accuracy and reliability to traditionally difficult and costly measurement points.

For example, Siemens Industry (Hauppauge, N.Y.; www.siemens.com) has recently introduced the Sitrans TO500 multipoint measuring system (Figure 1) for evaluating a large number of temperature measuring sensors, which are arranged on a very narrow fiber-optic measuring lance. The system consists of a read-out unit, the transmitter and the measuring lance, which can be connected to up to 48 temperature sensors on the transmitter at four channels. Up to four measuring probes can be used to process 192 measuring points at the same time by one Sitrans TO500.

The technology is based on fiber Bragg gratings (FBGs), which are arranged at individually defined points on the sensor probe. The transmitter sends light waves to the fiber-optic sensors and evaluates the reflected portions. In the transmitter, light is generated in the wavelength range from 1,500 to 1,600 nm and output to the sensors' measuring probe by means of a continuously tunable laser light. Each fiber Bragg grating reflects light of a defined wavelength. The wavelength reflected by the grating varies depending upon the temperature. The reflection at the FBGs pro-

Ametek Land Instruments

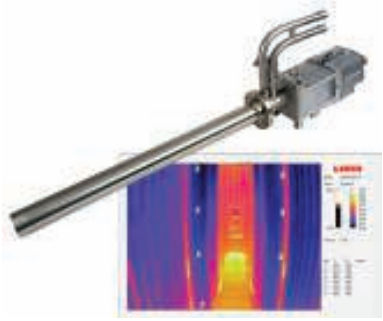


FIGURE 2. The NIR Borescope (NIR-B) 3XR is an imaging camera for continuous temperature measurement and furnace optimization and monitoring of steam-reformer and cracker tubes

vides a measure of the temperature at the respective measuring point. A gas cell with a fixed absorption line serves as a reference in the Sitrans TO500, and the wavelength determination is continuously adjusted by it. The transmitter provides the determined values for analysis in control systems via a Profibus DP interface and makes them available for management of the assets and

Emerson Automation Solutions

FIGURE 3. X-well Technology delivers accurate process temperature data without thermowells or process penetration

optimization of the process.

"We were approached by our chemical customers who were looking for a better way to do multipoint temperature measurement in tanks and vessels because the traditional method of placing a single-point measurement sensor every few feet and wiring that back to the control system is a very clunky and time-consuming way of getting multiple point measurements in a tank or vessel," says Justin DiNunzio, product marketing manager with Siemens. "It was also very costly because it often required a very large thermowell to

hold hundreds of these sensors, which sometimes necessitates the use of a crane to put the large and heavy thermowell into the tank and pull it in and out of service if one of the points fails."

The fiber optic technology, he says, provides users with a lightweight, simple method to take multiple point measurements inside large reactors, tanks or vessels, alerts the user to any issues and allows them to take corrective action quickly. "Picture a reactor and our lance installed vertically from top to bottom," says DiNunzio. "Chemical processors want to know what the temperature is every few inches or feet because if the reaction gets too hot at any of these points inside the reactor, it could bake or overcook the chemical or catalyst, which can be very costly. The fiber optic system gives a great indication of where hot spots are occurring and allows them take measures to cool it down."

Another challenging chemical process industries (CPI) situation is achieving continuous, accurate temperature monitoring in critical applications, according to Thomas Fortinberry, business development manager for industrial gas with Ametek Land Instruments International (Dronfield Derbyshire, England; www.landinst.com). "Traditionally, an operator takes a temperature reading once every shift or every few days, but this leaves a lot of time when the equipment is not being monitored, so issues may be missed or a situation could arise where equipment overheats and causes damage between readings," he says. "Also, it is not always the same operator and measurements are not taken in the same spot or under the same conditions, so you can't use the acquired data for any type of trending.

"However," he continues, "continuous temperature measurement becomes a very powerful tool for trending because with 24/7 monitoring, you get repeatable, reliable results that can be trended, allowing users to see how the equipment is operating over time. This allows them to tweak the process and prevent unwanted downtime."

To provide users with these benefits, Ametek Land has introduced the NIR Borescope (NIR-B) 3XR (Figure 2). The instrument is a short-wavelength radiometric, infrared borescope imaging camera for steam-reformer and cracker-tube continuous temperature measurement and furnace optimization and monitoring. It provides a high-resolution thermal image with realtime continuous, high-accuracy temperature measurements of both the tube wall and refractory wall surface. The camera measures temperatures in a single range from 600 to 1,800°C and uses wide dynamic-range imaging technology, making it suitable for applications with high differential temperature in the filed of view, such as tube and furnace walls.

And, for extremely challenging conditions such as the high-pressure, high-temperature and highly corrosive environments often found in the CPI, Emerson Automation Solution's Rosemount division (St. Louis, Mo.; www.emerson.com) has developed a technology that "solves the problem of having the measurement point in the process," says Ryan Leino, senior product engineer, marketing/business development with Rosemount. The X-well Technology (Figure 3) delivers accurate process temperature data without thermowells or process penetration. Measuring the ambient and pipe-surface temperature, this surface-temperature solution calculates the process temperature via a thermal conductivity algorithm. This calculation takes into account the thermal conductive properties of the assembly and pipe for reliable and accurate process temperature measurements, allowing the surface-temperature-sensor solution to accurately measure internal process temperature, simplify measurement point specification, installation and maintenance and reduce possible leak points.

"This non-intrusive measurement solution was designed to clamp onto the pipe so that there are no issues with materials, temperature and pressure compatibility of thermowells being placed in the harsh environment found inside the process," explains Leino.

Endress+Hauser

FIGURE 4: Shown here is Endress+Hauser's TM411 with QuickSens and StrongSens as an option

Improved traditional sensors

Challenging applications aside, the bulk of temperature measurements in the CPI are still made with thermocouples and RTDs. "The number of specialty applications in any given plant is a small minority compared to the bulk of measurements, which are standard pipeline measurement, process tank, storage tank and metering stations where temperature is needed as part of the flow calculations," says SOR's Johnson. For this reason, it is very important that traditional temperature measurement sensors are manufactured properly, he says. "The last thing you want is for a $100 RTD or thermocouple to fail and possibly shut down a

Tel-Tru

FIGURE 5. Digi-Tel thermometers provide digital display of key process temperatures in addition to reliable transmitter output to remote devices within the facility that can be integrated into expanded control systems to help processes run more efficiently

$2-million reactor or ruin a batch of product," he says. "So processors shouldn't necessarily view these instruments as a commodity purchase. Quality temperature sensor fabrication is a highly skilled, intricate manufacturing process involving precise welding and soldering of junctions and attaching small-gauge lead wires. So it is important to find a supplier that pays rigorous attention to the manufacturing process, ensuring that the process is very repeatable and includes multiple quality checks."

In addition to a high quality and reliable product offering, says Johnson, many temperature sensor manufacturers also provide engineering and technical support, particularly when it comes to thermowells (the protection tube that is installed in the pipeline or tank that protects and allows the temperature sensor to be replaced while the process is still running). "It requires a fair amount of engineering work based upon the velocity of the process to design thermowells so that vibration or process factors don't cause the thermowell to break apart and cause damage to the equipment or process. And, there's additional engineering work involved in specifying thermowells, which can be a challenge for many chemical processors because their knowledge base in this area is dwindling. This means as consumers of temperature measurement devices and thermowells, it's important to find a reliable vendor who can collaborate with you to provide the latest requirements per industry codes and standards, advances in performance capabilities, application knowledge and support. Experienced vendors can help solve problems and ensure that only the most reliable and accurate instruments make it into the process."

In addition to working toward achieving the highest manufacturing standards, many suppliers are developing variations on the standard temperature measurement offerings in an effort to meet the challenges of today's CPI. For example, Endress+Hauser (E+H; Greenwood, Ind.; www.us.endress.com) set out to improve the performance of RTDs. "Although RTDs generally provide higher levels of accuracy and repeatability, the downside is that they are slower to respond to temperature changes than thermocouples," says Ehren Kiker, product marketing manager for pressure and temperature products with E+H. "So we developed an RTD sensor that is still a three-wire RTD with the

Schneider Electric

FIGURE 6. RTT80 is a microprocessor-based temperature transmitter with HART communication that receives input signals from thermocouples and RTDs

accuracy and level of performance associated with RTDs, but that has the response time of a thermocouple to give customers the flexibility of having both higher performance and faster response time."

E+H's iTherm QuickSens offers a short response time (t_{90} = 0.75 s) combined with precise, fast and stable temperature measurement. It measures from –50 to 200°C and is vibration resistant up to 60g (g = 9.8 m/s^2). And, for plants that are exposed to vibrations, the iTherm StrongSens (Figure 4) offers shock and vibration resistance of >60g. "The StrongSens is important because one of the main causes of RTD failure in the chemical industry is vibration, so if the user has a sensor that continuously fails because the pipe where they take the measurement shakes violently, we can provide this sensor because it is more robust in these difficult applications. It saves time and money in that it doesn't have to be replaced every few months and, when there's a few hundred of these measurement points in one facility, there is real value to the user," says Kiker.

Another improvement is the addition of digital displays with added outputs on standard temperature measurement offerings, says Christopher Smock, vice president of operations and manufacturing with Tel-Tru (Rochester, N.Y.; www.teltru.com). "As we move more toward the Industrial Internet of

Things, driven by both technology and the regulatory environment, the automation of processes and process monitoring is a growing trend," he says. "And, as a result, we have recently added a 4–20-mA output on our Digi-Tel line of thermometers." Digi-Tel thermometers (Figure 5) provide digital display of key process temperatures in addition to reliable transmitter output to remote devices within the facility that can be integrated into expanded control systems to help processes run more efficiently. The new Digi-Tel series also includes a PC-based calibration software tool that allows users to quickly and easily adjust the number of significant digits on the digital display and to field calibrate Digi-Tel electronic thermometers to traceable or relative accuracy standards.

Taking it a step further, some suppliers are adding intelligence and diagnostics to temperature measurement devices. For example, the Foxboro division of Schneider Electric (Foxboro, Mass.; www.schneider-electric.com) offers Model RTT80 (Figure 6), which is a microprocessor-based temperature transmitter with HART communication protocol that receives input signals from thermocouples and RTDs. "One of the most important trends is diagnostic capability in a temperature measurement system," says Steven West, temperature product manager with Schneider Electric. "Users are looking for a means to detect corrosion of wires, broken wires and shorts or open wires that would alert them to a problem in the temperature measurement loop. We have developed a way to provide diagnostics based on dual sensors."

He says it is very common for a temperature probe to have two sensors and to have both monitored by the transmitter electronics. The RTT80 is capable of operating with dual sensors and has the ability to detect short or open circuits and has a "hot back up" or redundancy feature and can detect corrosion when used with a four-wire RTD. The transmitter is also rated for safety integrity levels (SIL) and the software has been vetted to comply with international standards for use in safety systems, so it can be used to turn on or off safety systems based on temperature measurements.

"Not only are these capabilities helpful for safety reasons, but also in a chemical-processing environment, the synthesis of a chemical or a chemical reaction is being monitored because these processes are very temperature sensitive," he says. "They may occur only within a certain temperature window or there may be an optimal temperature to achieve the greatest yield, so intelligent diagnostic capabilities in temperature measurement can provide great peace of mind and great savings for the user." ■

Joy LePree

Feeding and Weighing Bulk Solids

Dynamic Air Conveying Systems

Mettler Toledo

Eriez

Scaletron Industries

Single unit combines bin discharge and feeding

The Gyro Ex Bin Activating Feeder/Discharger (photo) is a combination bin discharger and high-accuracy feeder that provides a turndown ratio of up to 100:1. It uses a radial force to create a uniform circular motion on both the upper activation cone and the lower discharge cone, producing a controlled gyratory motion that withdraws granular materials from bins, storage silos and hoppers. — *Dynamic Air, Inc., St. Paul, Minn.*
www.dynamicair.com

Advanced design makes weighing tiny amounts easier

Laboratory projects involving expensive, rare or toxic substances often demand that only the smallest possible sample quantities are used. The challenge is to prevent waste by accurately weighing just a few milligrams, and minimizing the risk of out-of-specification results and costly reworking. The XPR Microbalance (photo) allows for accurate weighing of very small amounts (down to several milligrams). Features include active temperature control, which helps keep the balance temperature constant for improved accuracy. Its proprietary software provides easily identifiable, self-explanatory icons that are displayed on an intuitive, smartphone-like touchscreen, says the company. — *Mettler Toledo, Griefensee, Switzerland*
www.mt.com

Spare-parts kits for compact vibratory feeders

This company now offers spare-parts kits for its light- and medium-duty vibratory feeders (which have totally enclosed, patented magnetic drives). These spare-parts kits (photo) contain the parts needed to rebuild most the company's Model A, C and High Speed (HS) and High Deflection (HD) vibratory feeders. A typical kit includes a corded electrical assembly, diaphragm, shock mounts, elastomers (several versions), tuning springs (front and back), spacers and associated hardware. — *Eriez, Erie, Pa.*
www.eriez.com

Automatic volumetric feeder saves time, improves accuracy

The Model VMF-28 auger-style volumetric screw feeders, featuring a fully intergrated Scaletron scale (photo), are designed for the metered dispensing of powdered or pelletized additives (such as alum, carbon, lime, polymers, soda ash and other dry bulk solids) into water, wastewater and chemical-treatment processes. Precise dosage amounts are autmomatically weighed and added to treatment processes without requiring manual operator involvement. Data are displayed at a central monitoring station, where operators can quickly make adjustments, as needed, from the control panel. Heat, moisture and other environmental variables can cause additives (such as lime and carbon) to absorb or dissipate water, and such changes can result in not enough, or too much, material being introduced into the treatment process. By monitoring weight loss or gain, the company's feeders provide operators with constant, realtime assessment of the total mass of additive being used.— *Scaletron Industries, Inc., Plumsteadville, Pa.*
www.scaletronscales.com

Small-footprint weigh feeder can move a lot of solids

The Model 408 Series weigh feeders provide an economical and compact means to accurately and dependably feed a range of dry solid materials, with a compact footprint measuring just 18 in. × 28 in. The Model 408 feedrates range from a fraction of a pound, to thousands of pounds, per hour, with continuous metering accuracies ranging from ±0.25

Note: For more information, circle the 3-digit number on p. 102, or use the website designation.

to 1% or better error at two sigma, says the company. High-resolution weight sensing is accomplished by the company's Ratiometric Digital Weight Resolver, which instantaneously produces an unamplified, non-integrated, realtime weigh signal for precise feedrate control using one of the company's multiprocess controllers.— *Acrison, Inc., Moonachie, N.J.*
www.acrison.com

Move flexible products through a flexible conveying path

Spiroflow

The new heavy-duty Chainflow tubular chain drag conveyor (photo) provides gentle handling of powders and granular materials, particularly those that are fragile. The totally enclosed, dust-free chain-drag conveyor allows for flexible layout configurations, and can deliver materials continuously or in batches. Its crevice-free material-contact surfaces are suitable for food-grade applications, as well as higher-density materials or abrasive products, says the company. Similarly, its design is well-suited for non-smearing powders and high-density products, such as talcum powder, detergents, woodchips and pellets and more. This system offers a conveying capacity up to 370 ft^3/h (10.5 m^3/h), and can convey over long distances with maximum straight-line lengths to 250 ft (76 m) per conveyor, while multiple conveyors can be linked for longer distances. — *Spiroflow, Monroe, N.C.*
www.spiroflow.com

Advances improve feeder control and customization

The Disocont loss-in-weight feeder-control platform (photo) includes several new features, which have been added to simpify operation and allow for greater opportunities for customization. These include improved user-defined calibration sequences, detailed event messaging texts and the use of HTML5 for online equipment monitoring (a change from Java).This provides a wider range of access and compatibility through various web browsers and smartphones, says the company. Users can set up folders to ensure quick access to all of the different parameters that are critical and unique to each individual process. Parameters that are rarely used can be hidden, thereby eliminating the need to search through multiple parameters that are not relevant for the user's particular process. — *Schenck, Kansas City, Mo.*
www.schenckprocess.com

Schenck

Wide conveying system allows for better control while curing

Dymax

The Widecure Conveyor System (photo) has a 25-in.-wide belt, and is designed for the curing of light-curable materials on larger parts, or larger quantities of smaller parts. The conveyor can be outfitted with either a longwave (metal halide, UVA/Visible) or shortwave (mercury, UVB/UVC) bulb and delivers over 4 J/cm^2 of curing energy at a conveying rate of 5 ft/min. Users can control various curing parameters through a touch-screen control panel, to achieve greater curing flexibility tailored to their specific application. — *Dymax Corp., Torrington, Conn.*
www.dymax.com

Alliance Scale

Scale-calibration service helps users ensure quality operation

The Alliance Scale Calibration Service (photo) can be performed annually or at some other interval to ensure consistent accuracy and conformance to quality requirements. As a rule of thumb, if a scale is used for an hour or less per day, then an annual checkup is advised. If the scale is used for 1–2 h/d then calibration twice per year is recommended, while quarterly calibration is recommended for scales that are used for 3–4 h/d. Services include a visual and operation check of the operating mechanism, testing with NIST-traceable weights, and providing a calibration report and calibration certificate for an ISO audit. If necessary, a written report and estimated cost will be furnished for any scale requiring further maintenance, says the company. — *Alliance Scale, Inc., Canton, Mass.*
www.alliancescale.com

Flexicon

Testing facility lets users evaluate feeder configurations

This company's recently opened Technical Center in Duisberg, Germany now has four full test lines (with cranes that can lift standard packaging such as silos, drums, sacks and big bags), as well as smaller test areas, and separate areas that meet hygienic considerations, to carry out a broad array of both continuous and batch testing. The individual testing lines can be retooled independently, and entire processes can be simulated, to allow users to test potential feeding options. — *Brabender Technologie GmbH & Co. KG, Duisberg, Germany*
www.brabender-technologie.com

Ajax Equipment

Best Process Solutions

This weigh hopper improves pneumatic conveying accuracy

The new gain-in-weight hopper with a Fill/Pass Valve for dilute-phase conveying (photo, p. 33) is suspended from three small-scale load cells. Single or multiple hoppers can be positioned along a common vacuum or positive-pressure pneumatic conveying line for discharging of dry bulk solids by weight into single or multiple pieces of process equipment, storage vessels or downstream use points. The system's controller weighs a batch by changing the position of the valve, which diverts conveyed material into the hopper. As the hopper fills, load cells transmit weight-gain information to a PLC. Once the batch weight has been reached, the valve redirects material from the hopper and a controller actuates a slide gate valve to open, discharging the weighted batch. The unit is constructed of stainless steel, and can be finished to industrial or sanitary standards. — *Flexicon Corp., Bethlehem, Pa.*
www.flexicon.com

This agitated screw feeder reaches a new size milestone

This company's largest agitated screw feeder and screw conveyor produced to date (photo) was recently placed into service at a plastics-and-polymers facility. Capable of holding 3.5 tons of damp centrifuge cake, this stainless steel unit has a large-capacity hopper with multi-bladed agitator to provide gentle agitation to maintain a "live" product condition, disturb any potential consolidation and deliver positive infeed to the integral screw feeder. The screw feeder and conveyor both feature LynFlow ribbon flights, which inhibit adhesive materials from clogging the screw, says the company. — *Ajax Equipment Ltd., Bolton, U.K.*
www.ajax.co.uk

Loss-in-weight system batches powders or pellets

This company offers a variety of bulk-processing equipment, including bulk bag dischargers and fillers, vibratory tables and complete batching systems, which can be custom engineered to meet site-specific and application-specific requirements. The Model MTD-4K Bulk Bag Discharger and feeder (photo) is a loss-in-weight vibratory batch feeder system that provides accurate, uniform flow of a wide variety of materials. The discharger and feeder sit on load cells, with controls to stop the feed when it reaches the desired weight. — *Best Process Solutions, Inc., Brunswick, Ohio*
www.bpsvibes.com

Weight indicators enjoy expanded memory capacity

VPG Transducers

The recently upgraded, fully modular family of Intuition Series weight indicators (photo) provide expanded memory, which allows for the paperless storage of up to 100,000 individual weighing records (from 10,000 before). The indicators combine large, displays with an array of advanced features and communication interfaces, including multiple hardware and software options, yielding a scalable, user-friendly weight indicator option, says the company. Additional features include simplified calibration and instrumentation setup. — *VPG Transducers, Malvern, Pa.*
www.vpgtransducers.com

Accurately weigh grams per hour or tons per minute

VibraScrew

This company offer a broad line of continuous and batch weighing solutions for dry bulk-feeding applications in a range of chemical process operations. The system uses controlled vibration to promote flow, to ensure uniform density of the materials, and to completely fill and empties each flight of the feed screw, says the company. As a result, all weigh-feeding systems function as highly accurate volumetric feeders, eliminating inaccuracy during the refill cycle, says the manufacturer. The full line of product offerings includes weigh feeders with screw sizes from 1/4 in. to 18 in., offering a broad range of belt, pan and tube feeder-based systems. — *VibraScrew, Totowa, N.J.*
www.vibrascrew.com ■

Suzanne Shelley

Acetic Acid Production from Methanol

By Intratec Solutions

Acetic acid (also known as ethanoic acid) is a carboxylic acid found as dilute solutions in plant and animal systems. Industrially, the chemical is widely used in organic processes, primarily in the production of vinyl acetate monomer and acetic anhydride.

The process

The following paragraphs describe a process for producing acetic acid from methanol and carbon monoxide, based on rhodium-catalyzed carbonylation. Figure 1 presents a simplified flow diagram of the process.

Catalyst preparation. Initially, recycled rhodium catalyst is treated to recover the rhodium. The treated catalyst is mixed with fresh catalyst, a promoter (methyl iodide) and a stabilizer (iodide salt). The mixture is then dissolved in hot acetic acid under pressurized carbon monoxide.

Carbonylation. The reactor is fed with the catalyst solution, methanol and carbon monoxide, along with recycle streams. The reaction occurs in the liquid phase, where dissolved carbon monoxide combines with methanol to yield acetic acid. Gases vented from the reactor are cooled to recover unreacted methanol, methyl iodide and methyl acetate. Uncondensable species are sent to the methanol scrubber, to prevent the loss of low-boiling components, such as methyl iodide.

Liquid product is drawn off from the reactor at a rate sufficient to maintain a constant level, and is fed to a flash vessel, where the catalyst solution is withdrawn as a base stream and recycled to the catalyst preparation. The product overhead of the flash vessel — an acetic acid stream containing methyl iodide, methyl acetate and water — is purified in distillation columns.

Purification. In the crude acetic acid column, a gaseous stream from the overhead, containing water, methyl iodide, methyl acetate and some acetic acid, is condensed and recycled to the carbonylation stage. A crude acetic acid liquid stream, withdrawn as a side draw, is routed to the drying column. The bottom product, containing dissolved catalyst, is recycled to the flash.

In the drying column, water, methyl iodide and methyl acetate are removed from the crude acetic acid as an overhead distillate, which is further recycled to the carbonylation unit. The column bottom stream, containing acetic acid, is fed to a finishing column, where heavy ends are removed. The acetic acid stream is finally passed through ion-exchange resin beds to remove iodide contaminants. Heavy-ends from the finishing column are sent to the acetic acid stripper, where residual acetic acid is recovered as overhead product and recycled to the finishing column, while the bottom product is discarded as waste acid.

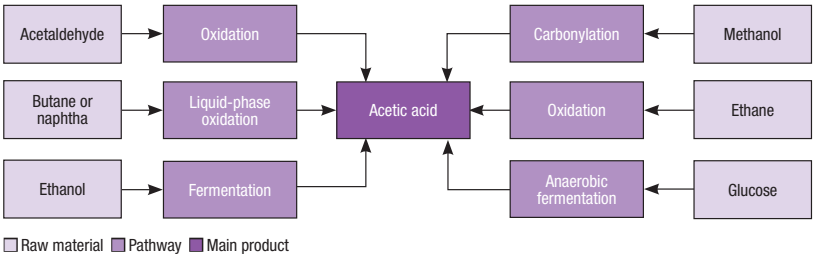


FIGURE 2. Methanol carbonylation is one of several possible pathways for the production of acetic acid

Production pathways

Currently, the most important production routes for acetic acid are based on methanol carbonylation and oxidation of acetaldehyde or light hydrocarbons. Figure 2 presents different pathways for acetic acid production.

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce acetic acid is about $560/ton of acetic acid. The analysis is based on data from the second quarter of 2013 using a plant with capacity to produce 650,000 metric ton per year of acetic acid.

This column is based on "Acetic Acid Production from Methanol – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/acetic-acid-production-cost. ■

Edited by Scott Jenkins

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

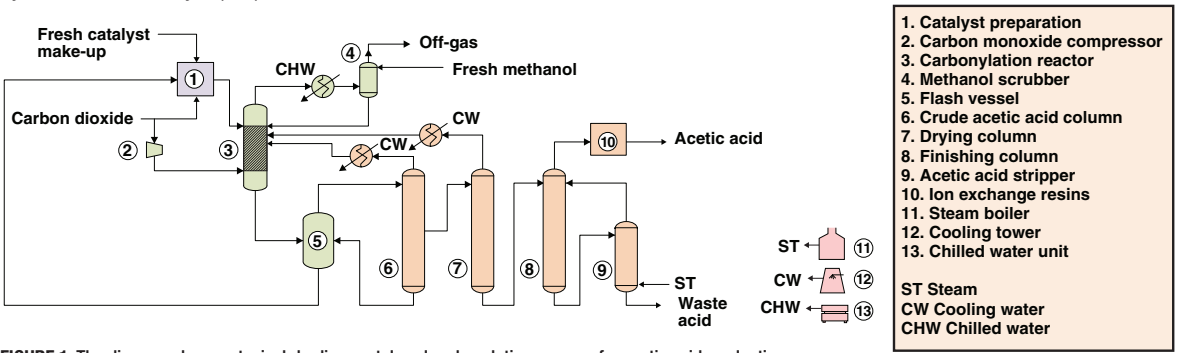


FIGURE 1. The diagram shows a typical rhodium-catalyzed carbonylation process for acetic acid production

Heat-Transfer Fluid Selection

Department Editor: Scott Jenkins

Heat-transfer fluid selection can be intimidating when considering the long-term impact on costs and operability. The right fluid will provide optimal performance and lifecycle costs, while freeing engineers for other assignments. Most engineers do not routinely consider fluid selection, so making the proper choice is a challenge. This one-page reference offers guidance in this area, and can serve as a basis for taking advantage of the expertise of heat-transfer fluid manufacturers.

Process requirements

The process will define the temperature and heat-duty requirements that must be met by the fluid and the supporting heat-transfer system. The heat-transfer fluid must have the requisite thermal stability to meet the process demands, while providing long fluid life expectancy.

The list of potential fluid candidates may be shortened considerably by defining the required operating temperatures. The fluid's bulk operating temperature must be substantially above the process temperature required in order to provide the driving force for heat transfer.

Next to consider are the remaining physical properties that are key to heat-transfer efficiency. These include: viscosity, density, thermal conductivity and heat capacity of the liquid. These terms combine to determine the fluid-side heat-transfer coefficient [Equation (1)].

$$h = C \bullet k^{0.58} \bullet \rho^{0.79} \bullet cp^{0.42} \bullet \mu^{-0.37} \quad (1)$$

Where, h is the heat-transfer coefficient (within a tube), k is thermal conductivity, cp is heat capacity, μ is the viscosity and C is a constant incorporating length, velocity and pipe diameter. Note the exponent for each term, which indicates the relative influence on the resulting heat-transfer coefficient.

Next, the overall heat transfer coefficient, U, is determined. This calculation considers process-side heat-transfer coefficient (h_i or h_o), wall (r_w) and fouling (r_f) resistances [Equation (2)].

$$\frac{1}{U} = \frac{1}{h_i} + \frac{1}{h_o} + r_w + r_f \quad (2)$$

This equation shows that a high process-side heat-transfer coefficient can make the fluid selection very important in increasing U and potentially decreasing heat-exchange surface area requirements.

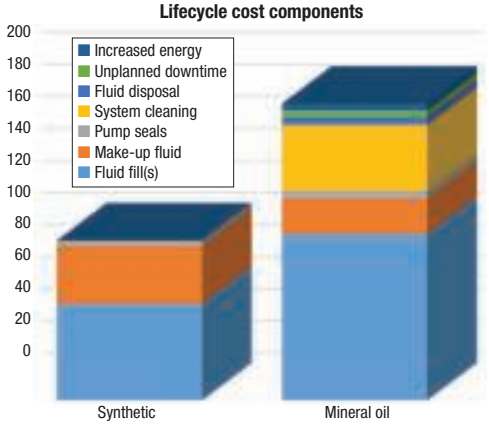
The combined effects of fluid properties under design conditions should be considered when comparing fluid performance.

Cost of ownership

Cost of fluid ownership is more than just the purchase price — lifecycle costs should be carefully considered. These include the following factors:

- Purchase price
- Impact on capital costs
- Operating costs
- Make-up addition rate and volume
- Fluid replacement frequency
- Impact on equipment costs
- System cleaning requirements

Consider an example 20-yr comparison of mineral oil with a synthetic heat-transfer fluid (Figure 1).



Product and data support

To support the necessary engineering calculations for initial system design and for later troubleshooting or modifications, complete and accurate physical properties for their fluid are necessary. These property data should be better than those found on graphs with wide plot lines, which can be ambiguous, and should fill gaps often found on material safety data sheets. These data should be detailed measurements and correlations capable of supporting the desired engineering accuracy. Usually the best way to access these data is through a heat-transfer fluid manufacturer with stringent quality controls, and one that has capably measured the properties of representative samples. This enables lower "safety factors" in designs.

Thermal oxidative stability

High-temperature organic fluids must be resistant to thermal and oxidative stress. Oxidation can be prevented by use of inert-gas blanketing of the system. Fluids with oxidation-stabilizing additives can become depleted and laden with solids, leaving the system vulnerable to sludge formation and fouling. Top-up with more additives exacerbates the fouling potential, which has a negative impact on the cost of ownership. Thermal stability is a characteristic of bond strength and fluid composition with minimal impurities. Thermal stability can be measured in the laboratory using ASTM D-6743 [*1*] (Standard Test Method for Thermal Stability of Organic Heat Transfer Fluids), followed by proper quantification of the degradation products formed. Fluid manufacturers may have decades of experience in field-verification of fluid life in a variety of applications and at different operating temperatures. Those with ISO-9001-certified processes for quality-assurance-management systems are recommended, to ensure that lot-to-lot product performance and reliability are consistent. ■

References

1. ASTM D-6743, Standard Test Method for Thermal Stability of Organic Heat Transfer Fluids.
2. Gamble, C. and Schopf, M., "Optimizing heat transfer fluid performance: How to avoid costly consequences," Eastman Chemical Co., white paper, 2014.

Author

Content for this column was provided by Conrad Gamble, senior engineering associate at Eastman Chemical Co. (Kingsport, Tenn.; www.eastman.com).

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New Products

Automated alarm management reduces manual calculation work

The newest release of the PlantState Suite (PSS) software, version 8.3, includes the new Alarm Mechanic feature, which is designed to improve console operator performance by minimizing nuisance alarms through automated analytics and recommendations. With the addition of Alarm Mechanic, PSS 8.3 fully automates complex analyses that determine alarm delay-time settings, a critical method for solving nuisance alarm problems. Alarm Mechanic replaces manual calculations and guesswork with automated, deterministic recommendations to enable consistent alarm settings. PSS 8.3 also incorporates custom alarm analytics, corporate operational excellence programs and risk-tracking dashboards. *— PAS Global, LLC, Houston*

www.pas.com

Easily detect seal and gasket wear in conveying applications

This company now offers metal-detectable (MD) and X-ray-inspectable (XRI) seal and gasket options on its magnetic separation equipment for gravity-fed and pneumatic-line conveying applications. The new seal and gasket options protect against elastomeric contamination in the processing line. Component parts can degrade over time due to low conductivity, and standard elastomeric material is often missed by even the most sensitive detection systems. The new offerings include the Detectomer line (photo) of Buna rubber seals and silicone gaskets, which all contain a select additive that can be spotted by metal detectors, X-ray systems and optical scanners, as well as be captured by magnetic separators. Available for products with 1- and 3-in. magnetic circuit configurations, the seals and gaskets are certified food-grade compliant, meeting the FDA Code of federal regulations for food safety. Users with existing magnetic separation equipment who wish to upgrade to the new MD/XRI seals and gaskets may also purchase a retrofit kit. *— Industrial Magnetics, Inc. (IMI), Boyne City, Mich.*

www.magnetics.com

Hazardous-gas detection with an array of sensor options

The GSM-60 hazardous-gas monitoring system (photo) is designed with an internal sampling pump and can use both internal sensors and remote sensor transmitters to continuously monitor up to four gases. The instrument is capable of utilizing an array of sensor technologies: infrared (IR), electrochemical (EC), photoionization detector (PID), metal oxide semiconductor (MOS), and catalytic (CAT). The GSM-60 can be configured to monitor a wide range of chemicals in ambient air, including volatile organic compounds (VOCs), carbon monoxide, carbon dioxide, oxygen, trace hydrocarbons, as well as many toxic and industrial gases. Additionally, the GSM-60 is capable of monitoring reactive gases, such as arsine, chlorine dioxide, ethylene oxide, hydrogen fluoride and ozone. The system is designed for monitoring ambient air in difficult environments, including the headspaces of tanks, HVAC ductwork, VOC-scrubber exhausts and wastewater-treatment plants. *— Enmet, LLC, Ann Arbor, Mich.*

www.enmet.com

Couplers to minimize product loss and cross-contamination

The new Twist-Lok dry disconnect coupler (photo) features 316 stainless-steel construction and an integral heavy-duty swivel to aid connection and minimize hose wear. In addition, this new coupler is designed with several safety features for the operator, such as the ability to be fully interlocked when connected, while it includes a locking mechanism in the open position. Product selectivity is also available via mechanical keying to minimize risk of cross-contamination. Twist-Lok couplers are offered in 1-, 2-, 3- and 4-in. sizes (with larger sizes available upon request) and are available with a range of seal materials. The Twist-Lok is pressure-rated up to 360 psi, making it appropriate for high-pressure applications. It is also suitable for vacuum service. *— OPW Engineered Systems, Inc., Lebanon, Ohio*

www.opw-es.com

Industrial Magnetics

Enmet

OPW Engineered Systems

GoatThroat Pumps

Elliott Group

Cole-Parmer

Caframo Lab Solutions

New pumps for handling flammable chemicals

The SCP Series of pumps (photo) for Class 1 and 2 flammable liquids is designed to minimize hazards associated with transferring flammable or combustible chemicals, such as alcohols, solvents and volatile hydrocarbons. SCP pumps allow for spill-free, environmentally safe transfer with no chance for vapors and VOCs to escape the container. This significantly reduces the chance of an ignition event. The pump features a grounding wire and a bonding wire, and is made of conductive plastic, allowing users of flammable liquids to ground the pumps, making them safe for use with Class 1 and 2 flammable materials. All pump components that come into contact with the fluid are created with conductive polypropylene, so there is grounding of the liquid and the pump. These pumps also meet the requirements of NFPA 77, which requires that the path to ground must prevent the accumulation of static electricity in conductive equipment. — *GoatThroat Pumps, Milford, Conn.*
www.goatthroat.com

Test turbine trip systems without disrupting production

This company's new, patent-pending pneumatic trip system (photo) with partial-stroke actuation provides quick testing of turbine trip systems while the equipment is still running. There is no disruption to production, and the trip valve will still work if an overspeed event occurs while testing is in progress. The pneumatic trip system verifies functionality without tripping the turbine and operates independently of the overspeed trip system. It can be initiated locally and remotely via a distributed control system (DCS). Adaptable to any equipment configuration, this system can be retrofitted onto existing equipment or affixed to new machines. The system provides a more cost-effective alternative to trip and throttle valves. — *Elliott Group, Jeannette, Pa.*
www.elliott-turbo.com

Use these pump heads for extremely shear-sensitive fluids

The new Masterflex L/S Cytoflow pump head (photo) was developed specifically for pumping live cells and shear-sensitive fluids in biopharmaceutical and microbiology applications. The Cytoflow pump head has a large-diameter rotor, resulting in high flowrates at low motor speeds. The pump head is available in two- and three-roller configurations — two-roller heads offer higher flowrates, while three-roller heads deliver less pulsation. The pump head is compatible with all Masterflex L/S drives that accept two or more pump heads. In addition to the high flowrates at low motor speeds, the Cytoflow pump head has a convex roller design that minimizes the impact on live cells and maintains the consistency of shear-sensitive fluids. — *Cole-Parmer, Vernon Hills, Ill.*
www.coleparmer.com

A portable mixer for laboratory and pilot operations

The Crossover 1540 overhead mixer (photo) features a 0.5-hp motor delivering 3,000 N·cm of torque for effective mixing in large laboratory, pilot-scale and small production volumes. The portable Crossover is designed to mix up to 200-L (50-gal) drum volumes from 50 to 1,500 rpm, with the option of clockwise or counterclockwise rotation. New to this product is the resistive touchscreen, allowing operation without removing gloves, which displays speed, time and torque during operation. Installation requires only a standard 120-V cord set and four-bolt mounting, and the mixer is said to be maintenance free. Mounting options include a C-clamp that is compatible with the side of a drum or a vertical plate, or a plate mount for a more permanent or custom installation. Other accessories that are available include large 4- and 6-in. propellers and shafts, as well as replaceable touchscreen protector covers. — *Caframo Lab Solutions, Georgian Bluffs, Ont., Canada*
www.caframolabsolutions.com

Highly reinforced low-VOC coatings

This company has introduced a new range of low-VOC coatings that provide 100%-solids epoxy lining performance. The coatings are reinforced and are capable of providing longterm protection under industrially corrosive

environments ranging from immersion conditions (temperatures up to 180°F) to vapor conditions (temperatures up to 250°F), says the company. The products can be applied by conventional spray or manual methods. The product line includes: SF/LF, a 100% solids high-build coating system used primarily in marine and wastewater sites; STP ep-hv, a surface-tolerant, high-viscosity, high-build coatings system; CN 1M V15H3, a nanoparticle-reinforced epoxy phenolic resin for aggressive chemical exposures; Synthofloor 8016, a low-viscosity, epoxy primer and sealer formulated to be used as a primer or augmented with clean dry silica sand and used as a sparge coat; and Synthofloor 8463, a low-viscosity, self-leveling epoxy floor coating for mild to moderate chemical resistance that also can be bulked up with clean dry silica sand to be used as a high-build, wear-resistant coating. — *Ceramic Polymer GmbH, a Chesterton International Subsidiary, Roedinghausen, Germany*
www.ceramic-polymer.de

These horizontal vortex pumps provide unrestricted flow

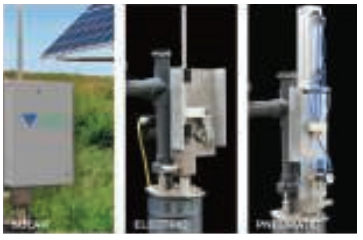
Vertiflo

The Series 1600 horizontal vortex sump pump (photo) features a fully recessed vortex impeller design that provides an unrestricted flow, since the impeller is not normally in contact with the solids being pumped. Industrial process applications include slurries, fragile food processing, pulpy solids, oils, pollution control and wastewater treatment. The pumps can handle solids up to 4-in. in diameter. The Series 1600 is designed for severe services with heads to 170 ft, temperatures to 250°F with flows to 1,600 gal/min. Construction options include cast iron, 316 stainless-steel fitted, all 316 stainless-steel, Alloy 20 and CD4MC. Two models are available: Model 1620 has a 0.875-in. shaft diameter with a 1.25-in. sleeve, while Model 1626 has a 1.25-in. shaft diameter with a 1.625-in. diameter sleeve. All impellers have wiping vanes that reduce axial loading and prevent dirt from entering the sealing area. The impeller is keyed to the shaft, and an impeller locking screw assures positive attachment. The vortex-type concentric design casing has extra heavy wall thickness for corrosion allowance. — *Vertiflo Pump Co., Cincinnati, Ohio*
www.vertiflopump.com

This piston pump has an interchangeable drive assembly

The new TopDrive piston pump system (photo, p. 28) for cleanup applications features a fully-interchangeable drive assembly that allows for

QED Environmental Systems



easy transitions between hand, solar, electric and top-drive pneumatic pumping without removing the well seal. This feature provides additional flexibility in pumping applications and the ability to pump most fluids under a wide range of operating conditions. Other design elements of the TopDrive piston pump include an interchangeable lower pump, which allows an upgrade to a higher flowrate, and an adjustable drop assembly with 5- or 10-ft lengths, optimizing pump inlet depth. The pneumatic-drive assembly features a linear bearing in addition to the internal pneumatic-drive cylinder bearing, which is designed to increase the durability and life span of the pump. *— QED Environmental Systems, Inc., Dexter, Mich.*
www.qedenv.com

ABB Jokab Safety Products

Safety sensors designed for increased vibration resistance

This company's Eden sensors (photo) now feature a solid-state, board-level design with radio-frequency identification (RFID) technology for increased resistance to vibration and greater security. RFID technology allows for large sensing distances and its vibration resistance decreases the risk of involuntary stops that are common in older technologies. The entire Eden line is IP69K rated, making these safety sensors suitable for applications that require resistance to dust and liquid ingress, such as washdown operations in food-and-beverage processing plants. Eden Dynamic safety sensors use dynamic-pulse, single-channel safety architecture and comply with Category 4/Performance Level e (Cat. 4/PLe) per EN/ISO 13849, indicating that failure of an individual device will not result in the loss of safety function. According to the manufacturer, the Eden product line also introduced the capability of uniquely coding safety sensors to comply with the demands of EN/ISO 14119 for hazardous applications. Eden safety sensors also have flexible, 360-deg mounting and a temperature range of –40 to 158°F. *— ABB Jokab Safety Products, Westland, Mich.*
www.abb.us/jokabsafety

Clark Solutions

These gas-detection systems are SIL-2 certified

The CGS-FlexVu UD10 combustible-gas detection system combines a catalytic-bead gas sensor with a multifunction universal display for detection of a wide range of hydrocarbon gases, as well as hydrogen, in harsh industrial environments. The explosion-proof system is third-party rated for safety integrity level (SIL) 2, and is suitable for high-temperature (up to 75°C) and hydrogen-processing applications, as well as in relative humidities up to 95%. The universal display also provides output and control capabilities, and can be used to calibrate and view information. The device features nonintrusive calibration using a handheld magnetic tool or a HART communicator and can be easily calibrated by one person. The display unit provides a linear isolated/non-isolated 4–20-mA output signal (with HART). *— Det-Tronics, Minneapolis, Minn.*
www.det-tronics.com

These gear pumps have built-in pressure control

Series UP6 electric gear pumps (photo) feature the option for built-in pressure control, whereby a factory-programmed pressure setting is maintained via a microprocessor-based variable pump-speed control circuit that utilizes an internal pressure sensor for loop feedback. UP6 pumps are self-priming and come equipped with 12- or 24-V d.c. motors. The pumps can handle flowrates as high as 6.9 gal/min, and pressures up to 29 psi, making them appropriate for small water- and chemical-processing systems. The pumps feature helical bronze gears, a nickel-plated brass body and stainless-steel shaft. The operating temperature range for UP6 pumps is 14 to 140°F. Suitable pumping media include water or diesel fuel with viscosity between 2 and 5.35 cSt. A 250–400 µm filter is recommended for applications where the fluid media contains particles. *— Clark Solutions, Hudson, Mass.*
www.clarksol.com ■

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Drones Take to the CPI Skies

Drones are quickly entering the chemical processing space as more companies begin to embrace their use for inspection and monitoring tasks

IN BRIEF

There is no doubt that drones, or unmanned aerial vehicles (UAVs), hold many promising opportunities for the chemical process industries (CPI), although, as with any new technology, some challenges may arise. "We're just starting to see some of the larger chemical manufacturers begin to use drone technology," says Bill Erny, senior director of security, regulatory and technical affairs at the American Chemistry Council (ACC; Washington, D.C.; www.americanchemistry.com). Equipment inspection, says Erny, is currently the most promising application for drones in the CPI. "Some equipment is challenging to access, such as flare stacks, large processing vessels and things of that nature," he explains. Some drones can actually fly inside equipment structures and execute visual inspections, or even non-destructive testing (NDT), eliminating the need for confined-space entry. Although equipment inspection is currently the most commonly seen application for drones in CPI plants, several other tasks have emerged where their use might be beneficial, including emergency response, security management, site surveys and environmental remediation.

AETOS Group

FIGURE 1. Some companies may custom-engineer a drone to carry out specific tasks, such as specialized non-destructive testing or gas detection

While drones certainly hold potential to provide security services, there are also some concerns associated with the unauthorized use of drones near chemical processing facilities. Commercial drone usage in the U.S. is regulated by the Federal Aviation Administration (FAA), but it has fallen to individual states to provide guidance on recreational or otherwise unauthorized drone usage near critical infrastructure, including chemical plants. Domestically, drone complaints have mainly been nuisance-related, but the potential is certainly there for more insidious actions to take place. "One of the key considerations here is to establish a mechanism where operators can report concerns about unauthorized drone use, and establish a formal mechanism for notifying the general public where recreational use of drones is not permitted," explains Erny. He emphasizes that the ACC supports future legislation regulating the use of unauthorized drones and for the FAA to fulfill its mandate to create new rules prohibiting the unauthorized use of drones near critical infrastructure.

Aviation and the CPI collide

The proliferation of drones into more and more applications has necessitated collaboration between the aviation and industrial sectors. Drone service provider AETOS Group (LaPorte, Tex.; www.aetosgroup.com) was formed by a group of commercial pilots in 2010, and began collaborating with a major global CPI company in 2011 to evaluate drone applications in chemical plants, focusing on safety and regulatory issues. In late 2015, AETOS was bought by Mistras Group Inc. (Princeton Junction, N.J.; www.mistrasgroup.com). "Once we progressed the data that the drones could deliver, we recognized the need to take it a step further and actually start building finished products," explains Nick Harwood, operations manager at AETOS. AETOS works with operating com-

Interactive Aerial

FIGURE 2. Special design and operating considerations must be taken for drones meant to be flown inside of large vessels

panies to develop bespoke drones and robotics (Figure 1). "We've done several custom-builds now that are unique to specific applications," adds Harwood. "We are allowing clients to get to places they could never get to before without major expenses," he continues.

The inspection of flare stacks is among AETOS' most popular drone services. "Shutting down flare stacks is extremely expensive, and with a drone you can do the inspection online, which is a huge benefit," says Harwood. Beyond equipment inspection, the company has developed drones equipped with infrared (IR) camera technology to detect leaks and fugitive emissions.

Improved drone capabilities have also enabled internal inspection of structures, such as tanks and vessels. Flying drones inside large storage tanks saves time and costs, as no scaffolding needs to be constructed and no personnel have to enter the tank. "In smaller pressure vessels, personnel don't have to make entry," says Harwood. He reiterates that while drone-based internal inspection technologies are still relatively new, they present benefits in numerous areas, including turnarounds and quality-control of new piping circuits.

In one recent project, AETOS custom-built a "crawler" robot to go into a large vessel and complete a visual inspection, as well as two different kinds of NDT. Typically, says Harwood, these types of NDT did not occur very frequently and would require extensive amounts of scaffolding, while incurring nearly $500,000 in costs. "We were able to outfit the tools on the drone and do these inspections in a day or two, and get complete coverage, with no scaffolding," he explains. Here, the major takeaway is that with drones, certain types of specialized NDT can be done more frequently, increasing reliability.

"There's a lot of front-end work before taking a drone into a facility," says Harwood, mentioning client concerns associated with aircraft operational safety, security and equipment inherent safety. "None of the drones today are intrinsically safe, so you have to understand the processes and ask the right questions," he continues. However, he says that these limitations have not hindered AETOS' work. For instance, the cameras affixed to flare-monitoring drones have sufficient zoom capabilities — they can reportedly decipher increments as small as 1/32 in. from 60 ft away — to operate at a safe distance and still collect useful data. He says that while there are applications to justify a busi-

Interactive Aerial

FIGURE 3. Drones can quickly provide high-resolution images for internal inspection of tanks, vessels, boilers and more

ness case for intrinsically safe drones, the development work for these devices is still very early. Furthermore, many large chemical companies have their own internal aviation departments to rigorously vet any drone technologies being used inside plants. "We make sure to use equipment that have encrypted links that are unique to the aircraft so that they don't interfere with plant sensors, and we have also tested them thoroughly," he explains.

One company working with AETOS to develop high-performance inspection drones is Interactive Aerial, Inc. (IA; Traverse City, Mich.; www.interactiveaerial.com). The company, said to be one of the few U.S.-based drone manufacturers, focuses on drones used for internal inspections of tanks, boilers, cargo ship hulls and other large equipment (Figure 2). The drones can quickly supply a large amount of internal inspection data via high-resolution photos and video (Figure 3). What sets IA's technology apart is a proprietary laser-based navigation and collision-avoidance system, says Christian Smith, president of Interactive Aerial. Typically, "off-the-shelf" drones use global-positioning systems (GPS) and internal compasses for navigation, but these functionalities run into difficulties when the drones are inside large steel or concrete structures. "We have a laser that spins around 360 degrees on the drone for navigation, allowing the drone to learn its environment inside the tank or boiler. When it knows its environment, it offers the collision-avoidance aspect," explains Smith. While other drones do include collision-avoidance capabilities, those systems may rely on cameras that typically do not properly function in a dark, featureless environment, such as the inside of a tank. The laser-based system works regardless of the lighting conditions of its environment, says Smith, and also takes into account the tanks' walls, floor and ceiling to create a virtual "bubble" around the drone for collision avoidance. This also eliminates physical interference between the drone and the inspected surface, whereas other drones may require a "cage" around the equipment to protect against collisions, which can hinder data collection. "This allows the operators to focus on gathering inspection data, rather than not running into things," he adds.

Beyond inspection, IA is seeing interest in using drones for emergency response purposes, for instance in evaluating the spill of a dangerous chemical, but these applications are still very new. According to Smith, the company is working with a local Federal Emergency Management Agency (FEMA) chapter to look at potential drone applications for emergency scenarios. "If there were a chemical spill, they'd want to send in a drone first before sending in a rescue team," Smith explains. "It'll be a big part of the drone world moving forward."

Smith believes that to better harness drones' potential in chemical-handling applications, autonomous, intrinsically safe equipment is the next natural progression. Although manufacturing drones to the safety standards dictated by certain industrial classifications would be quite demanding, there is confidence that companies will begin to investigate such offerings in the near future. "If we had a fully intrinsically safe drone, we could go into tanks without requiring commercial cleaning or degassing," Smith predicts. Currently, prior to inspection, tanks must undergo rigorous preparation per American Petroleum Institute (API) 653 standards. The next hurdle would be to use drones for in-service inspections, but developing capable equipment presents considerable challenges to drone manufacturers. "We would have to re-write the way drones work, essentially, to make that happen, and we are currently researching what that would take," he says. IA has recently acquired a large decommissioned fluid-storage tank to use for in-situ test flights of its drones for demonstration and research purposes.

With regard to autonomy, line-of-sight regulations present particular hurdles for pilotless drones. Earlier this year, Airobotics (Tel Aviv, Israel; www.airobotics.co.il) became the world's first company to receive federal authorization (from the Civil Aviation Authority of Israel) for Beyond Visual Line of Sight (BVLOS) operation of an autonomous drone. In an industry first, the company has deployed its autonomous drones for data-capture at the Worsley Alumina operations of Australian mining company South32 (Perth; www.south32.net).

In a cross-industry collaborative effort, AkzoNobel N.V. (Amsterdam, the Netherlands; www.akzonobel.com) is currently working to implement its InterPlan inspection system for coatings maintenance into drone surveys, which will decrease the time and cost required for such inspections, especially in difficult-to-reach areas, such as in marine installations (Figure 4). "With the even greater restrictions and issues around access involved in work-

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AkzoNobel

FIGURE 4. Pilot tests are currently underway to commercialze drones for the inspection of coatings in marine environments

ing offshore, we'll see greater efficiencies and benefits during the inspection process," says Chris Langley, InterPlan product manager. In tandem with research and development group Drone Ops, coatings specialist Safinah Ltd. and tanker operator Barrier Group, AkzoNobel is working to develop drones designed specifically for coatings and corrosion inspection in enclosed areas, including ballast water tanks and offshore wind farms. The project is progressing well, and a prototype bespoke drone is currently undergoing trial flights, according to Michael Hindmarsh, business development manager for AkzoNobel Marine Coatings. The team plans to deliver a working prototype later this year, although there are many challenges to address. "The project has to overcome many obstacles associated with the inspection of surfaces in confined spaces, including navigation through very small access holes and piloting outside of the line of sight, to name just two," says Hindmarsh. In Australia, AkzoNobel is currently testing drones for inspection tasks at remote production sites where access is limited.

Making the most of drones' data

Contextualizing, interpreting and organizing the massive amounts of data collected by drones is essential. At the forefront of integrating drone inspections with advanced analysis is Sky Futures (Hayes, U.K.; www.sky-futures.com). The company has recently signed expansive contracts with global manufacturing companies Eni S.p.A. (Rome, Italy; www.eni.com) and Petronas (Kuala Lumpur, Malaysia; www.petronas.com). Sky Futures not only provides drone-flying services, but also trains and encourages clients to learn how to use their own drones for everyday tasks. "The real benefits come when there is a drone on site at all times," says Colin Hickey, head of product at Sky Futures. "We've all got a laptop. Why shouldn't everybody have a drone?"

He emphasizes drones' potential to drastically shift asset-reliability practices by allowing more frequent plant assessments rather than depending on typical inspection cycles. "That's really the crux of what drones change. If you have a drone, you can do ten-minute flights to collect data rapidly and safely. It completely revolutionizes the way we gather information at a plant," he continues.

For instance, engineers can monitor flares with a thermal-camera drone and compare the data with the control-system feed and evaluate how the flare temperature is changing with the process flow. The imagery collected by Sky Futures' drones can be combined with other imagery sources, such as cameras on operator helmets or scope cameras that look inside pipes, for example, to formulate a more complete representation of the plant. "By putting all your data into a central repository, you're basically building a virtual version of the plant on your desktop that anyone can access," explains Hickey. In the past year, Sky Futures released additional imagery-analysis tools with algorithms that quickly pinpoint the most pertinent data from drone surveys, such as hot spots on pipe racks that can indicate potential leaks or corrosion under insulation. "We can process thousands of images in a few minutes and then tell operators where the faults are," he adds. Also, the algorithms can detect small anomalies that the human eye may miss, such as cracks in welds or small patches of corrosion. However, he reiterates that operators' expertise and input are still required to ensure the programs' reliability.

Hickey presumes that the next steps in the technology trajectory for drone-enabled analyses will involve more agile, autonomous drones that take into account weather and other site conditions to develop an optimal inspection schedule. Data would be automatically mapped and positioned onto servers and put through algorithms to allow for trending and predictive analysis. "As soon as you can spot a problem in an image, you can begin to trend that over time. That's the next thing we are working on," he says.

Designing a reliable drone can be somewhat analogous to process design. "Successful drone operators are the ones who think like process engineers," says Hickey on the importance of layers of protection in equipment design, even for drones. Multiple redundancies in GPS systems and duplicate propellers instill confidence in drones' reliability. However, while some organizations, including Oil & Gas UK (London; www.oiland-

gasus.co.uk), have drafted guidelines specific to the oil-and-gas sector, no comprehensive industry standards governing drones in chemical processing facilities are currently available. Similarly, testing and certification group SGS S.A. (Geneva, Switzerland; www.sgs.com) has written general audit standards for drone pilots, and the American Bureau of Shipping (ABS) has created certifications for drones in the maritime sector.

Drone imagery becomes reality

Bentley Systems, Inc. (Exton, Pa.; www.bentley.com) is using the data-capturing capabilities of drones to survey plants with the goal of creating "digital twins" that enable robust modeling and analytics. Bentley software processes a set of drone-captured 2-D photographs and compiles them into a 3-D reality mesh for a holistic view of an entire plant's assets (Figure 5). "The technology converts digital photographs into 3-D models very quickly," says Anne-Marie Walters, Bentley's industry marketing director for oil and gas. As the circumstances for utilizing drone technology have expanded and their capabilities have advanced, users' confidence in drone safety and reliability has grown as well, according to Walters. Bentley has partnered with surveying specialist Topcon Positioning Group (Livermore, Calif.; www.topconpositioning.com) to facilitate automated cloud services that interface with drone-captured imagery. "The work with Topcon focuses on capturing the as-is condition of assets, in as close to realtime as possible, so users can quickly make decisions," explains Walters.

Interest in these types of aerial surveys for chemical plants began to surface in the past 2–3 years, according to Jerard Marsh, application engineer for Bentley Reality Modeling Product Development. "What the drone gives you is a full 360-degree overview of your plant that you won't get with laser scanning. You can see the tops of pipe racks, you can see around pressure vessels, so it offers much more context," says Marsh. Even a very high-level overview of a plant based on drone-generated imagery can be useful in safety reviews and brownfield site modifications. According to Marsh, several thousand photos can be captured via drones in a matter of 2–3 hours.

A wide range of CPI companies, with different end-goals in mind, have utilized drone capture and reality modeling. Walter cites several examples, including biopharmaceuticals company UCB S.A. (Brussels, Belgium, www.ucb.com), which used drones to quickly appraise the options for decreasing the carbon footprint of a manufacturing site that was built in 1928. "They basically captured a reality model of the entire manufacturing site using a drone to quickly identify and communicate the practical ideas they had for making modifications to achieve their carbon-reduction goals," Walters explains. Using drones, UCB even identified some space at the site where solar panels could be installed.

In another example, a Kansas-based ethanol producer in the midst of a facility expansion faced difficulty in gaining regulatory approval to move forward with the project due to inadequate drainage plans. A surveying company used a drone and Bentley software to develop the drainage plans in less than a week. "A traditional survey would have taken three times as long," Walters suggests.

In another case, drones were used in a situation where two adjacent steel-manufacturing plants were merged into a single facility and no overarching site survey had ever taken place. "They needed to modernize their fume-extraction system for the entire complex, but no one had ever done one overall survey of the complex," says Walters. Imagery from both photographs and laser scans were combined to generate a reality model and quickly design the extraction system. The reality model was also used to reevaluate the structural integrity of some older parts of the factory. Additional drone users seen by Bentley include a Korean thermal-power operator, and a risk-based inspection provider in South Africa.

Despite the ease of conducting surveys, processing companies still harbor some concerns about introducing drones into their facilities. However, the rapid proliferation of drones for industrial use has led to enhanced onboard safety systems. "These drones are getting so advanced now, with so

Bentley Systems

FIGURE 5. The comprehensive aerial imagery provided by a drone survey can be used to formulate a 3-D reality model of a plant

many safety sensors put in place, that if anything goes wrong, the drone lands itself automatically," states Marsh. Although, as mentioned previously, no industry standards are currently available governing the use of drones in chemical plants, many companies have developed their own conservative safety and operational guidelines, in collaboration with inspection and surveying groups. "Individual companies are beginning to work out what the regulations should be locally. They go through their own rigorous safety protocol before they start to operate drones on site," explains Walters. "At the end of the day, it's just another piece of equipment you're using with your assets."

Smarter decommissioning

The many complexities of plant decommissioning and demolition require extensive planning and inspection. Dilapidated structures at long-abandoned facilities can present significant challenges and potentially put personnel at great risk. For the past few years, decommissioning specialist RVA Group (Borehamwood, U.K.; www.rvagroup.org) has been utilizing drones as part of their decommissioning services. Most recently, the company was appointed by SABIC (Riyadh, Saudi Arabia; www.sabic.com) to provide extensive decommissioning for several U.K. assets, and drones were deployed in order to inspect structures as part of the initial decommissioning strategy. "In the decommissioning arena, we are dealing with very old assets that sometimes have not been maintained for a number of years. So before we can send anybody in, we need to be sure of the safety and security of the asset itself," explains Matthew Waller, EHS & Engineering manager with RVA Group.

FIGURE 6. Drones outfitted with emissions-monitoring sensors can provide continuous reporting for mapping purposes

Aeromon

The remote viewing capabilities of drones provide quick and relatively inexpensive inspection of large, complicated plant structures, explains Richard Vann, managing director of RVA Group. Alongside other advanced technologies, such as ground-penetrating radar and laser scanning, drones provide inspection details that are infeasible or difficult to obtain with previous inspection techniques. "With drones, we literally get a bird's-eye view. We can fly into places where we wouldn't be able to send personnel without putting an enormous amount of manpower on the ground for initial inspections. It's given us a window of opportunity to speed up the investigatory process," says Waller. These initial inspections are especially crucial for sites where accurate records of the construction details are not immediately available, or where records may not be up to date.

Inspections are particularly challenging in long-dormant plants. "We are looking at assets on a project in the U.S. that have laid idle for 50–60 years, and they are overgrown with trees and moss. You wouldn't think of letting anyone use the access routes or the staircases," says Vann. Flying camera-equipped drones over the site revealed numerous hazardous situations, including holes in building roofs, collapsed staircases and even elements of structures that had become detached. According to Vann, the use of drones was essential in this project to understand how to best access the plant and to determine safe areas for personnel to work. "I'd rather lose a dozen drones than one person cut their finger," he says.

Of course, there are certain precautions that must be taken before flying drones into potentially hazardous areas, including plants where some portions are still operational. The first key hurdle, particularly when dealing with hydrocarbons, is safety, according to Waller. "Equipment that is to be taken into various areas of the plant must be rated appropriately for zoned areas with potentially explosive atmospheres." In some cases, the group's drones could only be used at a predefined distance from a certain asset. Also, limitations may be placed on whether the drone can fly inside of a structure, as the drones' transmission components may present a potential source of ignition. "To our knowledge, there are no ATEX-rated drones currently, but surely the market

RanMarine

FIGURE 7. The removal of solid waste in closed waterways is aided by the use of swimming robots

will quickly recognize this gap," says Waller.

Another concern is interference between the drone and the operating assets' instrumentation. Waller cites a project where drones were to be used nearby live operating assets, including plant-critical instrumentation. The team carried out a review of the potential for interference with drone signaling, since losing control of a drone could lead to collision with plant-critical structures with possibly catastrophic results. As a result of the review, the team implemented no-fly zones in certain plant areas to eliminate interference risks.

Another application for drones that RVA Group has found is for filming explosive demolitions. "From an engineering point of view, it's a good way to study collapse mechanisms, how a building or structure falls. From that, you can learn for future similar events," adds Vann.

Environmental remediation

Drones are also proving to be practical in the environmental and regulatory sectors. For instance, SeekOps, Inc. (Pasadena, Calif.; www.seekops.com) develops methane-gas sensors for drones. Earlier this year, SeekOps licensed a miniature gas sensor originally developed at NASA's Jet Propulsion Laboratory (www.jpl.nasa.gov). According to the company, the sensor is specifically suited for aerial configuration due to its miniaturized nature, and can detect methane in the parts-per-billion (ppb) range to precisely highlight small leaks before they begin to pose problems for operators. SeekOps is currently working toward a commercial release for drones equipped with these new sensors.

Aeromon Oy (Helsinki, Finland; www.aeromon.fi) is looking to bring drones into the emissions-monitoring arena through the creation of a sensor module designed specifically for aerial use. Weighing just 850 g, the company's BH-8 unit quantifies and maps emissions in realtime using up to eight different gas sensors simultaneously, with capabilities to measure up to 70 different gases, including combustible or explosive gases, refrigerants and VOCs, as well as particulate matter. Visualization of monitoring data is provided directly onto a map or aerial image in realtime (Figure 6). In addition to monitoring gaseous and particulate emissions, Aeromon has also enabled noise-monitoring capabilities into its devices. The company has had several successful pilot proj-

ects at industrial sites, including detecting leaks, mapping potential areas for toxic-gas release and reducing the risks associated with storing biomass by monitoring the presence of combustible gases. The BH-8 aerial sensor platform is slated for commercial release in late 2017, according to Aeromon.

RanMarine

FIGURE 8. Automated water treatment is a new frontier for drones

The potential applications for drones extend beyond the skies into the water. Swimming — rather than flying — drones can be deployed for cleanup tasks in waterways where it might be difficult or hazardous to send personnel. RanMarine Technology B.V. (Rotterdam, the Netherlands; www.ranmarine.io) develops autonomous drones for removing solid waste or chemical contaminants from bodies of water. RanMarine's waste-cleanup drone model, known as the WasteShark (Figure 7), can collect floating debris, such as plastic waste and other solid trash. Similarly, the company's PlantShark model targets alien, or pest, vegetation, whose presence can place stresses on water supply and threaten biodiversity.

The company's newest endeavor, the ChemShark, is equipped with proprietary internal filtration technology to remove contaminants in ports, canals, lakes or other similar bodies of water (Figure 8). According to Oliver Cunningham, RanMarine's chief commercial officer, the ChemShark is currently in the testing phase for advanced filtration technologies to efficiently remove a number of contaminants. RanMarine is working with a municipality in Sweden to deploy a ChemShark drone into a local port that has several chemical contaminants in its water, including cadmium, arsenic, copper, zinc, lead, polychlorinated biphenyl and dioxins. The company is also partnering with a potential customer in South Africa to institute a drone-based cleanup program for waste removal from a major commercial port. The company has also been investigating oil-spill-remediation capabilities for the ChemShark. According to Cunningham, RanMarine expects to have the first ChemShark in the water by early 2018.

Marine drones are a natural fit for cleaning up tight spaces in waterways where waste or contaminants may accumulate. "The value of our drones over other waste-collecting vessels is that they are smaller, more agile, lighter and cost significantly less," explains Cunningham. Furthermore, RanMarine is using solar-powered batteries in their drones, so the carbon footprint is extremely low. There is also no need for personnel to enter hazardous contaminated water, eliminating some serious safety concerns. And since the drones are fully autonomous and can run continuously, cleanup tasks can be completed more quickly. Furthermore, says Cunningham, the drones can work in intelligent teams, sharing information and effectively self-organizing to most effectively tackle the task.

One of the main concerns the company emphasized in the development of their technologies is the avoidance of unintended consequences for the ecosystem in a body of water. "To extract one chemical out of the water, you may have to introduce another chemical. The introduction of this new chemical might be problematic, so we are absolutely determined to think through these side effects first," says Cunningham. "We're also very mindful of wildlife and biodiversity. We've had zero animal or human injury to date," he continues. Another important consideration in the development of the ChemShark was the material of construction for the drone's hull, which has to withstand continuous exposure to harsh chemicals and potentially extreme conditions. The company decided on a silicon-resin polymer material that provides strength and resilience in corrosive marine environments.

On the horizon

The CPI's fast adoption of drone technologies for inspection purposes will likely soon expand to several other applications. The creation of consistent regulatory guidelines, along with drone manufacturers' efforts to tailor product offerings for industrial tasks, may enable drones to someday become as ubiquitous as engineers' laptops. Furthermore, research and development projects will help to craft drones for expanded applications, as more autonomous and even intrinsically safe options begin to take flight. ■

Mary Page Bailey

Odor Issues and Solutions for Wastewater Treatment

Increasingly, wastewater treatment plants must address odors due to volatile contaminants. This guide provides an overview of odor causes and possible remedial actions

Laura Haupert
OMI Industries

IN BRIEF

Processes and applications that emit odor-causing air contaminants are common across many sectors of the chemical process industries (CPI). In many cases, including wastewater treatment plants (WWTPs), paper mills, asphalt refineries and other operations, large volumes of odor-causing compounds are generated, and residents of the areas surrounding the facility can be exposed.

In the past, these odors were less of an issue because most industrial facilities tended to be located at considerable distances from large residential areas. In more recent times, however, there has been an increase in the number of industrial operations that are located within or near small towns and even large cities. When local residents constantly smell these industrial processes, unhappy neighborhoods are generally the result.

The collective voice of the public is now often strong, and has resulted in new regulations regarding odors and odor control at industrial facilities. Many industries can no longer produce odors without facing the consequences of either constant complaints, or fines from federal, state and local authorities. In addition to being a nuisance, these foul odors can pose a health and safety concern for the community, especially at high concentrations.

Furthermore, increases in population and associated industrial growth have driven an increase in the amount of waste requiring processing, and a subsequent increase in the odor problem.

FIGURE 1. Wastewater treatment plants can be sources of odor-causing gases, such as hydrogen sulfide, ammonia, mercaptans and others

This article provides information about common odor-causing compounds and about possible methods for controlling those odors, with a particular focus on WWTPs.

Odors and health hazards

In general, odors are subjective, so that a particular type of odor may bother one person while having little or no impact on another. The odor threshold is the minimum concentration of an odorous compound that is necessary to be detected by 50% of the population [*1*].

In principle, all chemicals can theoretically be toxic at high enough concentrations. For instance, water is not normally considered toxic. However, drinking an excessive amount of water under certain circumstances can create a condition called hyponatremia [*2*]. A similar situation applies to the concentration of odorous gases. At low concentrations (parts per billion; ppb), some gases can be detected by most humans. However, those gases are not toxic

TABLE 1. COMMON ODOR-CAUSING COMPOUNDS AT CPI FACILITIES

Substance	Odor threshold (ppm)	Characteristic odor	TWA[c] (ppm)	IDLH[d] (ppm)
Ammonia[a]	46.8	Pungent	25	300
Benzene[b]	37	Solvent	1	500
Ethyl mercaptan[a]	0.001	Earthy, sulfide	0.5	500
Hydrogen sulfide[a]	0.00047	Rotten egg	10	100
Methyl mercaptan[a]	0.0021	Sulfide, pungent	0.5	150
Styrene[b]	1.9	Aromatic	50	700
Toluene[e]	2.9	Sour, solvent	10	500
Trichloroethylene[b]	21	Solvent	25	1,000

a. http://dx.doi.org/10.1080/00022470.1969.10466465
b. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=40610&CFID=79236647&CFTOKEN=90216829
c. https://www.osha.gov/dsg/annotated-pels/tablez-2.html
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e. https://www.epa.gov/sites/production/files/2016-09/documents/toluene.pdf

until the concentrations reach low parts-per-million (ppm) levels. Unfortunately, many industrial processes produce odorous gases at concentrations that are both a nuisance and that can present real health hazards.

Ammonia, hydrogen sulfide, mercaptans and volatile organic compounds (VOCs) are examples of odorous gases that may be produced in the processes of several types of industrial facilities, including (but not limited to) WWTPs, asphalt refineries, hot mix plants, landfills, farms and others.

Table 1 lists several common odorous gases associated with these industry sectors. The table includes odor thresholds, characteristic odor, time-weight average (TWA) and immediately dangerous to life or health (IDLH) levels for each gas. The TWA represents the concentration of a given chemical that will not cause adverse effects when the exposure reaches eight hours per day. In most cases, the TWA is higher than the odor threshold; meaning that you can smell the odor before there is any potential hazard. The IDLH is the level at which a chemical can cause death or permanent adverse health effects. Notice that the IDLH is a higher concentration than the odor threshold for most of these chemicals. However, in the case of hydrogen sulfide, the human nose can become desensitized to the gas at concentrations lower than the IDLH. This means that humans may not smell the hydrogen sulfide at levels where it can cause severe harm or death.

The following descriptions cover several of the most common odorous gases found in the CPI.

Ammonia. Ammonia is a colorless gas that is highly irritating with a pungent odor at room temperatures. It is soluble in water, corrosive, and has alkaline properties. It can cause hoarseness, violent coughing, painful breathing, impaired vision, dyspnea and cyanosis when exposed to high levels [*3*].

Hydrogen sulfide. Hydrogen sulfide is a highly flammable, extremely hazardous gas that has a characteristic "rotten egg" smell. Hydrogen sulfide has an odor threshold of 0.00047 ppm, meaning that 50% of a human panel can smell it at that low of a concentration [*4*]. At a concentration of around 150 ppm, olfactory nerves can become paralyzed, resulting in humans having the sense that the smell disappears. Hydrogen sulfide is lethal at 700–1,000 ppm within minutes [*5–7*]. A complication with hydrogen sulfide is that your sense of smell disappears at only 150 ppm. Therefore, one could be exposed to higher levels of hydrogen sulfide and not know that it is present. It is soluble in water, corrosive and toxic to both humans and the environment.

Mercaptans. Mercaptans, such as ethyl mercaptan, are compounds that contain a carbon-bonded sulfhydryl group (–C–SH or R–SH, where R represents an alkane, alkene or other carbon-containing group of atoms). Mercaptans are flammable, have strong odors, and can be detected by the human nose at concentrations in the parts per billion range. Ethyl mercaptan is intentionally added to propane at low concentrations in order to help warn of a potential gas leak. At higher concentrations, according to OSHA (U.S. Occupational Safety and Health Administration; Washington, D.C.; www.osha.gov) regulations, ethyl mercaptan is classified as an acute toxic material for oral ingestion and inhalation, as well as for skin sensitization [*8*].

VOCs. VOCs, such as styrene, toluene and trichloroethylene, are organic chemicals that have high vapor pressures at room temperature. Their high vapor pressure allows them to either evaporate or sublime, respectively, from a liquid or solid to a gas. Hazardous VOCs present safety concerns, because they can be flammable, can cause cancer and chronic health effects, and may be lethal at certain concentrations. For example, toluene is a VOC found in many industrial applications, including both wastewater treatment plants and asphalt refineries. It has a high odor threshold of 2.9 ppm, which indicates that the presence of the odor may not be a good judge of safety for this chemical. Toluene poses a safety concern, as it presents acute toxicity hazards for oral ingestion. It is also a skin and eye irritant, and it may cause damage to organs through prolonged or repeated exposure. With an odor similar to paint thinner, it is an aromatic hydrocarbon, and is insoluble in water [*9*].

FIGURE 2. Odor-removal methods, such as the vapor-line system shown here, involve treating the air that contains the odor-causing species

Odors at WWTPs

Wastewater treatment plants (WWTPs) generate odors during many of their normal processes, including collection, treatment and disposal (Figure 1). Incoming waste includes both household and industrial sources, which both contain a number of different types of odor-causing compounds. Industrial sources often cause concern because the waste can contain a number of toxic chemicals. Other odor-causing chemicals do not directly come into a WWTP from households or industrial sources. They are generated by anaerobic biological activity that consume the organic material found in the wastewater.

One of the most common odorous gases found in WWTP is hydrogen sulfide (H_2S). It is produced in wastewater by the reduction of sulfate to hydrogen sulfide gas by bacteria. At a pH above nine, the hydrogen sulfide is in the form of hydrosulfide ion (HS^-), which does not have an odor. However, at pH below nine, hydrogen sulfide is released from the wastewater [*10*]. In addition, chemical reagents used at WWTP for treatment may be odorous and can produce odors during the treatment process. Common emissions from WWTP include hydrogen sulfide, mercaptans, VOC, ammonia and some nitrogen containing compounds.

At WWTPs, compounds are only noticeably odorous if the compound is volatilized into the air. For example, hydrogen sulfide dissolved into wastewater has little odor. However, turbulence in the wastewater, increased temperature, solubility changes and pH changes can all cause compounds, such as hydrogen sulfide, to volatilize to the gas phase, thereby producing a higher level of odor. In addition, the surrounding community often considers the odors coming from WWTPs as being problematic. The WWTPs have to evaluate the source of the odors. Many studies have determined the main sources of odors at WWTPs

to be the primary settlers, sludge-digestions tanks, sludge thickening, dewatering areas, raw wastewater, centrifugation and disposal systems [*11*]. Overall, two of the main contributors to odors are the primary treatments and sludge-handling areas. At this point, WWTPs have to consider what type of odor control to use.

Odor remediation methods

WWTPs can use a variety of methods to remove odors. The main odor control categories into which these methods fall are the following: operation control methods, liquid-phase addition and vapor-phase methods (Figure 2).

Operation control methods. Operation control methods involve changing a process or operation in order to reduce the odors. Operators can help prevent offensive odors by maintaining the correct dissolved oxygen concentration, for example, or by preventing excess sludge from degrading, preventing overloading and many other simple maintenance techniques. However, operators are often limited in what changes they can make and may lack the resources to make the necessary changes. If operators are unable to make changes to these processes, or the changes do not fix the odor problem, then they may look to other methods of odor control.

Liquid-phase addition. Liquid-phase addition involves adding a chemical to the wastewater in order to control the odors. The chemical addition may either prevent odor-causing chemicals from forming or may react with the odorous compounds to produce a safer, non-odor-causing species. Engineers may be able to take advantage of other benefits with this technique; namely, corrosion control. For instance, hydrogen sulfide will react with many of the liquid-phase chemicals, resulting in hydrogen sulfide not being released into the air stream. Therefore, hydrogen sulfide will not corrode the WWTP equipment.

Liquid-phase chemicals include, but are not limited to, oxidizers, pH modifiers and bactericides. Oxidizers typically react with hydrogen sulfide and other sulfur compounds. Bactericides work by either inactivating or killing anaerobic bacteria. The pH modifiers tend to prevent the hydrogen sulfide from volatizing into the air. The most common chemicals added to the wastewater are iron salts, ozone, nitrates, chlorine and hydrogen peroxide.

Vapor-phase approaches

Vapor-phase methods involve the treatment of the air or vapor that contains the odorous compounds. There are many different vapor-phase technologies that WWTPs utilize, including, but not limited to, scrubbers, biofiltration, activated carbon, masking agents and natural odor control using plant oils as the active ingredients to neutralize the odors. Below is a brief summary of the basic way each of these methods works.

Wet scrubbers. Wet scrubbers pump the contaminated air into an aqueous solution before it goes to the ambient air. The odorous compounds go into the liquid, and then the odor-causing chemicals react with the solution. Wet scrubbers typically use sodium hypochlorite, potassium permanganate, hydrogen peroxide or sodium hydroxide in the aqueous solution. If hydrogen sulfide is the main odor concern, sodium hydroxide is often used. However, if mercaptans or ammonia are also present, then a multi-stage scrubber is used, with both sodium hydroxide and sodium hypochlorite utilized in separate stages.

Biofiltration. Biofiltration uses soil, compost or some other material, such as a substrate for bacteriological population. The microbes remove odors from the air through the media. In order for the microbes to interact with the odorous compounds, there must be a large residence time in the media. By lowering the velocity of the air going through the media, longer residence times result. Biofiltration works on odors that are both biodegradable and water-soluble, including hydrogen sulfide and other sulfur-containing compounds. They do not work effectively on chemicals containing nitrogen.

Activated carbon. Activated carbon works by having the contaminated air stream pass through this adsorbent material. Activated carbon is porous, with a large surface area, which allows it to adsorb the odorous chemicals in the air stream. While activated carbon works well on sulfur-containing compounds, it is not as effective at treating nitrogen-based compounds [*12*].

Masking agents. Masking agents are chemicals that are sprayed into the air to cover up the odors produced at the WWTP. Masking agents use fragrances to cover up the odors. They often work by adhering to the outside of the odor molecule. After a short period, the fragrance and the odor separate, leaving the odor behind. While masking agents give an immediate cover to the odor, the odor will eventually return. As a result, not everyone in nearby communities will be happy with the overall outcome.

Natural solutions. Finally, natural odor control solutions can fully neutralize odors, and are atomized or vaporized into the air. These odor-control products contain natural plant oils, food-grade surfactant and water, and are both safe for the environment and the local community. When the natural odor control product is atomized into the air, small droplets are produced that cover a large surface area and attract odorous gas molecules through electrostatic charges. The electrostatic charge also facilitates the attraction of malodor molecules to the droplet surface whereby they absorb into the droplet. Once the malodor is in the droplet, odor neutralization occurs. The malodor then either naturally biodegrades in the droplet or an acid/base reaction takes place, producing a non-hazardous organic-salt and water.

Natural odor-control solutions often use plant oils. These products have the capability of neutralizing a broad spectrum of odorous chemicals, including hydrogen sulfide, mercaptans, VOCs, ammonia and amines. These solutions can be atomized into the air at WWTPs via air atomization systems, hollow bladed fans or by vapor-phase systems. The air atomization systems use water and nozzles to atomize the product into the air. The nozzle system can be suited to most applications at a WWTP. The hollow-bladed fan system is a uniquely de-

signed system that dispenses the product into the open air.

Current vapor-phase systems offer a simple, effective and economical delivery system specifically developed to disperse the water-based odor-eliminating neutralizers. Vapor-phase units are designed to produce sub-micron droplets of products. This is accomplished by a centrifugal pressure blower that intakes atmospheric air. The intake air stream is sprayed with product, pulled through the blower and finally dispersed on the outlet side of the blower. Additional water is not required. The sub-micron size droplet allows for a more effective dry vapor that absorbs more odor molecules than atomization systems.

In recent years, WWTPs have come under an increasing level of scrutiny from their respective surrounding communities. The perception of odors coming from WWTPs has resulted in many complaints from the community. Investigating the various odor-control methods described in this article can help minimize complaints. Overall, the best solution would be one that removes a broad spectrum of odors, and is safe for both the community and the environment. ■

Edited by Scott Jenkins

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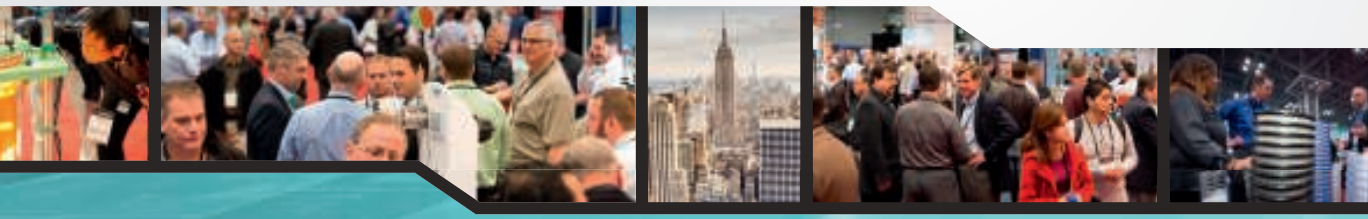

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Smart Water-Management Strategies: The Time is Now

Considering water-management strategies as a central component of infrastructure design at industrial facilities will unlock cost savings throughout the operation

Jürgen Engert
Schneider Electric

IN BRIEF

Mounting water shortages and resulting regulations across the globe are fueling the need for seamless and smarter water-management methods — particularly in industrial manufacturing environments where water usage, treatment and disposal is a critical part of all processes. In these settings, water control and management should not be isolated or treated as an afterthought, but rather included in plant infrastructure strategies from the onset. If water quality is poor, it compromises everything that follows, and can also affect the life expectancy of a plant's water systems, product quality and overall infrastructure. A strategy is needed that thinks beyond SCADA (supervisory control and data acquisition) systems to render all aspects of an industrial facility viewable as a single pane of glass, enabling manufacturers to access all information in one place for a "smarter" approach to water and product management.

Schneider Electric

FIGURE 1. The increasing scarcity of water as a resource is driving change in the production processes used by industrial companies

Achieving a smarter water-management strategy requires addressing some key industry challenges, such as aging and failing infrastructure, tightening regulations, pressing needs for water conservation and quality, among others (Figure 1). Despite the challenges, new monitoring and manage-

ment technologies are readily available today to optimize your assets, including both human assets and hardware availability, delivery, use and quality. These technologies help drive operational and maintenance efficiency, reduction of waste in energy, material and operation, and improves the bottom line.

This article provides an overview of best practices related to gaining a centralized perspective for an entire process network that includes water, in order to better manage human, hardware and stranded assets, reduce water leakage and reduce energy costs — all contributors to a plant's bottom line. Cost savings can then be re-invested back into the network and infrastructure for further efficiency and performance gains. The article discusses five key best practices, including: increasing operational efficiency; optimizing energy consumption, continuity of service and regulatory compliance; improving asset performance management; and using innovative technologies to achieve smarter water management.

Water resource challenges

The author Mark Twain once said, "Whiskey is for drinking; water is for fighting over." While the statement came from a much earlier time period, it's becoming increasingly relevant today.

Current forecasts suggest the possibility of a global water crisis is highly probable in the not too distant future. According to the United Nations, by 2030 the world water supply will fall short by at least 40%, as detailed in the World Water Development Report 2015. The report can be found at www.unesco.org. Those who have better prepared for this inevitability will fare better than the rest. The impact of a 40% shortfall will be felt well before 2030. What can be done today to minimize the likelihood of a business disruption or unexpected cost escalation due to water issues in the future?

In much the same way that petroleum was a 20th-century resource-management issue, water is quickly becoming our next resource challenge, and will likely be how the 21st-century is remembered, with far-reaching impact. With the realization that there are no renewable alternatives to water, it is a scarce resource that cannot be simply "manufactured." We need to use water without using it up — we must protect what we have, become more efficient and continue to push the boundaries of technology to secure a water-safe future.

This realization — in conjunction with increased water-related regulations across the globe — is fueling the need for seamless, smart water-management strategies, particularly within city infrastructures, highly populous regions and across industrial manufacturing environments, where water usage, treatment and disposal are critical needs. In these settings,

water control and management should be carefully considered as part of industrial processes and plant infrastructure strategies from the onset. If water quality is poor or water is wasted, all operations that follow are compromised, which negatively impacts operational performance, costs and the life expectancy of a plant's water systems and output.

Impact on industry

The increasing scarcity of water will be accompanied by cost increases, environmental hurdles and increased competition to simply find and secure available water. Operators of industrial facilities should anticipate tighter regulatory scrutiny across the world. These challenges will be far reaching and will have serious impacts on many organizations. Mining and power generation companies must accelerate innovation to transform processes to be more eco-friendly to better manage and reduce trace impurities in wastewater. Chemical and petrochemical facilities with extremely large wastewater streams must adapt to minimize liquid discharge and reduce water dependencies as costs escalate.

Although these challenges vary in nature and magnitude across industrial facilities, significant opportunities for improvement are closely connected. For instance, the volume of data collected around consuming and discharging water is expected to grow dramatically, as the use of smart meters and sensors spreads in the industry. However, it is not just about collecting, managing and analyzing data, but rather about improving the quality and speed of decision-making to transform the way water and water infrastructures are managed and used. Data-driven insights have great potential to transform the way both utilities and industrial manufacturers think about water as a resource and how the industry plans, invests and manages its water footprint.

Now is the time to rethink how smart water solutions can be implemented today to reduce the pending water availability constraints of our future. The first step is to change how we think about water — it is no longer a limitless resource that simply needs to be managed. The future will require a much closer examination of how water is collected, utilized and recycled in order to minimize the potential disruptive effects now on the horizon. Moving beyond SCADA solutions will be necessary, to not only react to how water is used, but to proactively engage with water-consumption processes as a potential to optimize and significantly transform the role water will play in industrial operations.

New intelligence extracted from an increasing reliance upon the industrial internet of things (IIoT) will reveal new tips that manufacturing facilities can adopt to achieve a more holistic approach to optimize water manage-

FIGURE 2. The role of mobile devices has greatly expanded to better visualize system performance and improve worker efficiency

ment. This "beyond SCADA" mindset will underscore best practices that will allow industrial organizations to better manage water as a precious resource through all production stages, from site assessment to the supply chain, and from raw material stages to production and distribution strategies that are highly focused on the recycling or reclaiming of wastewater.

Filling the void

SCADA systems have been around for decades. Yet despite the many technology improvements that have occurred in automation, collaboration and application development, a large proportion of SCADA devices and applications provide the same level of operational functionality as what was available 20 years ago. From a control room perspective, data acquired from control devices lets operators visualize what is happening in the field. When an out-of-tolerance event occurs, alarms are triggered to elicit an appropriate response. Once this transactional data has been acted upon, it is often discarded. Or, it is retained within the system, but is never accessed again.

Consider the following questions:

- When an alarm occurs, does your workforce have enough information to act accordingly?
- What do you do with the data collected from daily maintenance rounds?
- Does your SCADA system allow you to perform maintenance when it is needed, or only when something breaks?
- Are all of your systems integrated to provide a single version of the truth?
- Can you determine whether your processes today are better or worse than last week? How about between locations?
- Can you guarantee an event response is conducted as a standardized process? Or, if not, do you have visibility to understand what happened?
- Is your workforce accountable in a measurable way?
- Is your workforce properly trained to handle any situation?
- Can your SCADA system help to capture and analyze energy consumption data, in context, to then recommend suitable responses that are actionable?

All of the data necessary to answer these questions flow in and out of your SCADA system at near real-time speed. Going beyond the traditional mindset delivered by SCADA systems is what the term "beyond SCADA" is all about. Beyond SCADA solutions can provide longterm value, and a tremendous return on investment. Such solutions can achieve this through the following:

- Empowering your workforce with increased mobility, communication and intelligence (Figure 2)
- Enforcing operational standards with workflows and mobile, intelligent rounds
- Enabling return on investment by reducing maintenance and energy costs
- Energizing businesses with collaborative data in one environment delivering one version of the truth
- Ensuring consistent and accurate data to protect against compliance concerns

More importantly, a "beyond

SCADA" strategy can begin to reveal new levels of detail on how resources are consumed within production processes — including water. Process innovation can be tested and readily compared to past performance to identify opportunities for improvement and reduced resource requirements. Enhanced visibility from across all operations can then allow these improvements to be readily applied across all operations, consistently, to help amplify the effects of improved performance to much higher levels, as operational agility increases accordingly.

Going one step further, if there is a shift in how water resources are managed individually by businesses or utilities, and the elements of that shift are crystallized as industry best practices that enhance sustainable water management and water quality standards, then significant results can be achieved. It will only be with this level of collaboration and sharing of best practices that the forecast 40% reduction of water availability can be reached without disastrous consequences to industry.

Implementation strategies

Here are a few practical implementation practices that you should consider to be part of your company's global water strategy. These should then be revisited as a part of your continuous improvement and water optimization strategy:

Increase operational efficiency. Centrally monitor and manage all plants and assets, including water usage, water and wastewater treatment and water infrastructure. This allows plants to maintain continuity of supply and quality, enable benchmark consumption and save electricity with storage and analytics of key parameters. These actions help avoid unscheduled downtime and identify opportunities for process improvement. Regular analysis of asset status and data can also help identify parts of the network that may be under stress and predict early failures.

Optimize energy consumption. Expand visualization, modeling, analysis and reporting at an asset or site level for smarter energy consumption. The design, simulation, monitoring, reporting and equipment for water networks can optimize water delivery with full leak detection to minimize non-revenue water. For instance, better capabilities to gain insight on the root cause of leaks and remediate issues more quickly can help reduce the impact of disruption.

Improve continuity of service and regulatory compliance. There are plenty of applications with advanced data analytics tools to help gain visibility for operations staff, including historical data, alarms, events and reporting, including automatic notifications that help maintain regulatory compliance for the lowest possible cost, with the

highest continuity of service. Such models can also help better simulate future risk scenarios and improve intervention response.

Establish closed-loop solutions for asset performance management. The IIoT is empowering organizations to shift to a holistic, operations-centric view where condition-based, proactive and predictive maintenance strategies let frontline staff act before costly failures occur. As a result, companies can establish closed-loop solutions to monitor and control individual assets, improve operation of key processes and access to enterprise wide information for improved decision making.

Invest in operator training. Each of these initiatives can yield significant results, but only if they are actually executed upon and adhered to consistently across all of your operations. The mindset must evolve within industrial companies that water is a shared, global and scarce resource that must be treated accordingly.

The road ahead is long and will not be easy. But early adopters of these best practices are now seeing efficiency improvement at levels not previously considered possible. Investment in these types of solutions can have a break-even point in shorter periods of time than previously considered.

The benefits from implementing this strategy can extend years into the future, while at the same time providing cause for celebration when scarce water resources are better preserved and recycled. Employees working at industrial companies will be proud of the progress, as will your customers.

Collaboration across entire industries on water-related issues will transform business processes, and help avert significant environmental and cost ramifications. And, with the evolving global regulations certain to be in the future, those organizations that invest today in smart water strategies will avoid potential business disruptions and unexpected cost increases. It all starts with SCADA. Now is the time to do something with the data, to be proactive and add intelligence for a smarter future, by looking "beyond SCADA." ■

Edited by Scott Jenkins

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An Overview of Vacuum System Design

The design of vacuum systems deserves careful attention — there are multiple facets that affect efficiency, operability and cost

Patrick Govoni
DPS Engineering

IN BRIEF

Understanding vacuum and designing vacuum systems can be difficult, and there are many unique aspects that an engineer must take into account. Although some aspects of compressed-gas system design can be translated to vacuum-system design, for the most part they are two entirely separate subjects. This article discusses common misconceptions, such as units of measurement and calculation of flow. It also covers methods of producing vacuum and design aspects, such as minimizing air leakage, pressure drop, condensation and a specific approach to sizing vacuum piping. The design of vacuum systems is certainly a topic that deserves careful attention given that there are multiple facets that affect efficiency, operability and cost. After a few key changes in perspective, the reader will find the subject is not as intimidating as it first appears.

NOMENCLATURE

ACFM Actual cubic feet per minute, ft^3/min
SCFM Standard cubic feet per minute, ft^3/min
p Pressure, torr
T Temperature, °R
$F_{a,b}$ Mass flowrate of components a and b, lb/h
$MW_{a,b}$ Molecular weight of components a and b, lb/lbmol
q_{pV} Throughput, torr·ft^3/min
V Volume, ft^3
t Time, min
m Mass, lb
R Universal gas constant, 1,545 lbf·ft/(lbmol·°R)
C Conductance, ft^3/min
Δp Pressure differential, torr
S Pumping speed, *ACFM*
p_0 Pressure prior to pumpdown, torr
p_1 Pressure after pumpdown, torr
L Length, ft
f_D Darcy friction factor
ρ Density, lb/ft^3
v Velocity, ft/s
D Hydraulic diameter of pipe (internal pipe diameter of a circular section), ft
W Piping air leakage, lb/h
w Valve air leakage, lb/h
Q Volumetric flowrate, *ACFM*
A Pipe flow area, ft^2

Introductory concepts

Defining vacuum. The common definition describes vacuum as a space void of matter. However, at the current level of technology, scientists have not demonstrated that it is possible to remove all gas from a given space. The practical definition would be that vacuum is a space where the pressure is lower than atmospheric pressure. In casual conversation, the definition of vacuum is often incorrectly defined as the pressure differential or the force created between an area of lower pressure and an area of higher pressure. Whichever way it is defined, the functions and applications of vacuum are myriad and span across industries. The core applications include removing active atmospheric components that could cause physical or chemical reactions for dairy packaging applications, achieving a pressure difference for lifting, reducing heat or electrical energy transfer for insulation, or removing dissolved gas or volatile liquid from materials for freeze drying.

Units. Understanding units is the first challenge encountered when learning about vacuum. For most common pressure units, a particular pressure lower than atmospheric can be described in three distinct ways: an absolute pressure (4.7 psia), a gage pressure (–10 psig), and a vacuum pressure (10 psi vacuum). This ambiguity is prone to cause headaches, especially if more than one of these units are used in the same conversation or document. The torr unit (1 torr = 1 mm Hg) is therefore often preferable, because it is defined on an absolute scale and

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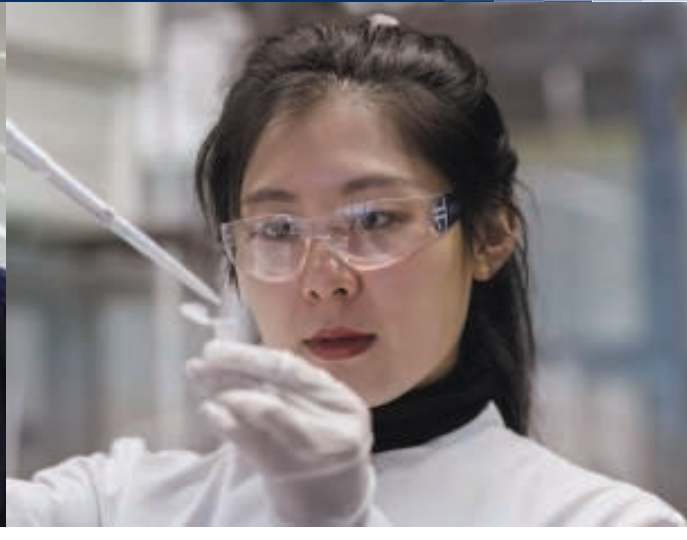

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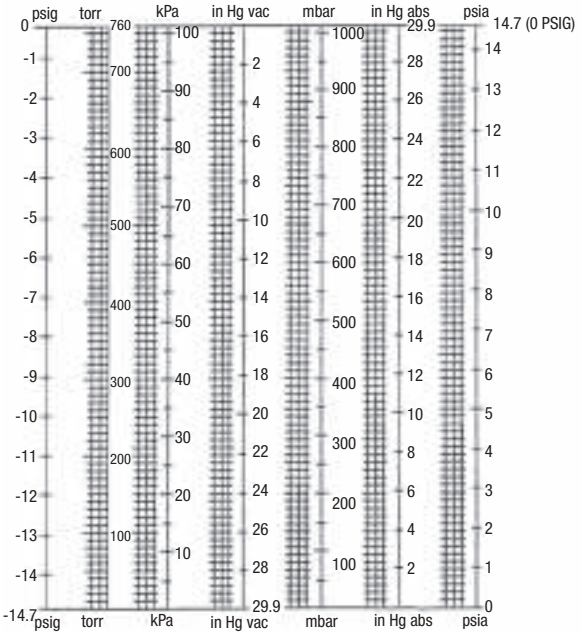

FIGURE 1. This graphic shows the different units one can use when discussing vacuum [*1*]

eliminates any ambiguity. The most common pressure units and their relative values are shown in Figure 1.

Flowrates. Flowrate is another main area that may confuse engineers new to the topic, namely the relationship between standard volumetric flow in standard cubic feet per minute (*SCFM*), pressure, and actual volumetric flow at the system pressure in actual cubic feet per minute (*ACFM*), as given by Equation (1):

$$ACFM = SCFM \cdot \frac{760}{p} \cdot \frac{T + 460}{520} \quad (1)$$

(Note: all parameters are defined in the Nomenclature box on p. 52).

For multiple-component gas mixtures, a slightly different equation must be used since condensable vapors, such as water, can significantly alter flow. This is shown in Equation (2) for a two-component mixture:

$$ACFM = \left(\frac{F_a}{MW_a} + \frac{F_b}{MW_b} \right) \cdot \frac{359}{60} \cdot \frac{760}{p} \cdot \frac{T + 460}{520} \quad (2)$$

Higher-pressure gas entering a lower-pressure piping system expands as a result of the pressure difference, thus *ACFM* will be larger than *SCFM* (Figure 2). But at the lower end of vacuum pressures, it becomes apparent this relationship is exponential. One standard volume of gas expands 7.6 times upon entry to a 100 torr system, 15.2 times to a 50 torr system, and 76 times to a 10 torr system. By contrast, in compressed gas systems, the pressure term changes less than 0.06 for every change of 50 torr. Consequently, this is why vacuum piping is often much larger than compressed-gas piping, even if flow demand is lower for the former.

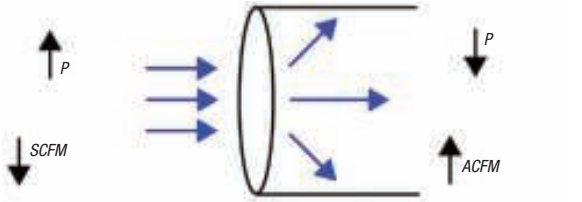

Figure 2. Shown here is the gas expansion that takes place upon entry into piping under vacuum

To account for this volumetric sensitivity to pressure, it is helpful to view flow using throughput, q_{PV}, as given in Equation (3):

$$q_{pV} = \frac{p \cdot V}{t} = \frac{m \cdot R \cdot T}{MW \cdot t} \quad (3)$$

Throughput, which is equal in value at all points of a closed system, is generally used to illustrate overall mass flow through a system. The addition of the pressure term adds context to the volumetric flow and often provides a better representation of system demand than a simple volumetric flowrate. However, the temperature must be constant throughout the system for throughput and mass flow to be related, unless one wishes to use significantly more complicated adiabatic flow equations. To understand flow at certain points in a system at a particular pressure, conductance, *C*, is used, as shown in Equation (4):

$$C = \frac{q_{pV}}{\Delta p} \quad (4)$$

As with electrical conductance, vacuum conductance is a reciprocal of flow resistance and indicates the ability to allow passage. Resistance in vacuum flow is caused by friction between gas molecules and the wall surface and friction between the gas molecules themselves, resulting in pressure differences and volumetric flowrate losses. Conductivities can also be connected by following the same rule as its electrical counterpart, adding individual conductivities when in parallel and adding the reciprocals of the conductivities, or resistances, when in series.

Pumpdown. Implementation of vacuum principles is very different based on application, such as whether the system flows or is closed. Where filtering or drying demands a constant flow of vacuum, evacuating and maintaining vacuum in an enclosed space demands a lower volumetric flowrate as the ultimate vacuum pressure, a parameter determined by the efficiency of the vacuum pump, is approached.

The ultimate vacuum pressure of a vacuum pump is specific to the design of that particular pump and depends on characteristics such as the vapor pressure of the oil or other sealing liquid and the degree to which the system leaks. The logarithmic rate at which a vacuum pump approaches its ultimate vacuum pressure, however, can be explained by a simple concept that applies to all types of mechanical vacuum pumps. The density of a vapor decreases as pressure decreases, and me-

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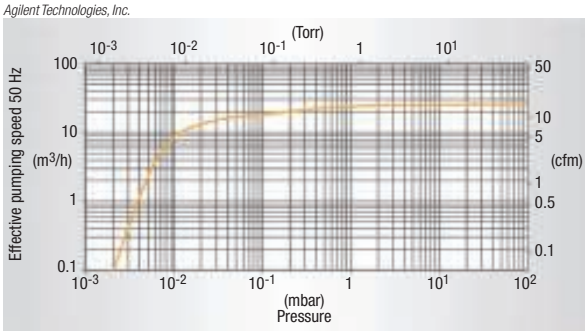

Figure 3. This graph shows the relationship between pumping speed and pressure of a typical rotary-vane vacuum pump [*2*]

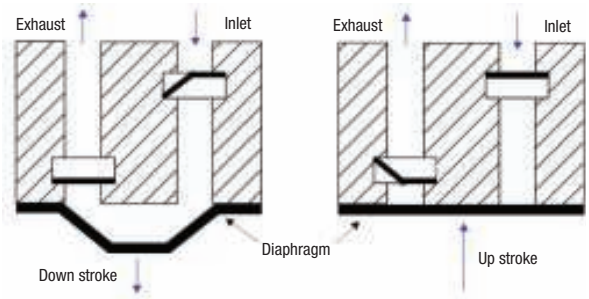

Figure 4. This diagram illustrates the operating principle of a diaphragm vacuum pump

chanical vacuum pumps are constant-volume devices. Thus, the number of molecules that are displaced in each successive volume is gradually less as a vacuum pump reaches the lower-pressure regime.

A simple illustration of this phenomenon would be a vacuum pump curve that shows a decrease in inlet capacity as inlet pressure decreases until the ultimate vacuum pressure is reached, such as shown in Figure 3. An estimate of the time required to pump down from a specific pressure, p_0, to another pressure, p_1, is given by Equation (5):

$$t = \frac{v}{s} \cdot \ln\left(\frac{p_0}{p_1}\right) \quad (5)$$

However, this time estimate is often shown to be consistently lower than the actual evacuation time due to leakages and pump inefficiencies.

Vacuum pumps

There are several types of vacuum pumps and each type has its own benefits and drawbacks that must be considered when making the best choice for a specific application. A vacuum pump is essentially an air compressor operating in reverse, where it compresses the air or gas in the vacuum system and discharges it into a vent.

Diaphragm pumps. The simplest vacuum pump is a diaphragm pump, which consists of an inlet valve, outlet valve, and diaphragm that sucks in gas on expansion and pushes gas out on contraction (Figure 4). Mostly used for laboratory benchtop or other small applications, diaphragm pumps are oil-less and water-less, with the pump mechanism sealed off from process fluids. These are best for low-flow applications (pressure greater than 100 torr) and for those with a fluid with contamination or other chemical sensitivities.

Rotary-vane pumps. Rotary-vane pumps are used in many different situations and can handle pressures below 10^{-3} torr. A rotary vane pump (Figure 5) consists of a single eccentric rotor with vanes inside a larger cavity. During suction, a vane brings in the gas, rotating until the other vane closes off a volume of gas from the vacuum system. There is further compression as the vanes rotate, eventually expelling the gas through the outlet valve.

Edwards Vacuum

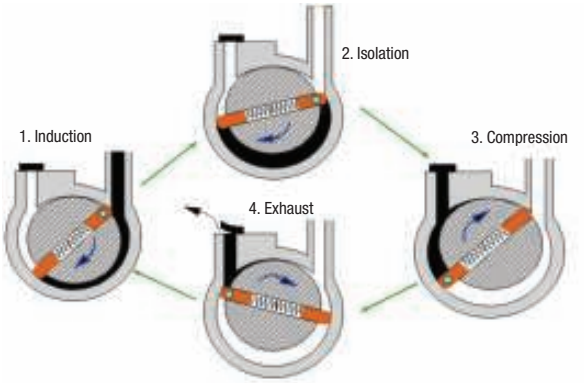

Figure 5. This drawing shows the operating principle of a rotary-vane vacuum pump [3]

This type of pump requires lubrication oil that may require an oil separator for exhaust. If the pump is pulling potential condensables, a gas ballast can be included that reduces the pressure needed to open the outlet valve, thus reducing the likelihood of vapors condensing in the pump cavity. A high volume of condensables, especially solvents, can negatively impact these pumps, as they have a tendency to mix with the seal oil and can corrode the pump internals if not handled properly.

Liquid-ring pumps. Liquid-ring pumps are common vacuum pumps; they attain pressures down to 25 torr, and are preferred from a reliability perspective because of their low-friction design. Similar to rotary-vane pumps, liquid-ring pumps consist of a single eccentric rotor that pulls gas with an initially expanding and later contracting cavity using a ring of liquid, usually water, that acts as the boundary between the gas volumes. Solvents such as hydrocarbons and other liquids can be used as well, depending on the application. A liquid separator on

TABLE 1. AIR LEAKAGE RATES FOR VARIOUS SEALS, CONNECTIONS, AND VALVES IN ROUGH VACUUM [7]

Component	θ = specific leak rate*, lb/h/in.
Static seals	
O-ring construction	0.002
Conventional gasket seals	0.005
Thermally cycled static seals	
T ≤ 200°F	0.005
200 < T < 400°F	0.018
T ≥ 400°F	0.032
Motion (rotary) seals	
O-ring construction	0.10
Mechanical seals	0.10
Conventional packing	0.25
Threaded connections	0.015
Access ports	0.020
Viewing windows	0.015
Valves used to isolate system	
Ball	0.02
Gate	0.04
Globe	0.02
Plug-cock	0.01
Valves used to throttle control gas into vacuum system	0.25
*Note: Assumes sonic (or critical) flow across the component	

Figure 6. This illustration shows the operating principle of a rotary-lobe vacuum pump [4]

the exhaust and filtration for contaminants that become trapped in the liquid may be needed. These pumps are quite amenable to a large condensable load; while temperature loss due to condensing vapors can lower efficiency, corrosion is not an issue as it would be for oil-sealed or dry pumps.

Rotary-lobe pumps. Rotary-lobe pumps, also called Roots blowers or booster pumps, consist of two lobed rotors that spin in opposite directions in a casing with tight clearances (Figure 6). This type of pump is limited by its design, in that a high pressure differential between inlet and outlet causes a significant amount of heat generation in the rotors, which can cause contact or seizure. This attribute is why a rotary lobe pump does not exhaust directly to atmosphere and is often paired with a mechanical backing pump. Although an overflow valve can be added to prevent this heat build-up, its addition would further limit the maximum possible pressure differential of the pump, making the backing pump even more necessary.

However, the maximum pumping speed of a rotary-lobe pump is limited to pressures between about 50 and 0.1 torr, which is where other mechanical pumps typically start to slow down and where water vaporizes at the highest rate. This is quite convenient on both counts, as water can add an excessive workload and increase pumpdown time considerably on single-pump systems. Rotary-lobe pumps are often paired with a backing pump to accelerate startup to steady state in sensitive applications where speed is critical. Because these pumps are most efficient in the lower pressure regime and the

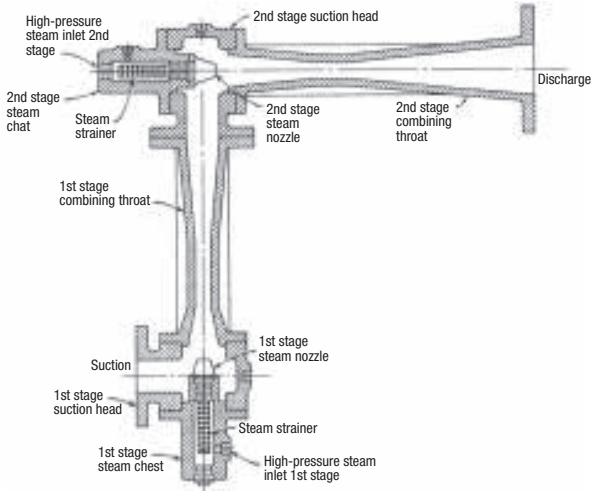

Figure 7. This cutaway diagram shows the operation of an ejector pump

potential heat build-up, these pumps are not started until the pressure has been reduced enough so that their motor is not overloaded.

Ejectors. As an alternative to a vacuum pump, a simple ejector (Figure 7) can be an elegant solution to vacuum generation. Ejectors, often called steam-jet ejectors, are inexpensive and simple to install, operate and maintain. Instead of using electricity for power, a motive gas must be supplied, usually steam or compressed gas, to create the suction force that generates the vacuum. The motive gas approaches the nozzle at a high pressure and low velocity. As it passes through the nozzle, the gas expands, dropping in pressure and increasing in velocity. The suction gas, at a lower pressure and low velocity, is drawn into the chamber via the high-velocity motive gas and is combined. The two fluids travel through the throat and begin to expand along the diffuser outlet, gradually decreasing in velocity and increasing in pressure to a slightly higher velocity and much lower pressure relative to that of the motive gas at the inlet.

Ejectors can be placed in series, both to increase and widen the operating range of vacuum level or flow. Condensers can be included before, in between, or after ejectors to increase the efficiency of recapture of the motive fluid. An ejector is particularly desirable over pumps in fast-cycling applications due to its lack of moving parts and speed to establish vacuum. If a constant, high-vacuum flow is required, however, ejectors may not be as energy efficient as a pump.

Vacuum system components

Valves. Valves used in vacuum applications are differentiated mainly by their conductances and leakage rates. Gate valves have a very high conductance in that they have an unobstructed, straight-through orifice and a short distance between ends. Because of their high conductance, gate valves are often placed between the vacuum system and the pump. However, these valves have higher leakage rates than other choices, so pump capacity must take this into account.

Ball valves are inexpensive, have a fairly high conductance, and a modest leak rate. Despite these favorable parameters, for inexplicable reasons, ball valves are not often used in many vacuum applications.

Butterfly valves are mostly used for conductance control, where the travel of the valve's disc varies between high conductance when fully open and low or zero conductance when fully closed. Depending on the application, an O-ring can be included on the disc to give zero conductance when the valve is closed or not included to give a fixed, low conductance.

Angle valves are often used on top of tanks or in other situations where space is an important consideration.

Emerson Electric Co.

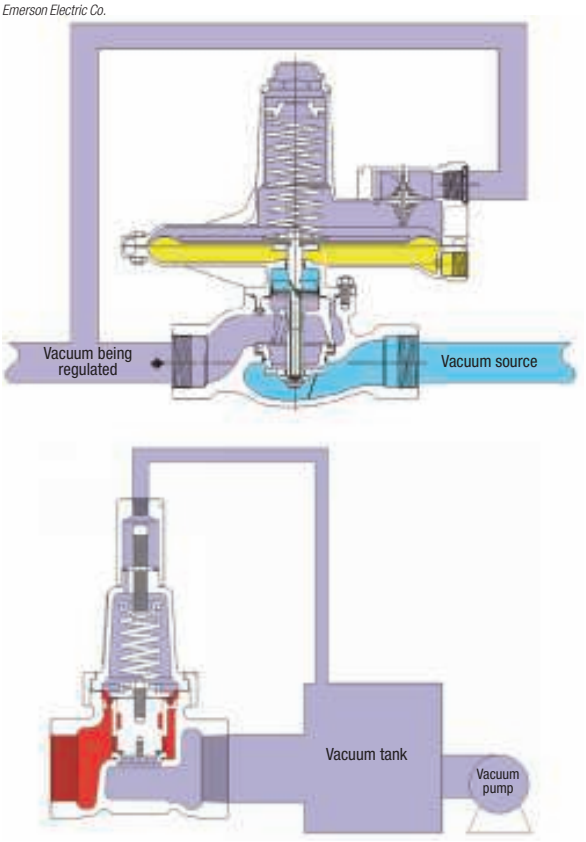

Figure 8: These diagrams show the priciples behind a vacuum regulator and a vacuum breaker [*6*]

These valves are simple to maintain and install, have low leak rates, but a lower conductance than similar, straight-through valves.

There are two main valves used for vacuum control: vacuum regulators and vacuum breakers (Figure 8). Vacuum regulators work by limiting decreases in vacuum level, essentially as pressure-reducing regulators in reverse. When the inlet reads a loss of vacuum, or an increase in pressure, beyond the setpoint, the valve opens. And the opening valve allows the lower pressure, downstream vacuum to restore the upstream vacuum to its original level. Vacuum breakers essentially work in an opposite fashion, by limiting increases in vacuum level.

Receivers. A receiver, or knock-out pot, is a tank in between a pump (or pumps) and a piping system that serves as both a vacuum pressure-stabilizing element and a liquid-catch tank. As the largest volume in a vacuum system, a receiver effectively increases the time required to both lower and raise pressure. By increasing the time required to change pressure, it provides a vacuum storage time in between pump operation and rising or falling demand from opening or closing inlets. In addition to steadying the vacuum level of the system, a well-designed receiver increases pump reliability by reducing pump short-cycling.

A receiver also provides a catch-tank for liquids to

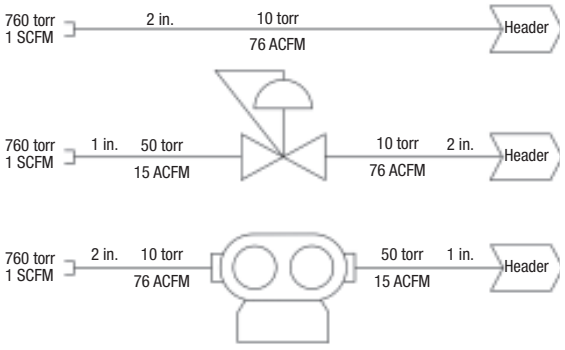

Figure 9. This drawing illustrates different design options for delivering two distinct pressures in a single system

provide a barrier between vacuum generation and piping system for both condensables entering through inlets and for liquid pump sealant traveling to the distribution network. Often, such a tank will have baffles or something similar to provide more surface area and a longer flow path for vapor to condense. A receiver should be sized based on pump capacity, piping system volume, desired operating pressure range, and desired vacuum storage time.

Condensers and traps. Condensers or traps should be considered if there is potential for a large amount of condensable generation in a given system. As pressure decreases, the rate of evaporation for any given material increases, and this continues until the saturated vapor pressure is reached, where evaporation becomes much more rapid. As long as such material exists anywhere in a vacuum system, the minimum pressure attainable is limited to that saturated vapor pressure.

Furthermore, condensables can cause considerable problems for vacuum pumps. Condensation due to condensable gases entering a liquid-ring pump results in a temperature rise, negatively affecting both the lowest pressure attainable and the capacity of the pump. A high condensable load for oil-sealed and dry pumps, on the other hand, can lead to corrosion and eventual failure. A receiver, as discussed above, can provide a simple gravity and surface-area separation method for handling condensables.

Vacuum traps work on one of two principles: sorption and condensation. Sorption traps use either adsorption or absorption to trap and hold liquid molecules. The effectiveness of sorption traps depends on the interaction between the particular condensables in that system and the trap media, and on the operation of the vacuum system. For example, while alumina balls can efficiently trap oil molecules, any water molecules that pass would be selectively absorbed over the oil and effectively displace any oil molecules that may be trapped. Condensation traps rely on a cold surface to condense vapor molecules. These traps would only be effective if the dewpoint of the vapor is greater than the cooling medium temperature and the pressure is greater than the vapor pressure of the cooling medium. Furthermore, consideration must be taken that the temperature is not low enough to freeze any liquid that may collect on the cold surface.

Pipe sizing methodology

Presented here is a step-by-step approach for sizing the piping in a vacuum system.

1. Identify and count the number of inlets.
2. Determine the required flowrate for each inlet. Approximately 1 SCFM can be assumed for laboratory inlets.
3. Select the location of the supply source, taking into account process piping, venting routes, drainage of condensables, and electrical routing.
4. Map out the piping layout from each inlet to header to source and approximate the location of all elbows.
5. Determine the system operating pressure. This varies widely according to the application.
6. Calculate the equivalent run of pipe by adding friction losses of individual fittings or adding a flat percentage, usually 15–50%.
7. Approximate line sizes to provide a base value.
8. Calculate pressure loss using the Darcy-Weisbach equation, given by Equation (6):

$$\frac{\Delta p}{L} = \frac{760}{14.7} \cdot f_D \cdot \frac{\rho}{2} \cdot \frac{v^2}{D} \quad (6)$$

9. Estimate piping air leakage rates, *W*, by using Equations (7), (8) or (9), depending on the pressure:

$$W = 0.026 \cdot p^{0.34} \cdot V^{0.60};\ 1 \le p < 10 \text{ torr} \quad (7)$$

$$W = 0.032 \cdot p^{0.26} \cdot V^{0.60};\ 10 \le p < 100 \text{ torr} \quad (8)$$

$$W = 0.106 \cdot V^{0.60};\ 100 \le p < 760 \text{ torr} \quad (9)$$

10. Determine approximate valve locations.
11. Estimate valve air leakage rates, *w*, by using Equations (10), (11) or (12), depending on the pressure values from Table 1.

$$w = \pi \cdot D \cdot \theta \cdot p^{0.34};\ 1 \le \text{p} < 10 \text{ torr} \quad (10)$$

$$w = 1.20 \cdot \pi \cdot D \cdot \theta \cdot p^{0.26};\ 10 \le \text{p} < 100 \text{ torr} \quad (11)$$

$$w = 3.98 \cdot \pi \cdot D \cdot \theta\ ;\ 100 \le \text{p} < 760 \text{ torr} \quad (12)$$

12. Calculate the velocity through the pipe by using Equation (13):

$$v = \frac{Q}{A} \quad (13)$$

13. Iterate until final pressure, leakage and velocity values are reached.
14. Increase line size when the velocity through a particular run of pipe exceeds 5,000 ft/min, or 4,000 ft/min if noise would be an issue.

15. Increase line size when pressure drop over entire system exceeds 10% of the pressure at the source.

Other design considerations

Piping design. General design of vacuum system piping closely follows two main variables: pressure drop and condensables. Wherever possible in the design of a vacuum system, pressure drop is minimized. Bends in the system should be kept to a minimum, and all bends that must be installed should be long-radius. To account for any liquid that could get into the system, piping should be slightly sloped toward the receiver tank on both sides of the system. Drainage should be provided at any points in the system where this favorable slope is not possible. Pump exhaust should be directed outside with as little impediment as possible with insulation to guard against condensation and a low-point drain valve. As an additional consideration concerning pumps, two pumps capable of the entire load are recommended for critical systems, whereas one or two pumps designed for a percentage of the load is acceptable for non-critical systems.

As much as generating and maintaining vacuum is an issue, keeping unwanted components out, such as particulate matter and oxygen, can also be a challenge. Sealing of piping systems and pump flanges should be considered to avoid drawing oxygen into a flammable mixture, for example, as well as to minimize pressure drop. Finally, caution should be given to the materials of construction, piping thickness and pressure rating of the system to avoid caved-in lines.

Diversity factor. In the majority of applications, vacuum is not a utility in constant demand. A diversity factor is often used to lower an estimated flowrate to a more reasonable level. However, there is a misconception on how to use a diversity factor that seems to trouble engineers new to vacuum design.

A diversity factor is a ratio of the sum of individual maximum demands of various system subdivisions to the maximum demand of the whole system. Applying a diversity factor to a network of vacuum inlets does not imply that the flow through each inlet on the network drops by a certain percentage. Instead, it is to illustrate that the stated percentage of the inlets have full flow through them at a given time while the other inlets are closed. Applying the diversity factor correctly results in maximum flow through the sections of vacuum pipe where inlets are all open and zero flow through sections where inlets are closed, whereas incorrect application would lead to undersized pipes.

In addition to applying a diversity factor, flowrate and pressure drop can be reduced by eliminating unnecessary valves to reduce air leakage, raising system vacuum pressure, or simply eliminating use-points.

Design for two-pressure delivery. Delivering vacuum at two different pressures poses an interesting problem, and there are a few potential design options (Figure 9). One option would be to design the distribution for the lower pressure, and place regulators downstream of inlets that require a lower level of vacuum. Although such a system could be initially perceived as an efficient method of system design, flowrate downstream would be identical with or without a regulator, as shown in Figure 9.

Alternatively, the system can be designed for the higher pressure, and booster pumps can be added to decrease pressure at inlets that require a higher level of vacuum. This method would allow for lower pipe sizes and a less expensive primary pump; however, it would require purchase and maintenance of additional vacuum pumps. A third option would be to design two separate systems for the two vacuum levels. Two separate systems would require two primary pumps and oftentimes more piping, but it may be worthwhile if the inlets are located at a distance or volume demanded at each of the two levels is substantial. ■

Edited by Gerald Ondery

The general design of vacuum system piping closely follows two main process variables: pressure drop and condensables.

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Inside:

Actuators solve tight space problem

AUMA modular actuators were the answer for a space-constrained upgrade at a Pittsburgh water treatment plant

The Allegheny County Sanitary Authority (ALCOSAN) had problems with manual valves controlling the flow of raw sewage into primary treatment tanks at its facility in Pittsburgh, Pa., U.S. The original 24-inch (600 mm) gate valves had non-rising stems whose exposed threads collected debris, making the valves hard to operate. The solution was to convert the valves to rising-stem types; at the same time, ALCOSAN decided to fit electric actuators.

In January 2017, **AUMA** supplied 72 SA multi-turn actuators with GK gearboxes, floor stands, new stainless steel valve stems and thrust blocks. All the actuators are equipped with AC controls and Modbus RTU communications.

The ability to fit into tight spaces was an important reason why ALCOSAN chose AUMA actuators. The center of each valve stem is less than 4 inches (100 mm) from a concrete block wall. With other suppliers, ALCOSAN would have had to make significant changes to the wall structure to get the actuators to fit. Thanks to AUMA's modular design, which offers flexible mounting positions, the compact GK multi-turn gearboxes fit neatly into the narrow space.

Thanks to their compact design and flexible positioning, AUMA actuators fit the narrow space between the valve stems and the wall

Price and previous experience were also significant factors behind ALCOSAN's decision. AUMA is the company's preferred actuator supplier and there are around 300 AUMA actuators on site. **www.auma.com**

First Iranian order after sanctions

BUTTING supplies piping components for seawater

These piping components are en route for the new desalination plant being built at a large Iranian petrochemical complex – BUTTING's first order in that country after the relaxation of trade sanctions

One of Iran's leading manufacturers of petrochemical products is adapting to increasing demand from the country's domestic market by constructing new central supply units and systems for producing energy and waste water treatment, notes German pipework specialist **BUTTING**. Water for the entire installation is supplied in the form of seawater from the neighboring Persian Gulf. The seawater, with a relatively high salt content of 4%, passes through a desalination plant to prepare it for use in the petrochemical complex.

For both wastewater treatment (brackish water) and the seawater desalination plant, the operator is purchasing piping components from BUTTING. These have nominal bores from 25 to 400 mm, and are made from UNS S32750 superduplex as well as TP 316L. The scope of delivery includes several hundred meters of pipes, elbows, reducers, flanges and distributors. All circumferential welds are subjected to a 10% X-ray test, and all fillet welds must be 100% checked. For piping components without site welds, the specification prescribes a pressure test.

BUTTING is one of the leading processors of stainless steels. The company's products include corrosion-resistant pipes, clad pipes, special pipes and components ready for installation, spools and welded components, vessels, tanks, columns, and assemblies. Its core competences are in forming and welding techniques and in materials engineering. BUTTING products meet the highest quality standards. Customers all over the world use the products of this family-owned company. **www.butting.com**

World's largest 3,000 ×g sludge dewatering centrifuge

At WEFTEC 2017, a century of German engineering from Flottweg supports centrifuge technologies that are leading the world's wastewater sludge remediation efforts

Flottweg Inc. has been perfecting centrifuge technology for 60 years. At this year's WEFTEC exhibition (Chicago, Ill., October 2–4), the company says it will prove the validity of this claim in the form of the new C8E Decanter.

The water industry's largest 3,000 ×g decanter: Flottweg's C8E

The company draws on a century of precision engineering focused on spin, speed and propulsion, from the earliest biplanes to the first motorcycles. A spin-off of the company's engineering capabilities became the Bayerische Motoren Werke, more commonly known today as BMW. "Move quickly" became the company motto.

Over the past 60 years, Flottweg has focused on advancing centrifuge technology. A key breakthrough was the company's invention of the Simp Drive, developed to independently control the differential speed between the bowl and scroll of a centrifuge, accommodating higher speeds and stability in large centrifuges. This Flottweg concept has since been adopted throughout the centrifuge industry.

Another core centrifuge technology, the Recuvane, literally uses spin to create more spin. The Recuvane recovers rotational energy from liquid centrate discharge to minimize the machine's energy consumption. This innovation is incorporated into virtually all municipal wastewater centrifuge applications today.

A company built on constant invention and innovation, Flottweg continues to work to perfect centrifuge technology, refining scroll design, incorporating adjustable impellers, developing tougher wear protection, and other engineering enhancements. Flottweg has also had 60 years to develop the best service and parts availability in the centrifuge industry; to prove this, the company suggests readers should ask other centrifuge manufacturers about their in-stock parts availability and turnaround time on a machine overhaul, before calling Flottweg.

At this year's WEFTEC show, *CE* readers are invited to visit the Flottweg booth (3416) to learn how a history of invention, speed and spin has led to the fastest, most powerful wastewater sludge centrifuge decanter in the industry: the Flottweg C8E Decanter. Visitors will be able to see the C8E in action, and to ask the Flottweg team about how the highest-performing wastewater centrifuge in the world was engineered.

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Plastic diaphragm valves are precise and versatile

GEMÜ plastic diaphragm valves are available in a wide range of configurations that share the virtues of simplicity, precision, and durability

GEMÜ plastic diaphragm valves are available with a variety of high-quality plastic body materials and connections. The plastic diaphragm valves support a large range of industries and applications including chemical, environmental systems, power generation, water treatment, solar, semiconductor, microelectronics, food and beverage, and processing – just to name a few. Many of the plastic diaphragm valves are supported by an extensive line of pneumatic operators that can be fully integrated into automated systems, allowing industries to save time and money on their operations, while increasing accuracy and efficiency in their performance.

The structure and function of the diaphragm valve is that of a completely enclosed connection with a weir and short intercepting shaft that accommodates the operation of a movable seal known as the diaphragm or membrane. This diaphragm is the essential part of the valve that controls the movement of media through the system the valve is integrated into. The diaphragm valve operates by pressing the diaphragm tightly against the weir, making a fluid-tight seal that prevents flow of the medium. Alternatively, the diaphragm is lifted away from the weir to allow partial to full flow. Operation of a diaphragm valve is very simple, as is the accommodation of various stages of full or restricted media flow.

GEMÜ plastic diaphragm valves are ideal for applications requiring pure media

GEMÜ leaves nothing to chance in the development and manufacture of plastic diaphragm valves. The plastic diaphragm valve is designed with the challenges of friction, turbulence, debris and trapped air in mind. The GEMÜ plastic diaphragm valve is flow-optimized by incorporating a smooth media transition structure which promotes low friction and low turbulence, and leaves no projections or dead spots that could cause air pockets to form or debris to collect within the valve body.

Additionally, GEMÜ plastic diaphragm valves utilize highly durable, low-maintenance pneumatic membrane actuators that give precise flow control even in high-cycle operation.

GEMÜ plastic diaphragm valves also take account of industry needs by having the same mounting height planes over multiple nominal sizes, compact design, low compressed air consumption for the pneumatically operated versions, and a variety of optional accessories for measurement and control.

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Bulk silos for high rates

Acrison silo systems use positive flow-inducing mechanisms for reliable feeding

Acrison silo systems are large enough to run for weeks or even months between refills

Acrison silo systems utilize positive flow-inducing mechanisms to ensure consistent and accurate feeding of dry chemicals into dissolving equipment at high rates.

When a treatment plant is required to feed a dry chemical such as hydrated lime or powdered activated carbon at high rates, it typically isn't prudent to have operators devote valuable time to frequently reloading a small storage hopper. If the rates are high enough, even a super-sac system can require too-frequent bag changes. An Acrison bulk storage silo and feed system, complete with integral dissolving equipment and controls, offers an efficient solution to this problem. Such systems are custom-designed for each application, and often sized to store thousands of cubic feet of material, which provides weeks, if not months, of uninterrupted operation before the silos need to be refilled.

Any silo system can store dry chemicals. Ensuring reliable flow out of the silo, into the metering and dissolving equipment beneath, and then into the process, is another matter. Here, Acrison's over 50 years of experience in the dry chemical metering and handling industry makes a critical difference. By using proven mechanical designs and control system strategies, an Acrison silo system ensures positive flow of the dry chemical into the feeder as needed, avoiding the issues typically created by other methods. Material flows from the silo into an Acrison rugged-duty, dissimilar-speed, double- or triple-auger/agitator metering mechanism. Here it is conditioned to a consistent state for reliable metering with accuracy on the order of ±1–2 percent. based on weight measurements at one-minute intervals.

Based on various parameters, including the location of the application point in reference to the silo, it is also important to choose the correct type of dissolving equipment to ensure a continuous supply of homogeneous solution to the process. Most applications are able to utilize Acrison's robust dissolving tank assemblies. These use mechanical agitation to dissolve the chemical, while an integral dust and vapor remover ensures a clean, maintenance-free installation. Separately, Acrison's high-capacity wetting cone system can be used for most applications involving powdered activated carbon. This device employs wash-down nozzles and an eductor to create an activated carbon slurry quickly and effectively, with active dust control.

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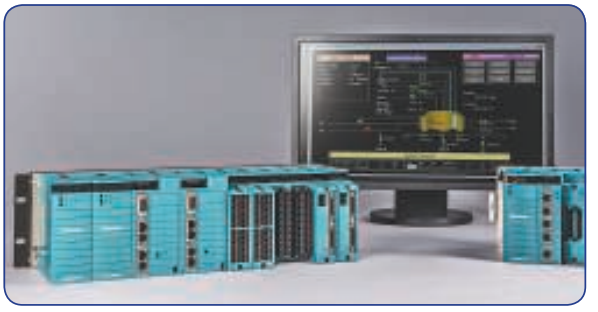
Think SCADA for water

Yokogawa's open architecture simplifies water management system upgrades



Used in conjunction with magnetic flow meters and analyzers for such properties as conductivity, pH and turbidity, an all-in-one SCADA solution could be a very cost-effective addition to a chemical process DCS for water management

Increasingly often, chemical process operators are facing requirements to update their control systems in order to enhance water management, notes process control specialist **Yokogawa**.

Many chemical processes use distributed control systems (DCSs). Ideally, spare I/O that is sufficient for the water management process is available in the DCS, but that is often not the case. Alternatively, the DCS can be readily expanded with network I/O. Either way, considerable engineering could be required to add the water management process. Is there a less-expensive alternative?

Although systems that are dedicated to water and wastewater control applications are widely available, integration of the water operations with the DCS remains a key issue. As one operator stated, "installing a PLC in conjunction with a magnetic flowmeter and an array of analyzers is the easy part. However, not only does the PLC system need to interface with our DCS, it must also fully support our requirements in terms of asset management, cybersecurity, IT and reporting."

One feasible solution is an open architecture SCADA add-on. Formerly applied only to operations that covered broad geographical areas, supervisory control and data acquisition (SCADA) systems have evolved to incorporate many new technologies such as Industrial Internet of Things (IIoT) architecture. They can drop into plant processes just as easily as pipelines and utilities.

The SCADA solutions offer multiple, open communications alternatives such as OPC UA and a variety of industry-standard protocols. Like PLCs, which are very commonly applied throughout the water and wastewater treatment industries, SCADA solutions offer pre-configured applications that reduce engineering project hours.

Unlike a PLC system, the SCADA solution supports information requirements such as asset management and predictive maintenance that are typical in the chemical process industry, but not as often used in the water and wastewater industries. The SCADA solution includes all the capabilities of a PLC. In addition, alarm management, asset management, historian, reporting capabilities and thin-client HMIs are integral.

As an open-architecture addition to a DCS, a SCADA solution could be a very cost-effective alternative for water management.

yokogawa.com/us

Custom-designed fans for heavy-duty applications

The New York Blower Co. designs and builds fans for the commercial, industrial, and highly specified markets

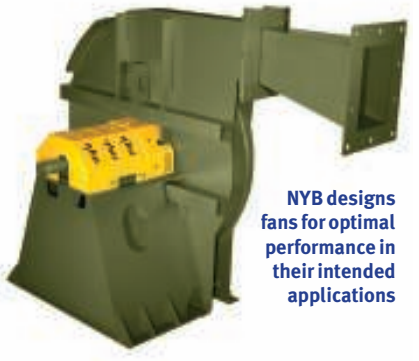
The New York Blower Co. (NYB) realizes that in the heavy industrial market, every job is unique, and each requires its own specifications and attention. For this reason, NYB offers a comprehensive range of customizable options to create the perfect heavy-duty fan for every job. From chrome carbide overlays to abrasion-resistant construction, NYB fans are durable and reliable enough to handle even the most demanding of applications.

NYB is a world leader in manufacturing premium-quality, engineered fans and blowers to the industrial marketplace; fulfilling the need for reliable air movement and timely delivery. The New York Blower Co. operates fan fabrication plants in Pennsylvania, Indiana, Kentucky and Illinois. International subsidiaries fabricate products in Australia, New Zealand, the Philippines, Singapore and Taiwan. NYB fan designs provide the highest aerodynamic efficiencies compatible with specific systems and gas stream requirements. Durable fan structures are designed for long life in the harshest applications. NYB's AMCA-registered laboratory allows for fans to meet the highest standards in product development and product performance testing. All NYB products undergo extensive air performance, sound and quality assurance testing prior to release to the market. That's why for over 125 years, New York Blower has always had the right answer, even for the most demanding operations.

The company's reputation for technical excellence is fueled by:

- unmatched experience and manufacturing expertise;
- consistent capital investment that results in the most modern equipment and facilities in the industry; and
- embracing uncompromising product quality as an everyday, company-wide commitment.

Durable fan structures are designed for long life in the harshest and most demanding industrial applications. Both U.S. Department of Energy (DOE) and new-build nuclear facilities use a variety of New York Blower fans for containment applications. Gas turbine cooling modules use both axial and centrifugal designs for turbine ventilation systems. Quarry trucks and draglines require cooling fans for their large DC traction motors. Crushing and grinding phases of ore processing use many types of NYB fans in environmental and ventilating systems. Some ore processing goes into a wet cycle where spray dryers and particle sizing systems direct products to chemical and food industries. New York Blower offers fans for all of these applications. **www.nyb.com**



NYB designs fans for optimal performance in their intended applications

Static mixers with low pressure drop

Ross LPD Low Pressure Drop Static Mixers are ideal for effective fluid mixing in water and wastewater treatment processes

The **Ross** Low Pressure Drop (LPD) Static Mixer enables more efficient dosing of flocculants, disinfectants, neutralizing agents and pH conditioners into a water stream. This simple-to-install heavy-duty device completely mixes treatment chemicals within a short length of pipe. When used in conjunction with automated instrumentation, the LPD delivers predictable quality control based on a virtually maintenance-free operation.

Four or six mixing elements are usually more than sufficient for effective mixing under turbulent flow conditions, Ross says. Diameters range from 1 in. through 48 in.

The LPD Static Mixer consists of a series of baffles or "elements" discriminately positioned in series. Each element comprises a pair of semi-elliptical plates set 90 degrees to each other. The next element is rotated 90 degrees about the central axis with respect to the previous baffle set, and so on. For even lower pressure drop, an LLPD model is also available, in which the plates of each element are oriented at 120 degrees relative to each other.

As the fluid moves through each LPD or LLPD element, flow is continuously split into layers and rotated in alternating clockwise and counterclockwise directions. This method of subdividing the stream and generating striations leads to highly efficient and repeatable mixing with minimal pressure loss. During turbulent flow, the baffles enhance the random motion of molecules and the formation of eddies. In most water and wastewater processes, four or six elements are more than sufficient to completely disperse treatment chemicals and create a very uniform solution or suspension.

Small LPD/LLPD mixers of 1 in. through 2.5 in. in diameter are welded to a central rod, while larger elements are welded to four outside support rods for maximum rigidity and stability. Available in a wide range of sizes up to 48 in. in diameter, these mixers can be supplied as pipe inserts or as complete modules with housing and injection ports.

In addition to Static Mixers, Ross also manufactures High Shear Mixers and Multi-Shaft Mixers used in the production of water treatment chemicals. The company offers no-charge mixer testing services and an extensive trial/rental program. **www.mixers.com**

Level transmitter eliminates troublesome capillaries

Endress+Hauser's Deltabar level transmitter eliminated level measurement problems a customer had with a capillary system

Level measurements in process or storage tanks are often made with sensors that measure pressure at the top and bottom of the tank, notes instrumentation specialist **Endress+Hauser**. Capillary tubes or impulse lines connect the high- and low-pressure sensors to a transmitter that measures the differential pressure (dP) and calculates level.

One specific customer had a dP system with capillary tubes that was producing incorrect level measurements. Small level ranges and ambient temperature fluctuations were causing errors. The small-diameter impulse lines were clogging from freezing or contaminants solidifying in the line. These problems were hard to trace, as the measurements looked reasonable until the line clogged completely. Because of the plant's location in a northern latitude, the customer needed a durable and reliable product to make accurate level measurements during harsh environmental conditions and changing ambient temperatures.

Endress+Hauser supplied Deltabar FMD71 electronic dP level transmitters, which use two pressure sensor modules, each connected electronically to a single transmitter. Using a Ceraphire ceramic sensor in the pressure sensor modules, the transmitter calculates the differential pressure and transmits the level, volume or mass as a standard two-wire loop-powered device.

The Endress+Hauser FMD71 uses electronics, not troublesome capillaries, to connect the pressure sensors

One sensor module measures the hydrostatic pressure (HP) and the other one the head pressure (LP). Each sensor sends a digital signal to the transmitter corresponding to the temperature-compensated measured pressure. This electronic system eliminates issues of traditional differential pressure measurements by doing away with impulse lines or capillaries and their related issues of icing, clogging, leaks, condensation, and changing ambient temperatures.

The FMD71 offers a standard 4–20 mA HART capable output. The dP level measurement is the default 4–20 mA signal, while dP level, head pressure and sensor temperature can all be assigned as HART variables. Each sensor in the FMD71 system has 0.075% reference accuracy, a maximum nominal measured pressure of –15 to +600 psig, and a –40°F to 302°F process temperature capability.

www.us.endress.com/FMD71

Precision progressive cavity pumps for process control

The unique design of a progressive cavity dosing pump has several advantages compared to traditional metering pumps, due to the simple pumping principle, says SEEPEX

The environmental industry assumes that chemical metering pumps must always be subject to heavy monitoring, frequent parts replacement, and disposal on a regular basis. Pumps are expected to pulsate, allowing a greater opportunity for unstable flow as operators are forced to over- or under-feed chemicals. All this causes unplanned variances, water quality issues, and increased cost and downtime.

Yet it doesn't need to be this way. **SEEPEX**, a leading provider of progressive cavity pumps and services, offers NSF/ANSI 61-certified dosing pumps, the most popular of its product line. For far too long, compromises were made to accommodate traditional chemical metering pumps that leak, lock up, and have erratic flowrates. SEEPEX progressive cavity dosing pumps are the exceptions to these universally accepted, detrimental norms.

SEEPEX dosing pumps provide several advantages compared to traditional chemical metering pumps due to the progressive cavity pump's unique design and simple pumping principle. A single helical metal rotor turns inside a double helical elastomer stator, forming compression-fit sealed, uniform cavities that progress from suction to discharge. The sealing aids process control because the flowrate is proportional to motor speed. This pumping characteristic provides precise, repeatable metering capabilities with very minimal pulsation and no vapor lock. Slip is minimized even when fluid temperature, viscosity, or discharge pressure fluctuates. Progressive cavity dosing pump users experience complete accuracy for process control, hazardous by-product minimization and chemical consumption reduction.

Stable, consistent, and minimal pulsation: advantages of SEEPEX dosing pumps

Vincent Munn, a County Operations Manager with 37 years in the field, states, "I've used progressive cavity (PC) pumps of all sizes for chemical metering, slurries and sludges. PC pumps provide better stability, consistent flow and a steady stream. They wear predictably and give the best results with analytical equipment. I consider myself a traditionalist, but I've found that what once worked in the past is always subject to evolving requirements. SEEPEX helps me adapt."

www.seepex.com

Portable filtration systems are clean and versatile

A portable filter cart with integral pump makes transferring liquid process ingredients, coolants and cutting fluids easy, clean, and reliable, explains Rosedale Products

Filter specialist **Rosedale Products** manufactures portable filtration systems for applications requiring flexibility in operation. The company's standard portable filtration cart, with a nominal flowrate of 25 gpm, provides efficient, clean filtration for batch processing or when transferring liquids from tanks or drums.

The bag filter features a carbon or stainless steel housing rated to 125 psi, with a compatible filter basket, and O-ring seals made from Buna N, EPR, or Viton. The housing accepts large #12 size bags, with a surface area of 5.6 sq. ft., for greater dirt-holding capacity. Quick-opening clamp covers require no special tools and cut time spent cleaning or replacing bags.

An air-operated double-diaphragm pump, optionally in polypropylene, connects to the filter housing via a 1-in. NPT port. Side-entry design prevents contaminant bypass around the filter bag, as well as spills and messes when opening.

The cart has a built-in drip pan, 9-in. air-filled tires, a compressed air filter/regulator, and 10-ft. inlet/outlet hoses with quick-disconnect couplings. Rosedale offers a four-wheel cart as an option.

Portable filtration cart with air-operated pump

The company also makes a specialized version of the filter cart for coolants and metalworking fluids with viscosities of 300 SSU (65 cP) or less that are compatible with aluminum and steel. The two-wheel hand-truck system features a bag filter and a high-flow, industrial-quality centrifugal pump driven by a 0.5-hp motor. It can prefilter and transfer fluids quickly and economically from a holding tank to a reservoir or from drum to tank.

The system is ideal for controlling particulate problems, Rosedale says, before they damage critical production equipment. Most new fluids are unfit for use in hydraulic and lube systems, the company notes, because contamination enters the fluid during processing, mixing, handling, and storage. As a result, solid particulate may be present in unacceptable levels. Use of a portable filtration unit helps keep fluids clean. **www.rosedaleproducts.com**

These scrubbers tackle a wide range of applications

From odor mitigation to acid gas removal, CR Clean Air has the solution to meet almost any emission challenge

CR Clean Air has been providing wet scrubbing systems across a wide array of process industries for almost 70 years. From the initial jet venturi fume scrubbers the company developed in the 1950s to the fully skidded packages it offers today, CR Clean Air has always been driven by engineering the best possible solution to meet a plant's emission control needs. Experienced in a wide range of applications, be it odor mitigation by removing H_2S and mercaptans, control of acid gases such as HCL and SO_2, and even the removal of fine and sub-micron particulates from contaminated vapor streams, CR Clean Air's depth and breadth of experience is unmatched. As a leader in clean air technology, the company has been at the forefront of dealing with many complex chemistries and challenging pollutants, from ethylene oxide mitigation to NO_x emissions.

CR Clean Air has the experience to engineer a system that will work first time, and the commitment to quality that ensures it will continue to work for decades to come – be it a standby scrubber to handle an emergency release of toxic vapor or an odor control unit that needs to run 24–7. From small manually controlled units to large automated systems with complex instrumentation and built-in redundancy, the company's team of electrical, chemical and mechanical engineers are able to assist in developing customized solutions. Offerings are available in a wide range of materials, both metal and non-metal, including carbon steel, stainless steel, corrosion-resistant alloys, FRP, polypropylene, PVDF, and dual laminates.

CR Clean Air has systems installed across a wide range of industries, including aerospace, chemical, municipal wastewater, pharmaceutical, and pulp and paper. The range of pollutants is also as varied, including HF, HBR, NH_3, silicates, dust and certain VOCs. CR Clean Air has a range of approaches in its arsenal, from once-through water to chemically scrubbed systems complete with recirculation. From arsenic to zirconium tetrachloride, CR Clean Air scrubs gases others won't touch. **www.crcleanair.com**

CR Clean Air high-energy venturi scrubbers can tackle almost any pollutant

Smart actuator optimizes control valve performance

Badger Meter's new smart electric valve actuator (SEVA) stands up to extreme conditions while providing exceptional position accuracy

Since 1905, **Badger Meter** has been recognized as a leader in the development and manufacture of flow management solutions. The company has now unveiled its advanced SEVA (Smart Electric Valve Actuator) solution. SEVA employs cutting-edge technology while providing a cost-competitive solution. The actuator is designed for extreme conditions, with military-grade components, while delivering exceptional accuracy and repeatability.

The initial SEVA release includes both 100-lb. and 200-lb. thrust models. SEVA utilizes the Industrial Ethernet Protocol (EtherNet/IP) and is certified by the Open DeviceNet Vendors Association (ODVA). It offers a dual-port Industrial Ethernet card for customers who demand a higher level of information in their systems. The actuator allows for both linear and Device Level Ring (DLR) ring network topologies.

SEVA provides an exceptional level of position accuracy (±1% of full scale) with five available positions when there is a loss of power: Continue Operations, Full Closed, Full Open, Hold Position, or Target Value. The device also features four positions when there is a loss of signal: Full Closed, Full Open, Hold Position, or Target Value. Both the Full Closed and Full Open positions are defined during setup.

In addition, SEVA has an internally powered (active) feedback signal, which actively communicates stroke position to the control system. Its feedback sensors are crucial in more precise applications. SEVA even provides a manual override capability to help the operator in loss-of-power situations.

The SEVA assembly has the option to include two user-adjustable limit switch outputs. An external signal is provided once the set points of the limit switches are met. Furthermore, the electric actuator can split the incoming 4–20 mA signal and use either the lower or higher range of the signal for full stroke operation. A hyper terminal server makes it possible to change the type of split range.

Badger Meter's SEVA actuator (photo) is accurate, yet tough

SEVA was specifically designed to minimize the number of models needed to work with different electrical demands. Its Universal AC Input with voltage protection will work with 115 V AC, 230 V AC and 24 V DC power supplies. This feature ensures confidence that the actuator will provide a single source for different process needs. SEVA can receive analog input signals from 4–20 mA, 0–5 V DC or 0–10 V DC. Lastly, SEVA has a maximum speed at maximum thrust of 0.153 in/s (SEVA100) and 0.073 in/s (SEVA200). **www.badgermeter.com**

Why hoses are made with UHMW-PE

DeWAL, a specialist producer of ultra-high molecular weight polyethylene (UHMW-PE), explains why this is the best material for hose linings and coverings in the water industry

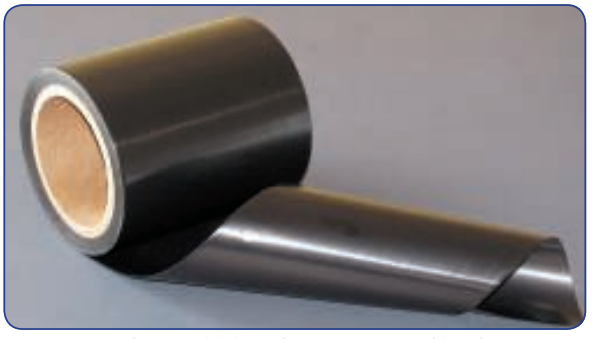
All kinds of hoses are used in water management. They may be vertically braided, with rubber or polymer layers between braids. They may be spiral hoses, with plies laid at different angles. They may be knitted, with seamless knit jackets covering extruded tubes.

Whatever kind of hose is best for a particular water management solution, one special film is preferred: UHMW-PE – ultra-high molecular weight polyethylene – used for both lining and covering all kinds of hoses.

UHMW has a number of benefits important in water management:

- It has a very low coefficient of friction, so water flows easily through it, reducing energy requirements.
- It has excellent temperature, abrasion and chemical resistance, so it is durable, despite harsh environments, flexing hoses or granular liquids.
- It vulcanizes, chemically bonding directly to rubber or polymers, eliminating the need for costly or undependable adhesives.
- Importantly, when water management involves food processing or potable water, UHMW carbon filler can be Food and Drug Administration compliant as reported by the raw material supplier.

DeWAL, part of the Rogers Corp., has been manufacturing dozens of high-performance UHMW films and tapes for more than 40 years. Films can be 3 mil to 30 mil thick, in sheets as narrow as 0.25 in. or as wide as 48 in., the widest sheets in the industry. Standard colors are black (DW 406BF) and white (DW 406WF). Custom colors are available.



DeWAL manufactures high-performance UHMW films from 3 to 30 mil and up to 48 in. wide for lining and covering hoses and belts

All UHMW films and tapes, like DeWAL's many PTFE films and tapes, are manufactured in DeWAL's Narragansett, RI, facilities. Sales offices are located around the world. DeWAL films and tapes are used not only in water management and CPI but in aerospace, automotive, electronics, oil and gas, rubber and plastic, thermal spray, and wire and cable. **www.dewal.com**

Monitor helps meet your critical water quality needs

Myron L Company's 900 Series is the reliable, accurate, simple and flexible answer to water quality monitoring across a wide variety of industries and measurement types

The world of water quality is downright complex. Whether the application is pool management, pharmaceutical manufacturing, maintenance of boilers or cooling towers, food production, brewing, printing, desalination, agriculture, aquaculture, wastewater management, or any one of many other industries, water quality can determine success or failure. The water quality instrumentation relied on by this exacting and varied array of applications must be reliable and accurate. It must be simple to use. It also must be very flexible.

Myron L Co.'s 900 Series Monitor/Controller is designed to meet exactly those needs, whether water is an end product, an ingredient, or a secondary but vital process component. The instrument can handle a variety of inputs and measurement types, and supply several different types of control and data outputs, all of which can be combined and configured to operate in the most complex water quality applications.

The 900 Series' suite of signal inputs can be configured to display a variety of measurement types: conductivity, resistivity, salinity, TDS, pH, ORP, temperature, mV DC, flow, pulse, and % rejection are all available. The 3.5-in. resistive touch-screen can show information from up to four different inputs simultaneously, each with a different measurement type. Need to precisely set the cell constant of your conductivity sensors? Cable length of your sensors an issue? The 900 Series can handle it.

The 900 Series' outputs also provide flexibility. The standard outputs include a 0–10 V DC recorder output and a single alarmable relay output. An optional output card adds more levels of functionality.

A 4–20 mA current loop output makes the device a *de facto* transmitter, while an RS-485 digital data output gives it the ability to do real data-logging. Need to control several water tanks interactively based on conditional criteria, while outputting relevant data to a digital storage device? Two additional alarmable relays make that possible. Alarm status is clearly displayed with attention-getting alerts.

Myron L Company's 900 Series: a flexible, high-level performer in water quality instrumentation

With all these combinations of inputs, outputs and control relays, it might seem that the 900 Series would be complex to operate. Not so: the instrument's intuitive graphical user interface makes it simple to set up and use. **www.myronl.com**

Building valve solutions for water treatment

Inline Industries has a proud tradition as a vertical manufacturer, designing and building a wide range of high-quality valves

Inline Industries is a pioneer in designing and building valve solutions for OEM equipment manufacturers, water treatment plant operations and potable water users.

The company has been providing innovative valve solutions to the treatment industry for over 24 years. Offering manual and automated valve assemblies along with control ball valves, Inline has built a strong reputation for manufacturing high-quality, consistent and reliable products.

Inline has been able to achieve this by designing and building its own valve products as a vertically integrated manufacturer. The company investment casts, machines, assembles and tests each series of valves to exacting standards.

Valves are cast with ASTM-grade materials and are designed and tested to ASME B16.34 specifications to assure buyers that the product will perform to the pressures and temperatures for which they are designed. Each casting goes through material testing and is then heat stamped and documented through an ISO 9001:2008 quality control process to provide consistency in the product and complete traceability. Certified Material Test Reports are available upon request.

Inline Industries 334F valve with pneumatic actuator

Inline offers a wide range of valve styles including valves with flanged, threaded or weld ends for process connections, and compression ends for chemical tubing feed lines. Inline also offers valves in full port, standard port, 3-way diverting and multiport configurations.

Inline can provide a variety of valves certified to meet the rigorous standards of the National Sanitary Foundation's NSF 61 specification for use in potable and feed water applications.

Direct-mount electric and pneumatic actuators are readily available and can be supplied with accessories such as limit switches, positioners, solenoids and other instruments that may be required. All accessories are factory mounted and tested before shipment.

At the heart of Inline's success has been its ability to deliver. Inline's headquarters, located in Rosemead, Calif., houses a multimillion dollar inventory, machine shop, clean room, automation center and fabrication facility, enabling the company to ship over 90% of all orders complete within a day or two after receipt of an order.

Inline products are made available through a select channel of highly trained distributors to help provide customers with the valve solutions they require.

www.ballvalve.com

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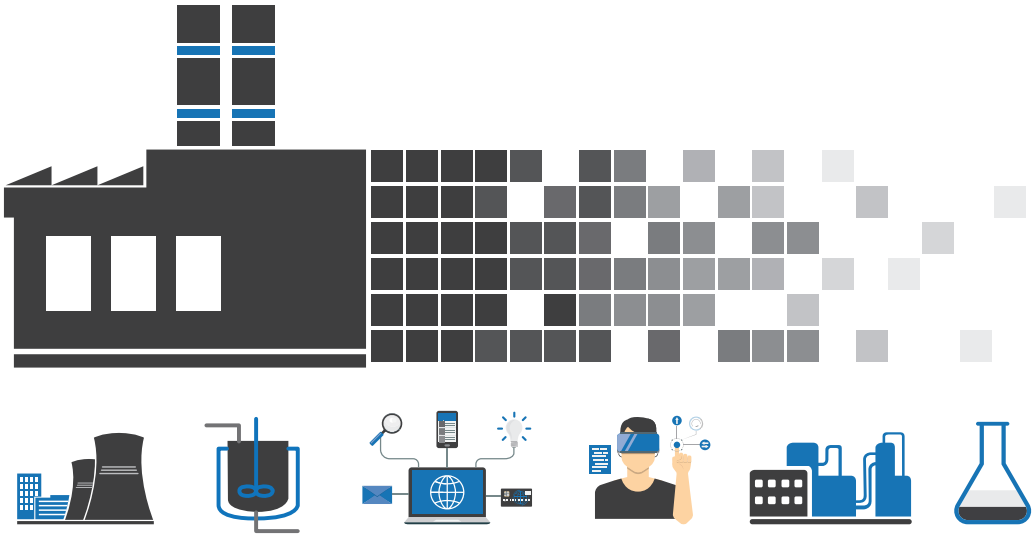

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Addressing Pumping Issues in Biopharmaceutical Operations

Quaternary diaphragm pumps deliver the low pulsation and shear that is critical to these biopharmaceutical and continuous-manufacturing operations

Glenn Hiroyasu and Sueli Roel Backes
Quattroflow Fluid Systems GmbH

Biopharmaceutical, pharmaceutical and nutraceutical manufacturing may come in a wide variety of forms, but every iteration of unit operation must adhere to an unbending set of operational parameters and structures if the desired outcome — a viable, contaminant-free drug suitable for human or animal administration — is to be realized. It is all about "controlled fluid transfer."

Three of the more common unit operations within the biopharmaceutical-manufacturing universe are chromatography, virus filtration and tangential flow filtration (TFF). In order for these unique operations to be implemented successfully, though, the operator must be aware of their specific operating characteristics. For example, chromatography requires constant fluid flowrates during their operations, but may have varying pumping pressures. Virus filtration, on the other hand, will feature constant pumping pressures, but flowrates will change as the filters become clogged or fouled. And in TFF, the main challenge is attempting to keep the flowrate and pressure unchanging throughout the process. All these characteristics are also fundamental for inline blending, a process commonly used not only in the biopharmaceutical segment, but also in the chemical, pharmaceutical and food and beverage industries, where constant flow and pressure ensure the quality of the mixture.

While fluid transfer is taking place in any of these specific unit operations, it is important to know that the materials that are being transferred can be highly sensitive and delicate (and, in many cases, expensive), meaning that the pumping action must be low-pulsating and low-shear, lest the material be damaged.

Quattroflow Fluid Systems

FIGURE 1. Shown here is a chromatography application utilizing three quaternary diaphragm pumps (center, right)

This article examines the material-handling challenges pertaining to flowrate and pressure in chromatography, virus filtration, TFF and inline blending processes, and illustrates why the design and operation of the quaternary diaphragm pump — rather than other technologies, such as the lobe or peristaltic (hose) pump — make it suitable for use in critical biopharmaceutical-manufacturing applications. Additionally, the article shows how the quaternary diaphragm pump's ability to operate consistently whether in a fixed stainless-steel production regime or in the increasingly popular single-use applications gives it the versatility to optimize biopharmaceutical-manufacturing maintenance, downtime, changeover and operational costs.

The unit operations

Let's start by taking a closer look at three of the more popular unit operations in biopharmaceutical manufacturing:

Chromatography columns. A typical chromatography column, whether it is glass, steel or plastic, is filled with resins that are compressed in a certain format through which the product-containing feedstream flows and purifies the product by selective adsorption to a stationary phase (resin). Chromatography columns contain complex target-product adsorbing media that need careful handling. Protein A resin, for example, can cost as much as $10,000/L, making proper feeding of the resin extremely important.

Some chromatography systems require buffer gradients in order to achieve purification of the proteins. Buffers are compounds that are immune to changes in their pH level when limited amounts of acids or bases are added to them. For exam-

DETERMINING FLOW AND PRESSURE PULSATION OF QUATERNARY DIAPHRAGM PUMPS

Using water at ambient temperature as the medium, pressure and flowrates were recorded for a quaternary diaphragm pump at free flow, 2 bars, 4 bars and 6 bars (29, 58 and 87 psi) pressure and at motor speeds of 250, 1,000 and 2,000 rpm. The measuring frequency was one measuring point per second (1 Hz), and the duration measuring point was approximately five minutes. Figure 2 shows the results that were observed.

The maximum flow pulsation measured by the quaternary diaphragm pump was 13 L/h (3.4 gal/h), which was approximately 1.2% of the average flowrate. Regarding pressure pulsation, the maximum value was 0.17 bar (2.5 psi), which is 4.2% of the average pressure. These results indicate that operation of quaternary diaphragm pumps is quite capable of minimizing harmful pulsation in critical biopharmaceutical-manufacturing and handling applications.

Quattroflow Fluid Systems

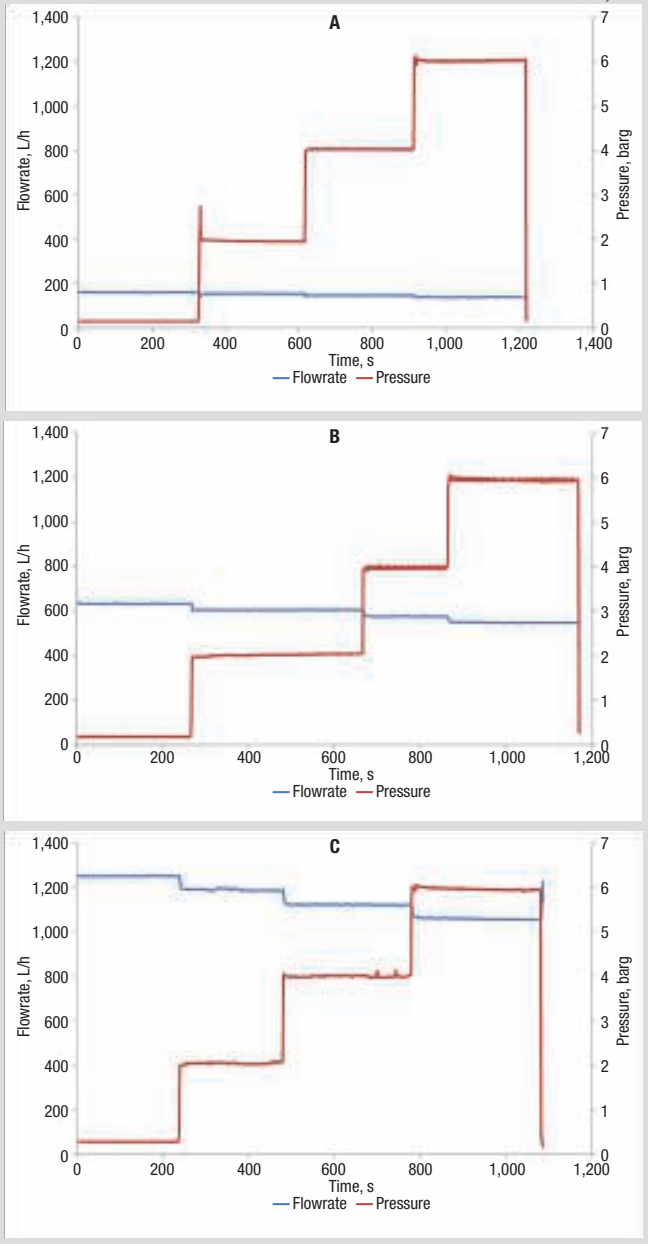


FIGURE 2. These graphs show the flow behavior of a quaternary diaphragm pump as at different pressures for three different pump speeds: 250 rpm (a), 1,000 rpm (b) and 2,000 rpm (c) (see sidebar text for details)

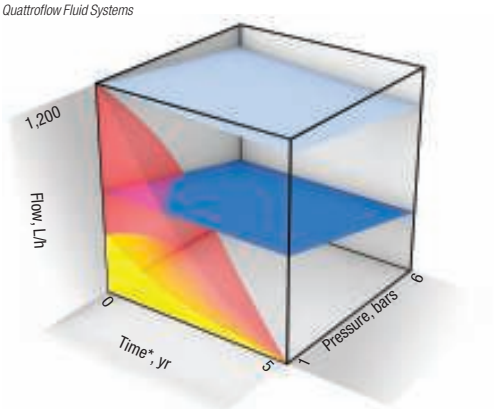
ple, buffering salts have a wide pH range and can effectively stabilize the pH level of the material.

Quite often, more than one buffer is required, which creates the need to use two or more pumps. In this application, high- and low-salt buffers are mixed continuously and with changing ratios in order to affect the adsorption of the target molecule to the chromatography resin. Because of this, precise pumping is required to achieve the right pH/conductivity conditions for specific adsorption and high-resolution purification. For example, a Buffer A and a Buffer B can be used to create a gradient that ranges from a low-salt buffer to a high-salt buffer in a linear fashion. Specifically, the process will begin with Buffer A producing 95% of the flow and Buffer B the remaining 5%. Over the course of the operation, the flowrates of Buffer A and Buffer B will decrease and increase in a linear fashion (90% for A and 10% for B, 75% for A and 25% for B, all the way to 5% for Buffer A and 95% for Buffer B) [*1*].

This requires a pumping technology that can produce a highly accurate flow with a high turndown ratio that can deliver low and high flowrates as the elution stage continues, and ensure constant flow. Pump pulsation should also be minimized to prevent disturbance of the packed column [*2*]. If the pump is not able to meet these requirements, the correct buffer concentration may not be attained. Also, if the pumping action produces excessive pulsation, the buffers can be susceptible to experiencing spikes in their conductivity.

This can affect the purification level of the product, as the salt level in the buffer could be compromised. Also, during the loading of the sample, it is not uncommon for the system's backpressure to increase. Pumps that do not slip offer benefits in these situations since their flowrates will remain consistent and the linear velocity will remain stable. Simply put, a pump with minimal slip will have a more easily controlled flowrate that will need only incremental adjustments to the pump's speed.

Virus filtration. In biopharmaceutical manufacturing, virus-filtration



- A quaternary diaphragm pump (QDP) at maximum speed (pump is only slightly influenced by pressure and wear over time)
- The same quaternary diaphragm pump at half speed (pump is only slightly influenced by pressure and wear over time; pump is able to match a lobe pump that slips at maximum speed
- Larger traditional lobe pump slips and needs to be oversized
- Smaller traditional lobe pump does not have needed flowrange (turn-down) to meet flow

*Note: For applications that experience loss of performance from pump wear.

FIGURE 3. This graph compares the performance of a quaternary diaphragm pump with a lobe pump

systems are used to ensure the viability and safety of the drugs that are produced through the removal of potential contaminants from products that are created using cell cultures. Whereas chromatography features constant flowrates and variable pressures, the operation of virus-filtration systems is the opposite — most virus-filter applications use constant pressures with variable flows. In other words, you may have to raise and lower the operation's flowrate or speed in order to maintain a constant pressure.

As mentioned, the flows change as the virus filter becomes clogged. Most typical virus-filtration systems run at a constant pressure, for example, 2 bars (29 psi), due to the nature of the tight pores in the filtering medium, but the flowrates will decrease as the filter's pores become fouled. When this happens, the flowrate will not decrease in a linear fashion, which will adversely affect the performance of the filter, product yield and overall quality.

Some virus filters have been designed with a flux-decay capacity of up to 90% of the starting fluxrate, which requires a pump that has both a high turndown ratio and produces minimal pulsation in the pumped fluid. Evaluation of viral clearance strategies requires demonstration of the equivalence of scalability from bench to manufacturing scale and vice versa [3]. Spiking studies for virus-filtration use a pressure vessel with a small surface area, which can be as little as 5 cm^2 and demand a pump that has low-shear and low-pulsation operation if commercial-scale production levels are to replicate the small-scale studies. The use of low-pulsing pumps in these circumstances can ensure that pressure conditions during validation of the particular filter are not outside of the validated range.

Tangential flow filtration (TFF). Also known as cross-flow filtration, in TFF the biologic feedstream flows tangentially across the filter membrane at positive pressure. As it passes across the membrane, the portion of the feedstream that is smaller than the membrane's pore size passes through the membrane. This is different from what is known as normal-flow (NFF), or "dead-end," filtration, in which the feed flows entirely through the filter membrane, with the size of the pores determining which portion of the feed is allowed to pass through and which will remain trapped in the filter membrane.

TFF is different from NFF in biologic applications because the tangential motion of the fluid across the membrane prevents molecules from building up a compact gel layer on the surface of the membrane. This mode of operation means that a TFF process can operate continuously with relatively high protein concentrations with less fouling or binding of the filter.

To scale up a TFF process, there are two variables that need to be successfully controlled. Recirculation (cross-flow) is required to minimize formation of the gel layer and pressure as the driving force to push the permeate through the membrane. The recirculation rate needs to work in conjunction with the pressure (known as the trans-membrane pressure, or TMP, which is the average amount of pressure that is applied to the membrane). Maintaining a constant TMP is critical because if it is too high, it can cause gel-layer formation that cannot be removed by recirculation, and if it is too low, it results in low flux that will reduce process efficiency (for more information on crossflow filtration, see "Crossflow Membrane Filtration Essentials," *Chem. Eng.*, April 2017, pp. 49–59).

Inline blending. Also known as continuous blending or inline mixing, inline blending systems, as well as inline buffer dilution, correspond to a new standard for just-in-time-production and reflect the next step in the evolution of continuous-production technology. In this type of process, liquid ingredients are fed proportionally to one main stream and are instantly mixed, since they are being transferred within a common manifold.

In order to obtain exactly the right product, this process requires good metering and volumetric efficiency capabilities that can facilitate the automation of the system. This is different from batch blending, where the product in the tank can be adjusted after measurement in the laboratory according to the parameters defined in the recipe. When this production is continuous, the blending is instantaneous and there is almost no space or time available for corrections.

In this instance, pumps that deliver low-pulsation flow characteristics will perform most reliably by decreasing the fluctuation in the variables. So, in considering the functional design of chromatography columns, virus-filtration systems, TFF systems and inline blenders, the common thread in guaranteeing efficient, reliable, cost-effective operation is found in identifying and using a pump technology that is capable of producing both low-pulsation and low-shear operation despite varying flowrates and pumping pressures that are accompanied by high volumetric efficiency.

The challenge

With these operational requirements in mind, over the years, various pump technologies have been tested and

Quattroflow Fluid Systems

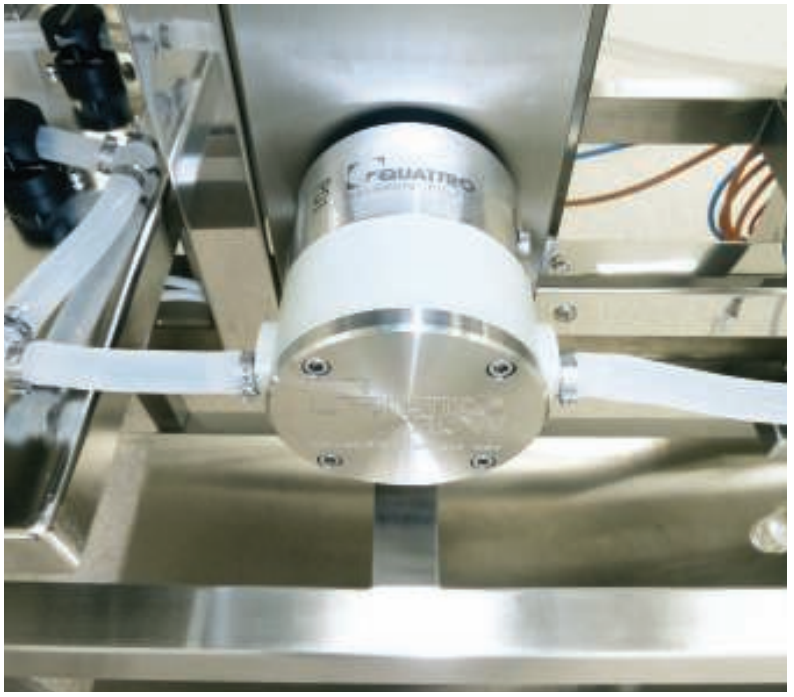


FIGURE 4. Among the advantages of using a single-use quaternary diaphragm pump, such as the one shown here, is the ability to use one pump head for one production campaign. At the conclusion of the production campaign, the pump chamber that has come in contact with the fluids is disposed of

used for chromatography, virus filtration, TFF processes and inline blending. Two that are among the more popular choices when positive displacement is required are lobe and peristaltic pumps. Both, however, have been found to feature operational inefficiencies that may make them insufficient for use in the processes described earlier.

Lobe pumps. Since many biopharmaceutical materials are contained in a low-viscosity aqueous solution, lobe pumps may not be a good choice because slippage can occur during their operation. Slippage can vary between 10% to 100%, depending on the system's backpressure. Slip will also result in increased shear damage and energy consumption, and if used in a long-duration recirculation loop, such as a TFF filtration system, there can be noticeable heat addition to the product, which can require significant cooling efforts to protect the product from overheating.

Lobe pumps also have mechanical seals, which can result in a controlled product leak and do not provide full containment unless special (and oftentimes expensive) seals and seal barriers are used. The sterility required in biopharmaceutical handling also means that no outside contaminants can be introduced into the purification process, which is something that pumps with mechanical seals cannot reliably ensure.

Additionally, the necessary contact between a lobe pump's internal parts can lead to wear and the generation of particles that can result in product contamination. Solid particulate matter, such as undissolved salt crystals, can cause severe damage to the lobes, resulting in damage to the entire manufacturing batch. Lobe pumps may ultimately cost more to operate because of the increase in power required to overcome the pump's slippage.

Peristaltic (hose) pumps. The main shortcoming of peristaltic pumps is also the most obvious: their method of operation will undoubtedly produce pulsation, and, as noted, pulsation is undesirable in biopharmaceutical manufacturing. Peristaltic pumps also have limited flow and pressure-handling abilities. For example, they cannot reliably produce the higher discharge pressures (such as 4 bars, or 58 psi) that are required in some fluid-handling applications.

They are also known to release some small quantity of hose material — in a process known as "spalling" — into the pumped product, which can compromise its purity. If the spalled hose material makes its way to the filter, it can foul the filter, making its operation less efficient than it need to be, and will also lead to contamination. Also, inconsistency of flowrate will result due to mechanical deformation of the hose during the pumping process. In the end, the shortcomings of lobe and peristaltic pumps come down to two main factors:

- If there is shear, which is common in lobe pumps, you will damage the pumped material
- If there is pulsation, an operational certainty with peristaltic pumps, you won't have even flow, and without even flow, you won't have accurate flow

A solution

An effective solution to the operational shortcomings of lobe and peristaltic pumps can be the quaternary diaphragm pump.

The operating principle of the quaternary diaphragm pump most closely resembles the operation of the human heart, because the four-piston diaphragm technology enables a gentle pumping action through soft "heartbeats." This action produces four overlapping pumping strokes of the pistons that efficiently reduce pulsation, since each stroke of the four diaphragms is generated by an eccentric shaft that is connected to an electric motor.

The quaternary diaphragm pump's method of operation allows it to gently, safely and securely convey low-viscosity aqueous solutions and biopharmaceutical materials that are highly sensitive to shear forces and pulsation while being pumped. Since the four-piston design of the pump does not require any mechanical seals or wetted rotating parts, total product containment is ensured without any abrasion or generation of particulate matter. The pump's method of operation also produces risk-free dry-running and self-priming capabilities with high turndown ratios. A pump technology with high turndown ratios allows for the creation of a

broad flow range, which makes the pump applicable for utilization in a wide range of process applications.

With regard to specific unit operations, quaternary diaphragm pumps can be used to pack chromatography columns and then pump the biopharmaceutical material through the column, both of which are critical concerns that require low pulsation with accurate and constant flowrates and pressures. In TFF applications, quaternary diaphragm pumps deliver the consistent flow control that is essential in producing optimal filtrate yields.

When speaking about blending, this technology facilitates systems automation due to its significant volumetric efficiency, while it also offers high turndown capabilities that grant flexibility in handling formulations that require a wide range of possible ingredient input flows.

Single-use pumps

In today's evolving manufacturing processes, quaternary diaphragm pumps are also rapidly becoming a first-choice technology in increasingly popular single-use production setups. Basically, a single-use pump enables biopharmaceutical manufacturers to eliminate the cost of cleaning and validating their pumps by using a pump with a replaceable pump head. The result is not only a quicker production process, but one that delivers preferred levels of product purity and sterility with no chance for cross-batch or cross-product contamination (Figure 4).

The following are some additional advantages that can be realized when quaternary diaphragm single-use pumps are used:

- Quaternary diaphragm pumps (single-use) can be used for one product or in one production campaign
- At the conclusion of the production campaign, the pump chamber that has come in contact with the fluids is disposed of
- Can be used for a set amount of time before the wetted parts are replaced, which eliminates elevated maintenance costs
- If the operator needs to use a stainless-steel pump, the plastic pumping chamber can be replaced with a stainless-steel one
- If there's a pump failure, the old chamber can be taken out and replaced with a new one in five minutes
- Used when cleaning in place (CIP) or steam sterilization is not practical or possible. This represents a significant simplification and cost reduction to the overall process, as there are no contaminated cleaning chemical and water solutions that need to be treated and disposed of. The costs to properly treat and dispose of the cleaning fluids can alone be the driver to require use of single-use alternatives

Of course, not every pump technology is completely perfect for every characteristic of a specific fluid-handling application. In this instance, the design and operation of the quaternary diaphragm pump limits it to handling fluids that have a maximum viscosity of 1,000 centipoise (cP) and that contains particulates up to 0.1 mm in diameter. ■

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Spill Containment: An Often-Overlooked Hazard in Research

With proper planning, spills can be managed properly and the risk of secondary events — which may be more dangerous and costly — can be reduced

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Spills are probably one of the biggest problems any laboratory or pilot plant operation faces. While spills are often cited as a potential hazard, the actual mitigation steps are often very generic and ineffective, reflecting the often cursory nature of the hazard analysis and risk assessment in this area. After all, spills happen and just need to be cleaned up.

Spills — defined here as an uncontrolled release of liquids or solids into the operating space — are very common, due to accidents that happen during transportation, material transfer, maintenance, equipment failure and human error. Spills may involve hazardous or non-hazardous materials. Hazardous materials (those harmful to people or the environment due to their flammability, toxicity or corrosivity) are clearly the most dangerous. However, even spills of non-hazardous materials can create operating problems, damage equipment, and cost time and money to clean up.

Fortunately most spills in laboratories and pilot plants are minor — due to the relatively small volume of materials being handled — and just require some cleaning activities. However, some have resulted in fire and explosions, leading to both personnel injury and significant equipment and facilities damage. So more than cursory attention is warranted to minimize the risk of an unanticipated hazard (Figures 1 and 2).

Whenever possible, spill protection should be provided for all equipment and operations. This can range from permanent, expensive protection, such as dikes and berms for tanks, to simple pans, pails and trays for smaller equipment. The key requirement is the same in all cases — the spill protection must be large enough to contain the maximum probable spill.

For a batch system, this is generally straightforward. The volume of the largest single component (tank, reactor, sample cylinder, piping and so on) must be contained. However, splashing and fluid impulse (waves) that can occur when a liquid is released from its containment requires additional volume to be included in the spill-containment vessel, to prevent transient effects from overflowing the containment vessel. Typical industry guidelines suggest this volume must be increased by at least 10%. The higher the distance the spill may fall, the greater the velocity it will attain, and thus, the higher the containment volume necessary.

The closer the spill-containment vessel is to the source, the more momentum it will still have and again, the higher the containment.

Neither of these scenarios is subject to easy analysis, but the author's experience with small systems suggests that sizing spill-containment vessels with excess capacity that is more on the order of 20–30% may be required for research-size laboratory and pilot systems. Paradoxically, smaller laboratory systems often require up to 50% extra volume.

Splashing from the added height is a definite issue and can result in significant amounts being cast outside the planned containment system. The amount of splashing or flow-

FIGURE 1. The plastic spill-containment basin shown here will not withstand even a small fire

FIGURE 2. Without effective spill containment in place, any spills that might result from these vessels would likely fall to the floor and potentially find an ignition source in the vacuum pump and more fuel in the solvent container located nearby

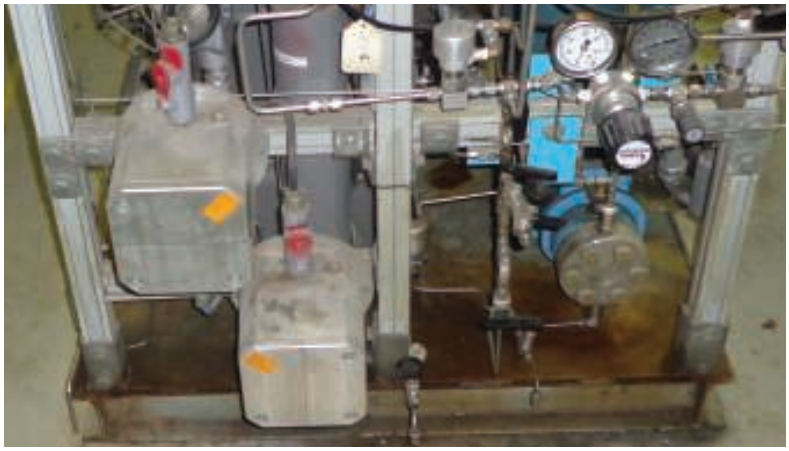


FIGURE 3. Shown here is an example of residual spill material remaining near a pilot plant pump. While trivial in itself, it does raise the potential for a fire to spread. One wonders if a simple drip pan could have eliminated the concern

ing over is important in determining safety. A few drops are unlikely to cause any issues. A few hundred cubic centimeters might be enough to find an ignition source or may pose a threat to personnel. A few liters is clearly an uncontained spill (Figure 3).

For a continuous system, designing an appropriate spill-containment system becomes much more difficult. Either the spill containment must be sized for the total system's volume — usually a physical or financial impossibility — or an appropriate alarm must be provided. Small laboratory systems may be able to capture the entire system's contents, but even moderately sized pilot plants can begin to make this difficult or impossible. In these cases, the containment must be large enough to let the system or the operators respond effectively.

In the author's experience, the time required for this response is often badly underestimated, particularly for manual responses. For this reason, automatic interlocks should be provided to rapidly shut down the source of the leak or spill, and any attendant dependent operations, immediately upon detection of a release. All too often, operators are temporarily absent or distracted, or fail to immediately recognize the problem and take effective action quickly enough, which leads to a larger spill. Systems that run unattended or off hours are particularly prone to major releases before the problem is discovered and corrected. Passing personnel and security guards can find it difficult to detect a spill until it has become so significant as to be blatantly obvious.

It is important to recognize that

FIGURE 4. Shown here is an installation that relies on the laboratory hood for spill containment. The hazard analysis that had been carried out here was shortsighted, in that it only focused on the relatively low flowrates presented by the small volume of fluid, rather than on a potential incident that could result in an entire bottle breaking, releasing its contents

utility feed streams, often overlooked as non-hazardous, can also be the source of very expensive spills, as they effectively present a potentially unlimited supply in the event of a breach. For instance, water, chilled water, oil, steam and similar systems can produce large releases in the event of a leak or component failure.

Laboratory hoses that feed hood units, hoses and plastic piping that feed laboratory or pilot plant equipment, and booster pumps (or, more accurately, their seals) on similar pilot plant systems, are all potential sources of major spills (Figure 4).

Similarly, laboratories on higher floors of a building are potentially at risk of causing major flood-related damage to equipment and facilities on lower floors. NFPA 45 Fire Protection for Laboratories Using Chemicals requires that all floor openings be sealed to prevent spills from spreading. Most building codes require similar measures but their focus tends to be on minimizing the spread of smoke or fire, not necessarily fluid spills.

NFPA 45 is careful to note that the spill protection must be compatible with the chemicals involved; if the containment system can be weakened or attacked after an exposure to the fluids in question, it must be repaired or replaced immediately. Sadly, most laboratories this author has seen over the past 40 years have had at least some areas that do not meet these criteria.

Unsealed or compromised penetrations between or behind laboratory benches go unnoticed. Modifications requiring floor or wall

penetrations over time fail to be sealed or, at least, sealed effectively enough. Age and normal wear and tear result in compromised seals. In general, almost any large spill in a laboratory setting tends to find its way to lower floors and adjacent spaces unless the organization has an effective inspection and maintenance program in place — which is rare (Figures 5 and 6).

Many laboratories that handle only small amounts of hazardous materials fail to recognize that a break in a cooling hose to a glass heat exchanger in a laboratory hood could lead to several hundred gallons of water cascading down to lower floors overnight. The response time for guard tours off hours and even passing personnel during on hours is almost routinely grossly overestimated.

First the person must recognize the problem, then contact an individual capable of taking action or at least knowing what action to take. That individual must locate the source and determine how to safely shut it off. Rarely does this sequence take less than 15–30 minutes (often it takes longer). Aside from the obvious damage from the spilled liquid, there is also the potential for electrical shock if the liquid is conductive.

Retain the spill safely

The spill-containment device or system must be able to withstand the normal wear, tear and abuse of daily operations and still be viable when required. It is common to see lightweight pans and even permanent rails or sides in place, but badly damaged by routine traffic and noticeable bows, bends or crushed sections. Dikes and similar structures are often cracked. All may have unsealed penetrations, penetrations with compromised seals (for instance, seals that are cracked, oversized, crumbling and so on) that will compromise their effectiveness.

Portable spill protection (such as trays, pans, buckets and spill pallets) is subject to being bumped, moved or nudged out of its proper position due to routine operations and, more commonly, maintenance or modifications. Hence, the use of portable systems should require routine inspection and adjustment in their position if required. Sadly, it is often easy for a spill container to be slightly moved and not be noticeable although rendered significantly less effective. The best approach is to design a restraint or frame into which the container fits so that it cannot be moved out of place but can be lifted or slid out for emptying if necessary.

Permanent spill protection is prone to being rendered less effective by modifications that often move major sources within the frame without evaluating the effect on the existing spill containment. Problems can include the addition of other potential sources, which could require more containment. Examples include new equipment or sources of a potential release that are placed too close to the edge of the containment, leading to the potential for the momentum of the release carrying the spill over the containment, or new equipment

FIGURE 5. Laboratory settings typically have multiple sources of spills and nearby ignition sources, so relying on the hood alone for spill containment is usually not sufficient

or sources that are located higher off grade, creating more kinetic energy to allow a spill to flow up and over the containment.

In some cases, modifications may extend past the spill containment altogether. Hence, all such modifications should be reviewed for their effect on the spill containment and should be part of the organization's management of change (MOC) process.

Maintenance often requires the removal of spill containment or at least parts of it. Yet, the potential for spills is often higher during maintenance-related activities. Hence the maintenance-activity plan should assess what temporary spill-protection measures are required.

The capacity and location of the spill-containment system also needs to evaluate the distance a leak or pressurized release could travel. Spill containment to capture a small slop stream running down the side of a drum or container usually does not need to be much bigger than the container. But spill containment for a small hole in a drum or a broken beaker can shoot out under head pressure and flow a much longer horizontal distance.

Plan for what happens next

For potentially flammable and combustible products, this requires that the spill containment be able to withstand a fire since this is always a possibility. Hence glass and plastic containers, soft-soldered trays, and similar low-melting temperature components are not suitable for laboratory operations. A contained fire is a hazard but an uncontained fire is always a major hazard.

Portable spill containment needs to be stable, so that when it is being filled or filling it cannot shift and result in liquid escaping. It must also be able to safely hold any debris that may be coincident with the spill, such as broken glassware or parts of a failed seal.

The work surfaces inside laboratory hoods are required to be fabricated so as to have some spill containment (for instance, in the form of a depression in the work surface, or by sealing around the edges to create a lip), in accordance with both industry standards and NFPA 45. However, many do not provide viable containment. Too often, the hoods were purchased without appropriate spill-containment capabilities, or were installed so that the containment is ineffective, or the existing containment has become compromised over time due to the loss of sealant, or scrapes, gouges or similar damage. Relying on a hood to contain a spill from equipment inside its interior, unless carefully tested in advance, is ill advised.

FIGURE 6. Even a well-designed pilot plant bay with floor drains will often have residual materials that could ignite near potential leaks and spill sources. If well maintained, as in this example, the residual risk should be minor

Absorbent pads, mats and temporary berms are valuable spill-containment tools. However, their capacity is limited so a careful assessment of their ultimate effectiveness for the duration of the spill is required. Too often, this author has seen almost

FIGURE 7. The spill containment on the left meets almost all the requirements for effectiveness, although it still requires manual clean up with a rag or absorbent pad. The area on the right, unfortunately lacks sufficient protection

total reliance on these inexpensive and easy measures which, upon analysis, can be shown to only provide limited mitigation, usually due to larger volumes of extended response periods. They are also often too easy to damage, leave gaps, or move and not be replaced during normal operations (Figure 7).

Plan for safe final cleaning

Even simple laboratory pans and trays need to be selected and placed so that they can safely and easily be removed for emptying or arrangements can be made to allow cleaning in place. Larger trays and pans are often cumbersome, bulky and easily tipped when moving. The author has seen numerous trays, pans and containers that only transfer the spill from the source to an adjacent area due to difficulties in removal and handling.

As the spill containers get larger in size and volumes they become exponentially harder to handle or difficult to lift safely. Hence, prudent analysis may suggest that they need to be evaluated in terms of how they will ultimately be safely drained — even if this adds cost and complexity to the system design. In many cases, particularly on pilot plants or larger laboratory units, this may not prove feasible.

When this is the case, the hazard analysis and risk assessment should address any hazards of residual materials or difficulty in cleaning. At the very least, thought should be given to providing handles or similar means to allow personnel to lift and grasp the pan, tray or container safely. The potential weight it must carry should be evaluated and this often requires a stiffer or heaver pan to prevent it bowing or folding during movement when filled.

Trying to empty a pan or tray without a spout of similar directional pouring mechanism makes it more difficult and often results in secondary spills. Smaller trays can often use their square corners as these directional means to empty the collected liquids. However, larger trays and pans often require some thought and care in their selection or design to provide them. Otherwise pouring out the contents frequently becomes a spill-producing activity itself.

FIGURE 8. Shown here is an example of a spill that can easily leak through the unsealed hole around the drain beside it

Permanent spill containment around pilot plants and support installations, such as tanks, requires a design that allows for easy cleaning. This usually means trying to design the containment with a slope to a low spot or

sump that will allow collected fluids to be vacuumed or pumped out. Common assumptions that the operators can easily sweep the liquid to a collection point are almost always spurious and result in significant residual spillage remaining after cleaning. At best this is a housekeeping problem; at worst, it can create a standing unsafe condition. Many "portable" trays around pumps or small tanks fall into this category, because to actually remove them requires removing the equipment first, something rarely ever done in practice.

Many laboratory spill-containment installations fail badly on this point. For example, providing a larger pan to hold a hot plate or stirrer plus the contents of the container being heated or stirred is common and often the only practical approach. However, a large number of these installations will prove to be ineffective due to lack of proper analysis such as the following:

- Failure to account for the volume of the equipment, which leads to overflowing
- Failure to recognize that the spill, usually due to container failure (breakage) or upset (human error), will almost always result in the spill being splashed outside the container
- Failure to realize the container is too close to the sides of the containment (leading to the liquid momentum causing the spill to splash over) or too high above the spill containment (leading to the height giving the spill enough kinetic energy to splash out or flow over the containment sides)
- Failure to consider how the resultant spill, and debris can safely be separated and drained to a safe location

FIGURE 9. A risk assessment of this area would need to address the consequences of a smaller spill leading to a larger conflagration. While appropriately electrically classified to minimize the potential for ignition sources, the addition of a spill containment system on each shelf might significantly lower the consequences of any potential spill

Review housekeeping efforts

Housekeeping procedures are an integral and critical part of proper spill containment. Any spill of flammable and combustible materials can lead to a fire. If the fire is contained, it can be extinguished more easily and with fewer consequences than if it is uncontained. In addition, a spill of a flammable or combustible liquid, if it reaches other combustible sources, can easily grow much larger. This means that a spill — or even a splashing — that ignites may be able to reach squeeze bottles of solvents, spare flammable or combustible chemicals, papers, lab notebooks, towels, or any of the other inevitable paraphernalia in a laboratory, causing the initial small fire to quickly grow into a large and dangerous conflagration. The author once saw a 500-ft^2 laboratory effectively burned out from a spill of only several hundred cubic centimeters of flammable liquids due to very poor housekeeping and a failure to recognize the numerous other "fuel" sources on nearby benches.

Poor housekeeping on a pilot plant (FIgure 8), particularly in terms of cleaning up all the residual materials from past spills, is critical in preventing a small flash-type fire that can easily damage other components and lead to a larger release (either spills or leakage). Similarly, keeping adjacent areas clear of other fuel sources, such as spare solvents, containers of feed or products, combustible materials and more, is also important in all cases, to make sure a fire stays localized and does not spread. The spill pan in a laboratory hood with the spare bottle of solvent right next to it rarely contains the secondary fire.

Providing spill containment for an entire area, such as a laboratory or pilot plant bay, is a common technique. Although initially expensive to provide, it is often viewed as a low-maintenance, easy way to minimize the risk associated with potential spills. This is often not the case. To be safe and effective, a few key guidelines should be followed:

- The hazard analysis and risk assessment must evaluate the effects of any spill on all adjacent equipment and operations. At the least, it should evaluate the effect of a small fire spreading to numerous other fuel sources. This is more probable if the area does not have an electrical classification as Class I Division 1 or 2 or Zone 0, 1 or 2 (Figure 9)
- The construction of the area must address the need for sloping to the floor drains, if provided, or to a sump or similar low point for collection and ultimate removal of captured fluids. Often floor drains are poorly installed so that they either stand "proud" of the floor (that is, they stick up above the floor slightly), which makes drainage impossible. Or they are oplaced in small shallow depressions, which, in the event of a spill, would only provide drainage for a few inches beneath the drain. Many floor areas are essentially level or they slope slightly (and often imperceptibly to the eye) in several different directions, making it difficult to determine in advance where the spill will flow. If the area does not have floor drains, then consideration must be given to where the liquid will flow. If it flows under benches, hoods, and fixed equipment then cleaning will be difficult and probably poorly done leading to residual risk
- If floor drains are provided, they must drain to a safe location that can contain the spills and allow them to be transferred safely for proper disposal. Several common problems are often associated with these systems. For instance, a failure to provide adequate alarms allows them to overflow (usually due to an accumulation of numerous relatively trivial spills over time, or one larger spill that was bigger than originally envisioned). Similarly, placing a holding tank in a regular municipal sewer line and assuming that it can be isolated and taken off line before any contaminants escape is rarely a failsafe approach. The spill-reporting time may be lon-

FIGURE 10. Note the modifications extending outside the spill containment

ger than expected, the spill may go unreported, other non-hazardous drainage may sweep the tank constantly leading to contamination, or a similar issues may arise. Finally, providing a complex treatment or separation system that requires frequent maintenance and care can lead to frequent failure when it is forgotten or at least often neglected for a time.

Spills can also occur due to leakage from fittings, seals, gaskets and similar components. And they may arise due to normal operations that provide frequent repetitive opportunities for small, individually trivial spills to arise, as these can collectively accumulate over time to eventually reach critical levels. Situations in which this scenario can arise include: baths where containers or samples are frequently removed and often drip nearby; sampling where residual materials may continue to flow for a moment after completion; emptying containers into hazardous-waste cans for ultimate disposal with the attendant routine drips, splashes and trivial spills, emptying or filling smaller containers into or out of larger ones for ease of use or process needs with similar consequences; and other repetitive or routine operations.

Such occurrences can often make areas around these operations less safe, due to residual materials increasing the risk of a fire spreading, increasing the risk of personnel contact with toxic materials, or at least creating increased slipping and tripping hazards. In many cases, some local spill containment may be prudent to both restrict the area into which these minor spills could spread and make cleanup easier. This extra local containment is often much larger than the minor spills required to allow for a longer interval between cleaning or to address the potential for a larger-than-normal spill (Figure 10). Conversely, it may occasionally be much smaller than might be required in the event of a larger spill (such as a person dropping the container to be emptied). The potential for requiring a larger spill containment, to account for human error, should always be evaluated. For instance, the possibility of dropping a container that is being transferred from a bath to the bench next to it, overfilling a waste can or smaller container, dropping the larger container, and similar human errors should be assessed.

It is not always possible, nor is it always necessary, to provide spill containment around every potential source in a laboratory or on a pilot plant. However, the hazard analysis and risk assessment should make sure to look at the potential hazards from leaks and spills carefully — perhaps more carefully than it has been done historically — to make sure that they do not create unrecognized and unacceptable risks, or that providing spill protection of perhaps a different type might not help to further reduce an already low risk with minimal cost and operability impacts. The hazards we recognize and evaluate are the hazards we usually mitigate effectively; the hazards we overlook or consider trivial are usually the hazards that come back to create the accident. ■

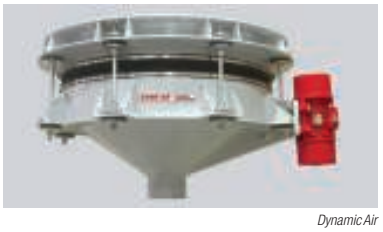
Edited by Suzanne Shelley

Author

Richard P. Palluzi, P.E., CSP, of Richard P Palluzi LLC (72 Summit Dr., Basking Ridge, NJ 07920; Email: rpalluzi@verizon.net; Phone: 908-285-3782) is a consultant to the pilot plant and laboratory research community on safety, design and research project management. He retired as a Distinguished Engineering Associate after almost 40 years at ExxonMobil Research and Engineering, where he was involved in the design, construction, and support of pilot plants and laboratories for ExxonMobil's research site in Clinton, N.J., as well as affiliates worldwide. Palluzi is the author of two books, and numerous articles and presentations. He is a past chair of the AIChE Pilot Plant Committee, ExxonMobil's Pilot Plant and Laboratory Safety Standards Committee, and ExxonMobil's Safe Operation Team for their Clinton Facility. He is on the National Fire Protection Association (NFPA) NFPA-45 Fire Protection for Laboratories Using Chemicals and NFPA-55 Industrial and Medical Gases committees. Palluzi also teaches several courses for the University of Wisconsin's Dept. of Engineering Professional Development. He has B.E. and M.E. degrees in chemical engineering from Stevens Institute of Technology.

POWTECH 2017

Sandvik Process Systems



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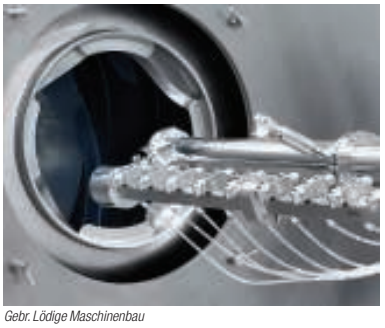


Gebr. Lödige Maschinenbau

Bulk solids experts, process technicians, engineers and plant operators from all over the world will gather in Nuremberg for Powtech 2017 (September 26–28; www.powtech.de). Around 900 exhibitors in six exhibition halls will be presenting their latest equipment and systems for the whole gamut of mechanical processing technology and for the analysis and handling of powder and bulk solids. A new feature in 2017 will be the special display area "Pharma Solids" for concentrated pharmaceutical expertise in Hall 3A.

Two forums will offer ongoing presentations and workshops on issues affecting the industry. Bulk solids practitioners will gather at the expert forum in Hall 2, where they can experience best practice examples by leading manufacturers and users in the form of compact presentations. Users involved in the pharmaceutical sector will find themselves at home in the "Pharma.Manufacturing.Excellence" forum in Hall 3A and will come away with useful tips on how to meet the challenges facing them.

A sample of some new products being exhibited at Powtech are presented below.

Pastillation-system solutions for hot melts, resins and more

Exhibiting under an umbrella message of "Go further, explore more possibilities," this solidification-systems manufacturer will launch its brand new ThermoCut system, delivering increased productivity and a better-quality end product with high-viscosity melts. The system works by blasting a narrow jet of high-pressure, heated air at the precise place where the drops are formed between the Rotoform and steel belt (photo). This powerful blade of hot air cuts the threads before they have chance to develop further. As well as delivering a more stable production process with perfectly formed pastilles, the use of ThermoCut equipment also results in a substantial reduction in the need to clean the machine. The company is also showcasing its specialized Rotoform 4G sc system, purposely designed for the pastillation of subcooling melts. Other themes will be the high-capacity solidification achievable using steel cooling belts up to 2 m wide, and the ability to deliver systems compliant with GMP (Good Manufacturing Practice) standards. Hall 4A, Stand 107 — *Sandvik Process Systems, ZN der Sandvik Materials Technology Deutschland GmbH, Fellbach, Germany*
www.processsystems.sandvik.com

A variety of solids-handling equipment presented here

At Powtech, this manufacturer will be exhibiting an operating pneumatic conveying system, as well as the Bella twin-shaft mixer and vibratory equipment. The company manufactures a complete line of dense- and dilute-phase vacuum and pressure pneumatic-conveying systems, process equipment and vibratory equipment for handling a wide variety of dry bulk granular materials. A fully operational dense-phase pneumatic conveying system will be on display, along with the Bella XN double-shafted mixer in 304 stainless steel food-grade design. This mixer provides a high-quality blend in an extremely short mixing time. Also on display will be its line of vibratory equipment, including the Stedi-Flo vibratory pan feeder and the GYRO EX bin-activating feeder and discharger (photo), which produces a controlled gyratory motion to positively withdraw granular materials from bins, storage silos and hoppers at any desired feedrate for a consistent and reliable discharge. Hall 3, Stand 204 — *Dynamic Air Ltd., Milton Keynes, U.K.*
www.dynamicair.com

This tablet coater now has a new design

The LC series of coaters (photo), specially conceived for coating tablets, has been the subject of extensive redesign. For example, a newly configured airflow now provides a significant boost in efficiency and availability of the machines. In contrast to the previous forced air feed via an intake boot, the air to the LC series of coaters flows through an air-injection manifold over a large circumference of the coater drum in the direction of the tablet bed. This enables even, largely turbulence-free entry of

a large volume of drying air into the drum. The innovative concept ensures a high drying capacity and hence high spraying rates. The undesirable effect of spray drying, resulting in spraying losses during coating, is effectively prevented. Advanced sensors also facilitate optimization of the spraying and drying process, and simple and safe adjustment of the nozzle arm makes handling easier. Hall 1, Stand 517 — *Gebr. Lödige Maschinenbau GmbH, Paderborn, Germany*
www.loedige.de

Packaging film that enables quick, easy opening without tools

This company's stretch-film packaging system, the Stretch Hood A, can be used in a variety of different industries. The system can now be supplied with a newly developed, easy opening hood, which enables employees in retail stores and logistics centers to quickly and easily remove the film when unpacking or repacking the goods, without the use of any cutting tools. To achieve this, the company partnered with a well-known film supplier to develop a technology that allows users to open the film along a precise tear line in the center (photo), without affecting the safety function of the stretch hood. The user can open the film quickly and easily, with no tools required. This considerably increases unpacking productivity. Hall 1, Stand 627 — *Beumer Group GmbH & Co. KG, Beckum, Germany*
www.beumergroup.com

These packing systems continue to get cleaner and smarter

The newly developed packing system of the Roto-Packer, Integra and Elementra families is said to have outstanding features when it comes to cleanliness, intelligence and profitability. In particular, the new Roto-Lock dosing unit delivers clean filling, reliable performance, intuitive operation and energy saving function. The company is keeping pace with the market demands for modular and future-oriented solutions for the complete process: from stocking to filling and loading. By using the Quattro System Monitoring (photo), companies are better secured against long downtimes and high maintenance costs. The automatic recording of all machine data saves time and provides reliable information that otherwise would not be assured by manual input. Using these precise data, the performance of the systems can be compared and comprehensively optimized — even when packing at multiple locations. Hall 1, Stand 535 — *Haver & Boecker oHG, Oelde, Germany*
www.haverboecker.com

Filtering iron and stainless steel from powders and bulk goods

The continuous cleaning Cleanflow magnet (photo) removes both iron and stainless steel from powders and bulk goods, and achieves capacities of up to 200 m.t./h. The system is suitable for installation in ATEX zone 20/22 and can be cleaned without stopping the product flow. It can be installed directly below the sieve or even just before the loading/packing point. The Cleanflow magnet is easy to integrate into existing production processes. In addition to preventing damage claims, magnets protect machines from seizure due to iron contamination and resulting expensive production standstills. The magnet has been developed for applications such as those found in the sugar industry, and can remove the very smallest particles (down to 10 µm) from the final phase of the production process. Hall 2, Stand 450 — *Goudsmit Magnetics B.V., Waalre, the Netherlands*
www.goudsmitmagnets.com

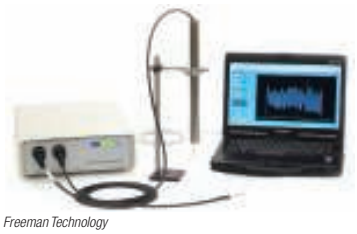
Realtime process monitoring and rheology measurements

At Powtech, this company will be demonstrating pioneering new technology for in-line, realtime process monitoring via an exclusive partnership with Lenterra Inc., manufacturers of optical flow sensor technology. Lenterra's Drag Force Flow (DFF) and Wall Shear Stress (RealShear) probes (photo) provide continuous, realtime data, via optical fibers, enabling users to assess processes and make decisions without the need to interrupt operations. The company will also present the FT4 Powder Rheometer, a unique and comprehensive powder tester that uses patented dynamic methodology, automated shear cells (in accordance with ASTM D7891) and a series of bulk

Beumer Group

Haver & Boecker

Goudsmit Magnetics .



Freeman Technology

amixon

Dinnissen Process Technology

Posi-flate

Messer Group

property tests to quantify powder behavior in terms of flow and processability. This is complemented by the new Uniaxial Powder Tester, which provides an accurate and repeatable measure of the uniaxial unconfined yield strength (uUYS) of a powder to assess and rank flowability. Hall 4, Stand 547 — *Freeman Technology Ltd., Tewkesbury, U.K.*
www.freemantech.co.uk

A conical mixer for particularly fast batch changes

This company's new mixing system (photo) features helical mixing tools that, despite low rotational speeds, achieve ideal mixing qualities within just 20 to 60 s. A rotationally symmetrical closing element lowers a few centimeters and allows complete discharge within a few seconds. This makes it possible to homogenize large volumetric flows with small mixers. The system has a compact, space-saving design, is hygienic with regard to regular wet cleaning, enables gastight execution (suitable for over-pressure operation) and is in conformity with ATEX standards. Hall 4A, Stand 304 — *amixon GmbH, Paderborn, Germany*
www.amixon.com

Reducing failure costs using virtual reality

This company will be demonstrating its virtual reality (VR) application at Powtech. A small group of engineers is currently working with VR in a research phase. "By applying virtual reality, we let the customer experience the new system without it being constructed. The customer sees exactly what they can expect," says the company. Because the customer can walk virtually through the installation together with this company's engineer in the "real environment," they can already anticipate in the design phase what they will encounter in the realization phase, creating a more complete picture (photo). Bottlenecks become visible even before construction takes place, whereby commissioning times are also shortened. This means that a new plant will produce faster, thus yielding revenues. Maintenance training can also already be done before the installation is finished. Future-oriented maintenance will be the next phase, for which VR offers something extra. That will be the next step, possibly supplemented with augmented reality, says the company. Hall 4, Stand 371 — *Dinnissen Process Technology, Sevenum, the Netherlands*
www.dinnissen.nl

These butterfly valves have inflatable seats

This company is exhibiting a heavy-duty inflatable-seated butterfly valve operating next to a typical resilient-seated valve to demonstrate how quickly a resilient-seated valve can wear in comparison to the air-operated valve. The inflatable seat design provides a better seal by utilizing air pressure to expand the seat against the disc, providing more sealing area and an even pressure distribution against the disc every time. The seat automatically compensates for wear when it inflates against the disc, extending valve life considerably. The Series 585/586 inflatable-seated butterfly valve (photo) is designed for the most severe applications. The heavy-duty seat has been designed for higher operating pressures and temperatures. The valve is ideally suited for very abrasive materials such as sand, feldspar, flyash and most other dry, granular materials, which can reduce valve life. Hall 3, Stand 301. — *Posi-flate, Milton Keynes, U.K.*
www.posiflate.com

Cold grinding, recycling and flash freezing with cryogenics

With this company's cold-grinding and flash-freezing techniques, it is possible for a wide range of different materials to be finely ground or recycled by using cryogenic gases, such as N_2 or CO_2. Materials such as thermoplastics, elastomers, waxes and paint additives can be handled, as well as spices, which would otherwise lose their flavors due to the high temperatures in grinding processes. Furthermore, bulk solids and pourable food products can be flash-frozen in paddle screws using cryogenic gases to extend their shelf life or improve their quality. This application is said to be less expensive and more efficient than conventional techniques. During the cryogenic grinding process (photo), the materials to be

ground are cooled with liquid N_2 or CO_2 to make them brittle resulting in a particularly fine grain. This allows composite materials to be separated into their individual components in a cost-effective and environmentally friendly manner. Hall 4A, Stand 531. — *Messer Group GmbH, Bad Soden/ Frankfurt am Main, Germany*
www.messergroup.com

A new twist on fiber feeding for recycling

Manufacturing carbon-fiber panels can generate a great deal of waste, which then requires disposal. Shredding these panels produces flakes and fibers that, when mixed together, make feeding extremely difficult. Most natural fibers have similar flow characteristics and difficulty feeding when used as a renewable raw material to reinforce plastics. Similar to carbon fibers, natural fibers mechanically interlock, often resulting in the formation of product bridges and starving of the feed screw. The new FiberXpert (photo) helps to solve this problem because it can feed a large range of long fibers. FiberXpert can be used with a wide range of very different materials, as it has many optional features.

Brabender Technologie

Other applications include the recycling of polypropylene (PP) and polyethylene terephthalate (PET) flakes or other shredded materials. Here, the intermediate recycling step of re-pelletizing can be eliminated if the flakes can be fed directly into the manufacturing process. Hall 4, Stand 237 — *Brabender Technologie GmbH & Co. KG, Duisburg, Germany*
www.brabender-technologie.com

A compact centrifuge skid for pharma pilot testing

The new Pathfinder GMP (photo) is a GMP-certified centrifuge skid pharma test centers and pilot plants. The system requires little space in the technical center and, thanks to its design, reliably fulfills even the most demanding technical tasks, says the manufacturer. Combined with technologies, such as the high-pressure PandaPlus 2000 homogenizer, it belongs to this company's portfolio of biopharmaceutical manufacturing lines and equipment. The Pathfinder GMP is exceptionally easy to operate. The centrifuge delivers a force of 20,000 g, enabling reliable separation of the finest particles, even with slight density differences. Three bowl sizes are available for flowrates of 15–300 L/h. All parts that come into contact with the product are made of high-alloy stainless steel, 316L or better, with surface finish of 0.8 µm. Hall 3A, Stand 312 — *GEA Group AG, Düsseldorf, Germany*
www.gea.com

GEA Group

Romaco Group

This laboratory-scale processor has reduced batch times

The laboratory-scale version of the Innojet Ventilus V 2.5 (photo) is used for granulating, drying and coating particle sizes from 10 µm to 2 mm. Due to its special design and enhanced processing efficiency, the Ventilus V 2.5 allows up to 25% shorter batch times, says the company. The homogeneous flow conditions inside the cylindrical product container enable extremely gentle intermixing of the batch. The process air is controlled by the Orbiter booster, which is a unique container bottom consisting of overlapping circular plates. Together with the Rotojet, the central bottom spray nozzle, the Orbiter booster forms an innovative functional unit that meets all the requirements for linear scaleups. The airflow bed technology ensures accurate control of the product movement and equally precise application of the spray liquids. The resulting formulations can achieve the required release profile with between 10 and 15% less spray liquid. Hall 3, Stand 327. — *The Romaco Group, Karlsruhe, Germany*
www.romaco.com

Atlas Copco Kompressoren und Drucklufttechnik

A new vacuum system for conveying bulk solids

Among other products, this company will exhibit its new DZM series, a dry-running multi-claw vacuum pump system (photo), which is particularly suitable for the conveyance of bulk material. It is characterized by low-noise operation, as well as user-friendly plug-and-play installation. The DZM pumps achieve a pumping speed of up to 1,260 m³/h and can also be used as a central vacuum supply for handling tasks or extrusion processes. Since the claw-shaped rotors in the pump chamber, which rotate in opposite directions, neither touch each other nor the chamber wall, the vacuum pumps are very durable and reliable. The DZM models combine two to four DZM claw vacuum pumps in a compact housing, depending on the required delivery capacity. The pumps operate oil-free and air-cooled and also in harsh environments with little maintenance. One of the pumps, which can be combined for one DZM, operates in a speed-controlled manner, so that the generated vacuum can be adapted exactly to the requirements. This efficiency improvement reduces the necessary power and therefore the energy consumption and CO_2 emissions. A final pressure of up to 140 mbar is achievable. Hall 4, Stand 357. — *Atlas Copco Kompressoren und Drucklufttechnik GmbH, Essen, Germany*
www.atlascopco.com

Kaeser Kompressoren

Reduce blower's energy costs with this air controller

The Sigma Air Manager 4.0 master controller, which previously revolutionized the rotary screw-compressor segment, is now also available for blowers. The SAM 4.0 (photo) benefits from "Industrie 4.0" services and forms the heart of this company's blower stations. This central controller acts intelligently to control the individual machines for optimal efficiency and adjusts their flowrate accurately to the overall flowrate demand profile. The SAM 4.0 analyzes operating data in a matter of seconds, simulates alternative management scenarios and selects the most efficient option. These powerful capabilities can only be harnessed when the components of a station deliver consistently efficient performance, which is what users can expect from the DBS, EBS and FBS screw blower series. Compared to conventional rotary blowers, the new screw blowers are up to 35% more efficient, while also offering significant double-digit energy advantages over many commonly available screw and turbo blowers on the market, says the company. Hall 4, Stand 236 — *Kaeser Kompressoren SE, Coburg, Germany*
www.kaeser.com

Pre- and fine grinding in a single instrument

The variable-speed rotor mill Pulverisette 14 premium line (photo, p. 89) offers impact, shearing and cutting comminution in one instrument. Its powerful motor is ideal for the particularly fast comminution of soft to

medium-hard, brittle and fibrous materials, as well as temperature-sensitive samples with an extremely fast sample throughput of up to 15 L/h, depending on the material and parameter settings. Features include: grinding speeds up to 22,000 rpm; AutoLock grinding chamber for safe operation; final fineness down to d_{50} < 40 µm; efficient cooling of material; and ease of cleaning. Hall 2, Stand 227. — *Fritsch GmbH, Idar-Oberstein, Germany*
www.fritsch.de

An add-on module that cushions forces from bursting disc

Targo-Vent (photo) is an opening angle limiter developed especially for bursting discs that guides the pressure relief specifically into areas, in which there is no danger for the adjoining infrastructure. Targo-Vent dynamically and progressively cushions the bursting disc situated beneath it, and can therefore also assimilate large kinetic forces resiliently. The damper absorbs the enormous repulsive forces of the explosion energy and guides the flames and shock wave in the desired direction. Depending on what is required, the flames and shockwave are diverted at a defined angle of approximately 30 to 45 deg upwards or to the side. Facility operators can therefore minimize the safety areas around the vent opening. The top module is made in all the typical bursting disc sizes, so that retrofitting in existing units can be undertaken without a problem. The system is made from maintenance-free stainless-steel materials and, in combination with the company's bursting discs and pressure relief panels, is type-tested in accordance with the ATEX Directive 94/9/EC (ATEX 114) and authorized in accordance with FSA 13 (ATEX 1637). Hall 3, Stand 244. — *Rembe GmbH Safety + Control, Brilon, Germany*
www.rembe.de

Gerald Ondrey

Fritsch

Rembe

weftec
the water quality event™

Rotork Controls

Assmann Corp. of America

GF Piping Systems

Krohne

From September 30 to October 4, the Water Environment Federation (Alexandria, Va.; www.wef.org), will host the Weftec 2017 Conference and Exhibition (www.weftec.org) at McCormick Place in Chicago, Ill. Focused on all aspects of water treatment and conservation, this year's event will feature more than 900 exhibitors and a comprehensive technical program with emphasis on a wide range of areas, including: membrane technologies; odor and air emissions; residuals and biosolids; laboratory practices; and more. The following presents a selection of the products that will be showcased at Weftec's exhibit hall.

These valve actuators provide flexibility

The CK range of modular electric valve actuators (photo) is designed to meet diverse actuation applications in the water-treatment industry. The design provides configurability of stock components to meet user needs. Maximum multi-turn output torque is 10,800 Nm and part-turn output is 205,600 Nm. Options and features range from a basic actuator requiring separate motor controls to more sophisticated versions equipped with an integral digital control unit that combines intelligent control and data-logging with integration to distributed control systems (DCS) using hardwired, analog or digital control. Booth 6944 — *Rotork Controls Inc., Rochester, N.Y.*
www.rotork.com

Double-walled tanks prevent spills and keep debris out

This company's line of double-wall tanks (photo) includes sizes from 20 to 8,850 gal and eliminates chemical spills without the expense of lined concrete containment. A heavier-top sidewall and dome prevent dome collapse, while a primary inner tank and a secondary locked-on outer tank ensures against chemical spills. The inner tank dome also overlaps the outer tank sidewall to help prevent rainwater, snow and debris from entering secondary containment, making these systems ideal for outdoor storage of chemicals. Double-wall tanks also help prevent cross-contamination, and eliminate possible dangers of co-mingling of reactive chemicals. Linear polyethylene tanks are certified to NSF/ANSI Standard 61 for potable water, and the high-density crosslink resin tanks are certified by NSF for chemical storage. Booth 5041 — *Assmann Corp. of America, Garrett, Ind.*
www.assmann-usa.com

A double-containment piping system with easier installation

The Double-See Vinyl double-containment piping system (photo) is a pressure-rated system with a primary (inner) and secondary (outer) pipe designed for safely transporting hazardous liquids. Both primary and secondary pipes are cut to the same length and can be joined simultaneously, which saves time with installation and prevents potential mistakes caused by staggered pipe-cut measurement errors, according to the manufacturer. Double-See is available in both polyvinyl chloride (PVC) and chlorinated PVC; either material may be primary or secondary, with clear PVC always an option for the containment pipe. The system provides a complete selection of pipes, fittings, leak detection and access tees, closure couplings and termination fittings. Other features include a 3-D thermal-expansion compensation centralizer, and a valve-in-valve design that provides full pressure rating in the containment piping. Booth 4052 — *GF Piping Systems Inc., Irvine, Calif.*
www.gfps.com

A new flowmeter for biogas applications

This company has introduced the new biogas-handling version of its Optisonic 7300 ultrasonic flowmeter (photo), which is suitable for methane-gas applications in wastewater-treatment facilities. The two-beam flowmeter is now Class 1, Div. 1 approved, and provides repeatable measurements over a wide bi-directional flow range of ± 30 m/s with 1% accuracy. The standard model uses titanium for optimized signal processing in challenging applications. Stainless-steel transducers are available on request.

The Optisonic 7300 biogas flowmeter features a maintenance-free full-bore flow sensor with no moving parts and robust construction with no exposed cables. The converter features a variety of measurement diagnostics and available methane content output. Booth 916 — *Krohne Inc., Peabody, Mass.*
www.us.krohne.com

Heavy-duty pumps for sludge and abrasive media

Watson-Marlow Fluid Technology Group

Bredel heavy-duty sludge pumps (photo) are designed for centrifuge and belt-press feed. They have only one wearing part — the hose — so there are no rotors, stators or lobes to replace, and no mechanical seals or packing to leak. Bredel pumps can handle flows as high as 475 gal/min with suction lift to 30 ft, and they are dry-running and reversible. The pumps are also suitable for applications that require processing abrasive materials. Bredel hose pumps do not require ancillaries, such as degassing valves or backpressure valves, to operate, which lowers overall costs, says the manufacturer. Booth 3116 — *Watson-Marlow Fluid Technology Group (WMFTG), Falmouth, U.K.*
www.watson-marlow.com

Monitor water-treatment systems via cloud computing

The cloud-based Eaglei technology (photo) reduces the time and effort required for onsite inspection of decentralized water and wastewater treatment systems. The solution is accessible via web browser, ensuring that it is possible to access system data from anywhere. The status of the system can be viewed remotely, and the set parameters can be edited via tablet, smartphone or laptop. At the same time, Eaglei

Phoenix Contact

can issue alarms and notifications via email or text message. Existing systems can be seamlessly integrated so that data can be recorded and evaluated. The data are subsequently collected and can be stored or transmitted to a control system. The integrated mobile interface enables communication with the virtual control system via a private mobile network. This ensures that data manipulation and unauthorized access from outside the network is impossible. Booth 7918 — *Phoenix Contact GmbH & Co. KG, Blomberg, Germany*
www.phoenixcontact.com

Mary Page Bailey

HOT PRODUCTS

Duo 11 ATEX – the new magnetically coupled rotary vane pump

The Duo 11 ATEX rotary vane pump, which meets ATEX directive 2014/34/EU, was brought to the market by Pfeiffer Vacuum for processes taking place in potentially explosive atmospheres or conveying explosive gases and vapors. As such, it satisfies the most stringent explosion protection requirements.

The ATEX certification applies for both the interior and exterior of the pump. The Duo 11 ATEX is classified as equipment category 3G and temperature class T4. It can convey all gases up to and including explosion group IIC. The pumping speed is 9 m^3/h at 50 Hz and 10.5 m^3/h at 60 Hz. The Duo 11 ATEX is equipped with a frictionless magnetic coupling.

Pfeiffer Vacuum GmbH

https://www.pfeiffer-vacuum.com

Circle 01 on p. 102 or go to adlinks.chemengonline.com/66432-01

HOT PRODUCTS

Versatile Diverter Valve for Pneumatic Conveying Applications

The precision machined PT45 diverter valve is designed to provide line switching for either dilute or dense phase conveying. As a two-way valve the PT45 can operate as a 1 to 2 way diverting valve or a 2 to 1 way converging valve in a pneumatic conveying system for powdered or granular materials.

The PT45 features a tunnel that rotates 45° port to port, which provides easy positioning of the tunnel to the diverter ports or the straight-through ports. A hard anodized aluminum housing provides excellent wear resistance.

Schenck Process

www.schenckprocess.com/us

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Top-quality pump and compressor packages

Pompetravaini has created a new company, FuturEng, to design and supply skid-mounted pump and compressor systems for industries including oil, gas, and nuclear

Modest in size yet proudly international in its outlook, Italian company **Pompetravaini** has been in business since 1929. Throughout its almost 90 years, the company has specialized in pumps and compressors for gases and liquids. These equipment items always require motors, piping, valves and instrumentation to carry out their roles within process plants, so it was natural that Pompetravaini should add rotating equipment packages to its core business of pumps and compressors. In fact, the company started producing industrial skids at the beginning of the 1960s, always designing these to customers' specific requests.

Within the last decade, after acquiring Pompetravaini-NSB and Pompetravaini-BORA, Pompetravaini has grown its activity in skid-mounted equipment. This now covers fully engineered packages for the oil, gas, nuclear, and aerospace sectors, representing the most advanced levels of technology and engineering.

To better support these new challenges, in 2014 Pompetravaini created a new company named FuturEng. This is a team made up purely of engineers and project managers, with solid experience in plant design and focused on rotating equipment. The industry-specific skills of the FuturEng engineers combine with the decades of knowledge of pumps and compressors to be found within Pompetravaini – one of the world's oldest companies to continue in its original line of business in pumps and compressors.

Today, the Pompetravaini Group produces skids in Italy, the U.S., Canada and Switzerland, delivering over 1,000 packages every year. They range from small to huge, and from simple to the most complex designs for the oil, gas, and nuclear industries – with all the necessary inspection, testing, and documentation. At Pompetravaini, a commitment to stay ahead is not just an empty slogan. It is the company's creed. **www.pompetravaini.com**

FuturEng is dedicated to engineering excellence

State-of-the-art efficiency in powder separation

Featuring an improved design fine-tuned through CFD, the Cyclone Extra Efficiency is a leap forward in cyclone performance, claims GEA

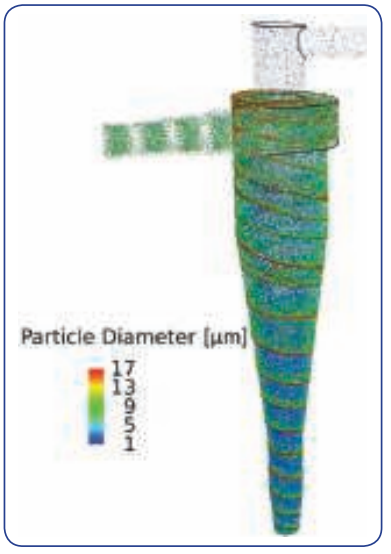
Based on extensive computational fluid dynamics modeling of a well-known yet complex unit operation, **GEA** has developed the CEE (Cyclone Extra Efficiency) for food, dairy, chemical and pharmaceutical applications. Improved cyclone performance and the resulting higher separation efficiency increase yield, reduce emissions, and have the potential to reduce the complexity of spray drying plants by minimizing the number of powder separation unit operations. The new cyclone design is currently undergoing large-scale tests in industrial spray drying plants.

The CEE is taller and slimmer than its predecessor. It features an improved scroll inlet and an optimized powder outlet. These features support the formation of a strong and robust vortex that facilitates separation. In addition, optimized positioning of clean-in-place (CIP) nozzles and a reinforced vortex finder provide reliable performance under industrial conditions.

In real-life tests the powder separation efficiency of the CEE was verified as being considerably higher than that of standard cyclones. All comparisons were made with the same pressure loss over the units. The efficiency was tested for a range of particle sizes and cyclone capacities; superior performance was verified for all combinations.

Exhibiting this year at POWTECH in Nuremberg, Germany, from 26–28 September 2017, GEA will highlight its innovative solutions and manufacturing expertise, showcasing new products and developments for a wide range of industries and applications. You can find GEA at Booth 312 in Hall 3A.

GEA is one of the largest suppliers of process technology for the food and other industries. The international technology group focuses on process technology and components for sophisticated production processes in various end-user markets. In 2016, GEA generated consolidated revenues of about EUR 4.5 billion, of which around 70% came from the food sector. The company employs about 17,000 people worldwide. **www.gea.com**



The tall, slim design of the CEE cyclone improves separation efficiency

Securely bagged and wrapped

BEUMER supplies complete packaging lines for the chemical industry: from form-fill-seal machines for bagging, through palletizers, to stretch hood units that secure the load

The **BEUMER GROUP** supplies complete packaging lines which fulfill the complex requirements of manufacturers in the chemical industry. These include highly efficient filling, palletizing and packaging systems. Customers also get comprehensive support.

When the BEUMER Group implements a packaging line in the chemical industry, here is how it typically works: The bulk material passes from the silo along a conveyor

BEUMER fillpac FFS machines seal product quickly and accurately into bags

section to the BEUMER fillpac FFS (form fill seal) system. This bagging machine is fitted with an integral, high-precision weigher which ensures the accuracy of the bag weights. High-performance palletizers from the BEUMER paletpac range then stack the bags quickly and accurately on pallets. Depending on the product requirements, the palletizers are fitted with a rotary clamp or double-belt turning device which moves the filled bags into the required position. Even bags filled with granulates can be gently palletized, remaining dimensionally stable when stacked. Customers use the high-performance packaging systems in the BEUMER stretch hood series to secure the load. For businesses in the chemical industry, efficient packaging of palletized goods is a crucial competitive factor. The film fits snugly over each product on the pallet, ensuring safe transport and good load stability. The film is highly stretchable and secures the material as it contracts. It is also very transparent and permits a clear view of the packaged goods. Barcodes on the products

BEUMER stretch hood machines create compact, stable pallet loads

can be read without difficulty. When a cover film is placed over the top of the pallet, this solution also protects the goods against external influences from all six sides.

Customers get a complete solution from a single source and have a reliable point of contact for the whole job.

www.beumergroup.com

Weighing module for dosing and filling applications

The Siwarex WP251 electronic weighing module from Siemens combines power and accuracy in a small footprint, and integrates seamlessly with Simatic systems

The Siwarex WP251 electronic weighing module from **Siemens** integrates seamlessly into the TIA Portal engineering framework. The Siwarex WP251 is capable of performing completely independent batching and filling tasks and comes with all the right credentials typically required for this type of process, such as accuracy and speed. Its features enable fast and easy commissioning and control of the scale.

With a measuring rate of 100/120 Hz and a resolution of up to one part in 4,000,000, the Siwarex WP251 offers very high accuracy. Thanks to its compact design, it takes up little space in the cabinet.

The weighing module can also operate independently when used in stand-alone mode without a CPU. It comes with four digital inputs, four digital outputs, one analog output, an Ethernet port (Modbus TCP/IP), an RS484 interface (Modbus RTU) and the S7-1200 system bus as standard, opening up wide scope for applications and integration – without added costs.

The "ready-for-use Siwarex WP251"

The Siwarex WP251 weighing module is powerful, yet compact

sample application comes free of charge, simplifying start-up and commissioning of the scale. This allows scales to be commissioned, adjusted and operated using only a touch panel or CPU. The Siwarex WP251 also offers an extended application range:

When integrated into a Simatic S7-1200, any customer-specific or plant-specific requirements can be simply added and programmed using the S7-1200 CPU, creating a freely programmable weighing solution using standard Simatic components. In stand-alone mode, all the parameters and functions can be accessed and edited using the Modbus RTU or Modbus TCP/IP communication protocol. A trace recording mode is available for scale optimization. Stored weighing values and the relevant statuses can also be displayed and analyzed in Microsoft Excel using Siwatool V7 parameterization software.

Control of the coarse and fine flow signals or the emptying signal can take place via the four available digital outputs on the module. Maximum accuracy is achieved since the weighing process is controlled completely independently of the CPU and its cycle time. This means that the CPU can be used at the same time to manage recipes and material parameters, for example.

www.siemens.com/siwarexwp251

Modular, flexible, safe, economical

JACOB modular pipework systems are easy to use

JACOB modular pipework systems are the lifeline of modern production systems. They transport raw materials and products, direct exhaust and extract dust. The applications are as diverse as the spatial requirements, making each pipework system unique. But they are identical in their efficient design, economical maintenance, and safe, hygienic operation.

The modular pipework system developed by JACOB is based on more than 8,000

Quick-connect rings make the JACOB system easy to install and dismantle

standard items, most of which can be supplied immediately. The possible range of different configurations is enormous. JACOB will also make any special part needed to meet individual requirements. Assembly is simple, too: Standard modular parts with lipped ends are fitted with a U-shaped seal and joined together with a pull-ring. The system is fast, airtight, and flexible.

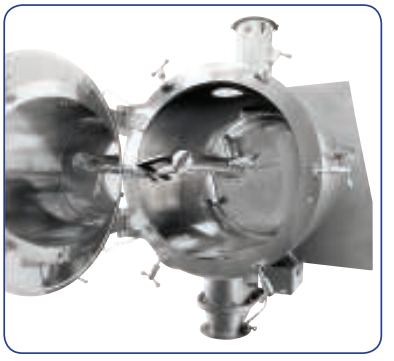
It is also robust, as evidenced by the ability to withstand explosion overpressures of either 3 or 10 bar. The QUICK CONNECT pull-ring requires only a single hand movement for both assembly and dismantling, so maintenance and cleaning are easily done. The result is a tailored solution suited to any challenge. **www.jacob-rohre.de**

Revolutionary idea for vacuum dryer

The Planex System from Italvacuum sets new standards for low energy consumption and gentle product handling

Drying is a special art which has to meet increasingly severe requirements, notes vacuum pump and dryer specialist **Italvacuum**. To offer the highest levels of quality and productivity while minimizing energy consumption, Italvacuum has developed the Planex System. This patented vacuum dryer won the Dry Trophy Innovation Award 2016, organized by NWGD (Dutch Working Group on Drying), sponsored by the Dutch government. It is ideal for the production of active pharmaceutical ingredients, fine chemicals and intermediates.

Planex System is a horizontal paddle dryer with an eccentric agitator featuring two independent movements, allowing it to simultaneously revolve around its own axis and to rotate tangentially to the drying chamber. The combined rotations of the agitator and its small size ensures perfect mixing – with energy consumption reduced by a factor of at least three compared to a conventional paddle dryer. Since this means a threefold reduction in mechanical and thermal stresses, even the most delicate products are treated with maximum care. The dryer takes is designed so as not to form lumps, and avoids the heat damage that can occur when product rubs against the chamber walls. Dedicated control software aids the drying of small batches.



Moving on two axes, the Planex System agitator mixes effectively yet gently

www.italvacuum.com

Continuous cleanroom pastillation

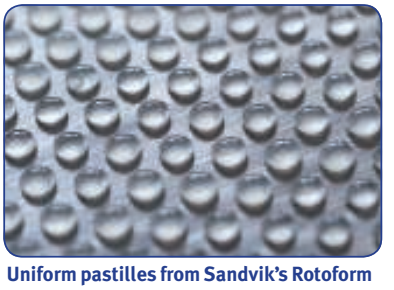
The Sandvik Rotoform system is designed and built for reliable performance under GMP conditions

A successful pharmaceutical audit for cleanroom pastillation requires a GMP-compliant production unit along with professional documentation. The **Sandvik** Rotoform granulation system meets these requirements, and can convert liquid melts into solid pastilles in less than a minute.

A pump delivers the molten product from a tank to the dropformer via heated piping. The Rotoform itself consists of a heated cylindrical stator, which is supplied with liquid product, and a perforated shell that rotates concentrically around the stator. The nozzle bar deposits droplets of product across the operating width of a continuously running stainless steel belt.

Heat released during solidification is transferred via the steel belt to cooling water sprayed underneath. This indirect cooling eliminates any risk of cross-contamination between product and cooling water.

Every aspect of the Rotoform system has been designed to ensure GMP compliance. All piping connections are quick-release type for easy cleaning, and the drive belt



Uniform pastilles from Sandvik's Rotoform

is maintenance-free. All contact parts are made from stainless steel with very low surface roughness, for easy cleaning and maximum hygiene, and all gaskets are made from approved materials. Hoods cover the whole machine, and a fan extractor avoids pollution of ambient air.

The Sandvik Rotoform system is widely used across the food, cosmetic and pharmaceutical industries for products such as chocolate, lipstick and suppository mass.

www.processsystems.sandvik.com

Protect mag-drive pumps from dry running damage

The RunSafe SiC coating system from CDR Pompe offers a proven solution to greatly increase the reliability of magnetically coupled pumps under critical working conditions

CDR Pompe is a leading Italian manufacturer of magnetically driven centrifugal pumps for chemical and pharmaceutical industry applications. Today the company is fully focused on pump reliability, especially when dry running is a possibility. Mag-drive pumps are extremely safe and reliable, but they have a weak point in the case of dry running: the silicon carbide (SiC) bushes and shafts traditionally used in this type of pump have poor resistance to dry running, cavitation, and other conditions leading to poor lubrication.

RunSafe SiC pump components have a low-friction diamond coating

In the absence of liquid, heat generated by friction causes the temperature of the SiC components to increase. The resulting thermal shock causes bushings to fail rapidly, with severe consequences for other components too. The CDR Pompe solution is RunSafe SiC – silicon carbide coated with diamond. RunSafe SiC components are made by laying down a strong and tightly-adhering coat of synthetic diamond on top of SiC. The diamond surface is extremely smooth, dramatically reducing the coefficient of friction (by about 80%) compared to traditional SiC components. This decreases the amount of heat generated under conditions of poor lubrication, and gives wider security margins during difficult start-up operations, when operating with low-boiling liquids, and in the case of dry running.

RunSafe SiC provides the following advantages:

- reduced risk of failure from incorrect pump start-up or priming failures;
- during dry running, the chance to stop the pump before severe damage occurs;
- greater range of application when working with liquids with low boiling points;

RunSafe SiC is available on all pumps from CDR Pompe

- significant increase in mean time between failures under critical conditions;
- unchanged chemical resistance compared to traditional SiC; and
- fast return on investment.

RunSafe SiC is available on all CDR pumps, including fluoropolymer-lined and stainless steel models. Top benefits may be achieved using RunSafe SiC combined with suitable instrumentation. **www.cdrpompe.it**

Eliminate entrapped air from liquid piping systems

A new combination air release/degassing valve from Plast-O-Matic Valves boosts pump efficiency and avoids any risk or airlocks by removing trapped air from pipework

There are three ways that air enters a liquid piping system, notes **Plast-O-Matic Valves**. First, and most common, is air entering during fill and drain cycles. Second is air that comes in through pumps, fittings, seals, pipe threads, and bearings whenever a partial vacuum occurs. The third way is through the liquid itself: for example, the average water system contains 2% dissolved air.

As air outgasses in a piping system, it collects at elbows and high points and creates pockets of air. At minimum, these air pockets increase head loss and reduce system efficiency. At worst, air pockets result in water hammer, pump deadheading, corrosion, and erratic operation. All of these can potentially damage a pump or filter and even destroy an entire system.

To maintain a safe, efficient system, this air or gas must be removed in two stages: air release at system start-up, followed by and continuous degassing during system operations. Usually, these functions are provided separately by single-purpose valves mounted at high points in the pipeline.

The Combination Air Release/ Degassing Valvefrom Plast-O-Matic Valves is an elegant way to maintain the performance of fluids handling systems

The first type is an Air Release Valve, which is open at system start-up and allows air to escape as the pipeline fills. Once liquid reaches the high point, the valve closes until the system is shut down again. The second type of valve is designed to repeatedly open and close during operations to allow trace amounts of air to escape; this is called the Degassing Valve.

A recent, patent-pending development by Plast-O-Matic Valves combines both operations in a single, all-thermoplastic design called a Combination Air Release/ Degassing Valve. This valve contains both functions in one unit, for convenience and cost reduction. The combination valve is best installed at a high point in the system to provide air release during filling, continuous degassing during normal pressurized operations, and vacuum protection while draining.

Through proper use and selection of this new combination valve, operators can improve system efficiency and safety in their liquid piping systems.

Founded in 1967, Plast-O-Matic designs and manufactures a wide range of specialist thermoplastic fluids handling products. **www.plastomatic.com**

Higher process reliability with Austrian technology

The Berndorf Band Group is an expert in steel belts and associated technology for the production of high-quality filter membranes and pastillated chemical products

The **Berndorf Band Group** is committed to optimizing chemical processes and ensuring long-term success by means of innovative technologies. Berndorf Band is a long-established firm with over 90 years of experience in belt production and developing plant to meet the specific requirements of its customers.

Only manufacturers with efficient production facilities will remain competitive in the future. Optimizing the effectiveness of existing production lines is therefore crucial. International chemical industry manufacturers rely on the Berndorf Band Group's innovations and comprehensive know-how.

Precise belt tracking is particularly important in chemicals production. The Berndorf Band Group's process belts stand out for their exceptional flatness, dimensional stability and flawless running characteristics – the results of intensive research and development. Thanks to high-quality processing of the material used – NICRO 85 super-duplex – Berndorf belts also excel when it comes to corrosion resistance. The high-end material offers high static and dynamic strength as well as resistance against chloride-induced stress corrosion.

Drawing on its extensive expertise, the Berndorf Band Group develops casters for precise, high-quality production of chemical products such as filter membranes. Specially manufactured upstream feeding systems and downstream processing components optimize manufacturing processes in terms of quality and productivity. The Berndorf Band Group also offers a virtual caster for complete process control, which can be used to perform a range of process optimization calculations.

To fully satisfy the needs of its customers, in addition to innovative technology, the Berndorf Band Group offers a unique portfolio of worldwide services. Berndorf customers benefit from detailed consultations with experienced engineers, custom solutions and swift, expert repair services as well as steel belt and belt system maintenance. Belt systems can easily be adapted and upgraded to meet new production requirements.

Quality belts yield quality products

www.berndorfband-group.com

No guesswork for hazardous liquids

Bungartz builds submersible pumps for critical duties

Bungartz: the name is synonymous worldwide with custom-built centrifugal pumps that work for decades under tough conditions. Safe and self-regulating, the MPATAN universal magnetically coupled pump is a vertical submersible design for potentially explosive or otherwise hazardous fluids. MPATAN pumps are typically used to remove boiling, solids-laden or toxic liquids from pits or slop tanks.

The MPATAN submersible pump is ideal for toxic, solids-laden, boiling, gas-entrained, explosive or highly contaminated media

Standard centrifugal pumps cannot safely run dry because their sleeve bearings rely on the pumped medium or an external water supply for lubrication. The MPATAN pump, in contrast, is safe for dry running, even with hazardous media. It uses roller bearings that are lubricated for life, and protected from contact with the pumped liquid by a hydrodynamic seal created by vanes on the back of the impeller.

A mechanical seal or gas-sealed lip seal keeps product vapors away from the bearings. The vertical layout prevents product contact with the seal, even if the sealing gas supply should fail.

On the atmospheric side, a magnetic coupling and ceramic containment can create a hermetic seal and allow the pump to run dry without damage. Monitoring equipment can be installed outside the pit, away from the hazardous atmosphere.

For highly corrosive or abrasive media, Bungartz offers strong and durable materials such as super-duplex alloys. The result is a maintenance-free pump that can completely empty tanks at submersion depths up to 5.5 m and medium temperatures up to 280°C.

www.bungartz.de

Pilot plant for hydrogenation tests

EKATO has opened a new test center dedicated to scale-up work on its customers' hydrogenation reactions

The **EKATO** Hydrogenation Test Center is located at the company's headquarters in Schopfheim, Germany. It was constructed within a year and with a budget of €2 million. The centerpiece is a hydrogenation reactor made of Alloy C22, with a working volume of 60 l. This can be operated at up to 100 bar and 250°C.

EKATO's new Hydrogenation Test Center

The flexible design of the Test Center allows realistic simulation of industrial hydrogenation processes at pilot scale, including catalyst handling and catalyst separation as well as the actual hydrogenation reaction. Additional reactors with working volumes of 3 l increase experimental flexibility and allow process parameters to be determined even with small product quantities.

"Our customers' requirements have changed, and binding commitments on costs, productivity, and product quality are now essential if we want to continue getting orders", said Werner Himmelsbach, Head of R&D at EKATO Rühr- und Mischtechnik GmbH. "To this end, we have to test hydrogenation processes under realistic conditions at pilot scale. The new Hydrogenation Test Center allows us to do just that."

EKATO has been active in hydrogenation for more than 80 years, and offers a comprehensive product and service portfolio for hydrogenation with more than 500 active references. EKATO is a single source for testing, scale-up, plant design, mechanical design, detailed engineering, and the supply of critical system components.

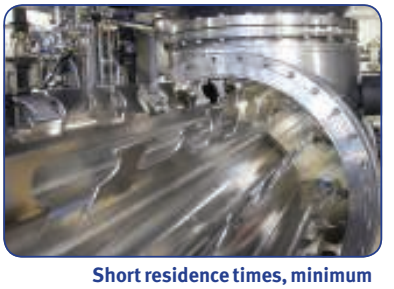
www.ekato.com/en/products/process-plants/pilot-plants/hydrogenation-test-center

Hygienic horizontal thin-film dryer

The flexibility of the CONTIVAC thin-film dryer makes it ideal for continuous processes, says Buss-SMS-Canzler

The special CONTIVAC horizontal thin-film dryer from **Buss-SMS-Canzler** is well suited for use in production processes with special hygienic requirements. The CONTIVAC processor provides all the usual advantages of continuous thin-film drying, such as minimum product holdup and extremely short residence times, which results in a considerable reduction of side reactions and color changes. In comparison to a conventional batch dryer, the residence time in a CONTIVAC thin-film dryer is reduced by a factor of up to 500.

Fast drying is only one of the advantages of the CONTIVAC. For manufacturers in the pharmaceutical, fine chemical, food and pet food industries, it offers new possibilities for process optimization and quality improvement, which are not available with conventional batch machines, the company says. Additional ingredients can be evenly sprayed onto the thin film within the CONTIVAC using rotating nozzles. For additional flexibility, the heating jacket can be split into different heating zones, and further feed nozzles can be added at several positions. This allows an extremely flexible design when handling thermally sensitive products.



Short residence times, minimum product holdup, and a highly flexible process configuration are the main advantages of the CONTIVAC

For pharmaceutical customers SMS delivers the required engineering, services and documents, all in compliance with GMP requirements and based on the User Requirement Specification (URS).

www.sms-vt.com

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Economic Indicators

2015 2016 2017

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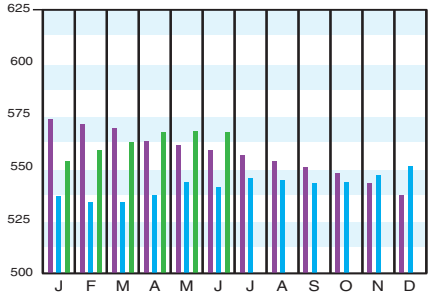
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	June '17 Prelim.	May '17 Final	June '16 Final
CE Index	567.1	567.3	540.9
Equipment	684.5	684.6	645.3
Heat exchangers & tanks	603.4	603.5	558.9
Process machinery	681.9	682.0	651.1
Pipe, valves & fittings	873.5	873.5	801.0
Process instruments	403.5	403.5	385.4
Pumps & compressors	979.6	979.6	970.5
Electrical equipment	516.4	516.4	506.8
Structural supports & misc.	737.1	737.1	708.4
Construction labor	325.5	326.1	326.0
Buildings	559.6	559.7	544.0
Engineering & supervision	313.0	313.6	315.1

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

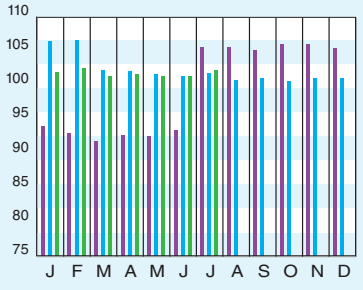
Annual Index:
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7



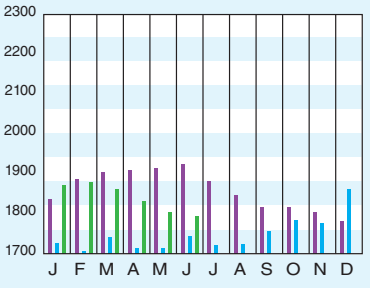
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS		YEAR AGO
CPI output index (2012 = 100)	Jul. '17 = 102.1	Jun. '17 = 101.8	May '17 = 101.0	Jul. '16 = 99.6
CPI value of output, $ billions	Jun. '17 = 1,794.1	May '17 = 1,803.4	Apr. '17 = 1,826.6	Jun. '16 = 1,728.9
CPI operating rate, %	Jul. '17 = 76.5	Jun. '17 = 76.4	May '17 = 75.9	Jul. '16 = 75.3
Producer prices, industrial chemicals (1982 = 100)	Jul. '17 = 244.0	Jun. '17 = 251.3	May '17 = 257.3	Jul. '16 = 225.2
Industrial Production in Manufacturing (2012=100)*	Jul. '17 = 103.4	Jun. '17 = 103.4	May '17 = 103.2	Jul. '16 = 102.1
Hourly earnings index, chemical & allied products (1992 = 100)	Jul. '17 = 180.0	Jun. '17 = 174.5	May '17 = 174.7	Jul. '16 = 169.6
Productivity index, chemicals & allied products (1992 = 100)	Jul. '17 = 102.4	Jun. '17 = 103.1	May '17 = 102.6	Jul. '16 = 101.3

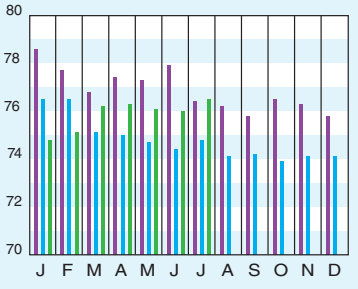
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the June *CE* Plant Cost Index (CEPCI; top; most recent available) dipped slightly compared to the previous month's value, and although the decrease was small, it ends a string of eight straight months of increasing values. All four of the major subindices (Equipment, Construction Labor, Buildings and Engineering & Supervision) saw small decreases from their previous month's values. The preliminary overall monthly CEPCI value for June 2017 stands at 4.9% higher than the corresponding value from June 2016. Meanwhile, the latest Current Business Indicators (CBI; middle) saw the CPI Output Index rise by a small margin in July, while the CPI value of output fell slightly in June. Producer prices for industrial chemicals fell in July.

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