CHEMICAL ENGINEERING
August 2010
www.che.com

pH Measurement and Control
PAGE 32

PUMP VIBRATION:
Advanced Diagnostic Techniques

PAGE 24

Substitute Natural Gas

Regulatory Document Management

Facts at Your Fingertips: Heat Transfer Fluids

Focus on Feeding and Conveying

Pressure Relief Devices

Access Intelligence

Fluids that Move Your World

It takes the right fluids to achieve high levels of performance, productivity and economy. For operating supplies that meet critical functional and protection needs in demanding applications, choose fluids from Dow. We supply advanced, proven, and reliable solutions for heat transfer, lubrication, fluid power, freeze and corrosion protection, and deicing.

• **DOWTHERM™ Synthetic Organic and SYLTHERM† Silicone Thermal Fluids** increase processing efficiency and economics in high temperature processing environments. *www.dowtherm.com*

• **DOWTHERM™ and DOWFROST™ Glycol-based Heat Transfer Fluids** help prevent system corrosion and freeze damage in water-based HVAC, food and beverage, and other systems. *www.dowfrost.com*

• **UCON™ Fluids and Lubricants** reduce wear and extend the life of industrial, mobile, marine and other equipment while offering important fire-resistance and economic benefits. *www.ucon.com*

• **UCAR™ Aircraft Deicing Fluids** help maintain winter aviation safety while contributing to on-time flight departure performance. *www.ucaradf.com*

We stand behind our fluids with a global support team that can provide the application, technical, regulatory, sales and customer service assistance you require. For fluids that perform, choose fluids from Dow.

To Learn More...

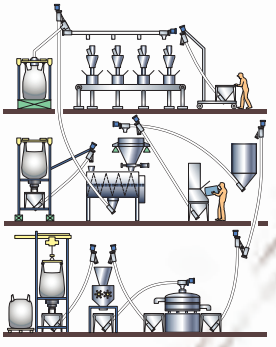
U.S, Canada, and Mexico: 1-800-447-4369
Latin America: (+55) 11-5188-9222
Europe: +800-3-694-6367* or (+32) 3-450-2240
Asia-Pacific: +800-7776-7776* or (+60) 3-7958-3392

DOW®

Circle 7 on p. 50 or go to adlinks.che.com/29253-07

Cut Your Cost 9 Ways with One Ultra-Economical Conveyor

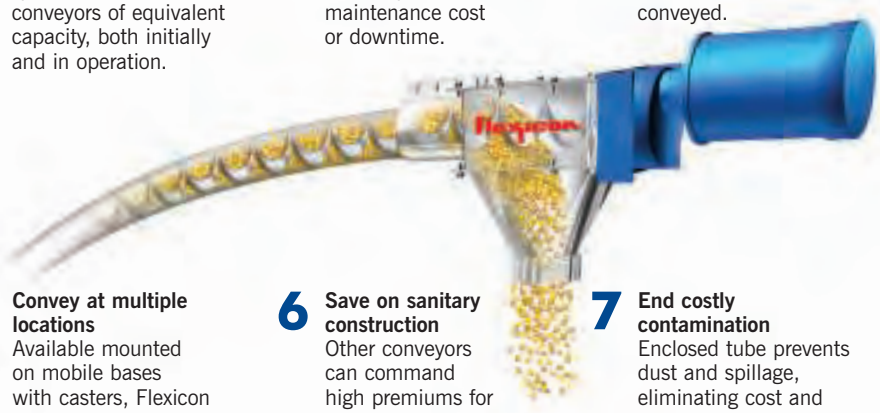
1 Cut installation cost
Easy conveyor routing at any angle (over, under or around obstructions, through small holes in walls or ceilings) conforms to process layouts, drastically cutting installation costs, while consuming minimal floor space.



2 Slash initial cost
Flexicon conveyors cost far less than drag chain conveyors, bucket elevators, pneumatic conveying systems and other conveyors of equivalent capacity, both initially and in operation.

3 Save on maintenance
Rugged inner screw is the only moving part contacting material (no internal bearings) yielding ultra-high reliability with little maintenance cost or downtime.

4 Use less energy
Low horsepower motors, simple gear reducers and ultra-efficient operation significantly cut energy cost per volume of material conveyed.



5 Convey at multiple locations
Available mounted on mobile bases with casters, Flexicon conveyors with hoppers, dust collectors and other accessories can operate at multiple locations, eliminating the need for dedicated conveyors.

6 Save on sanitary construction
Other conveyors can command high premiums for food, 3-A dairy and pharmaceutical models, but Flexicon conveyors can meet sanitary requirements at comparatively low cost.

7 End costly contamination
Enclosed tube prevents dust and spillage, eliminating cost and quality concerns associated with contamination of your product and plant environment.

8 Reduce cleaning costs
Removable end cap allows reversing of screw for evacuation of material, in-place flushing of crevice-free interior, or quick removal of screw for sanitizing—all with minimal labor or downtime.

9 Convey disparate materials
Handle sub-micron powders to large pellets including non-free-flowing products that pack, cake, seize, fluidize, abrade or smear, with no separation of blends, often eliminating the need for multiple units.

See why thousands of engineers like you have purchased more Flexicon conveyors than all competitive designs combined.

visit flexicon.com

Flexicon®.com

See the full range of fast-payback equipment at flexicon.com: Flexible Screw Conveyors, Pneumatic Conveying Systems, Bulk Bag Unloaders, Bulk Bag Conditioners, Bulk Bag Fillers, Bag Dump Stations, Drum/Box/Tote Dumpers, Weigh Batching and Blending Systems, and Automated Plant-Wide Bulk Handling Systems

USA
sales@flexicon.com
1 888 FLEXICON

UK +44 (0)1227 374710
AUSTRALIA +61 (0)7 3879 4180
SOUTH AFRICA +27 (0)41 453 1871

X-0779

Circle 11 on p. 50 or go to adlinks.che.com/29253-11

Think Ahead.

CLEAN ENERGY SOLUTIONS

It's predicted that the clean energy industry will be the third largest global industrial sector by 2020. At Sierra, we're committed to playing a leading role through innovative instrument design and lifetime support.

Steel-Trak 640S

Biogas/Wastewater/Landfill

The flagship of North America's best-selling (1) thermal mass flow meters, the 640S features patented dry sensor technology backed by a lifetime warranty, pinpoint accuracy and wide turndown.

(1) 2009 Flow Research Study, Yoder

Innova-Sonic 205

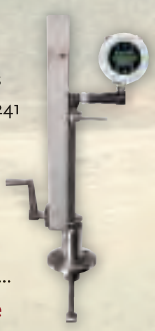
Water/Energy Conservation

Ideal for water flow measurement, Sierra's 205 clamp-on, non-intrusive ultrasonic flow meter is also designed to measure the thermal energy flow rate and totalized energy consumption in liquid heating and cooling applications.

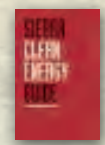
Innova-Mass 241

Geothermal/Solar Thermal

Measure five process variables with one instrument! Sierra's 241 insertion vortex drives steam measurement efficiency with improved accuracy, wider turndown, and reliability at a lower installed cost.



Free Clean Energy Guide



Download a free copy of our new *Sierra Clean Energy Guide* highlighting product applications for the full line of flow measurement tools we have developed to meet today's global environmental challenges.

sierrainstruments.com/cleanenergy

SIERRA®

EXPERIENCE OUR PASSION FOR FLOW!

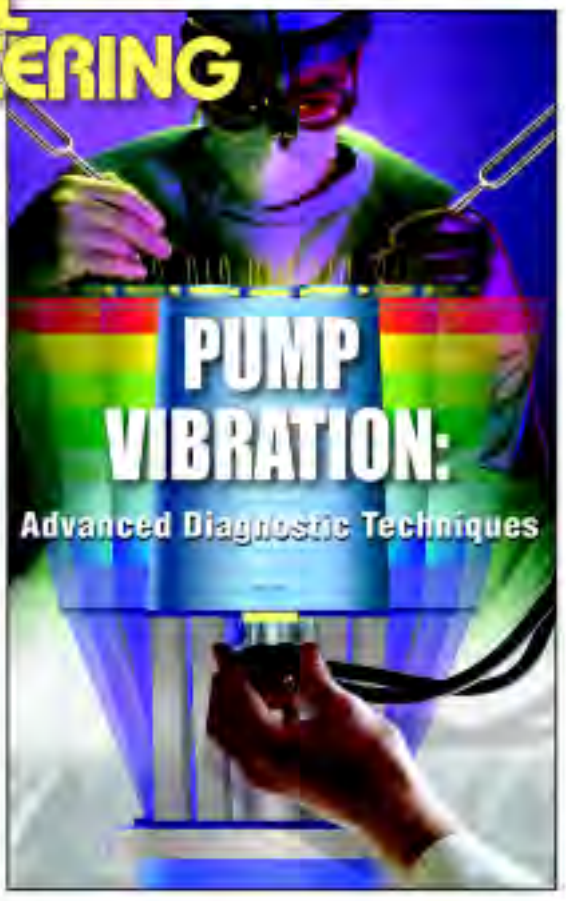
NORTH AMERICA
5 Harris Court, Building L / Monterey, CA 93940 / U.S.A.
www.sierrainstruments.com
800.866.0200 / 831.373.0200 / fx 831.373.4402

EUROPE
The Netherlands
+31 72 5071400 / fx +31 72 5071401

ASIA-PACIFIC
Shanghai, China
+8621 5879 8521/22 / fx +8621 5879 8586

The Big Sur Coast in Monterey County, California, home to Sierra's Global Headquarters

CHEMICAL ENGINEERING
www.che.com



COVER STORY

NEWS

ENGINEERING

EQUIPMENT & SERVICES

COMMENTARY

DEPARTMENTS

ADVERTISERS

COMING IN SEPTEMBER

Look for: **Feature Reports** on Temperature measurement; and Polymer-based piping; an **Environmental Manager article** on Fume-hood exhaust systems; **Focus** on packaging; **News articles** on Plant security; and Desalination; **Facts at Your Fingertips** on Membranes; a **Show Preview** for ChemInnovations 2010; a new installment of **The Fractionation Column;** and more

Cover: David Whitcher

We don't have a department dedicated to quality. We have a company dedicated to it.

Simulated computer modeling, dimensional testing, and electron scanning of raw materials – you name it, we'll go to any lengths to ensure that if it's from Swagelok, it's top quality. Because Quality isn't just one of our values. It's our attitude. It's the focus of every associate, affecting everything from our services to our products. And by using the same disciplines, practices, and technologies through every office in every country, that focus is constant. We know that quality isn't just a well-made product, it's customers served beyond what they were expecting. To see what that attitude can do for you, visit swagelok.com/quality.

Swagelok®

Value beyond the expected℠

Circle 28 on p. 50 or go to adlinks.che.com/29253-28

Winner of Eight Jesse H. Neal Awards for Editorial Excellence

CHEMICAL ENGINEERING

Published since 1902
An Access Intelligence Publication

Access Intelligence

BPA

Editor's Page

A winning formula for innovation

Innovation is the key to economic growth, and research and development (R&D) is key to innovation. While industry recognizes that R&D is vital to longterm success, it focuses, of course, on marketable results from research — after all, R&D is expensive, and cost without any foreseeable return is not good business. From my R&D background in the chemical process industries (CPI), I'm familiar with the struggle around keeping R&D efforts — particularly longterm programs — aligned with the scalable and profitable results sought by industry, while allowing the bright, scientific minds attracted to R&D the freedom that they need to explore and discover.

Various strategies have been developed and implemented to help bridge the gap, such as the stage-gating procedures that may allow great freedom in the early stages of research, but call for intermediate review measures to stop funds from pouring into research that does not look promising in terms of potential profitability. Some companies have coupled their R&D centers with their marketing teams to make sure that all R&D efforts start off with and continue to target a marketable end in mind. Industry also participates in cooperative efforts with university research teams. Boosts to innovative R&D have come from government economic stimulus funds in the past year. One example is in the area of battery development in the U.S. (see "CPI Energized by Battery Funding," *Chem. Eng.*, September 2009, pp. 16–23). And in Europe, Commissioner Máire Geoghegan-Quinn has recently announced a nearly €6.4-billion European Commission investment in research and innovation, covering a vast range of scientific disciplines and other sectors.

Meanwhile, another approach is demonstrating success in what seems to be a win-win situation for all involved. The Netherlands Ministry of Economic Affairs (the Hague, the Netherlands; www.ez.nl) supports a number of innovation programs where funding from both industry and government is combined with university resources in "pre-competitive" R&D efforts. Intellectual property arising from these efforts is typically shared among partners within a technology area, with various options available to both industrial and academic partners for further development. Two examples of this are the public-private partnerships, DPI (The Dutch Polymer Institute; www.polymers.nl), which conducts research on polymers and their applications, and M2i (Materials Innovation Institute; www.m2i.nl), which conducts fundamental and applied research on structural and functional (non-polymer) materials. Both programs are designed to operate at the interface of university and industrial R&D.

DPI manages over 180 researchers from various universities and has over 30 industrial partners. In addition to the opportunities arising from the actual R&D, DPI's program has a number of advantages. The student researchers are exposed to the industrial cultures of participating companies early on, while still in the university environment. It is reported that about 80% of the students find a job either in a participating company (~60%) or in a participating university (~20%). This itself attracts students to the universities, creating an influx of bright minds to R&D so that there is no shortage of new students. The prospect of potential employment also encourages good work during the program. In turn, companies have the opportunity to hire "tried and true" employees from the pool of students with whom they have already worked. Overall, this open innovation approach seems to be a winner for longterm success. ■

Dorothy Lozowski

Letters

Further comments on safety, ethics

June, Safety, ethics on the horizon, p. 5: As a thoroughly schooled, experienced engineer, I have read the news, watched television and listened to the radio for an engineering explanation of what went on as BP lost control of its oil well. All I have heard is name calling, political comments and threats of punishment. Often I have heard that the scientists failed.

Actually it was management that failed — corporate management AND government management. If a building were to collapse, the first inquiry would be a review of the design drawings and calculations. No science here. It's all management — first on the part of the city, next on the part of the builders. The main question asked would be: was the design done by a registered, licensed professional engineer? Did he or she stamp and sign the drawings? I have heard no such questions regarding BP and the Deepwater Horizon. If the job had been managed properly, stamped, signed drawings of the design should currently exist. The signatures need to be from licensed engineers: not only BP engineers, but U.S. Corps of Engineers too. I expect that these signatures are either missing, or affixed fraudulently — or even worse, that good design drawings were not even prepared.

This assertion underscores how disasters occur when professional reviews and the signing or stamping procedures are sidestepped, either purposely, or through ignorance. The National Society of Professional Engineers (NSPE) should endeavor to learn what designs, if any, were reviewed by licensed professionals working for BP, or the Corps of Engineers, or the Coast Guard, or any of the Gulf states. The disciplines that should have put stamps on the designs are: structural, mechanical, chemical, electrical and control systems. The designs requiring said reviews (and approvals) are those of the platform (the Deepwater Horizon), the blowout preventer (with close attention to the dynamic seal that enables movement of the drill rod), the well casing, the well discharge pipe, and the well termination (so-called X-mas tree), with special attention paid to the shut-off valve and the valve actuators.

Scott Mansfield, PE
Retired, San Gabriel, CA

Postcripts, corrections

June, Facts at Your Fingertips, Distillation Tray Design, p. 27: The equation for active area and V-load contained some terms that should have been subscripts. The correct equations for active area and V-Load are as follows:

Active area =
V-Load / $[TS^{0.5} (0.0762 – 0.00092(\rho_V{}^2)) – 0.011W_L]$
V-Load = $CFS_V [\rho_V / (\rho_L – \rho_V)]^{0.5}$

June, Just Cool It, p. 17: The caption for Figure 1 incorrectly suggested that the pictured equipment is used for particle size reduction. The LIN immersion freezer shown is used for food processing, but not particle reduction.

July, Feature Report, Aging relief systems – Are they working properly?, pp. 38–43: The definition of MAWP in the text on p. 40 should read "maximum allowable working pressure". Also, the valve types mentioned on p. 42 should read "conventional, balanced, pilot". ■

Developed for extremes.

Our experience counts!

Berndorf Band steel belts, made from high-tensile materials, have proven to be perfect for cooling applications in the chemical industry.

SBS Steel Belt Systems uses these steel belts for its cooling and pastillating equipment. The SBS Rolldrop® transforms molten products into pastilles with diameters ranging from 5 to 10 mm. Some advantages of the system are: easy removal of the solidified pastilles from the belt, effortless cleaning for quick product changeover, low-cost gaskets, simple assembly, rapid and low-cost maintenance, short downtime and low wear.

SBS USA

Partner of Berndorf Band

SBS Steel Belt Systems USA, Inc.

2525, Bath Road
Elgin, IL 60124
Phone: (1)847-841-3300
Fax: (1)847-931-5299
info@steelbeltsystemsusa.com
www.steelbeltsystemsusa.com

Circle 5 on p. 50 or go to adlinks.che.com/29253-05

Calendar

NORTH AMERICA

ACS 239th Annual Meeting and Exposition. American Chemical Society Meetings (Washington, D.C.). Phone: 800-227-5558; Web: acs.org
Boston, Mass. **Aug. 22–26**

International Acid Gas Injection Symposium. Sphere Technology Connection Ltd. (Calgary, Alta.). Phone: 403-619-6215; Fax: 888-984-4941; Web: agis2010.spheretechconnect.com
Calgary, Alta., Canada **Sept. 27–30**

3rd Intl. Symposium on Green Processing in the Pharmaceutical and Fine Chemical Industries. Guiding Green LLC (Channahon, Ill.). Phone: 815-325-4974; Web: guidinggreen.com
Boston, Mass. **Sept. 30–Oct. 1**

WEFTEC 2010. Water Environment Federation (Alexandria, Va.). Phone: 570-830-1545; Fax: 703-684-2492; Web: wef.org
New Orleans, La. **Oct. 2–6**

39th Turbomachinery Symposium. Texas A&M University Turbomachinery Laboratory (College Station, Tex.). Phone: 979-845-7417; Fax: 979-845-1835; Web: turbolab.tamu.edu
Houston **Oct. 4–7**

Polyurethanes 2010 Technical Conference. American Chemistry Council (Arlington, Va.). Phone: 703-741-5000; Fax: 703-741-6050; Web: americanchemistry.com
Houston **Oct. 11–13**

Materials Science and Technology 2010. American Ceramics Society (Westerville, Ohio) and others. Phone: 614-794-5894; Fax: 614-899-6109; Web: matscitech.org
Houston **Oct. 17–21**

ChemInnovations 2010 Conference & Expo. Tradefair Group / Access Intelligence LLC (Houston). Phone: 713-343-1879; Web: cpievent.com
Houston **Oct. 19–21**

World Congress on Engineering and Computer Science (WCECS 2010) and International Conference on Chemical Engineering (ICCE'10). International Association of Engineers (IAENG; Hong Kong). Email: info@iaeng.org; Web: www.iaeng.org
San Francisco, Calif. **Oct. 20–22**

60th Canadian Chemical Engineering Conference. Canadian Society for Chemical Engineering (Ottowa, Ont.). Phone: 613-232-6252; Fax: 613-232-5862; Web: csche2010.ca
Saskatoon, Sask., Canada **Oct. 24–27**

North American Industrial Coating Show. NACE International (Houston). Phone: 800-797-6223; Fax: 281-228-6300; Web: events.nace.org
Indianapolis, Ind. **Oct. 27–29**

Gasification Technologies Conference. Gasification Technologies Council (Arlington, Va.). Phone: 703-276-0110; Fax: 703-276-0141; Web: gasification.org
Washington, D.C. **Oct. 31–Nov. 3**

2010 AIChE Fall National Meeting. American Institute of Chemical Engineers (New York, N.Y.). Phone: 800-242-4363; Fax: 203-775-5177; Web: aiche.org
Salt Lake City, Utah **Nov. 7–12**

EUROPE

19th Int'l Congress of Chemical and Process Engineering. Czech Society of Chemical Engineering (Prague, Czech Republic); Fax: +420 221 082 366; Web: chisa.cz/2010
Prague, Czech Republic **Aug. 28–Sept. 1**

Organic Process Research & Development. Scientific Update (West Essex, U.K.). Phone: +44 1435 873062; Fax: +44 1435 872734; Web: scientificupdate.co.uk
Barcelona, Spain **Sept. 13–15**

IFAT Ensorga. Messe München GmbH (Munich, Germany). Phone: +49 89 9 49 113 58; Fax: +49 89 9 49 113 59; Web: ifat.de
Munich, Germany **Sept. 13–17**

15th International Congress for Battery Recycling (ICBR 2010). ICM AG (Birrwil, Switzerland). Phone: +41 62 785 10 00; Fax: +41 62 785 10 05; Web: icm.ch
Brussels, Belgium **Sept. 15–17**

Green Solvents Conference. Dechema e.V. (Frankfurt am Main, Germany). Phone: +49 69 75 64-333; Fax: +49 69 75 64-441; Web: dechema.de
Berchtesgaden, Germany **Oct. 10–13**

XIX International Conference on Chemical Reactors. Boreskov Institute of Catalysis, Russian Academy of Sciences (Novosibirsk, Russia). Phone: +7 383 326 95 36; Fax: +7 383 330 62 97; Web: conf.nsc.ru/CR-19-2010
Vienna, Austria **Oct. 20–22**

7th World Conference on Detergents. American Oil Chemists' Society (Urbana, Ill.). Phone: 217-359-2344; Fax: 217-351-8091; Web: aocs.org
Montreux, Switzerland **Oct. 4–7**

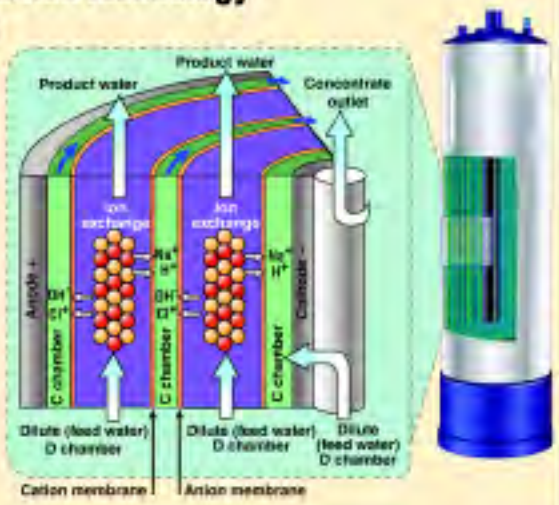
ASIA

5th World Recycling Forum. ICM AG (Birrwil, Switzerland). Phone: +41 62 785 10 00; Fax: +41 62 785 10 05; Web: icm.ch
Hong Kong **Nov. 15–18** ■

Scott Jenkins

Simplified electrodeionization technology reduces operating costs

Dow Water and Process Solutions (DW&PS; Minneapolis, Minn.; www.dowwaterandprocess.com), a business unit of The Dow Chemical Co., unveiled a simplified electrodeionization (EDI) product at the recent Singapore International Water Week event. The new version of the product reduces operating costs for industrial water treatment by up to 15% compared to its predecessor. The Dow Electrodeionization 310 Module (Dow EDI-310) can save not only operating costs, but capital cost as well, while producing ultrapure water with electrical resistance of up to 18 megaohms, the theoretical maximum for resistivity in water.



Chris Sacksteder, Dow strategic marketing manager for industrial water, says the reason behind the spiral-wound Dow EDI-310's ability to save money is a simplified design (diagram) that eliminates the brine recirculation loop, which reduces capital costs by eliminating the brine injection pump, as well as the brine tank, the recirculation pump and its associated plumbing. Further, operating costs are lower because "There's no more need to continually fill the system with salt," Sacksteder explains. "The new model has a once-through concentration stream that improves energy efficiency."

DW&PS engineers have developed a proprietary conductive spacer for the ion-exchange membranes that allows the module to operate effectively without the need to recirculate brine and add salt.

The first commercial production run for the product is underway, and the Dow EDI-310 should be available in late July, Sacksteder says. DW&PS envisions the new product will be installed to treat permeate from reverse osmosis processes. Other applications where the system could be used include purifying water for high-pressure boiler feeds, as well as rinsing applications requiring high-purity water.

Graphene

Researchers at Rensselaer Polytechnic Institute (RPI; Troy, N.Y.; www.rpi.edu) have developed an inexpensive way to produce large quantities of graphene. Using acid treatment and ultrasound, the method is a step toward mass production of the atom-thick, honeycomb-shaped nanomaterial, which is being studied as a possible replacement for silicon in nanoelectronics. The scientists dissolved 1-pyrenecarboxylic acid (PCA) in a water-methanol solution, then introduced bulk graphite powder. The mixture was then exposed to ultrasound, which agitates the graphite and weakens the bonds between the layers of graphite. As the interlayer bonds weaken, PCA molecules wedge themselves between the layers, generating flakes of graphene.

UGC-based fuel cell

Linc Energy Ltd. (Brisbane, Australia; www.lincenergy.com.au) has successfully demonstrated the operation of a hydrogen fuel cell using syngas derived from its underground coal gasification (UCG) demonstration facility in Chinchilla, in Queensland (*CE*, June 2009, p. 15). Linc Energy

(*Continues on p. 10*)

This new process promises substantial savings for aluminum production

Calsmelt Pty Ltd. (Melbourne, Australia; www.calsmelt.com) is marketing a new carbothermic process for producing metallic aluminum. Tradenamed Thermical, the process is said to entail significant advantages over Alcoa's carbothermic process, the Advanced Reactor Process (ARP). Under development for several years, carbothermic technology aims to eventually displace the standard Hall-Héroult electrolytic cell process, leading to reduced capital and operating costs, reduced process energy, and reduced CO_2 emissions for smelting.

Calsmelt says its Thermical process, while also called a carbothermic process, is in detail fundamentally different from previously proposed carbothermic processes. The process operates at temperatures about 500°C lower. According to Calsmelt, it allows reduced capital costs by up to 80%, reduced operating costs by about 40%, and lower power consumption by about 40%. Fluoride emissions will be completely eliminated, and the quantity of generated gases will be significantly lower.

The ARP process developed by Alcoa is a multistage system in which a molten slag bath containing alumina (Al_2O_3) and carbon is reacted to produce aluminum carbide (Al_4C_3) in a low temperature stage. The resulting Al_2O_3-Al_4C_3 slag then flows into a high temperature stage where the Al_4C_3 reacts with the Al_2O_3 to produce Al metal.

In the Thermical's first stage, process Al_2O_3 is mixed with molten Al in the presence of a carbon source, to form carbide. In a second stage, an intimate mixture of carbide and alumina reacts to produce Al and CO_2. There are three key patent applications for the process.

Calsmelt has just completed a proof-of-concept stage of its technology. The firm's goal is to take its technology through to full process definition and build a semi-works plant to demonstrate the process. Within a couple of years, the company expects to be ready to build its first small, but commercially viable, plant.

Note: For more information, circle the 3-digit number on p. 50, or use the website designation.

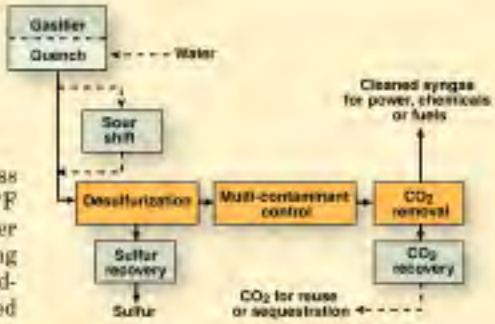
High-temperature process cuts the cost of syngas cleanup

A process that promises a significant reduction in the cost of removing sulfur from coal-derived synthesis gas (syngas) will be tested in a 50-MW_e demonstration unit at Tampa (Fla.) Electric Company's 250-MW_e integrated gasification-combined cycle (IGCC) power plant. RTI International (Research Triangle Park, N.C.; www.rti.org), the developer of the technology, has awarded a contract for front-end engineering and design to The Shaw Group Inc. (Baton Rouge, La.; www.shawgrp.com). Construction is scheduled to start sometime in 2011. The project is mainly funded by the U.S. Dept. of Energy (DOE; Washington, D.C.; www.energy.gov).

The standard way to capture sulfur is to use amines, but this entails reducing the temperature of the syngas from about 2,000°F to at least ambient temperature, says Raghubir Gupta, RTI's senior research director. After that, the gas has to be reheated to 500°F for input to a gas turbine to produce electricity.

In contrast, RTI's process (flowsheet) accepts 900°F gas — the temperature after the conventional first cooling stage. The gas is fed to a fluidized bed of a zinc-oxide-based adsorbent, which adsorbs and reacts with H_2S and COS to form zinc sulfide. Next, the sorbent ZnO is regenerated by air and recycled, while SO_2 is recovered for the production of elemental sulfur or acid.

The process has been piloted in a coal-gasification unit at an Eastman Chemical plant in Kingsport, Tenn., and reduced the sulfur concentration from around 10,000 ppm to below 5 ppm, says Gupta. He adds that the overall energy efficiency of an IGCC plant can be improved from 37% for the amine route to 41% for RTI's process, indicating an overall 10% reduction in the cost of electricity production. For the demonstration plant, RTI is also working on a process to remove multiple contaminants (such as mercury, arsenic and ammonia), and carbon monoxide.



Membrane bioreactor technology improves treatment of high-organic-content water

A next-generation, carbon-enhanced membrane-bioreactor (MBR) system improves treatment of industrial wastewater with high organic content and containing compounds that resist microbial breakdown. The system allows economic reuse of wastewater or discharge to meet stringent environmental standards. The new MBR, dubbed EcoRight, will be commercially available in early 2011. First envisioned by Saudi Aramco (Dhahran, Saudi Arabia; www.saudiaramco.com), the technology was developed jointly with Siemens Water Technologies Corp. (Warrendale, Pa.; www.siemens.com/water).

EcoRight's key technological innovation involves the use of granular activated carbon (GAC), rather than powdered activated carbon (PAC), to adsorb organic contaminants in the wastewater. In PAC-containing MBR systems, PAC can cause varying degrees of abrasion on microfiltration membranes, explains Siemens sales and marketing director Tom Schultz. "That can result in higher operating costs due to shorter membrane life." EcoRight technology isolates the GAC from the membranes, almost entirely eliminating abrasion associated with using PAC. EcoRight developers have invented a proprietary technique for keeping the GAC in suspension inside the MBR without using energy beyond that required for conventional aeration, Schultz says, which had been a major technological barrier to using GAC in the past.

An additional advantage of the technology is its considerably reduced carbon consumption compared to other PAC-based MBR systems or those using GAC polishing columns, because the granules are retained in the system longer. Longer retention allows a higher degree of biological regeneration of the GAC to occur, as microbes break down organics adsorbed inside the GAC pore structure. EcoRight allows effluent to be fed directly into reverse osmosis equipment for reuse as boiler feed, irrigation, utility or cooling water, the companies say.

Laboratory work on the technology has been completed, and testing has begun on a recently assembled, field demonstration unit built in Saudi Arabia by Saudi Aramco and Siemens.

(Continued from p. 9)

has an exclusive agreement with AFC Energy Plc. (Cranleigh, U.K.; www.afcenergy.com) for application with UCG and the delivery of an Alpha Unit Hydrogen Fuel Cell to the Chinchilla facility. The testing at Chinchilla follows successful trials at AFC's U.K. facilities with gas of comparative composition to that generated at Chinchilla. Upon successful completion of the trials of the Alpha unit, it is intended to install multiple modules at Chinchilla to form a larger (approximately 50 kW) AFC fuel cell system. All parties anticipate multiple installations of AFC Energy's 50kW system for full-scale commercialization.

The H_2 used in the field test was derived by a simple membrane separation from the UCG. Link Energy says the fuel cell was able to produce reliable and clean electricity from a much lower percentage H_2 content than required by other fuel cells.

Enhanced extraction

Jissen Kankyo Kenkyusho (JKK; Nagoya City, Japan; www.jissen.co.jp) has developed a process that uses superheated steam to extract oil from Jatropha seeds. The process uses steam at 200–500°C to decompose the seeds without thermal degradation of the oil, and recovers 35 wt.% of the oil — 75% higher than the 20 wt.% achieved by conventional pressing methods, says JKK. The company says the process is suitable for the production of biodiesel fuel for diesel-generated electricity, and the char remaining from the seeds is suitable for use as fertilizer.

(Continues on p. 13)

“复制美国工艺？我们做法一致！”

[“Duplicating your U.S. process in China? Now you're speaking my language!”]

Ross can help make your business more competitive in East Asia, Europe and the Middle East. With two plants in China, Ross can provide the mixing equipment you need to duplicate your U.S. process overseas.

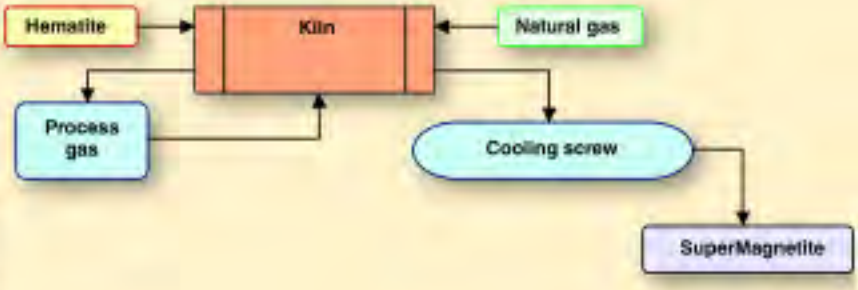
With genuine Ross engineering and quality standards, we can help eliminate end-product inconsistency. With worldwide manufacturing and distribution, we can also deliver fast – at a price that's impressive in any language.

Call 1-800-243-ROSS today.
Or visit www.mixers.com.

George Lu,
General Manager,
China Operations

ROSS

A new production route to high-purity magnetite



Last month, Pittsburgh Iron Oxides, LLC (Pirox; New Brighton, Pa.; www.piroxllc.com) was granted U.S. patent No. 7,744,848 for its process of producing high-purity magnetite (Fe_3O_4). The company produces synthetic magnetite, tradenamed SuperMagnetite, which has greater than 99% purity and exhibits a unique combination of magnetic properties (such as remnance, saturation and, coercivity) that are derived from its purity, particle size (2–3 µm) and shape. The product is used for making pure iron phosphate and in applications such as constructing electrodes, reducing SO_2 and Hg emissions and filler for zinc-rich coatings.

In the Pirox process (flowsheet) commercial hematite (Fe_2O_3) is continuously fed into an indirectly fired rotary kiln. A countercurrent flow of natural gas reduces Fe_2O_3 into Fe_3O_4, and the gaseous byproducts (H_2, CO, CO_2 and H_2O) are utilized as fuel. Tight control of the temperature profile prevents the overreaction of Fe_2O_3 into wuestite (FeO) or ferrite (α-Fe), explains Dale L. Nickels, Pirox's vice president and plant manager. Product magnetite is then fed to a cooling screw under an inert atmosphere, where it is cooled to below 50°C, then bagged.

Production costs for Pirox's process is "a fraction of its competitors," says Nickels. Conventional routes to magnetite, such as the Laux process, involve wet chemical precipitations that require additional filtration, drying and deagglomeration steps, which add significant costs, he says.

Pirox is now producing 250 ton/mo of SuperMagnetite at its New Brighton facility, which can be increased to 500 ton/mo with minimal effort, says Nickels. A second kiln has been purchased that will enable the firm to expand production to 950 ton/mo.

Size reduction of cementitious material

Flyanic LLC (Newark, N.J.; www.flyanic.com) has developed an industrial-scale and economical process for grinding cement, flyash and other cementitious materials to a median particle size of 1 micron, making them suitable for use in concrete and mortar. For example, flyash and slag ground less than 10 microns are highly reactive pozzolans for building products, such as high-performance structural concrete. Up to now it has not been possible to produce a 1-micron flyash product economically, says the firm. The processing costs have been reduced to the range of $30–77 per ton, depending on the feedstock, and can be scaled to industrial production levels.

Flyanic has licensed the patented technology (U.S. No. 6,802,898), which was developed by the New Jersey Institute of Technology (NJIT; Newark; www.njit.edu) involving years of R&D with cooperation from energy and cement companies.

Together with its development partner, RSG Inc. (Sylacauga, Ala.; www.ultrafinegrind.com), Flyanic recently applied this new size-reduction technology to the design of a vertical stirred-media mill to perform pilot-scale demonstrations. The company can arrange a sustained demonstration of the technology at a truckload scale, with a production rate of 1 ton/h.

New polymerization

Monomer Polymer and Dajac Labs (Trevose, Pa.; www.monomerpolymer.com) has licensed the RAFT (reversible addition-fragmentation chain-transfer) technology from CSIRO (Melbourne, Australia; www.csiro.au), which developed the patented polymerization technology that enables the creation of very complex molecules that can be used for a wide range of products. Monomer Polymers will market the technology worldwide, and the firm anticipates that its internal expertise with organosilanes will open up new uses of RAFT to create polymers with organosilicon functionalities in the architecture.

Super emulsion slashes biodiesel production costs by 25%

The research group of Kazuo Tajima at Kanagawa University (Yokohama, Japan; apchem2.kanagawa-u.ac.jp) have developed a new emulsification process that enables biodiesel fuels (BDFs) to be used without any purification process, thereby reducing production costs by one fourth. Tajima estimates that the process can produce BDF for about ¥20/L (about $0.20/L) as well as cut CO_2 emissions by 5% compared to existing BDF processes.

The new process involves the formation of a three-phase emulsion, which eliminates the need for adding surfactants as required in conventional emulsification. The emulsified BDF is made by mixing diesel and Jatropha oils with nano-sized (30–50-nm) droplets of ricinus oil (castor oil). The resulting stable emulsion has good combustion characteristics with reduced emissions of CO_2, oxides of nitrogen (NOx) and particulate matter. By skipping the transesterification of Jatropha oil, the production of this biodiesel fuel does not generate glycerin as a byproduct. The fuel has been tested with 2-ton commercial vehicles, which could drive 120 km per tank-full.

Nanopores improving sterile filtration

Researchers at the Fraunhofer Institute for Mechanics of Materials (IWM; Halle, Germany; www.fraunhofer.de) have developed ceramic membranes with uniform pore structure and tight pore-size distribution, which makes them more stable and delivers "considerably higher" flowrates than existing ceramic membranes, which makes them suitable alternatives for polymeric membranes, says IWM.

The membranes are made from highly pure aluminum, which is molded into the desired shape by extrusion equipment and thermomechanical structuring. The Al part then undergoes anodic oxidation in an acid bath, which creates a thin oxide layer with pores. Control of the electrolysis voltage and pH enables fine-tuning of the pore size. A final chemical etching step opens up the pores and removes residual aluminum metal from the ceramic layer. Pore diameters can be varied from between 15 and 450 nm. The membranes are expected to have applications in biotechnology.

This rheometer performs multipass measurements

Strata Technology Ltd. (Sunbury-on-Thames, U.K.; www.stratatec.co.uk) has commercialized the Cambridge Multipass Rheometer (MPR), which was developed by professor Malcolm Mackley at the Dept. of Chemical Engineering and Biotechnology, Cambridge University (www.ceb.cam.ac.uk) for advanced studies of the rheological properties of melts, liquids and soft solids. The device consists of two servo-hydraulically controlled pistons enclosed within temperature-controlled barrels on either side of a central test section (capillary or slit die). The sample is totally enclosed and it is displaced cyclically between the barrels via the test section. The speed of the pistons can be varied from 0.05 to 200 mm/s, enabling very high shear rates to be generated within the test section. The system is controlled by software developed by Omiga Technology Ltd. (Quedgeley, U.K.).

The MPR can perform multiple measurements on one sample at controlled flowrates, temperatures and pressures, and may be used to assess shear-aging characteristics. It can also be used in conjunction with other techniques, such as x-ray diffraction and optical birefringence to provide realtime, *in-situ* measurements of materials under shear. Because the sample is retained in the test section after shearing, it is also possible to study its relaxation behavior.

Single samples (up to 10 g) can be analyzed at variable pressures up to 200 barg and temperatures from –20 to 200°C.

Control mercury emissions from coal-fired plants without treating the fluegas

ADA-ES, Inc. (Littleton, Colo.; www.adaes.com) and Arch Coal, Inc. (St. Louis, Mo.), the U.S.'s second-largest coal producer, have signed an exclusive development and licensing agreement for an ADA-ES process that reduces mercury emissions from coal-fired plants by pretreating the coal. Designed for use with sub-bituminous coals, the process has reduced Hg emissions by up to 80% in full-scale tests in a power plant, says Michael Durham, president of ADA.

The common way to control mercury emissions is to inject activated carbon into the fluegas. The carbon absorbs Hg from the fluegas and is captured by an electrostatic precipitator (ESP) or a fabric filter. However, Western sub-bituminous coals, such as Powder River Basin (PRB) coal, contain elemental Hg, which is not amenable to carbon absorption because the coal has less chlorine and other oxidants than bituminous coal. To overcome this problem, ADA and other companies have developed processes that use halogenated activated carbon.

ADA's new process, in contrast, involves pretreatment of the coal instead of carbon injection. "We found something in the coal in one of Arch's mines that makes mercury amenable to capture by an ESP," says Durham. He declines to give more details, but says that ADA has chemically modified other coals to impart the same characteristics. Under the agreement with Arch, coals from various PRB mines will be pretreated and the coal will be delivered to power companies for full-scale testing. Durham says the process will be cost-competitive and simpler for plant operators than activated carbon processes. The U.S. Environmental Protection Agency is expected to publish a draft Hg regulation for coal-fired utility boilers next March. ■

(*Continued from p. 10*)

Last month, the company began marketing commercial units with processing capacities of 10–700 kg/h. The 10-kg/h unit costs ¥10 million ($10,000).

Filter for FCC units

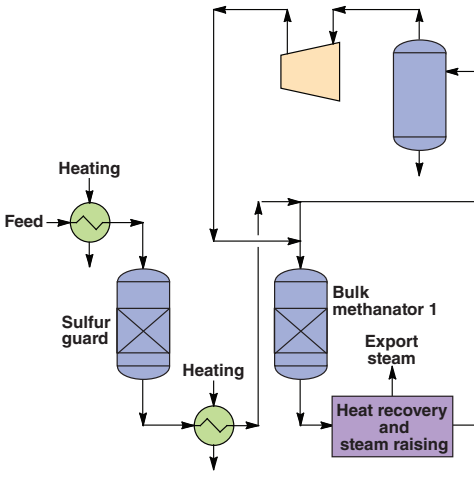
Seebach GmbH (Vellmar; Germany; www.seebach.com) has developed a new production process for making filter candles that are used in petroleum refineries for catalyst recovery. Large bundles of such candles are used in the FCC (fluid-catalytic cracking) slurry-oil filters, and due to the abrasive environment, represent a substantial cost in this process, says the firm.

The new filters consist of a wire-mesh laminate that is formed into a filter tube from a single piece, which eliminates the need for welded joints. The filter is superimposed onto the candle, and can be easily replaced. Because only the medium needs to be replaced after the wear, operating costs are reduced, says the manufacturer.

New FCC catalyst

Last month, BASF (Iselin, N.J.; www.basf.com) introduced the Multi-Stage Reaction Catalyst (MSRC) platform, which allows for FCC catalyst particles with staged reaction zones, having different properties for each stage. Commercial manufacturing trials of the first MSRC-based FCC catalyst were completed earlier this year, and a commercial performance trial is slated for Q3. ❑

SNG Déjà Vu



Technology developed 40 years ago to convert coal into substitute natural gas is making a comeback — processes to make Bio-SNG are approaching

Considering that a large fraction of the synthesis gas (syngas) produced today is made by steam reforming of natural gas, it might seem curious that in some parts of the world, syngas is being converted into substitute natural gas (SNG). Nevertheless, such role reversal is common where coal is abundant and gas is expensive. China, for example, imports most of its gas, either via pipeline from Russia or shipped in as liquefied natural gas (LNG). It was also the case in the U.S. a few years ago, when natural gas prices skyrocketed to as high as $10/million Btu, which initiated a number of massive coal-to-SNG projects in coal-rich regions of the country.

Today, coal-to-SNG projects are progressing full-speed ahead in China, while those in the U.S. are either awaiting financing or are being redesigned into coal-to-"something else" as a result of the recent fall in U.S.-gas prices. "The cost of gas in China is about 2–3 times higher than in the U.S.," says Don Anthony, chief technology officer at GreatPoint Energy (Cambridge, Mass.; www.greatpointenergy.com), so coal-to-SNG is one way to meet the growing domestic market there.

Why coal-to-SNG?

Making SNG is one way for China to use its large coal assets rather than importing energy, says Philip Eastland, vice president, Davy Process Technology Ltd. (DPT; London, U.K.; www.davyprotech.com) a Johnson Matthey Co. China also has tight logistics for moving coal with the rails and roads fully loaded, so access to deliver energy to the market place as SNG through the existing and expanding West/East pipeline network is important, he says.

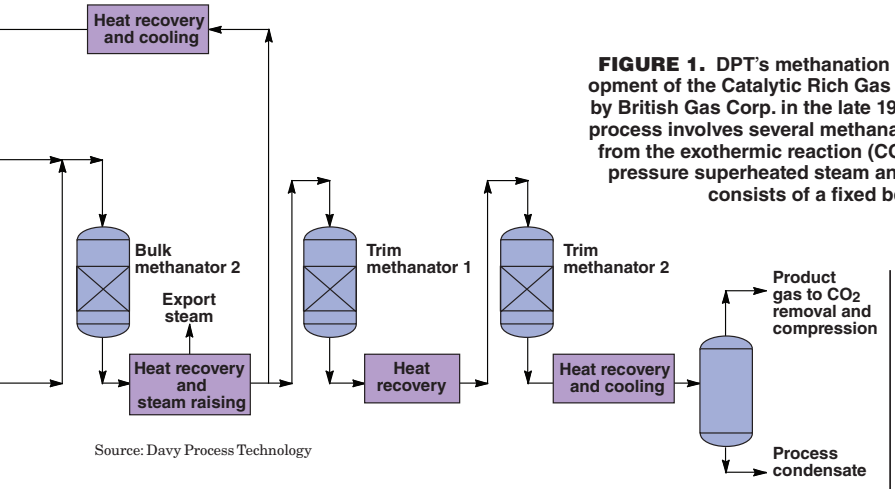
In January, DPT entered into contracts with Datang Energy Chemical Co. for a plant to produce SNG from coal — a first for China. The scope of the project includes a technology license, basic engineering design, catalyst and support services for the methanation unit (Figure 1) that converts syngas (mainly H_2 and CO) to SNG (mainly CH_4).

The plant, now in detailed engineering, will be located in Keshiketeng County, Inner Mongolia, and will have a capacity of 12-million Nm^3/d of SNG produced in three parallel units that will be constructed sequentially. The SNG will be sent by pipeline and will provide a significant portion of the domestic energy needs of Beijing.

DPT received a second Chinese contract in June from Xinwen Mining Group Co. (Shadong Province, China) to make SNG from coal. The plant, now in basic engineering, will be located in Yili, Xinjiang, and have a capacity of 6-million Nm^3/d of SNG produced in two parallel units that will be constructed simultaneously. In both of these projects, the gasification technology is supplied by the Chinese No. 2 Design Institute.

Making SNG from coal-derived syngas is not new; the technology was developed, tested and proven several decades ago. One of the biggest such plants is the $2.1-billion Great Plaines Synfuels Plant of Dakota Gasification Co. (Bismark, N.D.), which started up in 1984, and is the only SNG plant operating in the world. The facility uses Lurgi GmbH (Frankfurt, Germany; www.lurgi.com) gasifiers to convert lignite into syngas, which is then converted to SNG using DPT methanation catalysts. The facility produces about 153-million ft^3/d SNG, the majority of which is piped to Ventura, Iowa, for distribution in the eastern U.S. Since 2000, the facility has also been capturing 3-million metric tons (m.t.) of CO_2 per year, which is pipelined to Saskatchewan, Canada for use in enhanced oil recovery in the Weyburn and Midale fields. As of December 31, 2009, Dakota Gas had captured more than 17.4-million m.t. of CO_2.

Although developed in the 1970s when gas prices soared, Haldor Topsøe A/S's (Lyngby, Denmark; www.topsoe.com) methanation technology, called Tremp. is just now making its commercial presence felt, after a false start in 2007, when a $1-billion project to convert 4 million tons/yr of coal into SNG was announced for Power Holding's coal-gasification plant in Jefferson County, Ill. (*CE*, February 2007, p. 11). This project is still pending, partly due to the lack of clarity on the requirements for handling of CO_2 from coal-based projects in the U.S., says Jens Perregaard, Topsøe's general manager, New Technologies, Technology Division. This is not unique to this project, but also part of the reason that other SNG projects — such as the Lake Charles Cogeneration project, the Cline Group (Illinois Basin) as well as other projects where our Tremp technology has been selected — are being delayed, he says.



Source: Davy Process Technology

FIGURE 1. DPT's methanation process is a refinement and further development of the Catalytic Rich Gas (CRG) process, which was first developed by British Gas Corp. in the late 1960s to convert naphtha into town gas. The process involves several methanator reactors in series, with heat recovered from the exothermic reaction ($CO + 3H_2 \rightarrow CH_4 + H_2O$) used to raise high-pressure superheated steam and to preheat the feed. Each reaction stage consists of a fixed bed of CRG catalyst operating adiabatically

However, at the end of last year Topsøe signed a design contract with an undisclosed client in China for a new plant that will produce SNG from coal-derived syngas. When the plant comes on stream next year, it will produce close to 180,000 Nm^3/h of SNG, and will be the first large-scale order for Tremp technology, says Perregaard.

Tremp. Topsøe's high-temperature methanation process (for flowsheet, see *CE*, February 2007, p. 11), uses coal-derived syngas (H_2-to-CO ratio of slightly above 3), which has been passed through a sulfur-tolerant shift and acid-gas removal unit for removing H_2S and excess carbon (as CO_2). In order to protect the methanation catalyst — Topsøe's nickel-based MCR — from poisoning, the feed is first passed through a sulfur guard bed to remove traces of sulfur components. Desulfurized feed is then mixed with recycle gas to control the maximum temperature rise and passed to the first methanation reactor, where H_2 reacts with CO and CO_2 to form CH_4. The reaction is performed in a reactor with a very large ΔT and at the same time with a technology preventing the formation of nickel carbonyl. The ΔT ensures that heat can efficiently be recovered from the exothermic reaction and used for generating superheated, high-pressure steam. The cooled gas then passes through two or three methanation reactors in series for complete conversion. Products leaving the last reactor are cooled and compressed to meet pipeline specifications. The SNG is typically 94–96 mol.% CH_4, with a heating value of 950–978 Btu/scf.

Other SNG projects

In April, ConocoPhillips (Houston; www.conocophillips.com) completed an agreement with POSCO, a Korean steel-manufacturing company, to use ConocoPhillip's E-Gas technology in POSCO's Gwangyang coal-to-SNG project. The facility will produce 500,000 m.t. of SNG from approximately 1.8-million tons of coal. Preliminary design work had already begun in 2008. The methanation technology to be used for this project has not yet been announced.

The E-Gas technology is also being used at the Wabash River Coal Gasification Plant, near Terre Haute, Ind. and has been licensed by Mississippi Gasification LLC, an affiliate of Leucedia Energy LLC (New York), for a project planned for Moss Point, Miss. The later project, which will make SNG from petroleum coke (petcoke), recently received U.S. Dept. of Energy (DOE; Washington, D.C.) funding ($840,000) to demonstrate advanced technologies that capture and sequester CO_2 emissions from an industrial source. Mississippi plans to demonstrate large-scale recovery, purification and compression of 4-million ton/yr of CO_2.

In March, 2009, Siemens Energy (Erlangen, Germany; www.energy.siemens.com) delivered two 500-MW_{th} gasifiers and associated equipment to Secure Energy, Inc.'s (Decatur, Ill.; www.secureenergyinc.com) Gasification plant — the first Siemen's gasifiers to be delivered to North America. The massive units were planned to be part of a process for converting 1.4-million ton/yr of coal into 21-billion ft^3 of SNG. While detailed design work is currently underway, Secure Energy has revised its plans — due to the drop in natural gas prices in the U.S. — and the syngas will be used for a yet-to-be announced product other than SNG, says Lars Scott, co-managing member of Secure Energy.

Uhde GmbH (Dortmund, Germany; www.uhde.eu) is also involved in a number of SNG projects in China and the U.S., but these projects are still in the design stage, and cannot be disclosed at this time, says Karsten Radtke, head of Gas Technologies Div. at Uhde. He points out that SNG is just one of many possible products for gasification plants. "While we do see a growing interest in SNG, there is clearly no dominance for SNG visible, and all other products, such as methanol, gasoline, fertilizers, H_2 and chemicals are all being applied downstream of coal (and biomass) gasification projects around the world."

Uhde recently commercialized a direct water-quench version of its Prenflo gasification technology, known as PDQ (for details, see *CE*, November 2008, p. 14). This new achievement leads to an enrichment in the H_2 content of the raw syngas already in the gasification reactor and has a capacity of 1,200 MW_{th} per gasifier, which allows for compact design and lower capital costs, says Radtke. Because Prenflo gasifiers are based on dry-coal powder feeding, the gasifier has a high cold-gas efficiency, and can thus produce more SNG from coal than, for example, slurry-fed gasifiers, he says.

Hydromethanation

In February, Peabody Energy (St. Louis, Mo.; www.peabodyenergy.com) and GreatPoint Energy (Cambridge, Mass.; www.greatpointenergy.com) signed an agreement to develop coal-to-SNG and coal-to-H_2 projects in the U.S. and elsewhere around the world, along with carbon capture and

storage (CCS) projects. The projects would be developed around GreatPoint Energy's proprietary Bluegas technology, which uses catalytic hydromethanation to generate H_2 and SNG. The process is more efficient and cost effective than conventional gasification routes to SNG, says GreatPoint Energy's Anthony.

In the Bluegas process (Figure 2), a proprietary catalyst is dispersed with the feedstock (coal, petcoke, or biomass), and the mixture loaded into the reactor. Pressurized steam is injected from below to fluidize the mixture, which reacts to form CH_4, CO, H_2 and CO_2. The process operates at about half the temperature of conventional coal gasifiers. By performing the highly endothermic steam-reforming reaction and the exothermic methanation reactions in a single reactor, the overall reaction is thermally neutral, making the process highly efficient, says Anthony.

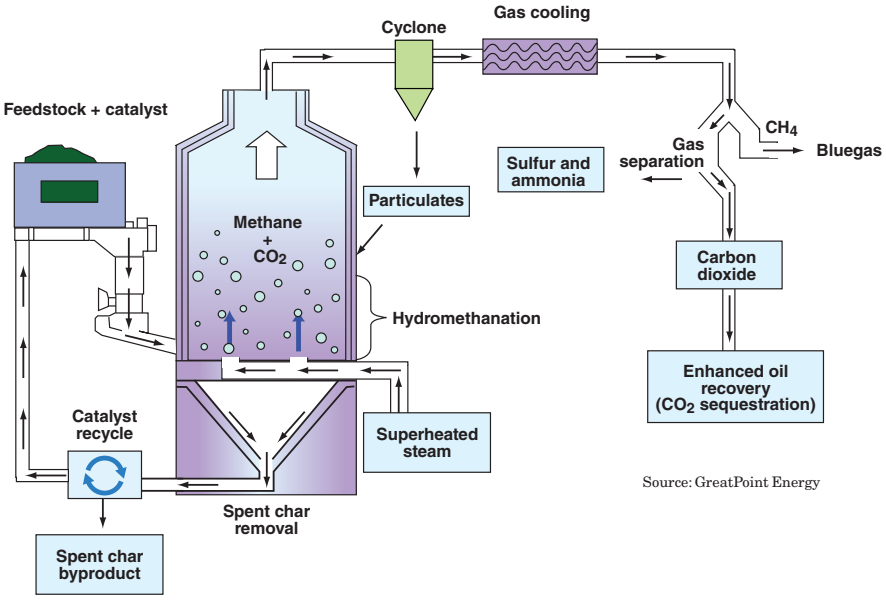


FIGURE 2. GreatPoint Energy's Hydromethanation process directly produces CH_4 and CO_2 by the reaction of steam with carbonaceous solids, such as coal, petcoke and biomass

The process has undergone three levels of pilot testing, most recently at the company's own pilot plant, the Mayflower, which handles a nominal feedrate of 1–3 ton/d, depending on the feed. The Mayflower is essentially an exact replica of a commercial system, just a smaller diameter.

The Bluegas process is competitive even if gas prices are below $4/million Btu, says Anthony. Although today's U.S. prices are around $4–5/million Btu, they are projected to reach $6–8/million Btu in the next ten years, which "is more than high enough for us," he says. The first commercial demonstration — most likely in China — will have a throughput of about 700–1,500 ton/d. Once this is built, it will be quick to duplicate, says Anthony.

In addition to Peabody Energy, GreatPoint Energy has three other strategic partners, The Dow Chemical Co. (Midland, Mich.; www.dow.com), Suncor Energy (Calgary; Canada; www.suncor.com) and AES Corp. (Arlington, Va.; www.aes.com). All four partners have invested in the technology, and each has its own strategic plans for the future of this emerging technology.

Bio-SNG

While coal-to-SNG technology makes a comeback in regions where coal is plentiful, other technologies are being developed to produce SNG from biomass, such as wood or straw. These numerous efforts to make so-called bio-SNG (or "green gas") will not only lead to applications in coal- and gas-scarce regions, but have the added advantage over coal-based SNG of being nearly CO_2 neutral — without CO_2 capture and storage, says Bram van der Drift, a process engineer at the Energy research Center of the Netherlands (ECN; Petten; www.ecn.nl).

ECN has been developing a biomass gasification technology, called Milena, which has a high cold-gas efficiency and high methane yield, making it suitable for gas-engine applications. The product gas can also be upgraded into SNG. ECN aims to develop large-scale SNG production with 70% energy efficiency (biomass to bio-SNG), and sees the gas engine as an application necessary for reaching large scale. Together with HVC (Alkmaar, the Netherlands; www.hvcgroep.com), the Bio-CHP (combined heat and power) technology is being introduced on a 10–30-MW_{th} scale.

The Milena gasifier consists of three parts: a riser, settling chamber and downcomer. The combustion section contains a bubbling fluidized-bed combustor and a sand transporter. Biomass is fed into the riser, and superheated steam is added from below. Hot (925°C) sand or olivine enters the riser from the combustor and heats the biomass to 850°C, causing the biomass to gasify. Hot product gas emerging from the gasifier enters ECN's "Olga" gas-cleaning unit, which removes tars and dust. Cleaned gas contains mainly CO, CO_2, H_2, CH_4, and C_2H_4, and can be used in gas boilers and gas turbines, or can be converted into bio-SNG.

Since 2008, ECN has been conducting pilot trials in an 800-kW_{th} Milena unit. A 10-MW_{th} demonstration unit is now being designed, and construction is planned to start next year at the HVC facilities in Alkmaar. Several commercial parties have already expressed an interest in licensing the technology, says Van der Drift, and a 50-MW_{th} SNG demonstration plant is scheduled for startup in 2015.

Uhde is also working on projects

for biomass to SNG, says Radtke. The plants are usually of smaller capacity and are less focussed on competing against natural gas than on creating a CO_2-neutral natural-gas substitute, he says. "Our Prenflo gasifier allows the combination of biomass and coal in one gasifier, so that the addition of biomass as co-feed can be flexibly handled."

Meanwhile, work is progressing on a bio-SNG project being carried out by a Swiss-Austrian consortium. A 1-MW_{th} bio-SNG pilot and demonstration plant — currently operating in a slipstream of a Bio-CHP plant in Güssing, Austria — features a fast, internally circulating fluidized-bed (FICFB) gasifier of Repotec GmbH (Vienna, Austria; www.repotec.at). Together with colleagues from the Technical University of Vienna (www.vt.tuwien.ac.at), scientists at the Paul Scherrer Institute (PSI; Villigen, Switzerland; www.psi.ch) have developed a process that cleans the product (H_2, CO, CH_4 and tars) from the gasifier and converts it into CH_4. The methanation process, which uses a nickel catalyst, was developed at PSI. PSI and CTU Clean Technology Universe AG (Winterthur, Switzerland; www.ctu.ch) scaled up the methanation technology. The consortium is aiming for commercial plants on the scale of 20–200 MW_{th}.

In April, Haldor Topsøe began participating in the design of what is said to be the world's first commercial plant for producing SNG from biomass. The project, owned by the Gothenburg Biomass Gasification (GoBiGas) consortium, with main owner Göteborg Energi AB (Sweden, www.goteborgenergi.se), aims to produce 20 MW of Bio-SNG to be fed into the existing gas grid. Approximately 300 ton/d of wet forest residues will be gasified. The plant, located next to the Rya District Heating Plant in Gothenburg, Sweden, is scheduled to start up in 2012.

Topsøe will supply gas conditioning and its Tremp methanation technology. The gasifier will be supplied by Metso Power (Helsinki, Finland; www.metso.com) and Repotec, and will use Repotec's gasification technology.

Meanwhile, a German-Austrian project is underway that aims to store surplus electrical energy generated from solar or wind power into methane. A process that combines hydrogen electrolysis with methanation has been developed at the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW; Stuttgart, Germany; www.zsw-bw.de) in cooperation with the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES; Bremerhaven and Kassel, Germany; www.iwes.fraunhofer.de). A demonstration system constructed by Solar Fuel Technology GmbH & Co, KG (Salzburg, Austria; www.solar-fuel.net) is now operating in Stuttgart, and the company intends to launch a system with 10-MW capacity in 2012. ■

Gerald Ondrey

Circle 22 on p. 50 or go to adlinks.che.com/29253-22

OH WHAT A RELIEF IT IS!

Improvements in pressure relief devices provide advanced process protection

FIGURE 1. When a pressure relief valve pops, it recloses itself after having relieved the overpressure condition, enabling the system to continue operation

FIGURE 2. With a 95% operating-to-burst pressure ratio and a performance tolerance of 3%, Opti-Gard has been tested to more than 100,000 cycles

In any given chemical processing facility, there may be literally hundreds of operational environments that require protection from excessive pressure. Both rupture disks and pressure relief valves, or the two used in combination, help protect against damage to equipment and injury to personnel. While the basic technology for either type of mechanism has not changed much in recent years, tweaking the manufacturing process has resulted in pressure relief devices that last longer and perform better.

Rupture disk trends

A significant change in the rupture disk industry is the rise of reverse buckling disks over forward acting disks. While reverse buckling disks are not new, *per se*, over the last few years manufacturers and users of overpressure products are seeing the benefits of reverse buckling products materialize.

"With forward acting disks, the pressure is on the concave side, but when you flip the disk over as with a reverse buckling disk, the pressure pushes against the dome," explains Mark Holt, vice president of engineering with Oseco (Broken Arrow, Okla.). "The benefit is that you change the stresses and start acting on a compressive load for the materials. In applications where there is a lot of cycling, it provides a longer life for the rupture disk and the ability to control burst pressure through the material itself."

He says each manufacturer may put different score patterns on the material to make the disk open in different ways, but the real benefit comes from the higher cycle life due to the reverse action.

Another distinct improvement is increased operating ratios (how closely to the disk's set burst pressure a user can operate the system). "What we've had over the history of rupture disks is an increase in this value because it benefits disk users to be able to run their system as close to the failure point as is possible so they may get the maximum process or product through their system," says Holt.

The upper limit used to be around 90%, but recently it has climbed to 95%, which is a result of increased manufacturing capabilities and variations in the processes used to make the disks.

Many of the newer disks combine the benefits and offer both higher cycling and higher operating ratios. Oseco offers the Opti-Gard, which is peripherally scored on the vent side for accurate burst control. With a 95% operating-to-burst pressure ratio and a performance tolerance of three percent, Opti-Gard has been tested to more than 100,000 cycles. And its architecturally engineered burst pressures allow the device to provide these advanced performance characteristics in liquid, gas or vapor applications.

Similarly, Fike's (Blue Springs, Mo.) Axius rupture disk is also high cycling and offers a high operating ratio. Designed for use in aggressive chemical and pharmaceutical applications, this reverse-acting rupture disk is available in corrosion-resistant materials and has very tight tolerances. It oper-

FIGURE 3. The partnership of CSI disk and CSR-7RS holder ensures that the disk bursts at or below its certified burst pressure even if the disk is installed in the wrong direction or becomes damaged

ates at up to 95% of its marked burst pressure for burst pressures over 40 psig and up to 95% of the minimum of the burst tolerance at 40 psig and below. Also, the device is capable of cycling from full vacuum to 95% operating ratio in excess of 100,000 times, even at the lowest burst pressures that are available.

"One-hundred-thousand cycles is more than any disk would see in a lifetime, and even after 100,000 cycles, it showed no fatigue of any kind," says Michael Zitariuk, global product manager for pressure relief with Fike.

Some manufacturers are also developing new disk-holder combinations with significant benefits. One such case is BS&B's (Tulsa, Okla.) Sure-SAF System, which includes the CSI rupture disk combined with the CSR-7RS Safety Head to provide accuracy and reliability. The partnership of disk and holder ensures that the CSI disk bursts at or below its certified burst pressure even if the disk is installed in the wrong direction or becomes damaged.

The CSI rupture disk uses SAF (structural apex forming) technology, the central feature on the disk dome, to enhance the accuracy of burst pressure. At its burst pressure, the CSI rupture-disk dome reverses and opens by shearing around a circular score line located at the perimeter of the dome. The CSR-7RS Safety Head out-

PRESSURE RELIEF PRODUCT PROVIDERS:

Aquatrol	www.aquatrol.com
BS&B Safety Systems	www.bsbsystems.com
Continental Disc	www.contdisc.com
Fike	www.fike.com
Oseco	www.oseco.com
Rupture Pin Technology	www.rupturepin.com
Tyco Flow Control	www.tycoflowcontrol.com

let contains an energy absorbing hinge that aligns with an unscored portion of the CSI rupture-disk perimeter that retains the CSI disk upon opening, avoiding fragmentation.

Should the disk in its holder be accidentally installed the wrong way, it will burst at or typically below its burst pressure. This "fail-safe" design feature is called the reversal safety ratio. If the CSI rupture disk is accidentally damaged, it will reverse at a reduced pressure and interact along its circular score line with stress raising features in the CSR-7RS Safety Head to open at a reduced burst pressure.

Relief valve improvements

In general, the design of pressure relief valves is not much different today than it was when the first spring-loaded models were invented in the 1800s, says Bert Lowden, president of Aquatrol, Inc. (Elburn, Ill.). "However, manufacturing technologies have improved over the years allowing valve makers to hold closer manufacturing tolerances, which have resulted in improved operation of the valves," he says. "Manufacturers have also changed the internal structure of the valves to maximize valve relieving capacities."

However, Rupture Pin Technology (Oklahoma City, Okla.), offers the Rupture Pin valve that Julian Taylor, president of the company, says is superior to rupture disks, spring-loaded conventional valves and pilot-operated valves. These valves consist of a piston on seat, restrained from movement by a slender round pin known as the buckling pin. The piston and seat have a bubble-tight seal while under pressure. The pin will buckle at set point from an axial force applied by the system pressure acting on the piston. Each valve is self-contained and self-acting. When the pin is buckled, the valve is full open in a matter of milliseconds, says Taylor. The pin is external to the system being protected and is tightly held in place at both pin ends.

Taylor says the benefits of Rupture Pin technology include the inability of the pins to fatigue, maximum operating pressures to 95% of set point, zero leakage to set point and nearly foolproof pin installation. ■

Joy LePree

DEVICE SELECTION

It is not always easy to decide whether a pressure relief valve, rupture disk or combination used in series is the most practical overpressure solution. Here, the pros and cons of each technology are considered.

Rupture disks

Rupture disks are preferred in many chemical processing applications for their simplicity and low cost, says Michael Zitariuk, global product manager for pressure relief with Fike (Blue Springs, Mo.). "They have no moving parts as they are made of a simple membrane that opens at a predetermined pressure and temperature based on the requirements of the application," says Zitariuk. "Because there are no moving parts, rupture devices are about as low maintenance as you can get. We recommend inspection at a minimum of annually, which — depending on the process, as long as you don't take it out from the holder — you can usually inspect and re-install if there's no visible damage or corrosion."

In addition, the simplicity of the disks allows them to be more cost effective in applications where corrosive media comes into play. It is much less expensive to fabricate a rupture disk and its holder from a specialty alloy than an entire pressure relief valve.

The ability to instantaneously open in overpressure situations and the fact that rupture disks do not leak or chatter make them more suitable than pressure relief valves in many processes. "Rupture disks provide a completely leak-tight seal," says Zitariuk. "Depending on how close the process is running to maximum operating pressure, valves can chatter, which often leads to the escape of some fugitive emissions and, in other situations, a valve may open and not seat properly after the event, leading to leaks."

Pressure relief valves

The primary advantage that a pressure relief valve has over a rupture disk is that the pressure relief valve recloses and the rupture disk does not, says Bert Lowden, president of Aquatrol (Elburn, Ill.). "When a rupture disk bursts, the system it is installed on must be shut down in order to install another disk," he explains. "When a pressure relief valve pops, it recloses itself after having relieved the overpressure condition, enabling the system to continue operation."

Obviously plant personnel should try to determine the cause of the overpressure condition to prevent its reoccurrence, but with a pressure relief valve, operation can temporarily continue and be restarted more easily if shutdown is required.

Combined forces

If you want the best of both worlds, pressure relief valves and rupture disks can be used together, with the rupture disk installed prior to the inlet of the pressure relief valve, notes Lowden. There are two common situations where processors tend to use the devices in series. The first is necessary isolation of the safety relieve valves from a corrosive process. When the chemical process environment is such that exposure of the pressure relief valve or its internals to the process chemicals can render the pressure relief valve inoperable, a rupture disk is often placed at the inlet of the pressure relief valve because it is leak free and will protect the valve from the damage that would otherwise be caused by the corrosive media, explains Steve Palmer, Strategic Operations Manager with BS&B (Tulsa, Okla.). In these cases, not only does a rupture disk prevent damage to the valve, it is also much less costly for the processor to install a Hastelloy rupture disk under a conventional pressure relief valve than it would be to have the relief valve made from Hastelloy, notes Lowden.

Another scenario for dual use would be when the leak-tightness of the rupture disk prevents the loss of very expensive or toxic materials. "A client once called me because he was extracting flavors and fragrances from orange peels and orchids," recalls Palmer. "These expensive vapors passing during distillation through the safety relief valve caused a significant loss of potential revenue for the company. This loss was eliminated simply by isolating the safety relief valve using a rupture disk."

Leak tightness is also important for environmental concerns, in that it can help prevent toxic chemicals from escaping into the environment. A rupture disk alone would remain open after an incident, allowing toxic chemicals to get into the atmosphere. And a pressure relief valve alone might chatter, allowing occasional escapes. But, in tandem, the devices will keep environmentally unfriendly gases within the process.

In each of these scenarios, if an over pressure did occur, the rupture disk would burst and then the pressure relief valve would pop and re-close. The system will now have to be shut down to replace the disk and examine the valve for damage, but not immediately because the relief valve would be closed and retaining pressure and process within the system, explains Lowden. (For more, see Combining Rupture Disks with Safety Relief Valves, *CE*, March 2009, pp. 42–44) ❑

CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
Department Editor: Scott Jenkins

Heat Transfer Fluids: System Filtration

OVERVIEW

Indirect heating of processes by organic thermal-liquid fluids offers highly reliable operation, and the heat transfer systems are generally treated as low-maintenance utilities. Occasionally, the heat transfer fluid can become contaminated, resulting in the formation of sludge particles, or other sources of dirt can infiltrate the system. This contamination can cause operational problems. The solid particulates can cause shaft-seal leakage in the circulation pump, valve stem wear, plugging of flow passages and sometimes fouling of heat exchange surfaces. After contamination, the fluid can sometimes be cleaned by in-system, side-stream filtration. For seriously fouled systems requiring more extensive cleaning, the heat transfer fluid can sometimes be cold filtered outside of the system. Side stream filtration may also enhance the performance of pump suction strainers on start-up of a system.

WHAT IS THE DIRT

Dirt can be a variety of materials, such as construction site debris left in the system, mill-scale that dislodges from the system piping during operation and reaction products of the heat transfer fluid with oxidizing agents, such as air, acids and process leaks to the heat transfer fluid.

Contaminants can also form insoluble products with metals, such as rust and metal oxides, in the heat transfer system. Some heat transfer fluids, when operated slightly over their maximum-use temperature limit, will form insoluble solids naturally.

FILTERS

For in-system filtration, experience shows that glass fiber-wound filter cartridges are generally the most satisfactory, since they can withstand system temperatures of 750°F (400°C), have excellent dirt-holding capacity, and are economical and disposable filter elements. Filters made of metal have the temperature capability, and can also be used. Earth filtration is not effective at high temperatures and should be backed up by mechanical filtration. The glass fiber-wound element size is generally 2.5-in. (6.4 cm) dia. with 10-in. (25 cm) incremental lengths. The glass fiber is wound around a perforated metal tube with the closeness of the fibers and the fiber size determining the particle-size removal capability of the element. The filtration is accomplished by the heat transfer fluid flowing radially inward, past the overlapping glass fibers and out of one end of the metal tube. The filter cartridges are fixed in the filter housing by a variety of end fixtures. The filter housing should be capable of high temperature operation. To help assure safe operation, the housing should meet local and national codes for the maximum heat-transfer-fluid temperature and the maximum system pressures expected in the heat transfer system. Many filter housings use O-ring elastomer seals, which are not safe for high temperature operation because they can lose strength and in some cases partially dissolve in the heat transfer fluid.

The seal should be made of a reinforced, flexible-graphite, flat gasket in a captured gland to help prevent fluid sprays in the case of gasket failure. Spiral-wound gaskets are a good choice for the filter housing. If springs are used to fix the filter cartridges in the housing, they should be made of materials that do not have much spring rate reduction at the maximum operating temperature. Carbon steel housings are adequate below 750°F (400°C) operation. If the decision is to filter the heat transfer fluid at ambient temperature, a large variety of filter media and filter types can be employed along with low-temperature filter housings. Media made of polyester, nylon and cellulose fibers are generally compatible at ambient temperatures. The filter manufacturer should always be consulted to determine the filter compatibility.

INSTALLATION & OPERATION

For the in-situ high-temperature operation, the glass fiber-wound filters can be placed anywhere there is a pressure drop between 20 and 40 psi (1.4–2.8 kg/cm²). The maximum flowrate through the filters should be no more than 1% of the main flowrate in the system and generally should not exceed 5 gal/min (18 L/min) per 10 in. (25 cm) of cartridge length. At the desired flow, the initial pressure drop through the filter should be 1 to 2 psi (0.07–0.14 kg/cm²). Under these conditions, one or more heat transfer system volumes should pass through the filter each day. To help protect the filter from excessive pressure drop, a bypass pressure-relief valve should be set at 25 to 40 psi (1.8–2.1kg/cm²). If there is a possibility of back flow through the filter, a check valve should be installed to help prevent filter rupture.

High-temperature gaskes made of reinforced flexible graphite or spiral-wound gaskets should be used to seal the filter housing cover. Elastomer O-ring seals are generally not stable enough for high temperature use. But as technology improves, O-ring seals are becoming viable, especially for use temperatures below 400°F (204°C). As is good practice in the rest of the system, the filter piping should be welded construction to reduce leakage. The filter housing can be insulated, but the insulation should be of a type that will not absorb heat transfer fluid (for example, cellular glass). The filter house should be placed in a location that is convenient to service. During operation, the pressure drop or flowrate through the filter should be checked and adjusted daily to determine if the cartridges need changing. If the pressure rise across the filters is gradual, it often will hold more solids before plugging. Hard solid particulates build a coating that can cover the string-wound texture of the filter, giving a glossy surface when wet. The used filters should be disposed of in an environmentally acceptable manner.

SIZING

Sample analysis determines the insoluble solids particle size level above 1 µm for used fluid samples. The insoluble solids level is determined by laboratory filtration through a 1-µm membrane filter with the solids on the filter being washed with acetone or pentane. These particles, larger than 1 µm, are responsible for the vast majority of problems in heat transfer systems. The units used to express the insoluble solids level are milligrams per 100 milliliters of filtered fluid or in parts per million (ppm). Assuming the heat transfer fluid and insolubles have a density of 1 g/mL, 1 mg/100 mL is equal to 10 ppm. The filters can generally capture between 40,000 and 100,000 mg of solids per 10 in. (25 cm) of filter length. Conservatively assuming the dirt-holding capacity of the filters to be only 40,000 mg per 10 in. (25 cm) of filter-element length, the number of 10 in. (25 cm) filter elements needed to clean up a system above the 1-µm nominal particle-removal rating of a glass string-wound filter usually can be determined through the following formula:

$$N = 0.00025\ (V)\ (IS)$$

Where N = number of 10-in. (25-cm) filter element segments
V = heat transfer system volume, L
IS = insoluble solids, mg/100 mL

While 1-µm filters could be used initially, there is always a danger of filter blinding or surface compaction. The better technique is to use a combination of nominal particle-removing elements starting out with coarse filtration, such as 50–100 µm elements and working down to 1–10-µm element levels. The frequency of filter element changeout needs to be balanced against the filter housing size, and the filter suppliers should be consulted on the filter housing sizing. Sometimes, depending on the nature of the insoluble solids and their level in the heat transfer system, the best clean-up method is disposal of the heat transfer fluid and total system cleaning. After the clean-up, a 5-µm filter should be kept in the system permanently as a continuous clean-up and diagnostic element to help detect any future contamination, should it occur.

REFERENCE

"Therminol Information Bulletin #3. Heat Transfer Fluid Filtration. How and Why" Pub. #72391238, Solutia Inc., 2004.

WHEN THE HEAT IS ON, PUT THE THERMINOL® PERFORMANCE CREW TO WORK FOR YOU.

In the heat transfer fluid race the competition can get pretty heated. That's why you need the Therminol® Heat Transfer Fluid Performance Crew working for you. From start to finish, the Therminol TLC Total Lifecycle Care® team of seasoned professionals is ready to support you with everything you need to win. For your people, we provide start-up assistance, operational training and a technical service hotline. For your facility, we offer system design, quality Therminol products, sample analysis, flush fluid & refill and a fluid trade-in program*. We provide everything you need to keep your heat transfer system at peak performance throughout its lifecycle. So join the winning team. In North America call 1-800-426-2463 or in Europe 32.10.48.12.11. You'll see no other heat transfer fluid delivers more proven comprehensive performance than Therminol.

www.therminol.com

THERMINOL®
Heat Transfer Fluids by Solutia

TLC

FOR YOUR PEOPLE
FOR YOUR FACILITY

Start-Up Assistance | Operational Training | Technical Service Hotline
System Design | Quality Therminol Products | Sample Analysis | Flush Fluid & Refill | Fluid Trade-In Program*

Therminol TLC Total Lifecycle Care is a complete program of products and services from Solutia designed to keep your heat transfer system in top operating condition through its entire lifecycle.

Circle 26 on p. 50 or go to adlinks.che.com/29253-26

AUGUST
New Products

3i's Technologies

Fluke

W.L. Gore and Associates

Get improved precision in batching and filling applications

This company's Rotary Scalpel technology (photo) can deliver small increments of a wide variety of solid materials with precisions of ±0.5 g. The technology consists of a large inlet area designed for consistent material flow feeding into a rotary feed drum, and a pneumatically controlled "scalpel" that ensures each vane of the feed drum is filled precisely, while the excess is recirculated to the material source. In batching applications, the Rotary Scalpel can be applied as a standalone batch-dribble system, or as a batch-dribble control system to complement a fast-fill batcher. It can also be used as a single-ingredient, loss-in-weight batch system, or as a single-ingredient, gain-in-weight batch process system. — *3i's Technologies, Vineland, N.J.*

www.3istech.com

Reduce filtration cost with these cartridge filters

A new family of cartridge filters (photo) can increase production capacity and reduce the total filtration cost for high-purity chemicals used in semiconductor fabrication and other microelectronics-manufacturing processes. The new filter family incorporates this company's proprietary expanded polytetrafluoroethylene (ePTFE) filtration media, allowing improved particle retention, higher flowrates and faster processing times. — *W.L. Gore and Associates, Inc., Elkton, Md.*

www.gore.com

Use this oxygen meter in field or laboratory applications

Designed for use both in the field as well as in the laboratory, the DOB21 benchtop dissolved-oxygen meter (photo) is ideal for testing water, wastewater, biological samples and others. The instrument automatically compensates for temperature, salinity and barometric pressure, and features automatic calibration. The DOB21 has a three-button keypad for programming and can log up to 99 data points. — *Omega Engineering Inc., Stamford, Conn.*

www.omega.com

This calibrator handles both analog and digital instruments

The 5080A multi-product calibrator (photo) handles both analog and digital test instruments. Its high voltage and current compliance allows the 5080A to calibrate accurately and economically. The instrument is said to be easy to use and works with analog meters, panel meters, digital multimeters and watt meters. With optional accessories, the 5080A can also calibrate clamp meters, megohmeters and oscilloscopes to 200 MHz. The calibrator incorporates pro-

Note: For more information, circle the 3-digit number on p. 50, or use the website designation.

New Products

tection circuitry that prevents it from being damaged by reversed input voltage. The 5080A includes tools to create calibration procedures quickly without programming, automate calibration, store calibration records and export data. — *Fluke Corp., Everett, Wash.*
www.fluke.com

No tipping required with this bin unloader

With a new system from this company, filled bins can be unloaded from the top without the need to tip the container. Designed for unloading tablets, the system features a smooth-moving suction wand that is controlled by a level-detection mechanism. Tablets do not have to flow under loads from the top, as is the case in discharging from the bottom under gravity. The whole system is designed to work under clean conditions, including filtration of all the conveying air needed to aspirate and move the tablets. — *Volkmann GmbH, Soest, Germany*
www.volkmann.eu

A portable videoscope system with a 7-in. screen

A new Portable Videoscope System (photo) is designed to meet the demands of the industrial inspection environment, with a self-contained system that combines state-of-the-art video technology, cordless operation, compact portability and rugged durability at an affordable price. The Portable Videoscope System is well suited for inspection of bridges, drill pipes, turbines, airframes, power generation equipment, process tanks and vessels, tubing and pipes, heat exchangers and hydraulic cylinders and other locations that are difficult to reach. The system offers a choice between a miniature, waterproof, 1-in. dia., removable, 120 deg field-of-view, color CCD (charge-coupled device) camera head with built-in, bright LED lighting or a waterproof, 1.5-in. dia., removable, 360-deg pan and 180-deg tiltable, color CCD camera head with built-in, bright LED lighting. Mounted to the end of a flexible, retractable push rod, the system's camera can easily negotiate 90-deg bends and inspect lengths up to 98 ft. — *Lenox Instrument Co., Trevose, Pa.*
www.lenoxinst.com

This sensor can be used with many energy-harvesting systems

EH-LinkT is a wireless sensor node that can draw power from a host of energy-harvesting systems, including strain, vibration, thermal gradients, solar, electromagnetic fields and piezoelectric harvesters. The device is compatible with any analog transducer, and so can be used with strain gages, load cells, torque sensors, pressure transducer and magnetic sensors. In addition to multiple harvesting inputs, EH-LinkT features an onboard triaxial accelerometer, as well as sensors for temperature and relative humidity. — *MicroStrain Inc., Williston, Vt.*
www.microstrain.com

A flowmeter with averaging pitot tube

The Deltatop differential pressure flowmeter (photo) includes an averaging Pitot tube, which provides excellent accuracy and reliability. Intended for accurate flow measurement on liquid, gas or steam, Deltatop flowmeters are designed specially for applications in accordance with ASME B16.36. The flowmeters are available with flanges of class 300 to 2,400. The flowmeters design makes it clog-free and precise, with a high signal-to-noise ratio. — *Endress+Hauser Inc., Greenwood, Ind.*
www.us.endress.com

A single-use-temperature sensor that needs no calibration

This disposable temperature sensor can be used for filtration and chromatography processes, as well as filling operations and general processing. The single-use sensor is connected to a monitor via a reusable 10-ft cable. The sensor will stand up to gamma-wavelength radiation, and is available in a wide range of sizes. It is accurate to within ±0.2°C and can measure temperatures between 0 and 70°C — *PendoTech, Inc., Princeton, N.J.*
www.pendotech.com

Zoneworks

Fabric containment enclosures that are fully configurable

Zoneworks enclosures (photo) are designed to provide enclosure to rooms or individual instruments for control of environmental conditions such as temperature, humidity, sound, odor, dust fumes and more to protect plant employees. Constructed of modular vinyl panels, the enclosures can be reconfigured for use in internal, external, conditioned or ambient surroundings. — *Zoneworks, Milwaukee, Wisc.*
www.zoneworks.com

These sensors have built-in transmitters that can communicate with digital and analog interfaces

ARC sensors feature a built-in microprocessor that can communicate with both analog and digital interfaces. The sensors are designed to measure pH, dissolved oxygen and conductivity. The built-in transmitter saves cost by eliminating the need for separate transmitters, and the signals produced are more robust and reliable than in classical measurement systems, says the company. ARC sensors can be precalibrated and configured in the laboratory, reducing installation time and downtime. — *Hamilton Co., Reno, Nev.*
www.hamiltoncompany.com

This filtration system optimizes downstream purification steps

Cadence tangential flow filtration (TFF) systems are designed to optimize downstream purification steps in biopharmaceutical manufacturing. The Cadence module incorporates a patented fluid-path design, enabling direct flow operation with a substantial reduction in system holdup volume. Cadence modules feature multiple TFF cassettes in series, which results in high conversions of feed-to-permeate in a single flow path. The Cadence also features a compact design requiring less production space. — *Pall Corp., Port Washington, N.Y.*
www.pall.com

Control medium-consistency fiber slurries and pulp stock with this valve

The V150E Vee-Ball valve features an expanded outlet that makes it effective at handling medium-consistency fiber slurries as well as pulp stock. The valve has a transitional flow contour that increases in flow area from inlet to outlet. Designed for installation directly on a medium-consistency

New Products

Malvern Instruments

pump-discharge flange, the V150E accommodates larger-diameter transfer lines. Its control element is a segmented V-notch ball, which has natural shearing action that is ideal for slurry flows. — *Emerson Process Management, St. Louis, Mo.*
www.emerson.com

This size analyzer is intended for battery designers

The Mastersizer 2000 (photo) laser-diffraction particle-size analyzer allows comprehensive characterization of small-sized particles often used in production of advanced battery electrodes. Designed to be fast and accurate, with a dynamic range of 0.2 to 2,000 µm, the Mastersizer features consistent sensitivity across this range. — *Malvern Instruments Inc. Malvern, U.K.*
www.malvern.com

Monitor particulate emissions with high accuracy

The Model PM 100 particulate-flow and emissions-monitoring system provides continuous realtime and averaged analysis of particulate emissions for compliance with U.S. Environmental Protection Agency (EPA) regulations. Designed for fabric filters, cyclones and process particulate flow monitoring, the PM 100 features short- and long-term averaging, high-accuracy, low-level monitoring and is compatible with several types of communications devices. As particles flow near and around the probe, a small charge is induced, which is processed into an absolute output that is proportional to mass flow. — *Filtersense, Beverly, Mass.*
www.filtersense.com

Lower NOx emissions with this burner

The ECOjet burner is designed for ultra-low NOx emissions when using a wide range of gaseous fuels, including natural gas, propane, refinery gas, landfill gases and offgas, as well as liquid fuel oils. The company says each aspect of the burner was strategically developed and tested. The burner features a staged-gas design to provide stable flames, and is applicable to package, industrial and utility boilers ranging from single- to multiburner arrangements. The ECOjet is available in capacities up to 400 MBtu/h, and can lower NOx emissions to less than 30 ppm without fluegas recirculation. — *Hamworthy Peabody Combustion, Inc., Shelton, Conn.*
www.hamworthy-peabody.com

These capacitance probes offer flexible time delays

ProCap dual-timer capacitance probes for level detection can be set to react immediately or with up to a 30-s delay when they detect a covered or uncovered condition. ProCap probes can be

used for high- and low-level detection in tanks, silos, bins, hopppers, chutes and other vessels used for material storage or process manufacturing. For example, the capacitance probe can be set to send an immediate alert when it reaches a covered state, but can be set to alert with a 15-s delay when it detects an uncovered state. The probes do not interfere with two-way radios or other equipment operating in the radio-frequency spectrum, and can be adapted to a variety of solid, liquid and slurry materials with a wide assortment of extensions. — *BinMaster Level Controls, Lincoln, Neb.*
www.binmaster.com

Achieve flows up to 400 gal/min with these cartridge filters

This company's new High-Flow Series cartridge filters can achieve flowrates of up to 400 gal/min for some applications. The series is a new line of horizontally mounted filter vessels containing between one and 18 high-surface-area pleated filter cartridges in either 40- or 60-in. lengths. The products are offered in carbon steel, as well as 304 and 316 stainless steel, and are designed for fast cartridge changeout. The flow path runs from inside-out, ensuring that collected solids stay inside the filter cartridges as they are removed. — *Rosedale Products Inc., Ann Arbor, Mich.*
www.rosedaleproducts.com

This excipient reduces tablet manufacturing costs

Methocel Direct Compression (DC) premium grade hypromellose polymers can reduce the costs of manufacturing pharmaceutical tablets by enabling processes that eliminate the wet granulation step. The polymers exhibit improved powder flow properties by virtue of their specially engineered particle morphology and size distribution. The result is the ability to carry out direct compression of tablets without the need for wet granulation. Methocel DC polymers offer comparable performance with regard to drug formulation attributes, including tablet hardness and controlled release drug action, to equivalent Methocel products. The new excipient also holds the same regulatory status as existing related excipi-

New Products

ent polymers. — *Dow Wolff Cellulosics, Horgen, Switzerland*
www.dow.com

This spill container is designed with a low-profile

The Ultra-Rack Sump is designed to accommodate up to four 55-gal drums on standard 40- by 48-in. or 48- by 48-in. shipping pallets. Its low-profile design remains positioned in the warehouse rack while allowing forklift access to a wooden pallet. Constructed out of high-visibility polyethylene, the spill-containment unit is resistant to chemicals and corrosion. — *Ultratech International, Inc., Jacksonville, Fla.*
www.spillcontainment.com

Submersible mixers with longer service lives

The new AmaRoc mixer stand was developed as a secure and durable foundation for the firm's AmaProp submersible mixers with their large (up to 2.5-m dia.) propellers. The propeller is capable of absorbing all forces generated by the mixer and of safely transferring these forces to the foundation of the sedimentation tank. As a result, the guide rail remains unaffected by the mixer forces. The rail only serves to keep the mixer in the correct position, so pipes can be laid up to 12 m long. The AmaRoc is made from NoriRoc, a polymeric composite material that dampens vibrations and is highly resistant to abrasion. — *KSB AG, Frankenthal, Germany*
www.ksb.com

This water-in-solvents analyzer offers cost savings

The MCP-200 is an infrared (IR) spectroscopy-based analyzer (photo) for real-time determination of water concentrations in a wide variety of solvents and gases, including hexane, acetone, oils, urea, gasoline, aniline, acetophenone and carbon dioxide. The company says it offers cost savings through long-lasting components and a reduction in the amount of work needed by laboratory personnel. The instrument continuously monitors a wide range of water concentrations and can withstand tough industrial conditions. — *Applied Analytics, Inc., Concord, Mass.*
www.a-a-inc.com

Handle sluggish materials with this conveyor

The Helix Hi/Lo flexible screw conveyor (photo) is designed for handling sluggish or non-free-flowing materials without the need for separate in-hopper agitation. The system encourages discharge of sluggish solids with an optional mass-flow hopper with a steep conical shape, and optional external vibration. The Helix is ideal for materials with high moisture content. The unit conveys material to heights of up to 12 ft and at rates up to 25 ft³/min. — *Hapman, Kalamazoo, Mich.*
www.hapman.com

A sifter designed with sanitation in mind

The QA36 Inline sifter is said to be ideal for HACCP solutions with a high level of sanitation required. Designed for moderate to high production volumes, the QA36 utilizes a gentle gyratory motion to reduce product degradation. The sifter's design is such that it can be inserted directly into a vacuum or pressure dilute-phase pneumatic conveying system. — *Great Western Manufacturing, Leavenworth, Kan.*
www.gwmfg.com

A new textile material that eliminates the need for padding

Deflexion technology is a performance textile and impact-absorbing material that is designed to protect without the added bulk and stiffness of traditional padding. The impact-protection technology is based on silicones and is suitable for a wide range of products, including apparel, luggage, footwear, equipment and medical devices. — *Dow Corning Corp., Midland, Mich.*
www.dowcorning.com

Remove iron from products, even in hazardous zones

The newly developed overbelt electromagnets are suitable for dusty, explosion-sensitive environments in ATEX 22 zones. These magnets are suitable for removing iron particles from recycling or bulk-handling material flows, such as wood, garbage, refuse-derived fuel (RDF), hard coal and cement. The conveyor belts are durable, so they easily capture separated iron particles and cast them off. An auxiliary magnet ensures removal of the iron from the magnetic field. An optional heat exchanger with fan can be added to control the cooling of the magnet. — *Goudsmit Magnetic Systems BV, Waalre, the Netherlands*
www.goudsmit-magnetics.nl

A seated ball valve with interchangeable ball and seat

A new line of Krombach Metal Seated Ball Valves features machining of the ball and seat to such high tolerances that ball-and-seat lapping does not have to be performed individually for each valve. The tight tolerances make the ball and seat freely interchangeable. Designed for specialty chemicals and mining applications, the valves feature a two-piece construction with a flange connection, as well as a self-cleaning system to remove excess particles, minimize leakage and extend

product life. — *Crane ChemPharma Flow Solutions, Cincinnati, Ohio*
www.cranechempharma.com

New, efficient decanters for environmental applications
Efficient acceleration of the product in the feed zone combined with an optimized discharge system enables the new C-Series environmental decanter line to boost a reduced power consumption of up to 20–30% for capacities of 20 to 90 m^3/h. This leads to a "huge monetary advantage," says the manufacturer. A complete revision of the decanter's bowl drive makes it possible to increase the capacity of the machines by 10–20%. As a result, a smaller machine can be used for the same federate, which means a lower investment cost and higher processing performance. — *Flottweg AG, Vilsbiburg, Germany*
www.flottweg.com

These sludge-dewatering belts feature a new seam
With dewatering belts made of polyester or polyphenylene sulfide, considerably dryer sludges can be attained in aerial dryers. These synthetic meshes cover working temperatures ranging from 80 to 200°C and pH values of 1–14. The belts, woven from robust monofilaments and given extensive subsequent treatment, can stand extremely high surface loads. Their specific structure also ensures excellent cleaning of the belt. The patent-pending GKD-PAD seam further develops the conventional hook seam, thereby providing operators with a considerably thinner seam than the previous glue-compressed seam while maintaining the high quality standards. The hook seam, which is covered by a textile pad, is melted and pressed together with glue into the mesh using a novel heating press. The seam is not only easy to use but also particularly durable and persistent. The GKD-PAD seam has proved its worth in various applications, especially in the sewage sludge dewatering and the fruit juice industry running on twin-wire belt presses. — *GKD – Gebr. Kufferath AG, Düren, Germany*
www.gkd.de

When space is limited, consider this ultrafiltration rack
The T-Rack vario ultrafiltration module is said to have a 60% smaller footprint than conventional racks. The unit's modular design means the rack can be configured to match each user's specific requirements. Each row can be operated as a separate filtration line, thereby maximizing flexibility in day-to-day operations. The feed and drain pipes are integrated into the end caps of the headers and the filtrate connections are welded to the module bodies and headers. There are no O-rings, and all flanges of the header pipes are mounted in the same plane.

Circle 14 on p. 50 or go to adlinks.che.com/29253-14

New Products

Modules can be configured in either two or four rows. — *inge watertechnologies AG, Greifenberg, Germany*
www.inge.ag

These connections are for gas & cryogenic applications
This line of connection solutions for demanding gas and cryogenic processing applications maintain safety and performance while reducing cost through faster fill times. The connection solutions comprise high-end flexible hoses and fittings with anti-whip armor casing that restricts violent movement during pressure surges, and contains gases in the case of leakage. All hoses and fittings in this line are designed for faster filling and lower production costs. — *Saint-Gobain Performance Plastics, Akron, Ohio*
www.saint-gobain.com

MKS Instruments

This ball valve accepts multiple input power signals
The electrically actuated Polypro valve will automatically accept virtually any input power signal. Designed for both water and chemical applications, Polypro valves are are available in sizes from 3/8 to 2 in. The electrical actuator can be assembled to the valve or sold separately. — *Plast-O-Matic Valves Inc., Cedar Grove, N.J.*
www.plastomatic.com

Use this valve in high-demand applications
The High Cycle Valve (photo) is a durable vacuum valve designed for demanding applications where a long cycle life is critical. The small, light and durable valve is rated for 10 million cycles, and is available with an air solenoid for electropneumatic control of the valve. It features a new formed-stainless-steel bellows to prevent outgassing, virtual leaks and particle entrapment. The valve is available in angle, inline and internal-only configurations. — *MKS Instruments, Inc., Andover, Mass.*
www.mksinst.com ■

Scott Jenkins

Successful revamps

My first distillation dream occurred about 30 years ago, and yet, I recall it as vividly as if it were yesterday. In it, my distillation-column design work started with a vapor-liquid thermodynamic model that was widely regarded as perfect. I had operating data from ten similar columns. The feed composition was precisely known, and there were no alternative feedstocks. The overhead specification was easy. The bottoms specification was easy. After determining the tray count, I added another 20%. After determining the column's cross-sectional area, I added another 20%. The column started and ran so smoothly that the plant manager eventually named his first three children "Mike," and two of them were girls.

Few, if any, distillation design engineers have ever had real experiences like the one of my dream. Very few plant managers' daughters are named Mike. More importantly, a very large portion of distillation engineering is revamp work — taking an existing column and increasing its capacity or improving the product purities or reducing its energy consumption.

It is never easy for a distillation engineer to take a bottlenecking distillation column and increase its capacity by 20% while increasing the product recovery by 10% and accommodating three different feedstocks. New contacting equipment, however, has facilitated such revamps.

Starting around 1970, many new packings and trays became available. Fractionation Research, Inc. (FRI) became the proving ground for most of those new products. Prior to 1980, FRI issued fifty-three Topical Reports regarding trays and only eight Topical Reports regarding packings. Subsequently, at least half of FRI's research work was packing related. As vendors developed superior random packings and distributors, FRI validated the vendors' claims and illustrated the critical importance of good initial distributions and the occasional need for redistributions. When structured packing came onto the scene, distillation "doubters" worried about fouling, costs, installations, inspections and more. Within a few years, however, trays were removed from the majority of ethyl-benzene recycle styrene columns, and structured packings were the new standard there. Prior to 2000, FRI issued only seven Topical Reports regarding structured packings. Subsequently, there have been 12.

Trays, however, would not go away. Augmented crossflow trays were developed, and then came counterflow trays and then came cocurrent flow trays. FRI tested most such trays. Imagine a contacting device wherein vapor and liquid streams flow, at least momentarily, in the same direction! FRI tested those, too. One such tray was tested in a sleeve, to prevent the FRI operators, engineers and members from seeing its highly confidential design.

Some of the new contacting devices that were tested at FRI performed below expectations. Those products were deemphasized or withdrawn from the marketplace by the product owners. Any plant manager will affirm that it is better to withdraw a device from the marketplace than withdraw it from a failed distillation column. ■

Mike Resetarits

Mike Resetarits is the technical director at FRI (resetarits@fri.org).

FRI is a distillation research consortium headquartered in Stillwater, Okla. Each month, Mike shares his first-hand experience in this column.

October 19 - 21, 2010 | Reliant Center, Hall E | HOUSTON, TEXAS

CHEM|INNOVATIONS 2010 CONFERENCE & EXPO

CONNECTING WITH THE FUTURE OF THE GLOBAL CHEMICAL PROCESS INDUSTRIES

ARE YOU 'IN'?

HERE ARE FOUR REASONS WHY YOU SHOULD BE:

LOCATION: Houston, Texas. ChemInnovations is strategically located in the center of North America's CPI.

NETWORKING: Meet face-to-face with 200+ exhibitors and over 125 speakers.

CONTENT: An in-depth conference to help solve your biggest processing challenges.

BUGDET SAVER: Get deep attendee discounts with early registration. We have all the tools you need to get approval, save money and increase ROI for your company!

Register early at **cpievent.com**
with code: CHEMREG

CO-LOCATED WITH

ISA Houston Section

HART COMMUNICATION FOUNDATION

PRESENTED BY

CHEMICAL ENGINEERING

PRODUCED BY

TRADEFAIR GROUP™ An Access Intelligence Company

STRATEGIC PARTNERS

chemicalweek

POWER

SRI CONSULTING A Division of Access Intelligence, LLC

HCS Harriman Chemsult Ltd

DIGITAL PLANT™ • INCORPORATING DATATECHPLANT

MBS GLOBAL CONFERENCES. STUDIES. PROJECTS.

MAACK BUSINESS SERVICES Plastics Technology and Marketing

WHO'S WHO


Nakata


Hertle


Moncrief


Stefano


Glaser

Masaaki Nakata joins **Malvern Instruments Ltd.** (Malvern, U.K.) as regional sales manager for process systems for Japan and the Asia-Pacific region.

Engineering and environmental consulting firm **GHD** (Sydney, Australia) promotes *Chris Hertle* to global market leader for the water sector.

Total Exploration & Production (Paris) announces the following: *Michael Borrell* becomes senior vice-president, continental Europe and Central Asia; *Arnaud Breuillac* becomes senior vice-president, Middle East; *Ladislas Paszkewicz* becomes senior vice-president, Americas; and *Michel Seguin* becomes special advisor to the company president.

Philip Moncrief joins engineering and IT firm **CDI Corp.** (Philadelphia) as senior vice-president and general manager of the Process & Industrial Div. in Houston.

Wilmington Machinery (Wilmington, N.C.) appoints *Andreas Lehnhofer* director of operations and product manager for the Injection Molding Div.

Wayne Devonport, Ph.D., joins **Arkema Emulsion Systems** (Cary, N.C.) as a global coatings research leader.

Novasep (Pompey, France) names *Stephen Stefano* president and CEO of Novasep North America, and *Patrick Glaser* president and CEO of the Novasep Synthesis Div. ■

Suzanne Shelley

Fine-tuning Pump Vibration Diagnostics

Advanced troubleshooting techniques are required for lesser-known, yet consequential, pump vibration issues

Maki Onari and Paul Boyadjis
Mechanical Solutions Inc.

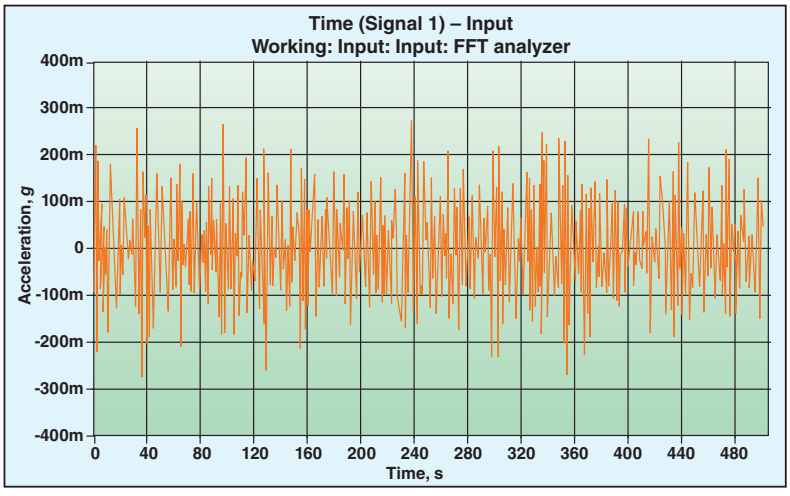


FIGURE 1. Plots of acceleration of the equipment versus time can be used to interpret pump vibration over relatively long time intervals

To unearth the fundamental causes of vibration-related pump troubles, pump end-users and original equipment manufacturers (OEMs) typically have relied on a concise array of vibration field-test parameters. Conventional trial-and-error vibration troubleshooting methods often fail to achieve the longterm, trouble-free pump operation sought, yet they can be time-consuming and increasingly costly to apply.

Traditional measurements consist of several vibration readings from the bearing housings and occasional displacement readings from the pump shaft. They are recorded during both transient and steady-state operating conditions of the pump. In approximately 90% of cases, the source of excessive pump vibration (for instance, rotor imbalance, misalignment or bearing damage) can be diagnosed with traditional readings from the bearing housings.

The residual 10% of pump vibration problems are more subtle, but can nevertheless generate chronic reliability issues, such as the premature wear of bushings and seals, bearing failures, structural cracks and looseness, coupling failures, and, in extreme cases, broken shafts. The synchronous excitation of structural natural frequencies is one relatively common example of the source of a difficult, chronic, vibration-induced pump problem. Difficulties also can result from sub-synchronous and super-synchronous vibration issues, which are caused by rubs, fluid dynamic instabilities, or resonances with higher-order excitation sources, such as vane-pass frequency.

Skillful troubleshooting is required to isolate the pump problem's source, and often it can be performed successfully by experienced plant personnel. Alternatively, the OEM or a qualified consultant can provide experience and modern tools for identifying and solving pump vibration problems.

Examples of the advanced tools that can help resolve pump vibration problems include analysis of vibration-versus-time plots and orbit plots, as well as vibration-versus-time trending and vibration-versus-frequency analysis (fast Fourier transform; FFT). Additional high-level analysis techniques also are used, such as operating deflection shapes (ODS) and experimental modal analysis (EMA), or "bump" testing, combined with finite element analysis (FEA).

When combined with FEA, vibration testing creates an outstanding toolset, and becomes especially valuable when good engineering judgment and experience alone have not been successful in the diagnosis and correction of vibration problems in centrifugal pumps and other types of turbomachinery. When properly applied, the ODS and FEA toolset has an outstanding track record of rapidly diagnosing and solving machinery-vibration problems. Testing and analysis costs are negligible compared to the net expenditures from repeatedly rebuilding damaged machinery components and from the associated downtime of the plant.

VIBRATION MEASUREMENT

Excessive vibration in rotating machinery is a frequent problem in a wide range of facilities, from power plants and petroleum refineries to pumping stations and wastewater treatment plants. Excessive vibration can waste energy through the wear of internal seals, as well as cause noise, environmental damage and physical danger because of exterior seal failures. Acute vibration levels ultimately can lead to catastrophic malfunction of costly rotating machines.

Aided by specialized instrumentation, the amplitude of vibration at key frequencies in rotating machinery can

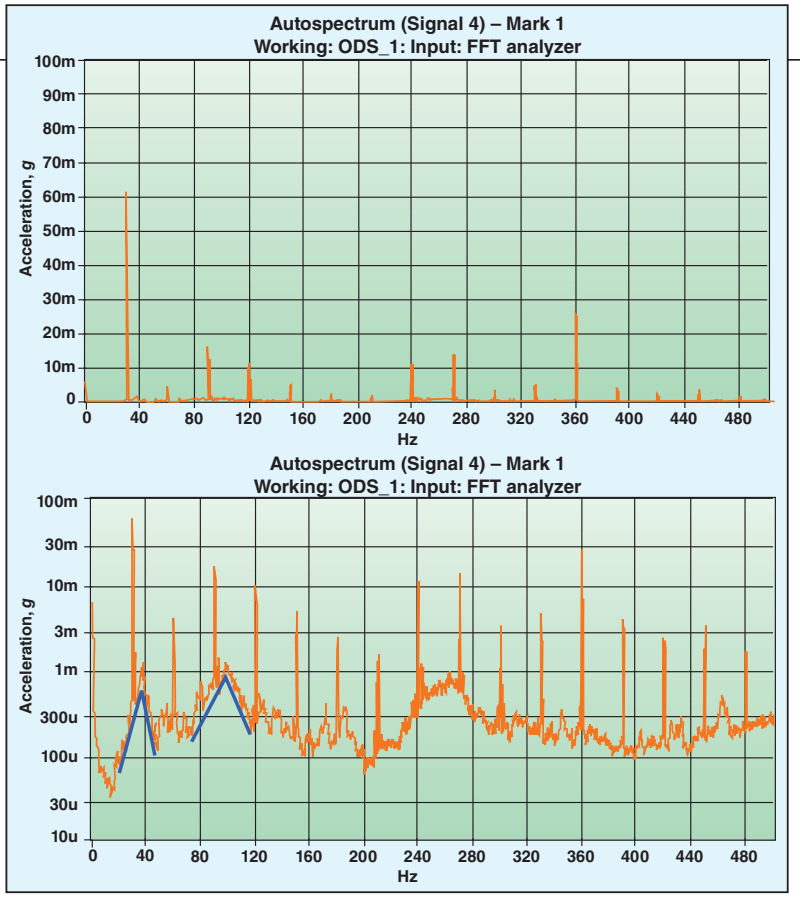


FIGURE 2. The scale of the vibration amplitude can be depicted either linearly (top graph) or logarithmically (bottom graph). Logarithmic scales often amplify broadband floor-noise to indicate key information for troubleshooting

be measured and recorded. With a fundamental understanding of vibration theory, these data can be used to characterize the "health" of the equipment, and can help suggest which corrective actions should be instituted.

Vibration fundamentals

In general, any mass with elasticity is capable of vibrating. Vibration can be classified as either free or forced vibration. Free vibration occurs when a system oscillates freely after a previously applied excitation, while forced vibration occurs when external forces excite the system. When the frequency of the external force coincides with the natural frequency of the system, resonance results. Resonance causes the system to vibrate with elevated amplitude, and should therefore be avoided.

Measuring machine vibration

Whether performing vibration measurements for routine condition monitoring or for specialized troubleshooting, the instrumentation required to collect the data depends on the application, the location and the purpose. For example, eddy-current proximity probes are used to measure shaft vibration in terms of the displacement response relative to the bearing housing, and provide data in units of mils (0.001 in.) or microns (μm). Velocity sensors are used to measure vibration in terms of the velocity response in units of inches per second or millimeters per second.

To measure vibration on the equipment bearing housings and casings, piezoelectric accelerometers typically are used. These transducers measure absolute vibration in terms of the acceleration response, often in units of *g* (average acceleration due to Earth's gravity). They can cover a wide frequency range, typically in excess of 10 kHz, and have resonant frequencies on the order of 50 kHz. Modern accelerometers are designed to reliably measure low-frequency vibration response down to 1 Hz, and in special cases, below 1 Hz.

When calculating the vibration response in terms of velocity or displacement, however, the measured acceleration should be integrated cautiously. Because each vibration peak is divided by its frequency in this process, integration errors could occur at low frequency spikes, where a small amount of low-frequency noise appears to translate to a substantial amount of displacement response, when in fact it is not.

Proximity probe data do not require integration since the proximity probes measure the relative displacement directly. Hence they are free of integration error at low frequencies and typically are considered adequate for frequencies up to several kilohertz, which is sufficient for pump applications. Probes that measure velocity directly also are available, though the construction of these probes results in a relatively limited frequency response range. In general, accelerometers are preferred over velocity probes, even though a degree of integration error will be present in the recorded data at lower frequencies.

Proximity probes are thread-mounted through the bearing housing cap or on a bracket that is located adjacent to the housing. These sensors are powered through a "proximitor" box which also converts the direct current (d.c.) output voltage into displacement measurements. Accelerometers usually are available with magnetic mounting bases for temporary use, but also could be thread-mounted to the pump casing with a stud of the appropriate thread size. For temporary use on non-magnetic surfaces, such as concrete, plastic, aluminum, or austenitic steels, the accelerometers can be mounted with an appropriate wax for relatively low-temperature applications, and with an epoxy for applications the are moderately above ambient temperature. Hand-held attachments also can produce good results if performed by a properly experienced technician and if taken at the same location on the equipment each time. To avoid grounding issues between the pump casing and the data analyzer, accelerometers always should be isolated electrically.

Accelerometers vary in construction in accordance with the applications for which they have been designed. For example, in high-temperature accelerometers, the signal conditioning electronics are located remotely from

the actual sensor to minimize the exposure to elevated temperatures of the sensitive electronics. Special models are made with an integral sealed cable connection for submersible applications, such as below-ground structural measurements on vertical pumps.

To measure simultaneously in one, two, and three perpendicular directions, accelerometers are available in single-axis, double-axis, and triple-axis configurations, respectively. Accelerometer sizes also vary greatly to suit different applications, and can be as small as 5 mm long and can weigh as little as 0.2 g. The typical accelerometer used for vibration troubleshooting purposes is about 25 mm long, weighs about 30 g without the magnetic mounting base, and features a housing with an integral 19-mm hexagonal cross-section to accept a wrench, should fastening to equipment via threads be required.

Additional instrumentation that can be of great value for troubleshooting includes the following:

- Dynamic pressure transducers to measure pressure pulsations and piping-system acoustic natural frequencies
- Microphones and hydrophones to perform cavitation testing
- Strain gages to measure the strain on casing nozzles, piping and shafting to calculate the mechanical stresses or the shaft torque
- A telemetry system or slip rings are necessary to measure the strain on rotating shafts

Recording vibration

Signal analyzers are used to provide power to the piezoelectric transducers and to record and process the raw vibration-data signals. The collected streams of data initially are in the time domain (that is, waveforms described in terms of amplitude versus time; Figure 1). Most modern versions of signal analyzers also process the complex raw-data signals internally into the typically more data-friendly format of amplitude versus frequency, by rapidly performing a mathematical operation known as the Fourier transform (FT).

Vibration signal analyzers can be classified into several broad categories. One popular type is the handheld portable signal analyzer, which typically possesses one or two channels and is equipped with memory to record the vibration data. Often they are utilized on a periodic basis by end users to collect routine vibration measurements. The collected vibration data are used to monitor the dynamic behavior of the equipment over time as part of an overall predictive maintenance program for a facility. This program usually is focused on vibration data that are taken at bearing housings where the interaction between the shaft natural response and the casing structure is dominant.

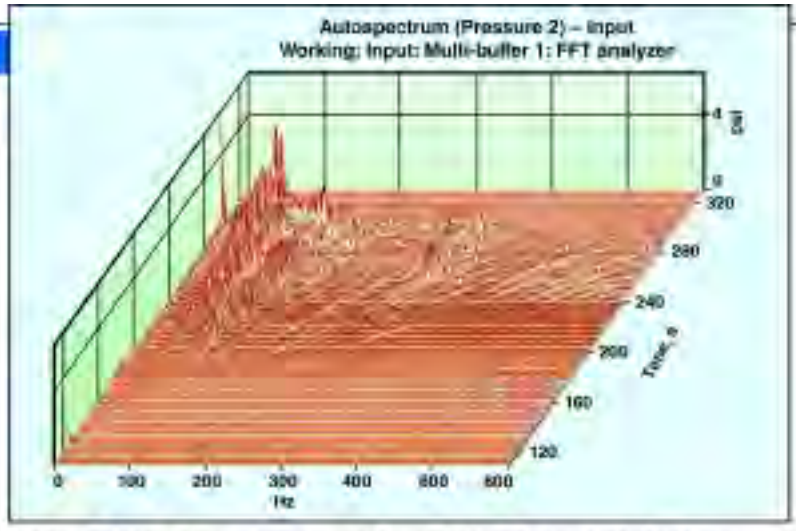


FIGURE 3. Three-dimensional waterfall plots display a related set of FFT spectra along a third axis, usually representing time, or in some cases, speed change

The multichannel analyzer is another common type of vibration signal analyzer used for troubleshooting. Usually multichannel analyzers incorporate from 4 to 40 or more input channels to record large volumes of vibration test data simultaneously. Situations that require such large amounts of data occur particularly when monitoring the responses of equipment during transient conditions (for example, throughout machine start ups, shut downs and variable speed or load operation).

Signal analyzers must be set up in accordance with the pump condition and the events that will be evaluated prior to recording the vibration measurements. This requires, for example, the definition of the frequency span that will be recorded, with 1.5 Hz to 1.6 kHz being a common frequency range. The frequency resolution or the number of lines in the frequency span, which falls typically between 50 and 6,400 lines, also must be specified. The types of data-averaging available are instantaneous or linear for the periodic and stationary conditions, or could be instantaneous or exponential for a transient condition. On some analyzers, a "peak-hold" option also can be selected, which maintains the highest vibration peaks that occur during transient conditions.

In addition, the signal analyzer requires the input of the high-pass filter setting, which is the minimum frequency of interest. For example, the frequency response of interest might require a filter setting from d.c. voltage to a frequency above 0.7 Hz, 7.0 Hz or 22.4 Hz. A high-pass filter setting that is too low can result in measurements that tend to "hang-up" due to constant overloading of the amplifier, combined with a long time constant for the overloaded amplifier to "clear."

Cables connect the instrumentation to the signal analyzers. Designed to minimize electrical noise, the cables used in troubleshooting typically consist of twisted pairs or use coaxial shielding with the shield grounded at only one end to avoid ground loops.

Displaying vibration test data

The signal analyzer displays the raw vibration-data waveform signal as a continuous plot of vibration amplitude versus time. Usually this type of plot is a complex combination of superimposed sine waves. It is used to interpret pump vibration over relatively long time intervals, or during pump transient events when variations of the speed and load are present (Figure 1 and 6). This plot type is also used when

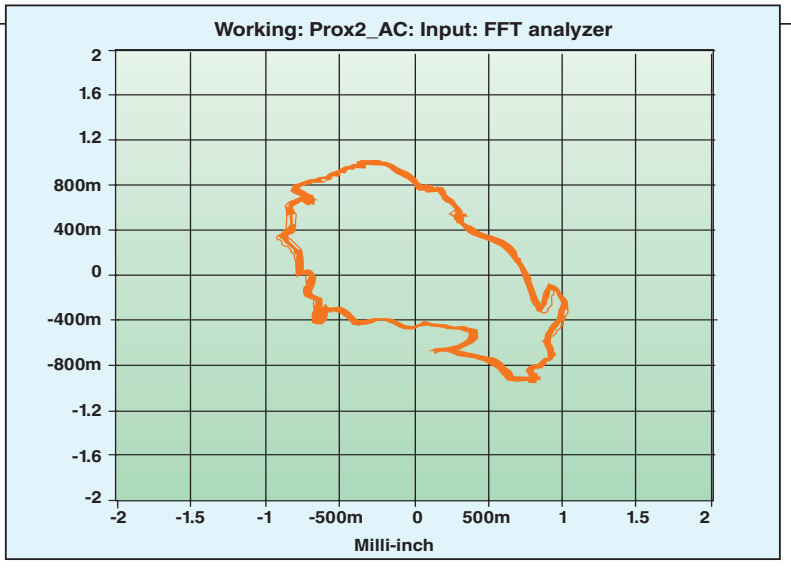


FIGURE 4. Orbit plots display the radial 2-D motion of the shaft center of a machine. They are based on vibration data that have been recorded on the bearing housing

rubbing or cavitation are suspected. The time trace allows the analyst to identify particular events that are related to nearly instantaneous changes in the process or system, including events such as cavitation phenomena, which appear as discrete "spikes" in the continuous data signal.

When the vibration event occurs periodically over time as a function of the rotational speed, FFT plots generally are more useful in investigating test data. Experimental modal analysis is a notable exception to be discussed later. These frequency spectra are calculated in the signal analyzer during the steady-state operation of the pump. The signal analyzer linearly averages a large number of vibration samples, with each sample covering a relatively short period of time (on the order of a second), depending on the frequency range and the number of lines in the spectrum. The spectra allow the analyst to identify the predominant vibration peaks or discrete vibration in terms of the amplitudes and the frequencies at which they occur. Simultaneously, the overall vibration level can be calculated, which equals the square root of the sum of the square (SRSS) of each discrete vibration amplitude within the frequency span of interest.

During predictive maintenance and most diagnostic procedures, the amplitudes of the discrete peaks, as well as the overall vibration levels, are compared with specification limits that have been developed by the OEMs or end users as guidelines. These limits establish the levels that identify when the pump or the driver has reached a condition in which the internal components can be damaged. The purpose of the vibration specifications is to protect the equipment, and to provide a consistent standard against which the end user, the OEM and the consulting companies can define reasonable acceptance criteria for pumps.

Acceptance limits that are too loose could result in damaged machinery, while limits that are too restrictive are unnecessarily costly to implement because they suggest the need to modify or to replace machine components prematurely. The vibration amplitude output that is available directly from the accelerometers is provided in units of *g*'s of acceleration at peak amplitude, or alternatively, in units of *g*'s rms (root-mean-square). The relationship between the rms, the peak and the peak-to-peak amplitudes for a sinusoid are shown in Table 1. End users in the Americas may be more familiar with velocity measurements in units of inches per second peak.

The scale of the vibration amplitude can be presented linearly or logarithmically. Linear amplitude scale is used by most vibration analysts, where the discrete vibration peaks are shown isolated with typically flat floor-noise across the frequency span (Figure 2). However, a logarithmic scale often will "inflate" the broadband floor-noise to reveal key information that could be important when troubleshooting to identify, for example, structural natural frequencies.

The two graphs in Figure 2 present the same FFT data, but the lower graph displays the data with a logarithmic scale, and therefore is able to emphasize the structural natural frequencies clearly. Moreover, this key information can be curve-fit by the analyst to determine the amplification factor at the natural frequency, and to calculate the separation margin from excitation sources of the pump (for example, the 1x fundamental harmonic of running speed, 2x rpm, and vane pass frequency).

In addition to the FFT spectra, several other specialized methods of plotting vibration test data also are used to help troubleshoot pump vibration problems. Waterfall plots are 3-D graphs that display a "family" of FFT spectra along a third axis representing time, or in some cases, speed change (Figure 3). Trend plots show either the vibration amplitude at any given frequency, or the overall vibration level, plotted in either case along the time axis. Another practical technique to plot pump vibration test data, the orbit plot, is based on the vibration readings from a pair of proximity probes that have been installed on the bearing housing to monitor the movement of the shaft. The probes have been positioned in two orthogonal directions such that the polar cross-plot in time can describe the motion of the shaft center (Figure 4).

VIBRATION TEST PRACTICE

Pump end-users frequently have sought satisfactory solutions to chronic pump vibration problems through trial-and-error methods, such as implementing basic structural modifications, or the progressive reduction of balance tolerances on the rotors. These approaches are time-consuming and cumulatively expensive, yet often they still fail to help end-users achieve trouble-free pump operation over the long term.

To successfully resolve pump vibration issues, a detailed analysis of the underlying mechanism of the vibration problem is needed. This can best be accomplished by developing a finite element analysis (FEA) model of the pump system, and by calibrating that pump system's FEA model with

operating deflection shape (ODS) and experimental-modal-analysis (EMA) vibration data recorded during field tests of the operating pump system. This combined analysis and testing approach will provide a robust platform for identifying potential corrective modifications and also for corroborating their effectiveness in eliminating the pump system's vibration problem. Further, the identification of the root cause of excessive pump vibration by this approach will impart a high degree of confidence that the prescribed modifications to the pump system will alleviate the primary vibration problem without introducing new problems.

ODS vibration testing

ODS analysis is a powerful troubleshooting tool that enables the visualization of most vibration problems in any type of turbomachinery. Animations that have been created from ODS test data show exaggerated but consistently scaled motions of the operating machinery at any given frequency. In most cases, ODS analysis provides enough diagnostic information to identify the root of the vibration problem, and to suggest one or more solutions to the problem. Combined with modal "bump" testing, which is conducted during operation, ODS becomes even more effective.

A thorough "natural excitation signature" test, ODS vibration testing is performed on the entire pump assembly and its surrounding structure. Usually, this entails collecting test data on the pump driver and the driven pump machinery, the associated nozzles and piping, the mounting baseplate, the foundation and the surrounding concrete floor. To capture the overall motion response of the pump system at any given frequency, ODS testing is performed while the pump is run over its typical operating range, and especially during the worst-case dynamic condition within this range. During the test procedure, it also is important to record potential relative motion that may occur between the adjacent components of the pump assembly. This type of motion will flag the existence of looseness in the structure or the presence of a soft-foot condition.

Detailed vibration data should be recorded when performing an ODS, to capture the responses of all of the flange-to-flange interfaces between assemblies, the flexible components, the supports and the concrete foundation(s), as well as the pump casing itself.

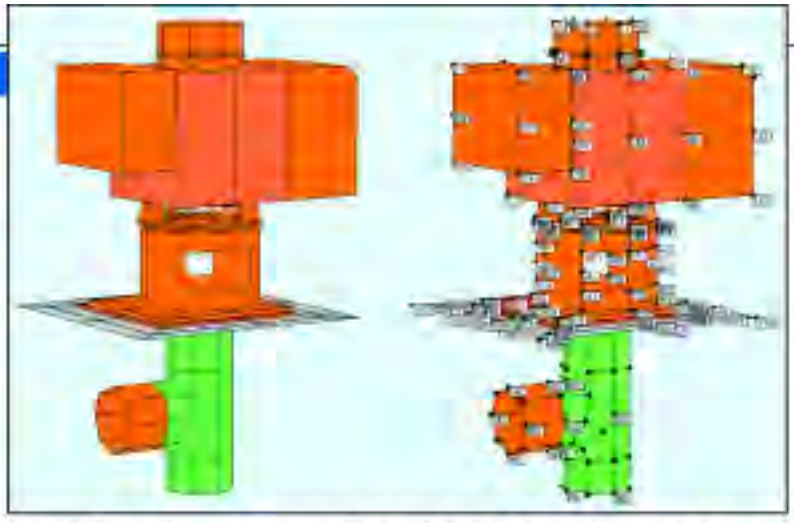


FIGURE 5. The locations of vibration data points on a 3-D model of a vertical pump help observe orbital motions of the shaft, and with the application of special techniques, torsional and axial shaft motion as well

To perform an ODS test, several roving accelerometers, typically of the triple-axis (triax) type, are used to measure pump vibration simultaneously in three mutually perpendicular reference directions. Data are recorded at a large number of representative locations, and depending on the nature of the vibration problem, as many as 300 to 400 combinations of data measurement points and reference directions eventually may be monitored. The test data points comprise all of the accessible and relevant structural portions of the pump and the surrounding system, and often include parts of any exposed or permanently instrumented shafting. Limitations in data collection that occur because of safety concerns or limited physical access can be supplemented later by the test-calibrated FEA model.

Figure 5 shows a typical vertical turbine pump along with the data points that were used during ODS testing of the pump. To collect pump-shaft vibration data, proximity probes or temporary shaft-rider sticks equipped with accelerometers are used to observe the shaft's orbital motions. By applying special techniques, axial and torsional shaft motion also can be detected.

The vibration response at each data point is recorded in the amplitude versus frequency format (that is, as FFT spectra) and the frequency span is selected to suit the nature of the particular pump vibration problem. An identical set of test data also is recorded digitally versus time over reasonable time intervals (~1 min per measurement). Additional key data at higher frequencies usually are recorded, and can be played back if necessary to investigate the vibration response of the pump assembly at different frequency ranges.

The complete set of vibration data is recorded such that one of the single accelerometer channels of the FFT signal analyzer is always kept at the same location and in the same direction on the pump assembly. This serves as a phase reference for each roving accelerometer, proximity probe, dynamic pressure transducer, microphone, motor current transducer, or other type of data collector. To obtain a strong signal for the phase angle reference, the single axis reference accelerometer usually is placed where a relatively high vibration level is present in the pump system across the complete frequency range of interest.

Due to the large number of vibration test data points that ODS requires, it is essential to document each measurement accurately. The location and orientation of each accelerometer must be identified clearly. Further, a detailed drawing with the actual measured dimensions of the pump system must be created. The field-recorded dimensional sketch or drawing also will provide a timely reference to help create the 3-D computer-assisted design (CAD) model with which the test data will be visualized, a key part of the troubleshooting process.

TABLE 1. THE RELATIONSHIPS AMONG THE VARIOUS FEATURES OF A SINUSOID CURVE ARE ESTABLISHED	
Amplitude of sinusoid	**Relationship**
RMS value	0.707 x peak value
RMS value	1.11 x average value
Peak value	1.414 x RMS value
Peak value	1.57 x average value
Average value	0.637 x peak value
Average value	0.90 x RMS value
Peak-to-peak value	2.0 x peak value

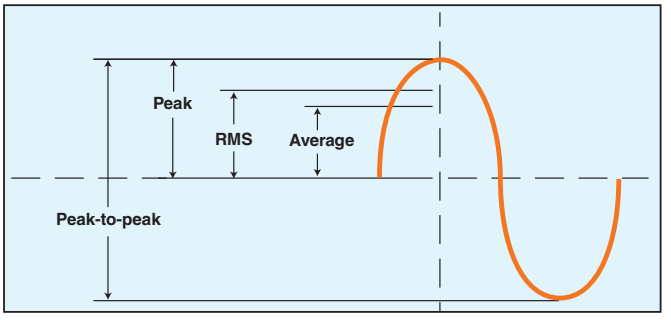


FIGURE 6. Signal analyzers display raw vibration data as continuous sinusoidal plots. Relationships among the curve features are established

The 3-D ODS model is created with purpose-specific CAD software by laying out the various sub-structures that represent key components within the pump system. These components include the motor, the pump bearing housings, the pump casing, the baseplate, the foundation, the floor, and for vertical turbine pumps, the discharge head and the column pipe. Each substructure is defined by sets of geometric points, lines and surfaces, which follow data that include the measured sketches that were made at the test site, the pump OEM's pump drawings, and the construction drawings. Although the ODS model will have a level of detail to show the relevant features of the test subject, it does not require the dense mesh of a finite element model because it is not a computational model. Therefore, the ODS model often will appear coarse when compared directly with a finite element model of the identical subject.

Once the ODS testing has been completed, each of the recorded vibration measurements is exported to the ODS computer software. Within the software, each vibration data point that has been recorded onsite is stored in a database called the data block. The data block is structured according to point number versus frequency, amplitude and phase angle with respect to the reference accelerometer for each data point. Each point number is associated with a unique combination of location and reference direction. The data block is assigned to the 3-D CAD model of the pump system while the consistency of the data point locations and the reference orientations (lateral, vertical and longitudinal) is maintained. Once the field test data points have been mapped to the 3-D CAD model of the pump system, interpolation equations are applied to each substructure or group of substructures within the model. This action assigns relative motion to those points in the model that are not associated with actual test-data points. In this manner, each component or substructure of the 3-D CAD model will have an independent, self-defined motion.

After this procedure has been completed, the ODS model of the pump system can be animated to display the set of vibration test data at any given frequency that was recorded. That is, the resulting animations will describe in exaggerated, yet consistently scaled motion, the pump system's vibration response at each of the selected frequencies. The visual display of the test data will enable the viewer to identify features of interest, such as the least stiff region of the pump structure, and the complex interaction of the moving components that occurs for the various mode shapes of the assembly. Figure 7 is a still image from an ODS animation of pump vibration-test data, which show how the pump rocked at running speed in a direction that was parallel to the discharge pipe.

From the field test data, the highest discrete vibration amplitudes already will have been detected at key frequencies, which usually are the excitation sources. Examples of these frequencies and the typical sources of excitation that correspond to them include one times the running speed (1x rpm) for imbalance, 2x rpm for misalignment, the impeller vane-pass frequency (VPF), the diffuser vane-pass frequency, the gear-mesh frequency (GMF) when gears are part of the system, and the subsynchronous peaks for shaft rubbing or rotating stall. Typically it is best to begin reviewing the test data with the ODS model at the running speed of the pump.

If an excitation frequency source fell close to a natural frequency, the ODS animation at this frequency would describe an approximate mode shape of that natural frequency. Traditionally, vibration modes that have been clearly identifiable from their shapes include the first, second and third bending modes of long cantilever structures, the horizontal- and axial-rocking-rigid body modes, vertical bouncing modes, and torsional modes.

Typically, two relatively straightforward techniques are used to increase the separation margin between the frequency of the excitation source and the structural natural frequency. One alternative is to increase or decrease the stiffness of the system to shift the natural frequency upward or downward, respectively. The other alternative is to add mass to the system to lower the offending natural frequency. In order to avoid the use of a "trial and error" process to detune a natural frequency in this manner, the FEA analysis approach, described later, is considered an excellent tool.

Experimental modal analysis

Similar in some respects to ODS testing at non-synchronous frequencies, EMA is a type of "impulse-response" test to establish the structural natural frequencies and the mode shapes of the pump system by using an instrumented hammer instead of the natural excitation of the pump. Therefore, the response of the machinery is measured through the accelerometers

from a known input excitation source (an instrumented hammer) that gives a broadband-excitation impact. An engineered impact hammer is provided with interchangeable tips of different materials, including rubber of varying hardness and metals such as bronze, to be used depending on the frequency response that is required. Harder tips will excite the higher frequencies. Since the response of the hammer will roll-off (decay) for higher-frequency responses, the tip should be selected such that the natural frequency of interest will lie within the frequency span that occurs before the first roll-off. For each measurement and accelerometer location, a number of impacts should be applied until the average of the frequency response spectra becomes steady. If the machine is not operating, the number of impacts per test typically will fall between 10 and 15. Because the natural frequencies of vibration usually act in-line with the principal axes of the pump, this EMA test is performed in the three orthogonal directions (along the horizontal, vertical and longitudinal reference axes). The pump component is impacted at a location close to where the highest magnitude of vibration was detected during the natural excitation test.

Modal testing is typically performed by end-users and OEMs when the pump is not operating. However, whenever practical, it is recommended that "bump testing" be performed without shutting down the equipment. By using a method such as the time-averaged pulse® (TAP) technique, the critical speeds and the structural natural frequencies of all rotating machinery can be determined effectively under the actual operating conditions. TAP is especially useful in the case of multistage, high-energy, variable-speed pumps, which have rotordynamic characteristics that depend strongly on the speed and load. A TAP test takes into account the added-mass effect of pumped fluid that is entrapped by the pump casing, as well as the energized bearing. In addition, it accounts for Lomakin Effect seal stiffnesses, and the gyroscopic effect due to the rotor's rotational speed. Therefore, it properly accounts for the boundary conditions, which are established by each operating condition. For example, the Lomakin Effect will both cause the center of a centrifugal pump's rotor shaft to rise and increase pump shaft stiffness. Consequently, the critical speeds of the operating pump will shift upward, and the attitude angle of the pump shaft at the stuffing box will deviate from its static position. Both are significant outcomes. In addition, a TAP test can identify natural-frequency-related problems without requiring downtime of the tested pump or adjacent equipment, which is an important consideration in many industries and applications.

The TAP technique incorporates time-averaging statistics to improve the signal-to-noise ratio rapidly within the pump's operating conditions. Time averaging reduces the amplitude ratio of the random, naturally excited vibration versus the impact-coherent vibration during the signal processing. This greatly emphasizes the effect of the "bump" while the machine continues in its normal modes of operation. Since natural excitation from the pump is present, this technique requires a large number of impacts to average-out and cancel the main and often-strong excitation sources, 1x rpm, 2x rpm, 1x VPF and 2x VPF.

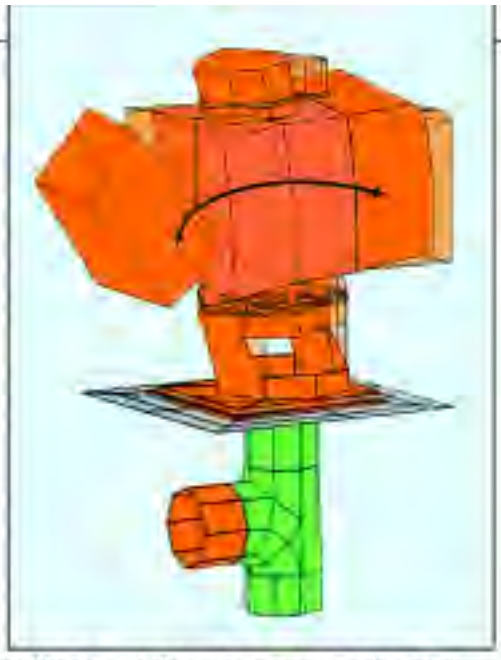


FIGURE 7. ODS Pump vibration test data show the behavior of key pump system components, including the motor, bearing housing, pump casing and baseplate

FINITE ELEMENT ANALYSIS

Once the ODS and the EMA animations have been created and analyzed at the particular frequencies of interest, a detailed FEA model of the pump system is produced. The FEA model incorporates the actual dimensions of the pump components, and typically is constructed from sources of information that include 2-D drawings and physical measurements, using both solid-modeling software and specialized FEA software. Each part of the FEA model is assigned the appropriate material properties, which take into account effects like the external-added water mass due to submerged columns, as is found in vertical turbine pumps.

The FEA model also includes the appropriate foundation and nozzle constraints, shaft geometry, impeller-inertia properties and a representation of the motor based on its weight, center of gravity, and the manufacturer-supplied rood frequency. Importantly, the completed pump-system FEA model is calibrated to match the problematic frequencies and mode shapes that were uncovered in the vibration test data.

After the FEA model of the pump system has been calibrated to the test data, proposed solutions such as the addition of stiffening ribs or mass, or the removal of material at strategic locations, can be simulated using the FEA model to predict the optimum course of action that will mitigate the existing pump-vibration problem without introducing additional problems. Typically an increase in the separation margin of at least 10–15% is desired and can normally be achieved with a high degree of confidence using field vibration-test data and a well-calibrated finite element model of the pump system.

FEA fundamentals

The detailed numerical concepts that underlie the finite element technique are beyond the scope of this article, but mention of some basic finite element concepts will give the reader some background to the method.

By representing structures as do-

mains of many small, well understood parts or elements, the finite element method enables the often complex responses of structures to be simulated consistently and accurately. Breaking up a structure's geometry into typically thousands of such elements is known as the mesh discretization process, and commercially available, off-the-shelf FEA software codes continually offer increased degrees of automation of this procedure. Within practical limits, the finer the breakup of the structure, the more accurate the results of the FEA can be. FEA software offers catalogs of widely varied element types to model different structural features. For example, shell elements often are used to model large diameter, thin-walled structures, such as pump columns and discharge heads. Beam elements, where detailed cross-sectional properties are entered, can be used for shafts, piping or struts. Mass and spring elements frequently are used to model impellers and bearing stiffnesses, respectively.

The stiffness matrices of simple rectangular elements with four corner nodes in the case of a 2-D shell element, or with eight corner nodes in the case of a 3-D brick element, are well understood mathematically. The connection of the elements at the node points allows for overall stiffness and mass matrices to be created that represent the entire structure. Using numerical methods that include matrix inversions, equations of these large matrices are solved by the FEA code transparently to the user. The form of the results is germane to the type of FEA that has been performed. For example, in the case of a modal analysis, the output will include a listing of the natural frequencies along with the corresponding mode shapes for each frequency. Graphical processing of the FEA results is common, and it enables the complex interaction of different components within a pump system to be visualized with relative ease. ■

Edited by Scott Jenkins

* Time-averaged pulse (TAP) is a trademark of Mechanical Solutions Inc. (MSI)

[Editor's note: To see case studies on pump vibration troubleshooting and a "Further reading" list, view the online version of this article at www.che.com]

Authors

Maki M. Onari is the manager of turbomachinery testing at Mechanical Solutions Inc. (MSI; 11 Apollo Drive, Whippany, NJ 07981; Phone: 973-326-9920; Email: maki.onari@mechsol.com). He is responsible for field vibration testing involving ODS and modal analysis. His career spans more than 12 years, primarily working with rotating equipment analysis and troubleshooting in the petrochemical, petroleum refining and power generation industries. Prior to joining MSI, Onari was a rotating equipment engineer in PDVSA-Venezuela responsible for the predictive maintenance of one of the largest petrochemical complexes in Latin America. Onari received a B.S. degree in mechanical engineering in 1996 from the Zulia University in Venezuela. He is a member of ASME and the ISO TC108/S2 Standards Committee for Machinery Vibration.

Paul A. Boyadjis is the manager of turbomachinery analysis at MSI (same postal address as above; Phone: 973-326-9920; Email: paul.boyadjis@mechsol.com). He has nearly 25 years of diverse experience in the analysis and design of rotating equipment. His specialty includes complex 3-D solids modeling of pump and compressor casings and rotating assemblies, and the performance of stress and vibration analysis using advanced finite-element techniques. Boyadjis has worked as a lead analytical engineer for major compressor and pump manufacturers such as Ingersoll-Rand, Ingersoll-Dresser Pump and Flowserve Corp. Boyadjis holds B.S. and M.S. degrees in mechanical engineering from Lehigh University. He is a member of the API Machinery Standards Committee and a Standards Partner of the Hydraulic Institute.

Feature Report

pH Measurement And Control

When measured correctly, pH can be an invaluable tool for both product and process control

Greg McMillan and Rich Baril
Emerson Process Management

The mechanical design and material science of pH-sensor technology have evolved dramatically over the last century. Current-day uses include a wide range of applications from high-purity pharmaceutical processing to wastewater treatment. Some of these applications pose high challenges to pH measurement, including high-temperature and otherwise harsh measuring environments, stability (particularly in pharmaceutical processes), low conductivity measurement and more-stringent pH control in processes. This article outlines the basics of pH measurement and control, with focus on some of these applications and explores recent advances — such as the development of embedded memory chips and transmitters with smarter diagnostics and wireless communication — that have been developed to offer predictive maintenance, portability and greater stability.

pH BASICS

Soren Sorensen of the Carlsberg Laboratory of Copenhagen defined "the hydrogen exponent" as the negative logarithm of hydrogen-ion concentration equated to ion activity. This introduced the concept of pH and started the era of its measurement. The science behind the pH-glass formulation, reference-electrode designs, electrolytes and buffer solutions rapidly developed [1, 2] and prompted the appearance of the first laboratory-type pH meters. Soon afterwards, industrial pH sensors were produced and environmental mandates prompted the use of pH electrodes in effluent streams throughout the chemical process industries (CPI). The recognition of the benefits of online pH control to improve product quality and efficiency created a demand for specialty sensors that could withstand harsh process conditions and sterilization. The need to reduce costs and improve reliability resulted in a number of improvements in design and intelligence of electrodes and transmitters. A summary of the current state-of-the-art follows.

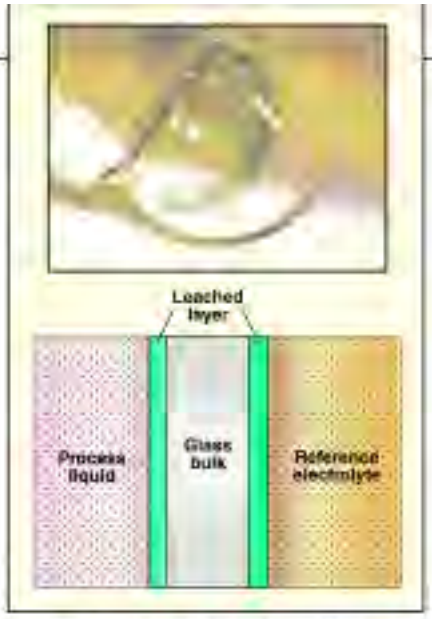


FIGURE 1. A typical hemi-bulb of the pH-sensitive glass of the industrial pH sensor is shown at the top and a schematic representation of the "leached" layer formation on the both sides of the pH-glass is shown below it. If the pH of the reference electrolyte and process solution are equal, then there is no potential (E) generated across the glass, $E = 0$. Typically, the reference electrolyte is buffered to pH 7, so no voltage is generated if the process liquid has the same acidity as the buffer. If the process liquid is acidic, then $E < 0$, and negative potential is generated. If the process liquid is alkaline, then $E > 0$, and positive potential is generated

Glass electrodes

It is the glass in a glass pH sensor that responds to the acidity level of the solution. The pH-glass formulation is the best-kept secret of any pH-sensor manufacturer. However, it is not a secret that alkali metals render silicate glass pH-sensitive. The "leached" layer is formed on the very surface of the glass membrane (semi-bulb) once it's hydrated (Figure 1). This phenomenon gives us a hint on how to store and maintain the life of the glass electrode — simply keep the tip in an aqueous solution. Once the glass is dehydrated, because the bulb is not immersed or is exposed to non-aqueous chemicals, the leached layer disappears and the sensor stops working or develops an erratic signal. The leached layer is very thin, only about 5–10 nm and about 100 nm for the transition layer. However, this layer contributes the most toward the conductivity of the pH glass. The electrical resistance of the surface layer increases as glass ages [3]. Most modern analyzers can measure glass impedance of the pH sensor. If the effect of process temperature on glass impedance can be addressed, the "health" of the glass can be monitored and the replacement of the electrode scheduled as necessary.

Aging and electrode life The impedance of the glass is proportional to the age of the glass. The simple rule of how to predict the life of the glass electrode is to monitor the glass impedance. A positive trend would indicate that the glass is aging. Interestingly, a process coating of the glass would create a similar effect. To distinguish between the two cases one needs to clean the sensor and re-measure the glass impedance in buffer solution. If the impedance drops to the original value of the glass, then the cause is a coating. An appropriate cleaning procedure should be selected and scheduled to insure a good service life. If the glass impedance value does not change after cleaning, then the cause is aging. Both coatings and aging can exhibit a sluggish response [4]. If the test time is long enough to see an entire response, aging may also show up as a decrease in the final change in the indicated pH. This loss in electrode efficiency or span

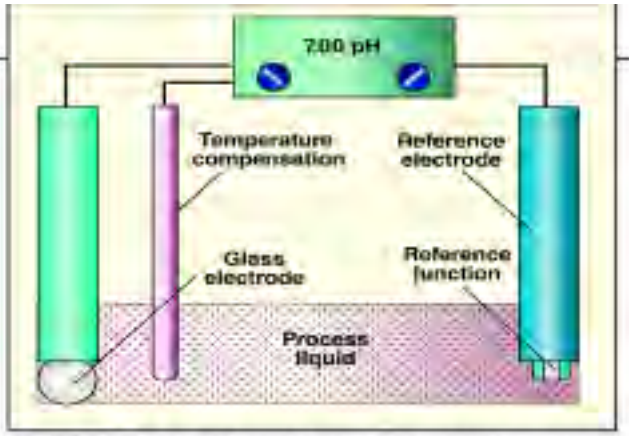


FIGURE 2. The glass electrode creates the potential proportional to the pH of the process liquid, while the reference electrode completes the electrical circuit and provides a small and stable potential as a reference for the pH signal. Electrode temperature compensation is not absolutely necessary for the pH measurements, however is highly desirable, especially at elevated temperatures

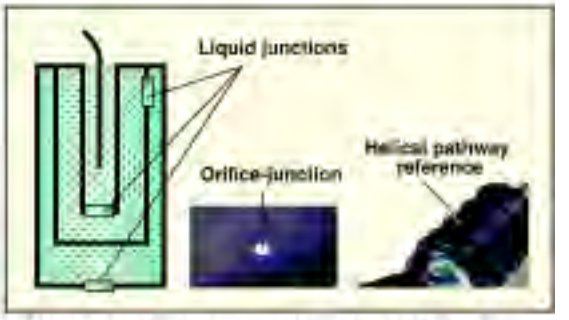


FIGURE 3. A cross-sectional view of a triple-junction reference electrode is shown on the left. Multiple-junction solutions are usually used for combating poisoning agents. The orifice-junction solution, shown in the middle (magnification 250X) is used in low-conductivity applications. A helical-pathway design (right) is used to prevent contamination (poisoning) of the internals of the pH sensor

occurs when the supply of alkali ions is exhausted and the sensor loses its sensitivity and the slope (mV versus pH) of the electrode decreases.

Interestingly, a decreasing electrode temperature has a similar effect, so it is important to monitor the temperature of the process and use the electrode temperature compensation for the change in millivolts generated per pH unit as defined in the Nernst Equation [1, 2]. Most pH sensors have built-in electrode temperature compensation. The solution pH is also temperature dependant. The temperature dependence of the water dissociation constant causes the pH to decrease with temperature by approximately –0.03 pH/°C above neutrality [2]. The temperature coefficient for an actual process can be different because of the temperature dependence of weak-acid and weak-base dissociation constants. The coefficient can be found by running temperature tests of the process liquid and monitoring the pH response. Solution temperature compensation, unlike electrode temperature compensation, is up to the user to identify and configure.

Operating temperature. The operating temperature is also important in sensor selection. Usually low impedance glasses (<10 MΩ) are used for low operating temperatures, mid-range impedance glasses (10–100 MΩ) are employed for ambient temperatures, and high impedance glasses (>100 MΩ) are reserved for high temperature applications. It is important to remember that glass impedance approximately doubles per every 10°C as temperature decreases [2, 3]. Even though the choice and performance of the glass is critical, the performance of the pH sensor also depends upon the design and integrity of the reference electrode.

Reference electrodes

The purpose of the reference electrode is to create a stable reference potential against which the pH signal can be measured. Having a constant reference potential is essential for high impedance measurement. After all, a pH sensor is essentially a high impedance voltmeter (Figure 2). The stability of the reference potential can be achieved through a variety of mechanical designs, such as single, double and triple-junction; differential design, which can be described as having a pH sensor inside the pH sensor; application-appropriate choice of the junction materials and electrolytes (Figure 3).

The typical reference in commercial pH sensors uses a potassium chloride electrolyte to satisfy all of the requirements for the reference fill solution [2]. The consistency of the electrolyte can vary from liquid to gel to solid in order to slow down the migration of process ions inside the reference that come in through the reference junction. Depending on the application, the chemistry of the electrolyte can be tweaked or even changed to satisfy specific requirements of the chemical process. The highly competitive marketplace offers "rebuildable" sensors with a variety of fill solutions.

The reference junction is usually a part of a rebuild-kit and is pre-soaked in the corresponding electrolyte solution. The choice of the materials for the reference junction can vary from Teflon to ceramic, to wood, to just a tiny hole, as shown in Figure 3. The purpose of the reference junction is to provide electrical continuity with the process liquid. It also serves as a guard to prevent the process liquid from penetrating and contaminating or poisoning the sensor.

Each and every component of the reference electrode contributes to the reference potential. This is why it presents an engineering challenge to create a stable design. Typically, the reference impedance is an order of magnitude less than the glass impedance. The reference impedance can also be monitored by the analyzer if the pH sensor has a solution ground. A gradual increase in the reference impedance is indicative of a coating of the reference junction. The sensor needs to be cleaned regularly to have an extended service life. However, an increase in reference impedance may also be symptomatic of a plugged junction and depletion or poisoning of the reference electrolyte. If the pH sensor is "rebuildable" instead of disposable, it's possible to prolong service life of the sensor by replacing the outer junction and refilling the electrolyte. The cost of ownership of the rebuildable type is usually less than that of a disposable sensor.

Installation and wiring

The process-installation procedure is an important factor for the service life of a sensor. Improper installation can cause incorrect readings and even destroy the sensor. Most glass electrodes

have an air gap inside the sensor to allow for thermal expansion. If this type of sensor is installed upside-down, an air bubble becomes trapped right against the pH glass and causes an erratic signal or loss of measurement. The sensor tip should point down about 20 deg from horizontal. Non-glass pH sensors are insensitive to this issue. Installing a sensor too close to an agitator or a pump can cause premature failure, noisy readings and electromagnetic interference. Sensors with integral pre-amplifiers allow longer cables and have less noise in the signal. However, long cables increase the installation, maintenance, and replacement cost. Quick disconnect cables offer some ease of use but do not eliminate the expense. Having a "pre-amp" on the sensor side dramatically improves signal reliability and signal-to-noise ratio. A typical pH-current signal is on the order of tenths of a nano-amp. It is only reasonable to amplify a signal that small before it is transmitted through meters of wires.

Choosing the right sensor

Typically, process and service engineers perceive the pH sensor as a tool or a "black box" that has to do the job. It's important, however, to understand that there is no "one" universal pH sensor for each and every application. Many specific application and maintenance challenges can be addressed by technologically advanced sensors. However, the increasing complexity and the cost of these specialty sensors may not be desirable for general-purpose applications. General-purpose applications imply relatively clean water, no coating, no poisoning ions, good conductivity, moderate temperature and pressure range and no sanitary requirements. In contrast, specialty sensors are designed to withstand high temperature and pressure conditions, combat fouling and coating, and perform well in low conductivity water as well as in poisoning applications.

High-temperature performance

High temperature processes (for example, ethanol production, geothermal plants, and breweries) put a lot of stress on a glass electrode. Premature aging and the decrease in the speed and magnitude of the response starts at temperatures above 50°C. The need to retain pH sensitivity and withstand thermal shocks has led to more-advanced pH-glass formulations and construction [5]. Most competitive high-temperature sensors have ratings up to 155°C at 400 psig, but their performance and life expectancies vary. The best way to extend the life of a sensor at high temperatures is to select high-temperature glass based on test results, use electrode temperature compensation and monitor glass impedance.

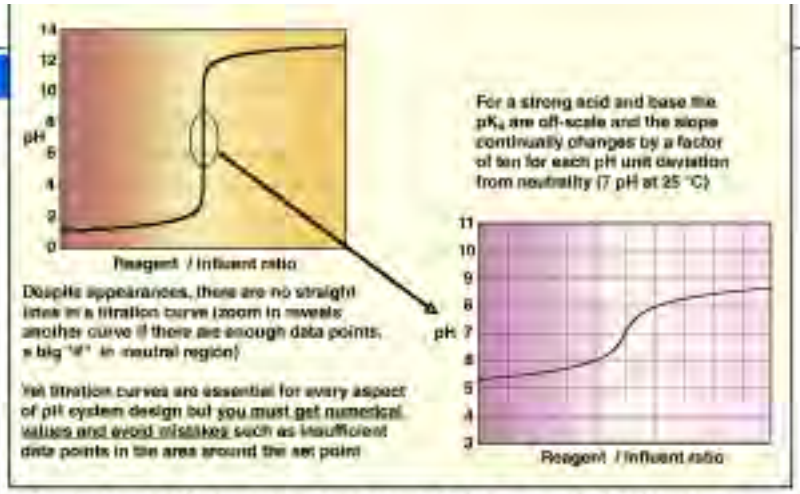


FIGURE 4. While titration curves are essential for every aspect of pH-system design, you must get numerical values for the spectrum of operating temperatures and feed conditions and avoid mistakes, such as insufficient data points in the control region near the setpoint

TABLE 1. TRENDING DATA AND FOLLOW-UP ACTIONS

Diagnostic trend	Sensor status	Actions
Glass impedance increases over time	Glass is aging or gets coated	Schedule maintenance/ inspection
Slope (mV versus pH) decreases over time	Glass is aging or gets dehydrated	Schedule maintenance/ inspection
Reference impedance increases over time	Coating or poisoning	Schedule cleaning and calibration check
Reference offset increases over time	Coating or poisoning	Schedule cleaning and calibration check

High-purity processes

Pharmaceutical processes. Repetitive thermal and chemical shocks, such as those in steam-in-place (SIP) and clean-in-place (CIP) procedures, create a challenging environment for pH sensors. Both SIP and CIP capabilities are usual requirements in the pharmaceutical industry. A pH sensor that retains its calibration after steam cycles or autoclaving is one of the biggest challenges for pH-sensor manufacturers. No where else is more at stake, in terms of pH performance. A faulty pH sensor, for example, can cause the loss of a batch worth ten million dollars that takes 10 to 20 days to process. As with electrodes designed for high temperature, recent improvements in sensor structure and glass formulation have significantly improved the performance and life of electrodes subjected to sterilization. The drift after sterilization has been significantly decreased and the number of steam and autoclave cycles that can be tolerated has been greatly increased.

Noise and accuracy in low-conductivity applications. High-purity (HP) applications with low conductivity (<10 µS/cm) present another challenge for pH-sensor design. A typical example is in the power industry for measurements in boiler water, return condensate and feedwater. The pH of the feedwater must be controlled within a very narrow range to minimize corrosion of the boiler hardware. The challenge of measuring pH in low-conductivity water manifests itself in the fact that there is not enough ionic strength to provide a pH signal. This means that additional charge carriers need to be

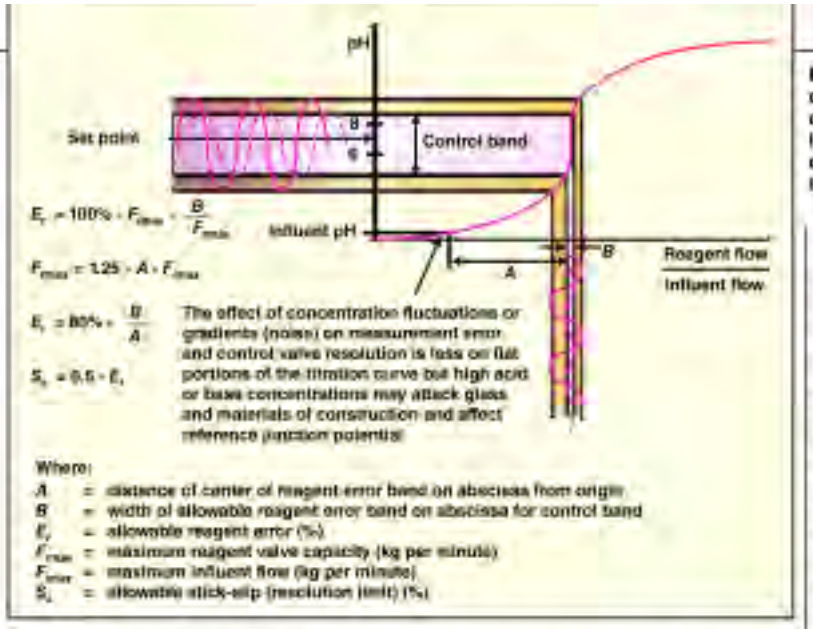


FIGURE 5. The titration curve is used to design the control valve and see the pH oscillations from valves, disturbances, loops, and non-ideal mixing in flow or concentration on the *x*-axis by numerical translation to the *y*-axis

introduced for stable readings.

A flowing junction type of sensor is typically employed for these applications because the small flow of electrolyte through the reference junction into the process maintains a smaller and more-consistent reference junction potential. Also, the sample flow past the sensor is kept low and constant by the electrode holder (cell) design, reducing erratic readings from streaming potentials. Having the controlled low-flow cell is extremely advantageous for good accuracy and a good signal-to-noise ratio. Usually this type of measurement is conducted in a side stream to avoid contamination of the process. In tightly controlled conditions, the achievable level of accuracy is about ±0.05 pH with a noise level less than ±0.02 pH. The best way to maximize the sensor life in low-ionic-strength applications is to know the stream composition (presence of contaminants), take measurements under controlled conditions, monitor the diagnostics, and have a conductivity measurement of the same stream.

pH-CONTROL CHALLENGES

The challenges of pH control are actually a separate subject from pH measurements. However, measurement is an integral part of the pH-loop performance for control. If you consider the scale of 0–14 pH, the glass electrode can measure hydrogen ion concentrations of 1 to 10^{-14} normality. The extraordinary range and sensitivity of the pH measurement creates exceptional challenges for pH control in terms of control-valve and equipment selection, mixing uniformity, reagent injection, and controller tuning [6, 7]. The most oscillatory loops in a plant are often pH loops.

Graphical deception

Nearly all of the implications for process control can be analyzed in terms of the slope of the titration curve, which is representative of the process gain (change in pH for a change in reagent addition). Systems with strong acids and bases are the most difficult to control because the slope changes by a factor of 10 for every pH-unit deviation from the neutral point (7 pH at 25°C), which translates into a process gain at neutrality that is potentially 10^7 times larger than the process gain at the ends of the pH scale. Most laboratory titration curves show a vertical straight line in the neutral region (4 to 10 pH), which gives the illusion that the process gain is constant and the process is linear. However, a zoom centered on the neutral point would reveal another S-shaped titration curve if there were sufficient data points (Figure 4). Successive zooms on what appears to be a straight line would reveal further S-shaped curves. Furthermore, the slope depends upon process temperature via the dependence of the dissociation constants for water (pK_w), acids (pK_a), and bases (pK_b) on temperature. The presence of a weak acid or base will cause a moderation of the slope centered at a pH equal to the pK_a. To spot this effect, the pK_b of a base is converted to the equivalent pK_a (where $pK_a = pK_w - pK_b$). The effect of the associated acid or base concentration and process temperature on the slope is the greatest at these points on the curve [6].

Controller tuning

The controller gain is inversely proportional to the process gain. Consequently, the change in controller tuning due to the nonlinearity of pH is way beyond what you experience in other process control loops unless you are lucky enough to have high concentrations of weak acids or weak bases and are operating close to their pK_a. Tuning settings are either scheduled based on pH, or the controlled variable is converted from pH (*y*-axis) to percent reagent demand (*x*-axis) based on a representative titration curve to reduce the nonlinearity. The scheduling and linearization is not perfect due to changes in process temperature and feed concentrations, but is better than no embedded process knowledge.

Control-valve design

The smallest change possible in a control valve position multiplied by the process gain at the setpoint must be less than the allowable deviation in pH from the setpoint. The smallest change in position is the resolution of the control valve expressed as a percent of the signal span and hence valve capacity. The typical source of a valve resolution limit is stick-slip. Integral action in the controller creates a sustained equal-amplitude oscillation (limit cycle) even if there are no disturbances, as the controller output ramps back and forth across the resolution limit. The best pneumatically actuated control valves with digital positioners have a resolution of 0.1% of span. Since the resolution is ultimately a percent of valve capacity, the resolution required depends on the distance of the incoming pH from the setpoint on the titration curve. Figure 5 shows how a reagent flow oscillation is amplified by the process gain and how the valve resolution required is proportional to the width of the allowable control deviation (B) and is inversely proportional to the distance

(A) traversed on the titration curve [*6*]. It is important that data are used rather than the plot from a laboratory titrator, that there be at least five data points in the control region, and finally that the x-axis be converted to a ratio of reagent to feed flow.

Concentration and feed disturbances are amplified by the process gain just as the disturbance from valve resolution was in Figure 5. Similarly, the variability in reagent concentration from non-ideal mixing is amplified. The smoothing of oscillations and fluctuations is inversely proportional to the residence time of a well mixed volume. The attenuated amplitude per Equation (1) must be translated from the x-axis (ratio of reagent to feed flow) to an amplitude on the y-axis (pH) of the titration curve to include the effect of the nonlinear process gain [*6*].

$$A_o = A_i \times \frac{T_o}{2 \times \pi \times \tau_p} \quad (1)$$

Where:
A_i is the amplitude of input oscillation into volume (reagent to influent ratio)
A_o is the amplitude of output oscillation from volume (reagent to influent ratio)
T_o is the period of oscillation, minutes
τ_p is the process time constant from mixing (residence time), minutes

Mixing and injection delays

A controller cannot compensate for a disturbance until it sees the change in pH and can get the reagent into the process at the same point as the disturbance. The total loop deadtime involved in the observation and compensation can be approximated as the sum of delays and small lags in the loop. This sum should include sample transport delay, electrode lag, transmitter lag and update delay, DCS execution time delay, DCS filter lag, control valve delay and lag, injection delay, and mixing delay and lag. The injection delay that occurs when a reagent valve opens or closes is often the largest and most insidious source of loop deadtime [*6*]. This injection delay can be approximated as the dip tube and piping volume between the injection point and the reagent valve divided by the reagent flow. The error from a process disturbance after control action is proportional to the total loop deadtime. An extremely effective strategy to minimize the amount of process nonlinearity is to minimize the loop deadtime [*6, 7*]. In other words, loops with minimal deadtime and well-tuned controllers keep the pH close to the setpoint. On the other hand, poor pH-system designs exhibit larger excursions on the titration curve and changes in process gain that make the problem worse.

FIGURE 6. A software screenshot shows the health status of the pH-sensor in a process. These variables can be historized to see longterm trends

Control solutions

Traditional solutions. The classical solution was to have a large, well-mixed vessel for every 2 pH units of the feed pH from the setpoint. For a feed around 2 pH or 12 pH, three well-mixed vessels in series were used. For the 2 pH case, the setpoints of the vessels were 4, 6, and 7 pH. The first vessel typically had the largest volume to cross neutralize the influent and the largest control valve to provide a coarse adjustment to move the pH most of the distance along the flatter part of the titration curve. The last vessel had the smallest volume and smallest control valve to provide a trim adjustment. The volumes were designed to be significantly different in size to prevent the resonance of oscillations since the natural frequency of the loop was thought to be mostly dependent on volume. These vessels had a large capital cost and footprint, and were prone to large and slow oscillations — from the limit cycle of the large valve on the first volume — that were not effectively smoothed by the last volume.

Alternative system solutions. Today, inline pH-control systems followed by a moderately mixed volume are used to reduce cost and space needs [*6–8*]. These inline control systems use pumps, piping fittings and static mixers to provide coarse mixing. Inline control systems have a much faster response and period of oscillation than a vessel control system. The downstream volume provides the needed attenuation per Equation (1). Signal characterization that translates the loop's controlled variable from pH to reagent demand (x-axis of the titration curve) is used to suppress reaction to mixing noise and to help the controller recognize the true distance of the incoming pH to the setpoint in terms of reagent addition [*6–8*].

MAINTENANCE

As we can see, the overall pH performance is a fine balance of many variables, and maintenance is one of them. The burden of maintenance is a challenge that should not be underestimated. The pH sensors have a finite life — both storage and service-life. The sensor performance depends on the process conditions as well as on proper maintenance and installation. Routine maintenance usually boils down to cleaning with water, and a two-buffer calibration check. If the coating is acidic, the use of a weak caustic solution (<4% NaOH) is recommended. If it's alkaline or a scale-coating, then vinegar or ~5% HCl can help. Oil, grease and organic compounds can be taken away by using off-the-shelf detergents or organic solvents that are compatible with the sen-

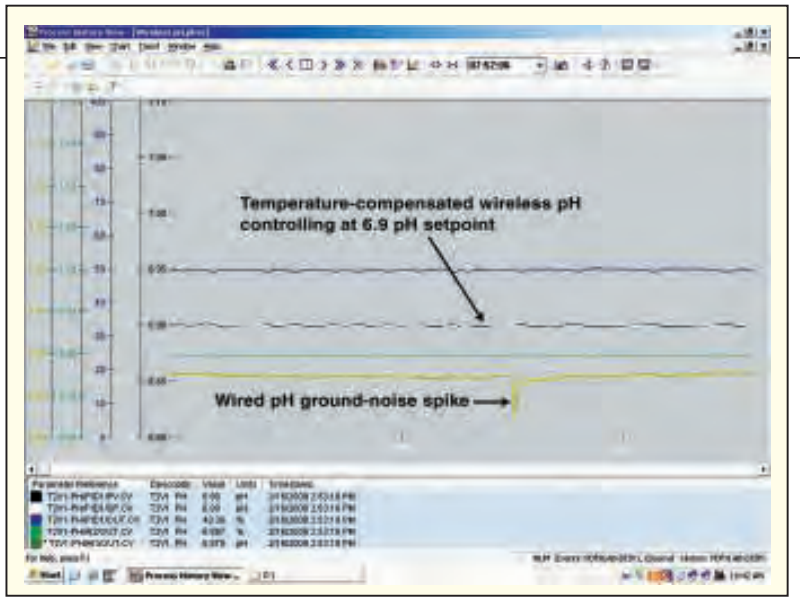


FIGURE 7. Actual trend recording of a single-use-bioreactor batch shows that a wireless transmitter did not show the noise spike seen by the wired transmitter, and the wireless control of the batch is within 0.001 pH despite a reduction in the number of communications by 60% to increase battery life

sor body materials. Monitoring the pH-sensor diagnostic parameters is very helpful for predictive maintenance. For instance, glass impedance can indicate if the glass is broken, coated or spent. The reference offset and reference impedance can indicate coating and or plugging. The pH span and offset can reflect the sensitivity and number of the standardizations. The low level of the pH signal makes it susceptible to noise. Installation of the sensor in close proximity to air conditioners, pumps, agitators, mixers and motors can result in electromagnetic interference. Piping material can make a difference in pH measurements. It's well known that metal pipes have far less problems with grounding than plastic ones or metal pipes with a plastic lining. Correct wiring and proper cabling also fall under the category of maintenance. Interestingly, some locations or installations for pH monitoring can be cost-prohibitive due only to the wiring. The cost to run the cables all over the plant or to a remote location can be excessive.

RECENT ADVANCES

Recent developments in sensor and transmitter intelligence and communication are an indication of the future trend of pH measurements to be smarter and more portable.

Embedded memory chips

Looking forward, it's becomes apparent that sensors with an embedded memory chip are gaining more popularity. Advanced diagnostics offer undisputable advantages to the plant operation. The pH sensor that can carry the factory calibration, serial number and several diagnostics data can ease the maintenance burden. First of all, this smart sensor does not need buffer calibration at the installation point. It means that the service engineer does not need to carry the buffers, beakers and rinse water to the place where the sensor is installed. It really makes sense if you are in unfriendly environmental conditions, such as rain, snow or blazing sun. The calibration can be done in the laboratory and can be remotely or locally digitally accessible after installation. Since the sensor has an embedded factory calibration, the instrument can always be reset to the default calibration, without any special efforts. Furthermore, several diagnostic data sets and time stamps stored on the memory chip make it easy to see the trend of the diagnostics data (Table 1). Until recently, this historization was possible only by manual data logging.

Wireless transmitters

Wireless signal transmission is taking pH sensors even further. Having advanced diagnostics stored inside the sensor and being able to transmit them wirelessly from the analyzer is a big step forward. It eliminates the need of wiring the transmitters to the main control room. The pH measurement can be wirelessly transmitted from the most difficult and remote location to a main computer. Sensor designs can be tested, and data for in-process samples can be communicated to the control system without any wiring. Sensors proven in laboratory tests can be installed in the process without any wiring. The sensors can also be readily moved, based on field results, to a location that minimizes fluctuations from imperfect mixing and process-transportation time delay. The sensor health can be monitored remotely, and the maintenance trips can be scheduled in accordance with diagnostic's records, as shown in Figure 6. It can save many dollars to the end user because needless maintenance can be avoided and catastrophic failure prevented.

Wireless control. A simple enhancement to the PID control algorithm has been developed, which combined with the WirelessHART communication rules can reduce the number of communications by an order of magnitude, thereby dramatically increasing battery life [*9*]. The communication rules provide a transmission of signal in the schedule time slot set up by the network manager, only if the difference between the new measured value and the last transmitted value exceeds a sensitivity limit, or the elapsed time since the last transmission exceeds a refresh time. The transmitter continues to measure the process at a fast rate but will transmit faster than the periodic reporting set by the refresh time on an exception basis set by the sensitivity limit. The optimum sensitivity setting should be larger than the maximum amplitude of measurement noise and larger than the resolution of the control valve multiplied by the process gain, but less than the minimum allowable deviation from setpoint [*9*].

The enhanced PID algorithm keeps the controller execution fast, to provide an immediate response to setpoint changes and fast disturbances via proportional feedback and feedforward control. The integral mode is only executed when there is a new value of the measurement. The integral contribution uses the external reset-mechanism and dynamic-reset

limiting that has been found to be important for cascade control. The reset time is set equal to the process time constant, and the contribution to the reset mode is based on the elapsed time since the last updated measurement to provide a correction that matches the time response of the process. The derivative mode only makes a change in the controller output if there is an update and computes the rate of change based on the elapsed time from the last update rather than the execution time of the controller. Thus, integral and derivative action only occurs when there is a measurement update. Figure 7 shows how the new communication rules and enhanced PID provided tight control of a single-use-bioreactor batch, while increasing battery life and ignoring a spike from ground noise [9].

In control studies, the PID enhancements improved the stability for any control system whenever there was a significant measurement-time delay. Figure 8 for a generic self-regulating (continuous) process, dominated by a large time delay, shows that the PID enhancement eliminates oscillations. This technological advancement in the PID for all loops is a fall out of maximizing the utility of the new wireless technology [9].The wireless communication and advanced diagnostics are taking us into the future of not only pH measurement and maintenance, but also the overall approach of running the plant.

FIGURE 8. The enhanced, wireless PID performance (bottom row) has value beyond wireless operation by providing tighter and more stable control of processes with significant measurement delays from at-line analyzers. The Lambda factor is used for computing controller gain, and is inversely proportional to it

Embedded process models

Dynamic models of the pH system will be embedded with prototypes of the control system in the DCS to provide a more efficient process design. In a recent example, the capital cost was reduced by 50% for neutralization of the regeneration effluent from a demineralized water system [*9*]. These embedded models will also be put online and adapted to provide better signal characterization and inferential measurements of influent composition for feedforward control and inferential measurement of pH as a third signal for middle signal selection. An application of an adapted embedded model for a RCRA (Resource Conservation and Recovery Act) waste neutralization system in a chemical intermediates plant demonstrated the concept and provided reagent savings of $100,000/yr [*10*]. In both cases, the key to model fidelity was matching the process gain (titration curve slope) of the model to the plant. ■

Edited by Dorothy Lozowski

References

1. H. Galster, "pH Measurement Fundamentals, Methods, Applications, Instrumentation", VCH Verlagsgesellschaft mbH, Weinheim, 1991.
2. C. C. Westcott, "pH Measurements", Academic Press Inc., 1978.
3. C. D. Feng, Aging mechanism of pH sensing glass in high temperature environment, Proceedings of the ISA 53rd Analysis Div. Symposium, April 2008.
4. Moore, Ralph, Good pH Measurements in Bad Process Streams, *Instrum. Control Syst. (I&CS)*, December, 1990.
5. N. Starostin, New trend in pH-technology, *Processing*, April 2008.
6. McMillan, G.K. and Cameron, R.A., "Advanced pH Measurement and Control", 3rd Ed., ISA, Research Triangle Park, N.C. (2005).
7. Shinskey, F.G., "pH and pION Control in Process and Waste Streams", John Wiley & Sons, 1973.
8. McMillan, G.K., Reedy, R.D., and Moulis, J.P., Virtual Plant Provides Real Insights, *Chem. Process.,* January, 2009.
9. McMillan, G.K., What have I Learned — Unexpected Wireless Benefits, February 9, 2009, http://www.modelingandcontrol.com/
10. McMillan, G. K. and Sowell, M.S., Virtual Control of Real pH", *Control*, November, 2007.

Authors

Gregory McMillan is a principal consultant to Emerson Process Management's Process Systems and Solutions Group (Research Park Plaza, Bldg. 3, 12301 Research Blvd., Austin, TX, 78759; Email: Greg.McMillan@Emerson.com). McMillan is a retired senior fellow from Solutia/Monsanto and an ISA Fellow. He received the ISA "Kermit Fischer Environmental" Award for pH control in 1991, was inducted into the Control "Process Automation Hall of Fame" in 2001 and received the ISA Life Achievement Award in 2010. He has a B.S. in engineering physics from Kansas University and M.S. in electrical engineering from Missouri University of Science and Technology. McMillan is the author of numerous books on process control, the most recent being Essentials of Modern Measurements and Final Elements for the Process Industry. His expertise is summarized on his Website: www.modelingandcontrol.com/

Richard Baril is the product marketing manager for Emerson Process Management, Rosemount Analytical (2400 Barranca Parkway, Irvine, CA, 92696; Phone: (800–854–8257; Email: Richard.Baril@Emerson.com). He has been active in the drinking water and wastewater process industries for more than 20 years. Baril holds a B.S. in Chemistry from Long Beach State and an MBA from the University of La Verne. He is a current member of the International Ozone Assn., has spoken at several industry conferences, and has authored numerous articles in a variety of publications.

Foolproofing Regulatory Document Generation

Software helps ensure that you always have the right data in the right format

Jay Deakins
Descom, Inc.

An integrated ERP system automatically populates the proper document template, such as a bill of lading, with the proper data so the system does the data work – not your employees

When it comes to managing regulatory documents such as product labels, bills of lading, and certificates of analysis (COA), virtually all manufacturers in the chemical process industries (CPI) face the same challenge — getting the right information into the right document formats for every shipment. This challenge becomes more complicated when you ship to customers with unique labeling and reporting requirements. This article examines why regulatory document management is such a challenge, and shows how to take that challenge and make it an opportunity.

Technology and human error

The challenges of regulatory document management are typically rooted in the type of technology you use to run your business. Many chemical manufacturers start out using multiple software tools, such as spreadsheets and basic accounting systems. As business grows, more systems are added — a new laboratory management system, an inventory management system and so on. A separate system for regulatory reporting and labeling is often added to the mix as well.

For most companies, that regulatory reporting "system" is nothing more than a series of word processing documents. That means you have to rely on an individual or team within your company to manage this manual process. With your data scattered across multiple systems, the person assigned to this task must search several locations for the formula, batch, quality assurance (QA) and quality control (QC) information for each shipment. Then, because different customers may have different document specifications for the same products, all of these data must be cross referenced with the customer files. Finally, he or she has to select the proper document format and correctly enter the information. Meanwhile, if more than one person is involved with this task, the level of complexity is even higher.

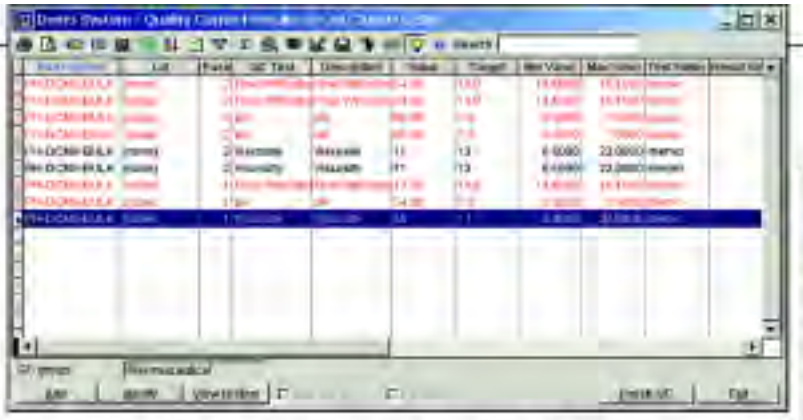
Beyond the obvious bottleneck, you also face the possibility of human error every time your facility prepares a new shipment. There is always a chance that someone will choose the wrong form, make a formatting mistake, or enter incorrect QC and formulation values from time to time. And it's quite likely that the incorrect information will then be passed on to your customers. Making matters even worse is the fact that returned shipments will reenter your bottleneck, where similar mistakes can happen again. In this scenario, it won't take long for your customers to start looking at your competition for a more dependable supplier.

So the question remains: How can you ensure your regulatory documentation always has the right data in the right formats? The trick is to integrate all of your business processes — formulation, sales, purchasing, inventory, production, QA and QC, lot tracking, accounting and regulatory reporting — in one software system. Integrated enterprise resource planning (ERP) software does this, giving you one location to manage all your data. Using one system means there's no need to reenter information. It also gives you greater control over your processes and reduces the opportunities for human error.

Configuring it to your needs

Well-designed ERP software helps you get the right data into the right document formats by allowing you to configure regulatory document templates. The term configure means you can adapt the system to your business without altering the basic programming code. The benefits of configurable templates include cost efficiency, quick installation, and long-term ease of maintenance.

Modern ERP systems can even use



Fully-integrated ERP software provides the process controls necessary to prevent data entry errors by halting users during the QC process. Consider, for example, if a value falls outside a predefined reporting range. Here, failed tests are highlighted for easy identification

the familiar functions of Microsoft Word to lessen the learning curve of document configuration. Using the data from your ERP system through the Word application, you can insert and arrange data fields, logos, and other characters according to your own specifications to configure a document template for each regulatory form you use. This list could include product labels, COAs, Material Safety Data Sheets (MSDS), packing lists, bills of lading and so on. Depending on the complexity of your regulatory reporting needs, you could configure product- and customer-specific templates, as well.

The configuration of regulatory document templates ultimately simplifies matters on your shipping dock. When your employees print the regulatory documentation for a shipment, whether it's going to Cleveland, Canada, or Katmandu, the system would automatically populate the proper template with the proper data. The system — not the individual — does the data work.

Simplifying the human role

While integrated ERP software eliminates redundant data entry, a human still has to enter QC data into the system as you run tests. This is a major problem area when using multiple systems, because it's very difficult to apply process controls across several applications. But with one point of data control, you can establish rules that restrict data entry.

Setting QC reporting ranges is one example. If you set the reporting range for the pH of a product at 8.6 to 9.2, and an employee accidentally enters 88 instead of 8.8, the system would automatically stop the process. The employee would be prompted to fix his or her mistake before moving on. If this datum was entered into a separate system, you might not be able to catch the error. Process controls such as QC reporting ranges are the only way to ensure your data are always accurate.

A science, not a science project

Whether you make one product for one customer or 1,000 products for 1,000 customers, regulatory reporting is an important part of your business. It gets your products where they're going, keeps you in good standing with regulatory agencies, and provides your customers with the data they need to run their operations effectively. By using ERP software that integrates configurable regulatory document templates with all your business processes in one system, you can turn the challenge of regulatory reporting into an opportunity to establish your company as a reliable supplier. ■

Edited by Rebekkah Marshall

Author

Jay Deakins is the president of Deacom, Inc. (960 West Valley Rd., Suite 3000, Wayne, PA 19087; Phone: 610-971-2278; Email: info@deacom.net), the producer of an integrated accounting and ERP software system for specialty chemical manufacturers. Prior to establishing Deacom, Inc., he founded and served as president of Sun and Earth Co., a manufacturer of all-natural cleaning products.

FOCUS ON

Feeding & Conveying

Feeder combines speed with accuracy

The PosiPortion feeder (photo) offers a 2-in-1 feed screw option that dramatically improves batch accuracy without compromising speed. A two-speed delivery scheme, consisting of a fast turning "bulk-mode" and a slower "dribble-mode", are used to meet batch set points. The system comes with a performance guarantee, and additional equipment can be paired with it for further cost savings. — *Hapman, Kalamazoo, Mich.*
www.hapman.com

Pneumatic system promises to be dust- and contamination-free

The ProClean Conveyor (PCC; photo) pneumatic conveying system creates a dust- and contamination-free atmosphere, enables conveying of toxic, moist or other difficult products and is well suited for transporting materials in an inert atmosphere. Vessels can be charged both in low-pressure and overpressure atmospheres. The system employs a specially designed filter head that can be accessed easily for changeout. An optional clean-in-place unit does not have to be dismantled for filter replacement. — *Hecht Technologie GmbH, Pfaffenhofen, Germany*
www.hecht.eu

Hecht

Bucket conveyor will 'go anywhere' you need it

Known as the Go Anywhere Conveyor (photo), this unit uses cantilevered buckets that move vertically and horizontally and can turn any direction up to 90 deg. without having to transfer the load being conveyed, making it very flexible. This unique feature lets users fit the conveyor within their production facility instead of modifying their facility to accommodate the material handling system. The multi-axis capability is the result of its patented chain design and the cantilevered wedged shaped buckets that come together and overlap at the load station. The patented rack and pinion system assures full discharge with a 360-deg bucket rotation on selection and quick return to the upright position for maximum flexibility. — *Gough Econ, Inc., Charlotte, N.C.*
www.goughecon.com

Conveyor tilts down for portability and cleans easily

The new Bulk Conveyor with Tilt-Down Portable Base (photo) fits through tight spaces and provides easy access for removal of the flexible screw. It features a reduced footprint that enables the caster-mounted frame to maneuver through narrow aisles and around corners. With the hopper, support boom and conveyor assembly tilted down, the unit fits through standard doorways and orients the conveyor tube horizontally, allowing the flexible screw to be removed easily for thorough cleaning and inspection. Each unit is custom configured. The hopper, which is equipped with a hinged lid, feeds a flexible screw conveyor that transports bulk ingredients ranging from sub-

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

Vac-U-Max

micron powders to large pellets. The enclosed conveyor tube prevents product and plant contamination, while the gentle rolling action of material being conveyed prevents the separation of blends. The rugged inner screw is the only moving part contacting material, resulting in reduced maintenance and increased reliability. — *Flexicon Corp., Bethlehem, Pa.*
www.flexicon.com

Feeder boasts up to 75% greater speeds than standard feeders

This AC Series of Hi-Speed Feeders has been designed for exceptionally high speed feeding — up to 75% greater than standard feeders — of light, bulky materials. These feeders boast greater economy and efficiency in mixing, weighing, batching, packaging and bagging operations and are ideal for use in conjunction with many weigh scale and packaging machines. The Hi-Speed Feeders' spring-system design consists primarily of an elastomeric torsion spring with high damping properties that allow the feeders to tolerate high deflections without the danger of early failure. The spring system also has quick stopping characteristics due to the rapid decay of vibratory energy when the unit is de-energized, which is useful in product applications such as packaging, where overruns of material cannot be tolerated. Tuning, when required, is accomplished through simple replacement of an easily accessible, glass-fiber tuning spring. No other adjustment is necessary. — *Eriez, Erie, Pa.*
www.eriez.com

Vacuum conveying system achieves high batch accuracy

Designed for use in the chemical, pharmaceutical and food industries, the Batch Weigh Vacuum Convey System (photo) delivers powders and granules to process vessels with accuracies of 0.5% of the batch size. This type of vacuum conveying system al-

Thayer Scale-Hyer Industries

lows for greater control of product quality and inventory control of materials. Material can be conveyed from drums, bags or super sacks. Complete systems are custom designed for the specific needs of each application. — *Vac-U-Max, Belleville, N.J.*
www.vac-u-max.com

High accuracies in weighing and feeding

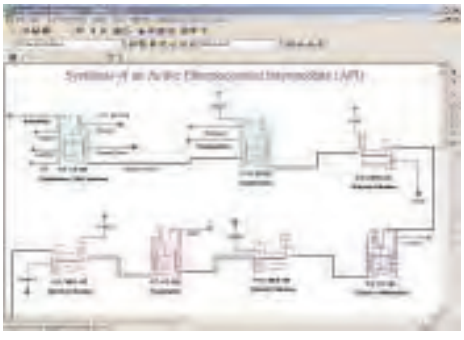
When higher accuracy is required in measuring weight using conveyor belt scales, weigh belt feeders, and loss-in-weight feeders, the Force Measurement Suspension System (FMSS) has proven effective in high-speed, high-volume to low-density, low rate applications where control quality and productivity are critical (photo). The FMSS is the arrangement of active mechanical elements interposed between the load receptor, such as a platform, hopper or belt, and the load cell. In this way, the FMSS functions as a force-vector filter that permits the sum of the chosen unidirectional force components (material weight) to pass through the system to the load cell while blocking out all other nuisance, erroneous or destructive force-vector components. By providing mass counterbalance of tare weight, the FMSS is said to create a superior signal-to-noise ratio in weight sensing that allows for precise realtime measurements that are not possible with standard scales: allowing for accurate weighing at speeds in excess of 500–600 ft/min, in conveyor-belt-scale applications. The FMSS is available in a number of capacity ranges and configurations to suit the particular needs of continuous weighing and feeding equipment. — *Thayer Scale-Hyer Industries, Inc., Pembroke, Mass.*
www.thayerscale.com ■

Rebekkah Marshall

Intelligen Suite

The Market-Leading Engineering Suite for Modeling, Evaluation, Scheduling, and Debottlenecking of Single & Multi-Product Facilities

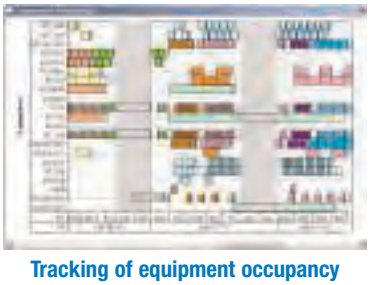
SuperPro



Use SuperPro Designer to model, evaluate, and debottleneck batch and continuous processes

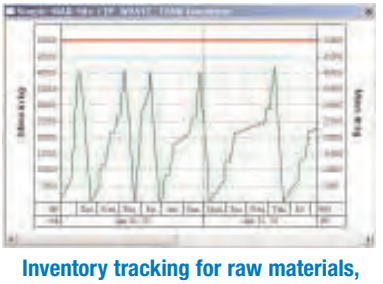
SchedulePro

Switch to SchedulePro to schedule, model, and debottleneck multi-product facilities



Tracking of equipment occupancy in multi-product facilities

Tracking demand for resources (e.g., labor, materials, utilities, etc.)



Inventory tracking for raw materials, intermediates, products, and wastes

SuperPro Designer is a comprehensive process simulator that facilitates modeling, cost analysis, debottlenecking, cycle time reduction, and environmental impact assessment of biochemical, specialty chemical, pharmaceutical (bulk & fine), food, consumer product, mineral processing, water purification, wastewater treatment, and related processes. Its development was initiated at the Massachusetts Institute of Technology (MIT). SuperPro is already in use at more than 400 companies and 500 universities around the world (including 18 of the top 20 pharmaceutical companies and 9 of the top 10 biopharmaceutical companies).

SchedulePro is a versatile finite capacity scheduling tool that generates feasible production schedules for multi-product facilities that do not violate constraints related to the limited availability of facilities, equipment, resources and work areas. It can be used in conjunction with SuperPro (by importing its recipes) or independently (by creating recipes directly in SchedulePro). Any industry that manufactures multiple products by sharing production lines and resources can benefit from the use of SchedulePro. Engineering companies use it as a modeling tool to size utilities for batch plants, identify equipment requirements, reduce cycle times, and debottleneck facilities.

Circle 240 on p. 50 or go to adlinks.che.com/29253-240

Visit our website to download detailed product literature and functional evaluation versions of our tools

INTELLIGEN, INC. • 2326 Morse Avenue • Scotch Plains, NJ 07076 • USA
Tel: (908) 654-0088 • Fax: (908) 654-3866
Email: info@intelligen.com • Website: www.intelligen.com
Intelligen also has offices in Europe and representatives in countries around the world

SOFTWARE

NEW & USED EQUIPMENT

NEW & USED EQUIPMENT

Advertisers' Index

* Additional information in 2010 Buyers' Guide

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

Classified Index - August 2010 (212) 621-4958 Fax: (212) 621-4976

Send Advertisements and Box replies to: Helene Hicks
***Chemical Engineering*, 110 William St. 11th Floor, New York, NY 10038**

JustFAXit! or go to www.che.com/adlinks

Fill out the form and circle or write in the number(s) below, cut it out, and fax it to 800-571-7730.

Go on the Web and fill out the online reader service card.

Name _____ Title _____

Company _____

Address _____

City _____ State/Province _____ Zip/Postal Code _____

Country\ _____ Telephone _____ Fax _____

Email _____

FREE PRODUCT INFO
(please answer all the questions)

YOUR INDUSTRY
01 Food & Beverages
02 Wood, Pulp & Paper
03 Inorganic Chemicals
04 Plastics, Synthetic Resins
05 Drugs & Cosmetics
06 Soaps & Detergents
07 Paints & Allied Products
08 Organic Chemicals
09 Agricultural Chemicals
10 Petroleum Refining, Coal Products
11 Rubber & Misc. Plastics
12 Stone, Clay, Glass, Ceramics
13 Metallurgical & Metal Products
14 Engineering, Design & Construction Firms
15 Engineering/Environmental Services
16 Equipment Manufacturer
17 Energy incl. Co-generation
18 Other_____

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

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

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

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

If number(s) do not appear above, please write them here and circle: _____

Fax this page back to 800-571-7730

ADVERTISING SALES REPRESENTATIVES

Mike O'Rourke, **Publisher**
Chemical Engineering
110 William St., New York, NY 10038-3901
Tel: 215-340-1366; Fax: 609-482-4146
E-mail: morourke@che.com
Alabama, Canada, Connecticut, Delaware, Florida, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York (minus Western New York), North & South Carolina, Pennsylvania (minus Western Pennsylvania), Rhode Island, Tennessee, Vermont, Virginia, Washington, D.C., West Virginia, Latin America

North America
Jason Bullock,
District Sales Manager
Chemical Engineering
8325 Broadway, Ste. 202/PMB 261
Pearland, TX 77581
Tel: 281-485-4077; Fax: 281-485-1285
E-mail: jbullock@che.com;
Arkansas, Arizona, California, Colorado, Georgia, Kansas, Louisiana, Missouri, Nevada, Oklahoma, Texas

George Gortz,
District Sales Manager
Chemical Engineering
2612 Edgerton Road
University Heights, OH 44118
Tel: 216-932-2700; Fax 216-932-5810
E-mail: ggortz@che.com
Indiana, Illinois, Iowa, Kentucky, Michigan, Minnesota, Ohio, Western New York, Western Pennsylvania, Wisconsin

Helene Hicks,
Inside Sales Manager
Chemical Engineering;
110 William St., New York, NY 10038-3901
Tel: 212-621-4958; Fax: 212-621-4976;
E-mail: hhicks@che.com
Product Showcase, Literature Reviews, Classified Display Advertising
Alaska, Hawaii, Idaho, Mississippi, Montana, Nebraska, New Mexico, North & South Dakota, Oregon, Utah, Washington, Wyoming

International

Petra Trautes
Chemical Engineering
Zeilweg 44
D-60439 Frankfurt am Main
Germany
Phone: +49-69-2547-2073
Fax: +49-69-5700-2484
Email: ptrautes@che.com
Austria, Czech Republic, Benelux, Eastern Europe, Germany, Scandinavia, Switzerland, United Kingdom

Dipali Dhar
Chemical Engineering
110 William St., New York, NY 10038-3901
Tel: 212-621-4919; Fax: 212-621-4990
E-mail: ddhar@chemweek.com
India

Katshuhiro Ishii
Chemical Engineering
Ace Media Service Inc., 12-6, 4-chome
Nishiiko, Adachi-ku, Tokyo 121, Japan
Tel: 81-3-5691-3335; Fax: 81-3-5691-3336
E-mail: amskatsu@dream.com
Japan

Ferruccio Silvera
Chemical Engineering
Silvera Pubblicita
Viale Monza, 24 Milano 20127, Italy
Tel: 39-02-284-6716; Fax:
39-02-289-3849
E-mail: ferruccio@silvera.it/www.silvera.it
Andorra, France, Gibraltar, Greece, Israel, Italy, Portugal, Spain

Rudy Teng
Chemical Engineering
Professional Publication Agency
6F-3 # 103 Fen Liau St Neihu
Taipei 114 Taiwan
Tel: 886-2-2799-3110 ext 330;
Fax: 886-2-2799-5560
E-mail: rudy_teng@ppa.com.tw
or idpt808@seed.net.tw
Asia-Pacific, Hong Kong, People's Republic of China, Taiwan

BUSINESS NEWS

PLANT WATCH

Siemens' technology to be used for IGCC project in the U.S.

July 19, 2010 — Siemens Energy (Erlangen, Germany; www.siemens.com) has been awarded a front-end engineering design contract by Summit Texas Clean Energy LLC to provide coal gasification and power block technology for the Texas Clean Energy Project, which will be located in Penwell, Tex. The new polygeneration integrated gasification combined-cycle (IGCC) project will have a gross capacity of 400 megawatts (MW_e). The plant will also produce urea for the U.S. fertilizer market.

UNPZ selects CDTech for gasoline desulfurization unit

July 15, 2010 — Catalytic Distillation Technologies (CDTech; Pasadena, Tex.; www.cdtech.com) has received a contract by OAO UNPZ Ufa Refinery for the license and basic engineering of a fluid-catalytic-cracking gasoline hydrodesulfurization unit in the Russian Federation. The unit is designed with a treating capacity of 1.26-million metric tons per year (m.t./yr).

Süd-Chemie invests €60 million in LFP production

July 12, 2010 — Süd-Chemie AG (Munich, Germany; www.sud-chemie.com) is investing approximately €60 million in the production of lithium iron phosphate (LFP), a high-performance energy-storage material used in batteries. A production plant for LFP using a new, proprietary production process is planned on the site of the company's wholly owned Canadian subsidiary, Phostech Lithium Inc. (Candiac, Quebec, Canada). Commercial production will start in 2012 to reach a rate of 2,500 ton/yr.

New contracts for Borouge 3 amount to approximately $2.6-billion

July 2, 2010 — Borouge (Abu Dhabi, UAE; www.borouge.com), a joint venture (JV) between the Abu Dhabi National Oil Co. and Borealis (Vienna, Austria; www.borealisgroup.com), has signed several contracts for its Borouge 3 expansion in Ruwais, Abu Dhabi. The first contract worth $1,255 billion for the construction of two Borstar enhanced polyethylene (PE) and two Borstar enhanced polypropylene (PP) units, as well as the second contract worth $400 million for a 350,000 m.t./yr low-density polyethylene (LDPE) unit, were signed with the JV consortium Maire Tecnimont of Italy and Samsung Engineering of South Korea. The capacity of the new PE units is 1,080,000 m.t./yr and that of the new PP units is 960,000 m.t./yr. A third contract, worth $935 million for the utilities and off-site facilities for the expanded plant was signed with Hyundai Engineering and Construction of South Korea. These investments will quadruple Borouge's production capacity to over 4.5-million m.t./yr by 2013.

ABB to supply three photovoltaic solar-power plants in Italy

July 2, 2010 — ABB (Zurich, Switzerland; www.abb.com) has won an order worth $50 million from Actelios SpA, through its subsidiary Actelios Solar SpA, in Italy to supply three photovoltaic solar-power plants in western Sicily. The plants will have a total power capacity of over 13 megawatts (MW). The main plant will be erected in Spinasanta with a capacity of 6 MW. Additional plants will be built at Cardonita (3.8 MW) and at Sugherotorto (3.3 MW). Once connected to the grid, the plants will supply around 19 gigawatt hours (GWh) of renewable electric power each year. The project is expected to be completed by the end of 2010.

A new copper-mine project is planned in Chile

July 1, 2010 — Fluor Corp. (Irving, Tex.; www.fluor.com) has been awarded a contract by Minera Lumina Copper Chile S.A. to deliver services for the company's new Caserones copper-mine project in central Chile. Minera Lumina Copper Chile is jointly owned by Pan Pacific Copper Co. and Mitsui Co. The project has an output of 3.6 million tons of fine copper and 87,000 tons of molybdenum. The project is currently underway and has a projected completion date in the 3rd Q of 2013. When it reaches completion, the Caserones mine project is expected to process around 105,000 ton/d of primary and secondary copper ore.

Lanxess expands butyl-rubber capacity in Belgium

June 28, 2010 — Lanxess AG (Leverkusen, Germany; www.lanxess.com) will expand the production capacity of its butyl rubber plant in Zwijndrecht, Belgium, by 10% to meet growing global demand for regular butyl and halobutyl synthetic rubber. The company will invest €20 million to increase capacity by an extra 14,000 m.t./yr. The current capacity of the plant is about 135,000 m.t./yr. The expansion is expected to be completed in the 2nd Q of 2012.

MERGERS AND ACQUISITIONS

AkzoNobel strengthens packaging coatings portfolio

July 15, 2010 — AkzoNobel N.V. (Amsterdam, the Netherlands; www.akzonobel.com) has agreed to acquire the assets of Sweden-based company Lindgens Metal Decorating Coatings and Inks, including its majority stake in the Server Boya JV in Turkey. Closing is expected to take place in the 3rd Q of this year. Financial details were not disclosed.

...and divests its National Starch business

June 21, 2010 — AkzoNobel N.V. has announced the sale of its National Starch business to Corn Products International. The seller will receive $1.3 billion in cash, and the buyer will assume certain pension and employee benefit liabilities. The transaction, which has been approved by the Boards of both companies, is expected to close at the end of the 3rd Q of 2010, subject to regulatory approvals.

Evonik establishes independent carbon black company

July 12, 2010 — Evonik Industries (Essen, Germany; www.evonik.com) is reorganizing its carbon black activities. On July 1, Evonik Carbon Black GmbH was founded as a legally independent management company under the umbrella of Evonik Industries. Jack Clem is CEO and Rainer Wobbe will take over the position of CFO. The operational headquarters of the company, currently in Frankfurt, will move to Hanau-Wolfgang on October 1.

BASF merges its Swiss group companies

July 1, 2010 — BASF SE (Ludwigshafen, Germany; www.basf.com) has announced the merger of its Swiss group companies BASF Orgamol Pharma Solutions SA, and BASF Fine Chemicals Switzerland SA, to a single organization. The company arising from the merger is called BASF Pharma SA and is based in Evionnaz, Switzerland.

...and plans to buy Cognis

June 23, 2010 — BASF SE has reached an agreement with Cognis Holding Luxembourg S.à r.l. to acquire Cognis for an equity purchase price of €700 million. Including net financial debt and pension obligations, the enterprise value of the transaction is €3.1 billion. The acquisition is subject to clearance by the competent merger control authorities and is expected to close by November, 2010. ■

Dorothy Lozowski

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

August 2010; VOL. 117; NO. 8
Chemical Engineering copyright @ 2010 (ISSN 0009-2460) is published monthly, with an additional issue in October, by Access Intelligence, LLC, 4 Choke Cherry Road, 2nd Floor, Rockville, MD, 20850. Chemical Engineering Executive, Editorial, Advertising and Publication Offices: 110 William Street, 11th Floor, New York, NY 10038; Phone: 212-621-4674, Fax: 212-621-4694. Subscription rates: $120.97 U.S. and U.S. possessions, $146.97 Canada, and $249 International. $20.00 Back issue & Single copy sales. Periodicals postage paid at Rockville, MD and additional mailing offices. Postmaster: Send address changes to Chemical Engineering, Fulfillment Manager, P.O. Box 3588, Northbrook, IL 60065-3588. Phone: 847-564-9290, Fax: 847-564-9453, email: clientservices@che.com. Change of address, two to eight week notice requested. For information regarding article reprints, please contact Lori Noffz at lori.noffz@theygsgroup.com. Contents may not be reproduced in any form without written permission. **Publications Mail Product Sales Agreement No. PM40063731. Return undeliverable Canadian Addresses to: P.O. Box 1632, Windsor, ON N9A7C9.**

FOR MORE ECONOMIC INDICATORS, SEE NEXT PAGE

Economic Indicators

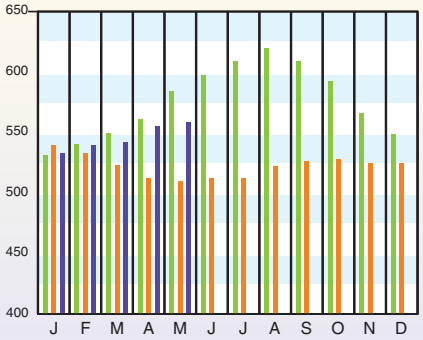
2010 2009 2008

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

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	May '10 Prelim.	Apr.'10 Final	May '09 Final
***CE* Index**	558.2	555.3	509.1
Equipment	670.2	666.0	596.8
Heat exchangers & tanks	629.9	622.6	529.9
Process machinery	631.8	625.4	583.0
Pipe, valves & fittings	828.3	829.5	748.1
Process instruments	424.8	426.7	389.0
Pumps & compressors	903.1	902.4	896.7
Electrical equipment	473.2	472.5	458.9
Structural supports & misc	697.5	688.7	602.4
Construction labor	327.4	327.3	326.6
Buildings	513.9	508.9	485.4
Engineering & supervision	339.7	341.4	347.9

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

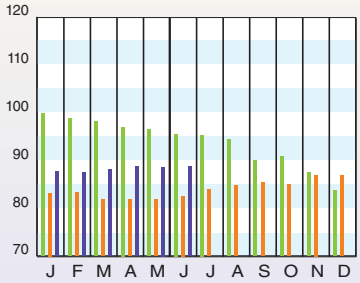


Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics

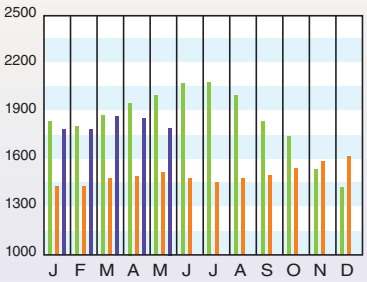
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS		YEAR AGO	
CPI output index (2007 = 100)	Jun.'10 =	88.6	May.'10 =	88.6	Apr.'10 =	88.7	Jun.'09 =	82.6
CPI value of output, $ billions	May.'10 =	1,796.3	Apr.'10 =	1,854.6	Mar.'10 =	1,866.7	May.'09 =	1,519.0
CPI operating rate, %	Jun.'10 =	71.6	May.'10 =	71.4	Apr.'10 =	71.5	Jun.'09 =	65.4
Producer prices, industrial chemicals (1982 = 100)	Jun.'10 =	267.7	May.'10 =	272.8	Apr.'10 =	274.0	Jun.'09 =	232.8
Industrial Production in Manufacturing (2007=100)	Jun.'10 =	89.6	May.'10 =	90.0	Apr.'10 =	89.1	Jun.'09 =	82.7
Hourly earnings index, chemical & allied products (1992 = 100)	Jun.'10 =	154.1	May.'10 =	91.0	Apr.'10 =	90.1	Jun.'09 =	83.7
Productivity index, chemicals & allied products (1992 = 100)	Jun.'10 =	120.6	May.'10 =	92.0	Apr.'10 =	91.1	Jun.'09 =	84.7

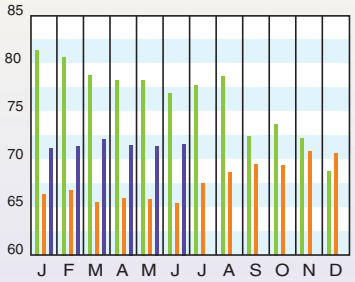
CPI OUTPUT INDEX (2007 = 100)



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



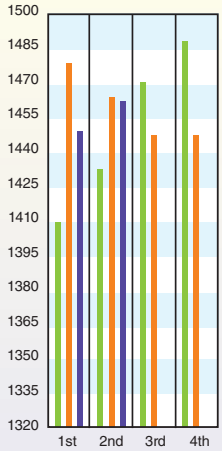
Current Business Indicators provided by Global Insight, Inc., Lexington, Mass.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)	2nd Q 2010	1st Q 2010	4th Q 2009	3rd Q 2009	2nd Q 2009
M & S INDEX	1,461.3	1,448.3	1,446.5	1,446.4	1,462.9
Process industries, average	1,522.1	1,510.3	1,511.9	1,515.1	1,534.2
Cement	1,519.2	1,508.1	1,508.2	1,509.7	1,532.5
Chemicals	1,493.5	1,481.8	1,483.1	1,485.8	1,504.8
Clay products	1,505.6	1,496.0	1,494.3	1,495.8	1,512.9
Glass	1,416.4	1,403.0	1,400.1	1,400.4	1,420.1
Paint	1,527.6	1,515.1	1,514.1	1,515.1	1,535.9
Paper	1,430.1	1,416.4	1,415.8	1,416.3	1,435.6
Petroleum products	1,625.9	1,615.6	1,617.6	1,625.2	1,643.5
Rubber	1,564.2	1,551.0	1,560.5	1,560.7	1,581.1
Related industries					
Electrical power	1,414.0	1,389.6	1,377.3	1,370.8	1,394.7
Mining, milling	1,569.1	1,552.1	1,548.1	1,547.6	1,562.9
Refrigeration	1,786.9	1,772.2	1,769.5	1,767.3	1,789.0
Steam power	1,488.0	1,475.0	1,470.8	1,471.4	1,490.8

Annual Index:

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



CURRENT TRENDS

Capital equipment prices (as reflected in the May *CE* Plant Cost Index) continue to climb according toward a typical mid-year peak, but the gap between the 2010 index and the 2008 index is widening.

Meanwhile, Current Business Indicators from Global Insight, Inc. show that CPI output was essentially flat from May to June, and the operating rate climbed only slightly. Note that industrial production, and hence the CPI output index, was changed from a 2002=100 to 2007=100 base on June 25. Likewise, the basis for Industrial Production in Manufacturing changed.

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

Ultra high viscosity index poly alpha olefin plants provide an acceptable rate of return at prevailing 2010 bulk sales prices.

Process Economics Program Review:
ExxonMobil's Ultra High Viscosity Index Poly Alpha Olefin Lubricant Blend Stock

The two dominant ultra high viscosity index (UHVI) poly alpha olefin (PAO) producers across all grades are ExxonMobil and Ineos, with 35% of market share each. SRI Consulting's (SRIC) latest review looks at the UHVI PAO market and examines closely one of the dominant producers, ExxonMobil. ExxonMobil owns a PAO trademark with its Mobil-1™ formulated brand of fully synthetic blend stocks for high severity lubricating oil applications, and uses the trade name SpectraSyn Ultra™ for this viscosity range grade of products (150-600 cSt).

In this review, SRIC's analysis shows that a grass root, stand alone UHVI PAO plant with a design capacity of 5,000 metric tons per year can be built on the US Gulf Coast with a total fixed capital cost of approximately $US10 MM. When operating at full capacity the total manufacturing cost for the UHVI PAO plant is approximately $US 2500/mt, providing an acceptable rate of return given the premium pricing for these product grades.

The review includes:

- Introduction
- Industry Status
- Suppliers
- Demand Growth
- Product Pricing
- Synthetic Fuel Business Impacts
- Overview of UHVI PAO Technology
- Proposed Process Design Basis
- Proposed Process Design
- Process Economics

For more information and to purchase this review, contact Angela Faterkowski, +1 281 203 6275, afaterkowski@sriconsulting.com or visit our website.

www.sriconsulting.com/PEP

Smart Research. Smart Business.

SRI CONSULTING®

A Division of Access Intelligence, LLC

MENLO PARK • HOUSTON • BEIJING • NEW DELHI • RIYADH • SEOUL • TOKYO • ZÜRICH

Circle 27 on p. 50 or go to adlinks.che.com/29253-27

Put a stop to energy loss.

For energy consumption and plant efficiency to be assessed objectively and true savings measures implemented, targeted energy monitoring is required. At Endress+Hauser we provide tailor-made energy monitoring for steam, air, gas, oil, water, electricity, heating and cooling. Additionally, we offer everything you need to achieve your energy-savings potential: precise measuring instruments, intelligent devices for data recording and transfer, and the support you need to analyze and evaluate measured energy data. www.us.endress.com/ems

Endress+Hauser, Inc
2350 Endress Place
Greenwood, IN 46143
inquiry@us.endress.com
www.us.endress.com

Sales: 888-ENDRESS
Service: 800-642-8737
Fax: 317-535-8498

Endress+Hauser
People for Process Automation

Circle 8 on p. 50 or go to adlinks.che.com/29253-08