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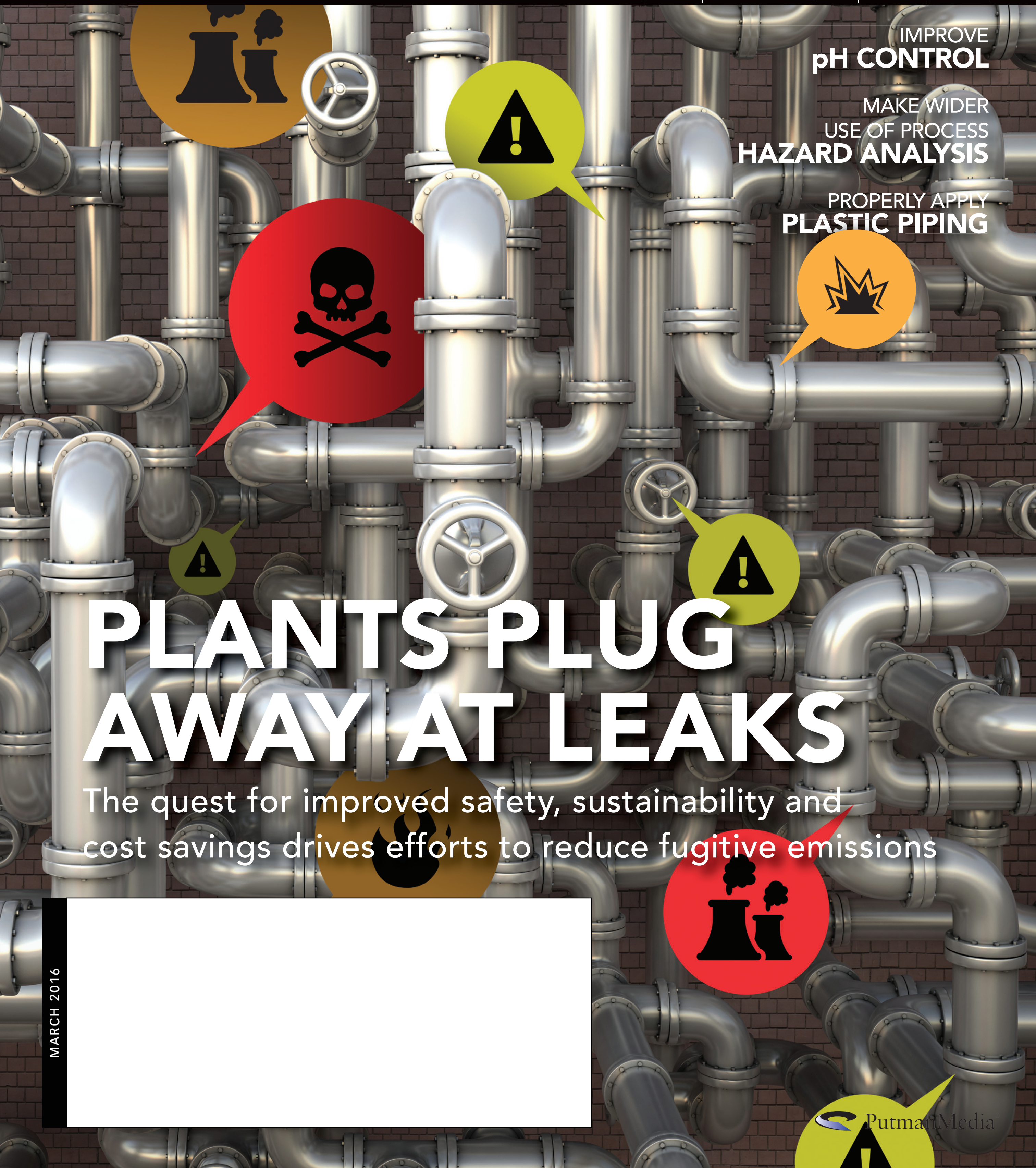

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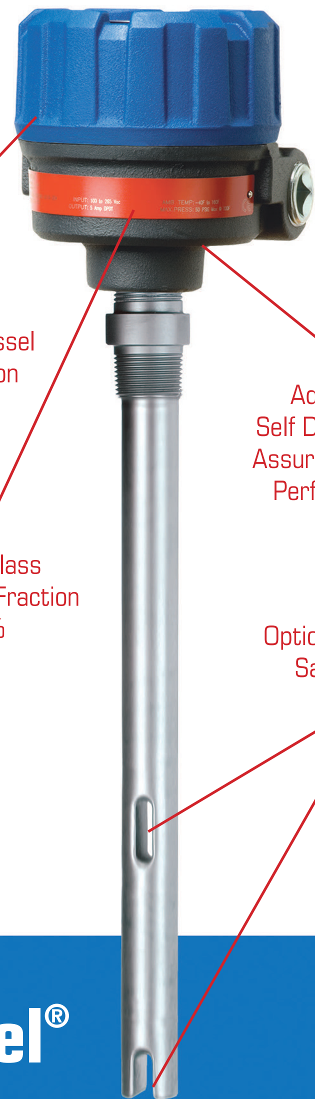

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You Must Blow the Whistle!

A leading professional society now requires such action

CHEMICAL ENGINEERS who encounter or uncover a corporate misdeed that could impact the public's wellbeing must act — at least if they're members of the Institution of Chemical Engineers (IChemE), Rugby, U.K. It recently revised its "Rules of Professional Conduct and Disciplinary Regulations" to oblige members to "raise a concern about a danger, risk, malpractice or wrongdoing which affects others ('blow the whistle') and support a colleague to whom the member has a duty of care who in good faith raises any such concern."

IChemE director Andy Furlong explains: "We have strengthened our code of conduct and this move provides further protection and support for chemical engineers who come across illegal practices. IChemE membership is a signal of trustworthy professionalism and it strengthens public trust in chemical engineering."

Judith Hackitt, chair of the U.K.'s Health and Safety Executive and an IChemE past president, adds: "It is vital that all chemical engineers think about how they will uphold the high standards of our profession and who they will speak to if they need to report concerns about unethical or bad practices."

No specific incident of whistleblowing or lack of it led to the rules' revision, says IChemE. The institution simply decided it was time to explicitly address the issue.

IChemE provides a much clearer and stronger mandate than that, for instance, issued by the American Institute of Chemical Engineers (AIChE), New York City. Its "Code of Ethics" hints at the need for whistleblowing in some situations but doesn't demand it. The code states that AIChE members should: "formally advise their employers or clients (and consider further disclosure, if warranted) if they perceive that a consequence of their duties will adversely affect the present or future health or safety of their colleagues or the public." Perhaps it's time for AIChE to revisit the code.

Requiring members to whistleblow or support people who do certainly is a worthwhile move. However, it puts the onus on members but lets the professional society itself off the hook for providing support. IChemE believes it might have a role to play. Indeed, it now is investigating the viability of setting up a mechanism to support whistleblowers. However, the institution cautions it's too early to say whether such a move is viable and what the mechanism might involve. Stay tuned!

We never can forget that many of the materials our industry uses and produces and the processes it operates can pose significant risks beyond the plant gate. That's why, of course, safety and environmental protection are such priorities. However, lapses occur — unfortunately, sometimes deliberately. When we come across miscues or misdeeds that threaten the public wellbeing, we should not stay silent. Morality and ethics should compel taking action whether or not our professional societies demand it. That takes real courage, though. Speaking out can incur significant personal consequences, as Dirk Willard recounted last year in "Blow The Whistle," http://goo.gl/7Io4Uz. In addition, perseverance often is needed — I covered a classic example of this in "A Milestone Book Turns 50," http://goo.gl/EM2xew, which focused on "Silent Spring" and its author Rachel Carson.

I applaud IChemE's move. Telling members to whistleblow when necessary is worthwhile — but easy. Actually providing institutional support to whistleblowers is an important and all too rare action that IChemE certainly should consider.

Lapses occur — unfortunately, sometimes deliberately.

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Don't Err About Fluidization

Consider its under-appreciated advantages and broader utility

High pressure drop ensures uniform distribution of the gas.

ANYONE WHO knows me will say: "He's crazy about fluidization." That's the absolute truth. The heat transfer is greater, the mixing can be better if you're careful, and fluidization often provides the lowest cost option for processing. One of our plant's operators observed that the only thing his product didn't stick to was air, so he became a fan of fluidized beds. Not all products are well-suited for this type of operation, though. Attrition and segregation of the product may pose concerns. However, you can design around these limitations or even turn them to your advantage. Here are some examples:

- A granular product having some fine particles was being loaded into drums, which was an easily contained operation. However, when the lid was removed, the excess fines created a dust and handling problem. Fluidizing the product as it was loaded enabled stripping off the fine particles, eliminating the problem.
- Coal fed to a calciner produced an emission of fine particles that would be very expensive to collect at 2,000°F. Rather than install emission controls, the site added a fluidized bed that removed the coal fines before the calciner. This worked well because larger coal particles have less inorganic chemicals than the fines.
- Fine crystals that form in solution often are more reactive than grown crystals that are ground down to the desired size — and thus frequently command a much higher price. So, eliminating the grinding operation, using a fluidized bed and segregating the finer particles during the drying process can boost profits.

Attrition often is cited as a reason not to use a fluid bed. However, particle-particle impact is much more damaging than impact between a particle and a gas or even a particle and a wall. In one study of a cyclone, we found most attrition occurred when the cyclone was removed and the solids discharged directly into the bin. One of the major concerns of designers of fluid beds is maintaining adequate fluidization of the bed; so they use too high a velocity, which can impact attrition. To compensate, they don't provide enough pressure drop at the fluidization grid to prevent larger solids from settling on the grid, which in a dryer can cause fires or burn the product. Note I said pressure drop, not velocity. High pressure drop ensures uniform distribution of the gas, whereas high velocity may increase particle-particle impact and attrition.

Pneumatic conveying systems, including so-called dense-phase ones, count on fluidization to transport particulate solids. Clearly, dilute-phase systems rely on fluidization — most of their operational problems stem from not maintaining fluidization all along the line. In these systems, we not only are fluidizing the particles but also are accelerating them to some velocity below the gas velocity. Gas velocity is increased at the feed point to help in this process but the effort is wasted if the travel distance before an elbow or diverter isn't sufficient. Also, we know that putting two elbows close together is a well-known recipe for defluidization, which increases the solids/air ratio and pressure drop. In dense-phase systems, fluidization is less obvious with the typical dune or even plug flow. Some particulate solids need some sort of gas bypass to refluidize and maintain motion down the pipe.

Have you ever tried to coat a large particle with a fine powder? Mechanical devices frequently fail because of the clumping of the fine powder or lack of uniform coverage on the larger particles. The fluid bed coater often is a better option. It exposes the full surface of the larger particle to the gas that contains the fine particle. Any excess fines can be scrubbed off in the bed and returned for coating.

One of the more important aspects of fluidization is heat transfer. Not only is more surface area available but also convection is more effective than conduction. In addition, fouling of heat transfer surfaces is less of an issue, even when in-bed heat transfer surfaces are involved. By the way, in-bed heat transfer is an often-overlooked technology for high-solvent particulate. It allows use of much lower inlet gas temperatures, which can be especially valuable with heat-sensitive products. So the next time you want to move, dry or dedust a product, get a fluidizing device.

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Learn from "Mad Men"

The television series provides a lot of parallels with work at engineering firms

"When people get what they want, they realize how limited their goals were." — Joan Holloway.

"WE'RE GONNA sit at our desks typing while the walls fall down around us because we're the least important, most important thing there is here." That's a quote from Don Draper, the creative director at an advertising agency, who is the lead character of the television series "Mad Men," describing the creative department at the ad agency. This statement strikes me as applying equally well to process engineers who work at an engineering, procurement and construction (EPC) firm.

Like the ad agency in "Mad Men," an EPC firm survives on salesmanship and original thinking — and often is one handshake away from success or failure. You're only as good as your last idea. And that idea lives or dies on how you present it to the client. "Success comes from standing out, not fitting in," counsels Draper. Original thinking is only part of success.

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Lately, I've heard lots of bellyaching about clients not being able to answer our questions; I admit I've complained about it a few times myself. However, that's why they come to EPC firms! Draper concisely summarizes the client's point of view: "It's your job. I give you money, you give me ideas."

Winning contracts also is about meeting client expectations. "People tell you who they are, but we ignore it because we want them to be who we want them to be," warns Draper. Too often, salespeople at an EPC firm think they know what their clients want but really don't. We see the clients for their products, not the problems nagging their manufacturing: reliability, quality and regulatory compliance. We should strive to help them solve such underlying and, perhaps, unstated difficulties. To make that happen, the EPC firm must set itself apart by not only seeing where the client wants to go but also visualizing possibilities the client never imagined. "One good idea can win a client over," advises Draper. A good example from "Mad Men" is Kodak's wheel — Draper renamed it a carousel: "It's a time machine…. it takes us to a place where we ache to go again." Now, that's a sales pitch! In our context, imagination means seeing the possibilities of a tank layout for improving maintenance access to key equipment — not waiting until the client brings it up.

Did I say meeting client's expectations? I meant managing a client's expectations. Once convinced of your expertise, a client is completely vulnerable. "People want to be told what to do so badly that they'll listen to anybody," confides Draper. This is an awesome challenge when a client realizes you're the one who can solve its problems! Sometimes, you can promise too much, as ad agency account manager (salesman) Roger Sterling relates: "I told him it was a stupid idea, but they don't always get our inflection." Managing is important because resources are finite: "We're flawed because we want so much more. We're ruined because we get these things and wish for what we had," cautions Draper.

The truth is that all sales relationships are doomed to failure. Or, in the words of Sterling: "The day you sign a client is the day you start losing them." I wish someone could explain that to me: familiarity breeds contempt, a failure to meet the lofty promises of a sales pitch or, perhaps, the temptation of a sweeter deal? Maybe Joan Holloway, a partner at the ad agency, put her finger on it: "Sometimes when people get what they want, they realize how limited their goals were."

EPC management must have a strategy for what to do when this relationship ends and how to gear up when business grows. Again, Draper offers insights: "There are snakes that go months without eating and then they catch something, but they're so hungry that they suffocate while they're eating…"

Instead, most EPC firms react reflexively, firing and hiring talent as business ebbs and flows. That's okay — the engineers land elsewhere, perhaps at outfits with better planning.

Engineers should pay heed to another bit of Draper wisdom: "I have a life, and it only goes in one direction: forward."

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Joint Effort Brightens Prospects for Sought-After Feedstock

Novel fructose-conversion process could lead to more sustainable, high-performance products

TWO MAJOR processors are teaming up to build a demonstration plant for a process that produces furan dicarboxylic methyl ester (FDME) from fructose. The process has the potential to expand bio-based materials offerings with applications in packaging, textiles, engineering plastics and many other industries, say scientists at DuPont Industrial Biosciences, Wilmington, Del., and Archer Daniels Midland Company (ADM), Chicago, which jointly developed the route.

DuPont and ADM believe the process opens the door to new polymer groups and creates a more efficient, economically viable process. The two companies are partnering on the research and development project, combining ADM's expertise in fructose production and carbohydrate chemistry with DuPont's biotechnology, chemistry, materials and applications know-how.

The U.S. Dept. of Energy has identified FDME as an important potential building block for bio-based chemicals. However, the material has not been available at commercial scale and at a reasonable cost, note DuPont and ADM. The new FDME technology is simpler than conventional synthesis methods, and boasts higher yields, less energy use and lower capital costs, they claim. Compared to current methods, which also make other byproducts, DuPont and ADM's technique uses all sugar in the feedstock, either to produce FDME or for energy recovery. It involves first dehydrating fructose from corn starch. The products of this reaction are oxidized to form furandicarboxylic acid (FDCA), which then reacts with methanol to form FDME.

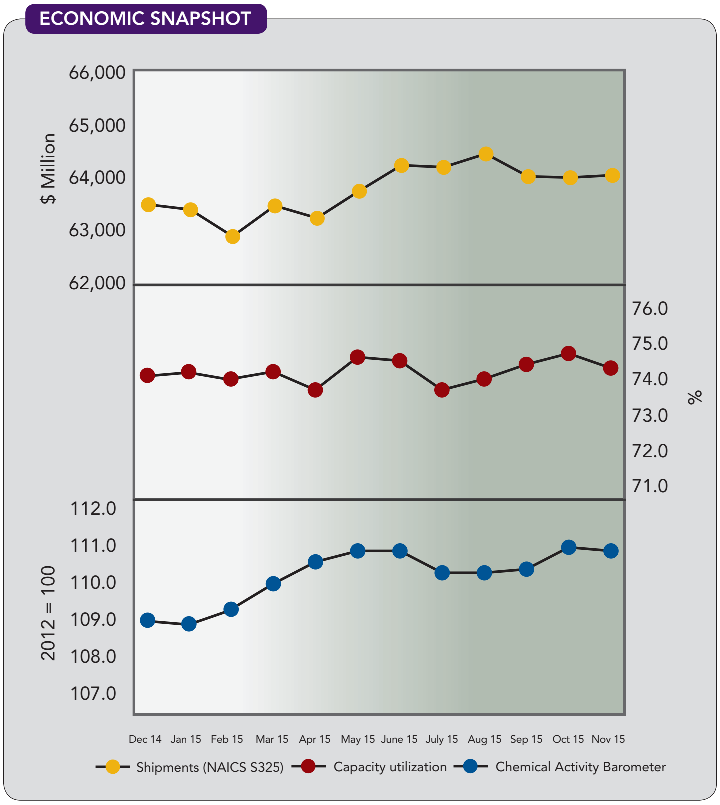
This means increased performance for all products that will use FDME as a building block, including high-performance renewable chemicals and polymers (polyesters, polyamides, plasticizers and polyurethanes) with applications in packaging, textiles, engineering plastics and many other industries, the companies claim.

"This molecule is a game-changing platform technology. It will enable cost-efficient production of a variety of 100% renewable, high-performance chemicals and polymers with applications across a broad range of industries," says Simon Herriott, global business director for biomaterials at DuPont.

Polytrimethylene furandicarboxylate (PTF) is one of the first polymers under development utilizing FDME. PTF is a 100% renewable and recyclable polymer that can substantially improve gas-barrier properties when making bottles and other beverage packages. This reportedly makes PTF ideal for improving a beverage's shelf life.

"Other polymers might include the polyester made from ethylene glycol and FDME, known as PEF as well as the polyester made from butanediol (BDO) and FDME known as PBF. We are excited to work with customers to develop many other polymers and uses for FDME as it becomes available at a competitive price," says a spokesperson for DuPont and ADM.

The integrated 60-t/y demonstration plant in Decatur, Ill., now being planned will provide potential customers with FDME for testing and research. DuPont says it will use some of the FDME output to make and test PTF.



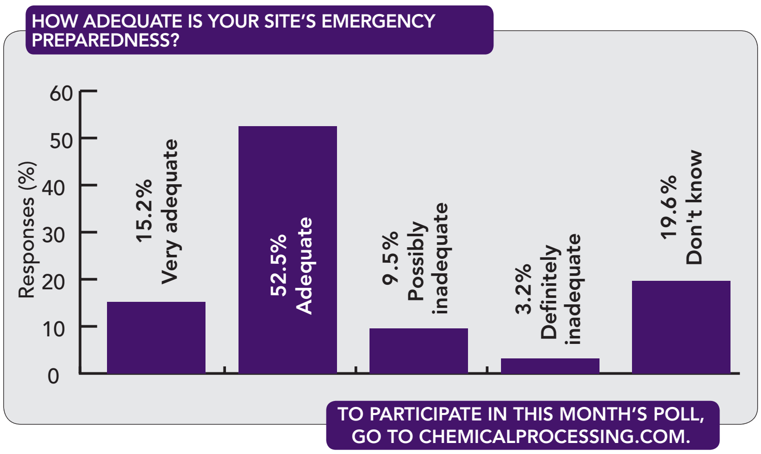
Indicators show mixed results but only modest changes. *Source: American Chemistry Council.*

Better Bioprocess for Acetic Acid Beckons

PRECIPITATING NANOPARTICLES of a semiconductor on a bacterium that does not normally engage in photosynthesis enables the organism to use light to reduce carbon dioxide to acetic acid at high yields, report researchers in California. The semiconductor, cadmium sulfide (CdS), acts as a light harvester, spurring photosynthesis.

The process combines the highly efficient light harvesting of inorganic semiconductors with the high specificity and low cost of biocatalysts, say Kelsey Sakimoto, Andrew Wong and Peidong Yang, all of whom are in the Department of Chemistry at the University of California – Berkeley and in the Materials Science Division of the Lawrence Berkeley National Laboratory, both in Berkeley, Calif.

The photosynthesis of carbon dioxide to acetic acid by the bacterium, *M. thermoacetica*, and CdS involves two steps in a single pot (Figure 1), they explain. First, growing the bacterium in the presence of cadmium and cysteine triggers the precipitation of the CdS nanoparticles. Then, the bacterium uses electrons generated by illuminated



Over two-thirds of respondents said emergency preparedness was at least adequate.

CdS nanoparticles to perform the photosynthesis. The calculated yield of acetic acid is about 90%. More details appear in a recent article in *Science*.

The hybrid system, the researchers believe, offers advantages, such as the ability to tune the effective light flux per bacterium, over natural photosynthesis, and also promises improved efficiencies compared to traditional biological approaches to nanoparticle synthesis that use ligands.

At this point, the development is at the proof-of-concept stage.

"There are a couple of things we are doing as the next step. We are attempting to include water oxidation, the other part of the half reaction of the photosynthesis. We are also looking into the fundamental electron charge transfer at the semiconductor/bacteria interface," notes Yang.

Key challenges remain to be addressed, he admits. "There are many — decorating the bacteria with [a] less-toxic semiconductor with better light absorption; completing the other half part of the photosynthesis; and understanding the fundamental electron transfer across the semiconductor/bacteria interface."

However, Yang is optimistic that the hybrid system ultimately might serve for commercial production of acetic acid.

NANOPARTICLE-STUDDED BACTERIUM

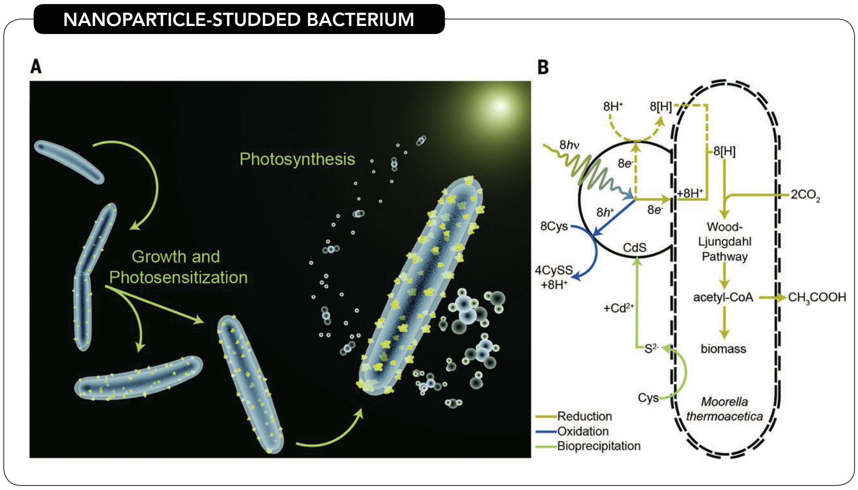


Figure 1. Deposition of cadmium sulfide enables bacterium to use light to reduce carbon dioxide to acetate. *Source: University of California – Berkeley.*

Mind Your Refrigeration Systems, Part II

A periodic energy assessment can spur some low-cost energy saving measures

We run more compressors than needed to meet the refrigeration load.

IN PART I of this two-part series, we talked about fluid management (http://goo.gl/yHXAeE). Now, let's discuss some minimal or low-cost measures in refrigeration and chiller systems that can provide some "quick wins" for better energy efficiency. Refrigeration-and-chiller-system performance and energy efficiency are not key performance indicators in most plants that I have worked. Because these systems are part of the plant's utilities infrastructure, they typically get the least amount of attention due to other pressing issues at a plant. Hence, they continue to function year after year and the single key parameter monitored is the refrigeration temperature the process requires.

Although the actual system configuration and components vary significantly from one system to another, the over-arching principles and thermodynamics are consistent across all systems. There are two types of refrigeration and chiller systems: mechanical vapor compression systems (>95%) and thermally activated absorption systems. This article will focus on mechanical vapor compression systems, but I plan to talk about absorption systems in a future column. Nevertheless, some of the measures will apply to both systems.

An electric- or steam-powered refrigerant compressor drives the system; we spend our energy and money to run the compressor and in return get the refrigeration temperatures and heat-removal capability. Reducing the compressor's work leads to energy efficiency and savings without sacrificing production, throughputs, run-rates, etc. The compressor energy is a function of the lift (difference between saturation temperatures of the condenser and the evaporator) and the refrigerant mass flow rate (operating load) through the compressor. The compressor has an isentropic efficiency, which depends on the type of machine, as well as its design, controls and operating load.

One of the most common conservation measures for these systems is to reduce the entering condenser water temperature (aka floating head pressure). This allows the system to lower the compressor discharge pressure and thus reduce the compressor work. Fan power on the cooling tower or fin-fan will increase — albeit minimally compared to the compressor energy savings. Typically, reducing cooling water temperature could obtain 0.5–1.0% energy savings per °F. This depends on the refrigeration temperature; lower temperatures would provide higher savings. The main constraints to this implementation include processes with varying cooling water temperatures and the ability to transport refrigerant liquid/vapor to the end-user from the central utilities area.

Minimizing operation of multiple compressors is another low-cost energy opportunity. A compressor, being a turbo-machine, has an operating curve and an associated efficiency at part-load conditions. Centrifugal machines have inlet guide vanes, speed control and hot-gas bypass as methods to match loads and continue reliable operation. Screw machines use variable speed control, slide valves, etc. Most plants are set up without a master controller and operation is very basic with full burden on the operators to figure out sequencing of machines. The net effect is we run more compressors than needed to meet the refrigeration load. I recommend "N+1" compressor operations and doing a study to identify the best configuration match between loads and which compressors to run to minimize overall system energy usage. Developing a basic matrix for operators to follow in different load conditions can easily save 3–5% of the energy, increase system reliability and reduce maintenance costs.

The refrigeration temperature may not be something that can be changed but I would highly recommend during the periodic energy assessment you ask what is the critical process or end-user that requires the lowest refrigeration temperature. Follow up that question with a discussion on possibly raising that temperature from the design or current operating conditions. Processes change over time and as our reactors become more efficient, so the need for the refrigeration temperature may also change. It's possible in certain systems to save as much as 1.5% per °F increase in refrigeration temperature.

To summarize, a significant amount of energy system optimization can be done in refrigeration and chiller systems, including pinch analysis, and this article just scratches the surface. Hopefully, I have stirred enough interest for you to undertake an investigation to better understand and operate your refrigeration and chiller systems so that they don't feel neglected and run down.

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OSHA Offers Weight-of-Evidence Guidance

Document aims to assist manufacturers evaluating hazardous chemicals

Understanding the Guidance is essential.

ON FEBRUARY 16, 2016, the U.S. Occupational Safety and Health Administration (OSHA) released for public comment its "Guidance on Data Evaluation for Weight of Evidence Determination." The document aims to help employers consider all available information when classifying hazardous chemicals for labeling and safety data sheet (SDS) completion purposes. Because of the critical importance of satisfying these regulatory obligations correctly, understanding the Guidance is essential.

BACKGROUND

As part of OSHA's efforts to protect workers from the potential hazards chemicals may pose, the agency plans to issue new guidance on how to apply the weight-of-evidence approach when dealing with scientific studies. According to OSHA, the approach assists manufacturers, importers and employers in evaluating scientific studies on a chemical substance with a view toward assessing the chemical's potential health hazards and determining what information must be disclosed on the label and in the SDS in compliance with the Hazard Communication Standard (HCS). The Guidance is a companion document to a recently posted Hazard Classification Guidance, on which OSHA is not accepting comment.

Regulatory changes necessitated the need for new guidance. In March 2012, OSHA aligned the HCS with the U.N. Globally Harmonized System of Classification and Labeling of Chemicals (GHS) (For details on GHS, see: "Prepare for the GHS Compliance Deadline," http://goo.gl/JRTL08.) The GHS expressly allows criteria that include the use of a weight-of-evidence approach when evaluating the health hazards of a chemical. Under the HCS, chemical manufacturers and importers must review all available scientific evidence concerning the physical and health hazards of the chemicals they produce or import to determine if they are hazardous.

This evaluation is required under several provisions of the HCS. First, chemical manufacturers and importers must evaluate the hazards of chemicals they produce or import under 29 C.F.R. § 1910.1200(d). Second, for chemicals found to be hazardous, the manufacturer or importer must prepare an SDS and container labels must be transmitted to downstream users of the chemicals. Employers also must maintain an SDS in the workplace for each hazardous chemical they use (29 C.F.R. § 1910.1200(f) and (g)). Finally, all employers must develop a written hazard communication program and provide information and training to workers about the hazardous chemicals in their workplace (29 C.F.R. § 1910.1200(e) and (f)).

Given the introduction of a weight-of-evidence approach in determining health hazards that must be disclosed on a product's label and SDS, OSHA properly recognized that guidance on how to conduct a systematic application of this approach was needed. The Guidance sets forth the elements of such an approach that, in OSHA's view, is consistent with the GHS criteria and explains the various types of information that must be considered to establish classification under the HCS. The Guidance aims to help the label and SDS preparer apply the weight-of-evidence approach when dealing with complex scientific studies.

OSHA notes the Guidance isn't a standard or regulation, doesn't create any new legal obligations, and is intended to assist employers in providing a safe and healthful workplace. The recommendations are advisory in nature, informational in content, and intended to educate scientists and non-scientists alike who prepare labels and SDSs so that they provide accurate and consistent information.

DISCUSSION

This is important guidance and a weight-of-evidence approach is essential to evaluating hazardous chemicals. Stakeholders will appreciate that in the past, if a single positive study on a chemical was identified, OSHA could permissibly rely on this single study for classification and labeling purposes. In light of HCS 2012, a weight-of-evidence approach can take a more systematic assessment of possible hazards relying upon a careful review of all available pertinent data and information. This is good news, so a careful review of the Guidance is recommended.

OSHA will accept comments until March 31, 2016. The document is detailed; stakeholders may request more time to review and comment on this important document.

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Lynn is managing director of Bergeson & Campbell, P.C., a Washington, D.C.-based law firm that concentrates on chemical industry issues. The views expressed herein are solely those of the author and should not be construed as legal advice.

Plants Plug Away at Leaks

The quest for improved safety, sustainability and cost savings drives efforts to reduce fugitive emissions

By Seán Ottewell, Editor at Large

CHEMICAL COMPANIES such as BASF and Dow are working hard both to identify and deal with the sources of their fugitive emissions. Meanwhile, vendors such as Garlock and Honeywell Process Systems are developing technologies and procedures to make the job faster and more cost-effective.

Fugitive emissions may pose significant hazards to people and the environment as well as sizable economic penalties from loss of materials. "Fugitive emissions cause losses during production, transport and storage. Many of the substances concerned are toxic and it requires know-how and state-of-the-art technology to contain their release," notes Christoph Moritz, coordinator air quality, BASF, Ludwigshafen, Germany.

To reduce fugitive — also known by BASF as diffuse — emissions, the company implements strategies at its sites that meet local, national and international standards. At the heart of these strategies are three basic rules.

First is avoidance. "Here, we use state-of-the-art equipment such as low-emission seals that have been designed for use with critical chemicals. We also run quality assurance programs for mechanics and operators, who are properly trained in special courses according to latest standards, for example, VDI 2290 in Germany," he adds. (The VDI 2290 guideline deals with flange connections for liquid and gaseous media to meet emission control requirements; it covers various metals and applies to services with a maximum operating temperature of 400°C.)

"Besides regular inspection and maintenance, our plants are controlled by means of pressure drop sensors. Seals and flanges are replaced at defined intervals," says Moritz.

The second basic rule is detection of emissions and leaks (Figure 1). Typically, plants rely on a conventional flame ionization detector (FID) that is sensitive to organic substances. Analysis of the substance begins at a pre-set threshold concentration, for example, 500 ppm. If such a concentration is exceeded, operating staff takes immediate action.

An infrared (IR) camera often serves as a preliminary detection device (Figure 2). Set in a "fume sensitive" mode, it can spot an increased concentration of a substance; a more precise check with an FID immediately follows.

"All plants are equipped with such sensors and any leaks detected are instantly repaired. The detection procedures themselves may vary from country to country depending on local regulations and the requirements of the respective authorities," he explains.

The final basic rule is calculation of emissions; the methods used depend upon the relevant standards (EPA, DIN, etc.). To create a proper comparison between the different standards, BASF has carried out internal studies and sponsored several postgraduate research theses. "These have revealed valuable information about the correlation between 'sniffed' concentrations of organics and the corresponding leakages in g/h — i.e., mass flow. Moreover different methods of calculation for diffuse emissions were compared and quantified," Moritz says.

LINK TO SUSTAINABILITY

For Dow Chemical, Midland, Mich., reducing process spills from equipment and decreasing fugitive emissions are part of its overall sustainability strategy. Launched last year, its 2025 sustainability goals commit the company to maintaining world-leading operations performance in natural resource efficiency, environmental protection, health and safety.

To this end, Dow has set a goal to reduce severe process safety and containment events by 70% by 2025, a target the American Chemistry Council, Washington, D.C., suggests for its members. The company's fugitive emissions strategy covers small emissions of gases or vapors from equipment flanges, seals and packing components that are difficult to detect without specialized equipment.

"Our current focus on reducing fugitive emissions centers on improving Dow's leak detection and repair (LDAR) management system. This includes improvements to LDAR training, work processes, tracking tools, quality assurance and control and self-assessments. Additional improvements will focus on the technology used by contract providers," notes a spokesperson.

Dow's site in Lauterbourg, France, provides a prime example of this work in action: the plant has reduced process spills and associated emissions by 75% over the past four years.

The key driver of this change was an improvement project that focused on three main actions.

The first was having plant leadership set clear expectations about the reporting of actual and potential leaks and spills of any size. All such events require a root cause investigation and the assignment of corrective actions.

Figure 1. Plant technician uses a flame ionization detector to check seals and flanges on a set schedule. *Source: BASF.*

Figure 2. Readings from a camera can provide the first warning of a leak, and spur follow-up checks with a flame ionization detector. *Source: Sage Environmental.*

The second was creating an improvement team to lead overall efforts and implement projects identified. These projects included rearranging equipment, using color-coded caps to distinguish hazardous from non-hazardous chemicals, labeling valves to indicate those that only should be opened in exceptional circumstances, and implementing checklists and double-checking by a second operator to ensure proper valve resealing.

The third action was ensuring that all operations team members — plant operators, engineers, maintenance and leadership — contribute to the reporting of leaks. This involved setting individual goals, measuring performance against these goals, and factoring participation in leak-reduction efforts into team member recognition and performance management.

To support the initiative, the site also upgraded its assets, e.g., replacing circle pumps with screw flasks, introducing valves that only can be opened by key, and installing leak detectors that can shut down equipment automatically.

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IMPROVING TECHNOLOGY

Advances in technology are helping chemical companies both to better identify the sources of their fugitive emissions and meet evolving legislative demands, says Jim Drago, principal applications engineer, Garlock, Palmyra, N.Y.

Identifying sources is critical, he notes, citing a 1997 study "Analysis of Refinery Screening Data" (Publication 310 of the American Petroleum Institute, Washington, D.C.) that found 90% of all such emissions coming from fewer than 5% of the 50,000 components subject to fugitive emissions compliance. This 5% included components with high magnitude leaks, typically greater than 10,000 ppm. "Consider the fact that the threshold for categorizing a component as leaking is usually 500 ppm and one asks the questions: 'Why are we monitoring all these components that are not leaking or are small leaks? How can we identify the components with large leaks and eliminate 90% of our emissions?'"

VOC MEASUREMENT

Figure 3. Current sniffing technologies for monitoring volatile organic compounds rely on a probe with a small diameter. *Source: Team Industrial Services.*

One emerging technology is high-flow sampling. The current sampling techniques, designated in EPA Method 21, measure volatile organic compound (VOC) concentration at the probe's end, which is fairly small — about ¼-in. in diameter (Figure 3). With high-flow sampling, the size of the probe end is 1½–2-in. in diameter (similar to that of the hose of a household vacuum cleaner) and so the probe takes in a much larger volume of sample of the ambient atmosphere around the equipment of interest. "This is accepted as being a full sampling of the entire leak, so it can be an easy leap to quantifying the leak in kg/h," notes Drago.

IR camera technology also taken a big leap forward, he says. Originally the cameras just were used to "see" leaks and were go/no-go instruments heavily dependent on factors such as the ambient atmosphere and wind conditions. They often were not accurate with leaks below around 2,500–5,000 ppm and sometimes weren't even useful below 10,000 ppm, Drago explains.

"Companies such as Rebellion Photonics, Houston, Texas, have changed all that with gas cloud imaging (GCI) camera technology. This now gives you the ability [to] carry out continuous or mobile monitoring with a camera and immediately get a leak rate," he says. The GCI camera (Figure 4) detects gases' unique spectral signal, which enables advanced algorithms to identify specific hydrocarbon fingerprints within an emission; operators are immediately alerted to potential hazards on a site.

Meanwhile, seal manufacturers, including Garlock, are focusing on installation techniques. "We're not seeing 'OMG that's new' products for, for example, valve stem seals, which are the primary emission source on any plant. Rather, we are refining and tweaking what we do. At conferences and in discussions with customers, we are really stressing the importance of good installation practices and the quality of the installers themselves and the people who oversee them."

Valve manufacturers and seal makers are engaging in much greater review of valve designs, says Drago. Both are becoming much more serious about getting certification to API 624 — a standard that specifies the requirements and acceptance criteria for fugitive-emission-type testing of valves.

Finally, he expects much of the open forum discussions and conferences this year to focus on what the next generation of LDAR regulation from the U.S. Environmental Protection Agency (EPA) will look like. "It seems they will be very much in line with its NextGen strategy," he notes.

Running from 2014–2017, NextGen, which is the EPA's plan to improve the effectiveness of its compliance program, brings together five interconnected components: easier-to-implement design regulations and permits; promotion of advanced emissions/pollutant detection technology; greater use of electronic reporting; increased transparency, making information more accessible to the public; and development and use of innovative enforcement approaches such as data analytics and targeting to achieve more-widespread compliance.

WIDER ROLE FOR WIRELESS

Development of robust, cost-effective wireless technologies is helping companies achieve their goal of zero incidents, says Diederik Mols, global business leader industrial wireless solutions, Honeywell Process Solutions, Amsterdam, The Netherlands. "Every leak could lead to an incident; look what happened at Buncefield," he stresses. (For details on the explosion at the Buncefield fuel depot in the U.K., see "It's Time to Tank Complacency," http://goo.gl/kCa0xw.)

Since the incident at Buncefield, liquid leak detection has gotten much greater priority because of the dangers posed by explosive vapor clouds formed by fugitive emissions via

GAS CLOUD IMAGING

Figure 4. Camera can identify specific hydrocarbons and also generate a leak rate. *Source: Rebellion Photonics.*

evaporation from such spills, notes Mols. Tank roof monitoring also has become more a priority, firstly to avoid overfills and secondly to ensure that floating roofs are kept even to avoid gas vapor leaks, he adds.

In addition, he has noticed that companies are getting much more stringent in their detection-to-alarm time demands. Here, he cites a customer in Qatar that runs one of the world's largest integrated liquefied-natural-gas complexes. The company wanted a warning system to alert personnel in the administration area of any toxic gas leakage. One of the critical requirements was to generate audio and visual alarms within three seconds of detecting a gas leak — a demand that had proved the stumbling block for another vendor who could not meet the required latency period. Honeywell's success lay in the use of its

OneWireless infrastructure and the XYR 6000 Universal I/O wireless transmitter, which together enabled the rapid audio and visual alarming required.

Advances in personal gas detectors also are bolstering the protection of personnel from the danger of leaks. For instance, later this year, Honeywell plans to introduce new technology specifically designed to reduce the risks for operators working on their own in remote areas of the plant, such as tank farms or wastewater treatment facilities, or even outside the perimeter. It monitors vital functions, hazardous gas levels and whether or not an operator is down. Any alarms from the detector will be displayed and triggered in real time in the control room. “Not only do you get better gas-detection information, but also the system can be the difference between life and death for a field operator,” says Mols.

The future of emissions detection technology lies in further miniaturization and improved cost-effectiveness of sensors — along with closer tailoring of the technology to the demands of regional legislation, he believes. ●

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MAKE WIDER USE OF

PROCESS HAZARD ANALYSIS

The technique can provide important insights for strategic decisions

By GC Shah, Wood Group Mustang

MANY COMPANIES miss significant opportunities to take advantage of process hazard analysis (PHA) beyond the narrow confines in which they currently use the technique. In particular, a PHA can provide crucial inputs for a number of strategic considerations. Here, we'll look at its potential value for:

- Divestitures and acquisitions;
- Multiplant sites;
- Joint venture projects;
- New technologies;
- Differing risk perceptions;
- Information management;
- Cyber-security concerns; and
- Aging plants and legacy controls.

DIVESTITURES AND ACQUISITIONS

Divestitures and acquisitions (D&As) probably have occurred for as long as chemicals have been made. D&As should consider not only business-specific issues but also safety and environmental ones. This involves thorough and thoughtful due diligence. Unfortunately, some companies still make high-level decisions without properly assessing the safety and environmental implications of D&As. Some executives, although financially astute, may lack familiarity or appreciation of potential safety liabilities. Safety professionals can make valuable contributions in such cases. Here are some pointers:

- Corporate executives tend to focus on business risk — e.g., market volatility, industry-specific concerns and legal issues. So, how can safety professionals persuade the executives to appreciate safety risk? They certainly should stress that ensuring the safety of workers and neighbors is both a statutory and moral obligation of an organization. Safety professionals must convince the executives that safety makes business sense before, during and after a divestiture or acquisition. To do this effectively, they should make themselves familiar with "business terminology."
- Perform a PHA prior to the start of "serious talks" about D&As.
- Soon after completion of an acquisition, harmonize the best safety practices of both organizations.

MULTIPLANT SITES

Such locations present unique risks stemming from the interfaces among the plants. Typically, various operations at the site share or exchange utilities and waste management systems such as flares or incinerators. It is important to carefully consider the safety implications. Common problems are:

- Inadequate protocols to deal with management of change at one or more operations on the site;
- Poorly defined criteria to ensure compliance of environmental systems such as flares or incinerators, particularly that they have adequate capacity to deal with "worst-case scenarios" on a site-wide scale;
- Difficulties in adequately protecting workers from exposure to hazardous materials and safeguarding equipment during "loss of containment" events because of tight spacing between the units; and
- Uncoordinated emergency response systems.

JOINT VENTURE PROJECTS

Typically, joint ventures (JVs) involve large projects; so, the importance of clear communications can't be overstated. Today's project management tools are well equipped to deal with massive flows of information and interaction in an efficient manner. However, large projects also present issues that could scuttle a PHA. Project sponsors may have widely

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divergent perceptions of hazards and risk. They also may use different risk assessment systems. Therefore, prior to the start of the PHA, the PHA facilitator should ensure all sponsors agree on risk assessment, documentation and risk management methodologies.

NEW TECHNOLOGIES

Companies continually adopt new technology — ranging from entire processes to individual elements such as particular instruments. Introducing a new technology creates risks as well as benefits. Doing so on an ad-hoc basis is a risky move. Use a PHA to delve into a number of critical issues:

- Is there safety infrastructure (e.g., trained staff, tools to maintain technology, waste disposal, permitting and vendor support) to manage the new technology?
- What's the fallback if the technology doesn't function as expected? For instance, in the event of a major failure, is it possible to revert to the existing technology or systems without incurring unacceptable level of risk?
- Does the technology pose any new potential hazards? The PHA facilitator should inquire about the number of sites where the technology already is used and problems, if any, encountered. Obviously, a brand new technology requires thorough risk-based scrutiny. Several organizations use standard procedures that address the issue of new technology adoption.

DIFFERING RISK PERCEPTIONS

Unfortunately, despite the maturing of the PHA process, widely differing risk perceptions still exist, often even within the same assessment team. This may reflect generational differences. Veteran professionals with operations experience, who have had some accidents at their plants, are much more risk-averse than others. Moreover, it's not that uncommon even today for some members of the PHA group to regard the PHA as an unnecessary step. In addition, tight schedules and work demands may foster pressures to speed through the PHA. The facilitator must appreciate these issues and take steps to address them.

First, the person must understand the organization's culture. Most companies regard safety as an integral and crucial part of productivity. However, a few firms have impressive safety slogans but little in terms of safety practice at the project or plant level. Project managers or plant managers at these organizations are under tacit pressure to "get things done." In contrast, other firms go overboard, creating a safety bureaucracy that makes resolving even relatively simple issues a long, drawn-out process.

A week or so prior to the start of the PHA, consider sending team members some case histories of relevant accidents that have occurred elsewhere in the same industry. Also, if possible, try to gain an understanding of the PHA team members' backgrounds. At the start of the PHA assessment, give examples of accidents, near-misses, or mishaps in situations germane to the PHA at hand.

Ask veteran staff to share their experiences with the other team members prior to the start of the PHA process. This is an example of where you can harness diversity to enhance safety.

INFORMATION MANAGEMENT

Today, leading organizations recognize that the information gleaned from collected data can serve as a powerful tool to enhance safety in the long run. However, this demands effective information management, which is a formidable task, especially for large, multinational organizations. For some multinationals with mammoth databases, it's not uncommon to run into situations where staff avoids accessing the databases because the steps needed are so complex and tedious.

Success requires taking some strategic steps:

- Developing safety portals that house databases on plant safety (unsafe occurrences or near-misses), accident investigations, PHA assessments and follow-up actions on recommendations, and equipment failure rates.
- Employing statistical techniques to extract information and knowledge from these data.
- Providing easy-to-understand and streamlined methods to access these important safety data. A person should not have to contact information technology (IT) professionals for help accessing these data.
- Establishing processes to modify plant or processes based on findings from accident investigations and PHA assessments.
- Minimizing the frequency of modifications to IT and information-management systems.
- Performing periodic training on the use of safety systems and safety databases.

CYBER-SECURITY CONCERNS

Preventing attacks on control and safety systems is rapidly becoming a crucial issue for the process industry. A PHA should look at cyber security concerns as a part of the overall risk assessment. However, given the size and complexity of large process control and safety instrumented systems, it may be appropriate to conduct a separate risk assessment just for them. Keep the following in mind:

- The priorities for IT systems differ from those for control/safety systems. So, in conducting risk assessment of the control/safety networks, IT and control/safety engineers should collaborate.
- Use a systems approach to minimize cyber risk. Employ best practices — e.g., for worker training and awareness, system monitoring, access control (physical as well as logical), patch management and defense-in-depth. Specify cyber-security-certified components and install recovery programs to ensure quick rebound from cyber mishaps. Conduct periodic risk assessments.

AGING PLANTS AND LEGACY CONTROLS

Old plants and infrastructures pose special hazards such as corrosion, outdated design standards (under which the systems were designed and built) and frequent breakdowns, among others. In legacy control systems, the flow of information could be so slow that it could cause safety mishaps. Long-term risk considerations may dictate replacement with robust modern systems. In the meantime, you must manage risk by administrative controls (e.g., corrosion monitoring programs and plant inspections) that check system integrity on a periodic basis, and provide adequate resources for safe and efficient repairs of these systems.

AN ONGOING EFFORT

PHA isn't a one-time activity but a continuing process. It should account for all factors that could impact safety and security; these factors change in their form and intensity. Strategically designed PHAs should consider these dynamic changes.

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PROPERLY APPLY PLASTIC PIPING

Use of such piping requires careful consideration of a number of issues

By Amin Almasi, rotating equipment consultant

FOR YEARS, process plants have relied on non-metallic piping as a cost-effective alternative to stainless, alloy and other expensive metallic piping in applications posing high corrosion rates or requiring stringent cleanliness standards.

Plastic piping affords excellent resistance to attack by many chemicals, including most acids, alkalis and salt solutions. Such piping comes in schedule-40, schedule-80 and other common sizes, with wall thickness usually corresponding to that of steel piping. In addition, some plastic piping, e.g., PVC, is offered with standard dimension ratio (SDR) ratings, which mean the piping system will maintain a more-or-less uniform pressure rating at a specified temperature regardless of pipe diameter.

However, some issues — e.g., thermal movement and other thermal effects, and liquid hammer — demand more attention with plastic piping than with commonly used metallic piping. Most plastic piping materials exhibit a relatively high coefficient of thermal expansion. Elevated temperatures may seriously affect plastic piping; for some materials, pressure/temperature ratings drop substantially at temperatures above 50°C. So, plastic piping should not be located near steam lines or other hot surfaces. When liquid flow in a piping system stops suddenly (for instance, because of a quick-closing valve), a pressure surge known as liquid hammer (or often water hammer) develops and can easily rupture a plastic piping system.

Plastic piping systems usually require closer support spacing than metallic ones, particularly at elevated temperatures. Proper support for plastic piping is essential. As a very rough indication, allowable span is around half that of equivalent metallic piping (same size, schedule, etc.); check the values of allowable span published by the plastic piping's manufacturer or consult a specialist. Supports and hangers can be clamps, saddles, angles, or other standard types; supports should have broad, smooth bearing surfaces, rather than narrow or localized contacts, to minimize the danger of stress concentrations.

Vibrations can damage most plastic-piping systems. Therefore, you must properly assess the piping under dynamic forces and apply mitigation techniques as needed. For instance, plastic piping connected to a large pump might experience high power vibrations, which might necessitate a vibration isolation device. However, such vibration isolators may pose operational or reliability problems, so install them only in special applications where they really are required and no other solution is viable.

Non-metallic piping systems most often rely on a fitting, such as a tee, to provide a branch connection; the fitting usually provides adequate strength to sustain the internal and external pressure of the piping. A branch connection made directly on a pipe weakens the pipe at the location of the opening; unless the wall thickness of the pipe sufficiently exceeds that required to maintain the pressure, you must provide added reinforcement. Assess the amount of reinforcement per applicable codes and specifications.

PLASTIC OPTIONS

Several types of thermoplastics are available as piping. So, let's look at those most commonly used.

Polyvinyl chloride (PVC) is stronger and more rigid than many other thermoplastics and has relatively high mechanical strength, tensile strength and module of elasticity. It is both lightweight and low cost, and demands little maintenance. Additionally, various solvent cements or other methods can fuse PVC pipes together to create permanent joints that are virtually impervious to leakage. Moreover, the material exhibits excellent chemical resistance to a wide range of corrosive liquids. However, PVC requires careful installation to avoid longitudinal cracking and over-belling, and certain liquids such as aromatics and some chlorinated hydrocarbons can damage it.

The allowable span for PVC piping generally should not exceed around 40%–50% of that of equivalent steel piping; the allowable span increases more slowly with diameter compared to steel piping systems. As a very rough indication, for typical steel piping systems, the allowable spans are 3 m, 5 m and 7 m for 2-in., 6-in. and 10-in. piping, respectively. You also can conservatively estimate the allowable span of steel piping via $S = 2\ D^{1/2}$ where D is the pipe diameter in inches and the span is in meters. In contrast, for PVC piping, allowable spans are 1.8 m, 2.5 m and 3 m for 2-in., 6-in. and 10-in. piping, respectively; you conservatively can estimate the allowable span of PVC piping via $S = 1.4\ D^{1/3}$, again with diameter in inches and span in meters.

Chlorinated PVC (CPVC) offers higher heat resistance than PVC; because of its excellent corrosion resistance at elevated temperatures, CPVC finds use at temperatures up to 90°C versus the normal limit of 60°C for PVC. However, it is more expensive. Therefore, CPVC primarily gets selected where such benefits are required, such as in certain chemical or relatively hot liquid services.

CPVC shares most of the features and properties of PVC; it, too, is readily workable, including by machining, welding and forming. However, CPVC requires specialized solvent cement. (For more on such piping, see: "Put CPVC Piping In Its Place," http://goo.gl/GoIJFT.)

CPVC is more ductile than PVC — allowing greater flexure and crush resistance. Because of its mechanical strength, CPVC is a viable candidate to replace many types of metal pipes in conditions where susceptibility to corrosion limits metal's use.

Polypropylene (PP) is rugged and unusually resistant to many chemical solvents, bases and acids. It is one of the lightest plastics used in piping systems and comes in various forms. For example, fiber-reinforced-polymer (FRP) wrapped piping combines the excellent chemical resistance of PP with the mechanical strength of FRP.

STRAINS AND STRESSES

Thermoplastic piping requires flexibility analysis that incorporates appropriate elastic behavior. In many systems, the strains generally will produce stresses of the overstrained (plastic) type, even at relatively low values of total displacement strain. Often, the displacement strains (those due to thermal movements) will not cause immediate failure but may result in detrimental distortion. Progressive deformation may occur upon repeated thermal cycling or with prolonged exposure to elevated temperatures.

Piping layout often offers adequate inherent flexibility through changes in direction, wherein displacements chiefly produce bending and torsional strains of low magnitude. The amount of tension or compression strain (which can produce larger reactions) usually is small.

Where piping lacks inherent flexibility or is unbalanced, you must provide additional flexibility by one or more of the following means: bends, loops or offsets; swivels or similar; and other special devices and arrangements such as flexible joints. Choose corrugated, bellows or slip-joint expansion joints only where other solutions aren't feasible.

While different codes and specifications give some general guidance to ensure adequate flexibility, they often don't provide either specific stress-limiting criteria or particular methods for stress analysis of non-metallic piping systems. This is because of the significant difference of the stress-strain behavior of non-metals versus metals. In particular, Poisson's ratio varies greatly for the various plastic materials and temperatures; the simplified formulae used as the piping code design basis for stress analysis of metallic piping may not be applicable or valid for some non-metals. Certain codes require the piping system layout to provide substantial flexibility to ensure minimizing displacement stresses; while this approach should allow for a high degree of safety, it isn't always cost effective. The reality is stress and flexibility analysis of non-metallic piping often depends more on the engineer's experiences and knowledge of specific non-metallic piping under study.

KEY CONSIDERATIONS

Temperature is an important parameter. Each thermoplastic generally has a fixed maximum service temperature, which identifies the upper limit to which pipe may be heated without damage. When heated above this temperature, the pipe will soften and deform. Upon cooling, it will harden to the deformed shape and dimensions.

Another important factor for plastic piping is the long-term hydrostatic strength. This — which serves the basis for the piping's design pressure — is determined by finding the estimated circumferential stress that, when applied continuously, will produce failure of the pipe after around 100,000 hours (say, about 11 years of continuous operation) at a specified temperature. In addition, design calculations generally include a service factor that takes into account certain variables together with a degree of safety appropriate to the installation. The service factor most often reflects long system life (say, about 40 or 50 years). This design method usually doesn't include the fittings, joints or cyclic effects such as liquid hammer. Most pressure ratings for

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thermoplastic pipes are calculated assuming a water environment; so, adjustments usually are needed for other fluids. As the temperature rises, the pipe becomes more ductile and loses strength; therefore, you should decrease the rating to allow for safe operation. These factors differ for each pipe material.

Aging can degrade the physical and chemical properties of plastic piping, and generally depends upon temperature. The changes can occur naturally through normal atmospheric or temperature fluctuations and ambient light, or can develop because of conditions in the process, such as elevated temperature of the fluid in the piping. One way to determine the onset of aging is to measure thermal stability (oxygen induction time) using differential scanning calorimetry.

Fire conditions greatly accelerate the degradation of plastics. In the early stages of a fire, most plastics melt and lose their structural shape and strength. As the temperature rises, they chemically decompose, often releasing toxic chemicals. This decomposition happens at a lower temperature than ignition. By the time ignition occurs or is possible, a relatively long period of chemical emission has elapsed. When thermoplastic pipe burns, it releases smoke and toxic gases, provides heat that increases the intensity of a fire, and may offer a path for flame to spread along its length. All organic materials are flammable but this is particularly true of polyolefins. It is well proven that many polymers actually are difficult to ignite; addition of flame retardants can further impede ignition.

Continuous application of load on a plastic material creates an instantaneous initial deformation that then increases at a decreasing rate. This further deformation is called creep. Removing the load at any time leads to an immediate partial recovery followed by a gradual creep recovery. However, if the plastic is deformed (strained) to a given value that is maintained, the initial load (stress) created by the deformation slowly decreases at a decreasing rate. This is known as the stress relaxation response. The ratio of the actual values of stress to strain for a specific time under continuous stressing or straining commonly is referred to as the effective creep modulus or effective stress-relaxation modulus. Time significantly affects this modulus. Experience shows that all plastic pipe will creep — with the actual extent influenced by time of loading, temperature and environment. Therefore, standard data-sheet values for mechanical properties may not suffice for some design purposes. The stress-strain responses of plastic reflect its viscoelastic nature. The viscous, or fluid-like, component tends to dampen or slow down the response between stress and strain.

Different piping codes identify special protective considerations when using non-metallic piping systems. For instance, some codes recommend safeguards and protection against possible impact because plastic piping systems often are vulnerable to accidental impact or similar damaging situations; consider safeguards for any above-ground plastic piping from which a spill or leakage can pose safety or environmental hazards. Take into account the lack of ductility and poor resistance to thermal and mechanical shock of some plastic piping systems and provide proper protection. In addition, during design incorporate methods to minimize the build-up of potentially dangerous electrostatic charges in piping that handles electrically non-conductive fluids.

Plastic fittings present a special problem; the geometry of some fittings can result in complex stress patterns that offer some stress concentrations and amplify the apparent stress cycle. A seemingly harmless pressure cycle thus can produce a damaging stress cycle that eventually can cause fatigue failure. This issue is particularly important in the case of branch fittings such as tees. In addition, the existence of stresses from other sources — for example, bending stresses induced by flexing under hydraulic thrust in improperly supported systems — can aggravate the situation. Because the design of plastic fittings isn't completely standardized, consult fittings manufacturers for recommended derating factors for cyclic loading conditions. Usually you must consider plastic fittings separately from plastic pipes regarding dynamic loading, cyclic analysis and fatigue. ●

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Improve pH Control

Widely applicable, fast and robust pH models can enhance process performance

By Christopher Stuart, Rehman Fazeem and Gregory McMillan, Mynah Technologies, and Daniel Forciniti, Missouri University of Science and Techology

THE MEASUREMENT of pH provides a resolution and rangeability in indicating process composition that is orders of magnitude better than any other analysis. With this exceptional capability comes an extraordinary sensitivity to the control strategy, controller, measurement, mechanical equipment, piping, and valve design and installation. A slight deficiency in any of these aspects that normally would be of no consequence to other control systems can cause a pH system not just to fail but to fail miserably. No other control system demands such stringent requirements for getting everything right.

Dynamic simulations can play a key role in success. They provide the details to understand the nature of the problem and to develop, prototype and test a solution. Making the simulations part of a virtual plant enables testing the actual control system configuration and displays, and training plant personnel to understand and work in concert with pH system to improve performance and onstream time. This translates into higher production rates and better product quality for process systems (e.g., crystallizers and reactors), elimination of environmental violations for waste treatment systems, and lower total lifecycle cost for all systems. The key innovative part of the simulation to achieve these benefits is the charge balance used to compute pH.

The charge balance documented by Shinskey in "pH and pION Control in Process and Waste Streams" [1] was generalized and extended to acids and bases with three dissociations by McMillan in "Advanced pH Measurement and Control," 3rd Ed. [2]. Here, we further improve the charge balance to include monovalent, divalent and trivalent conjugate salts that greatly affect slope of the titration curve in the pH neighborhood of the logarithmic acid dissociation constant (pK_a) of the associated weak acid or weak base. The charge balance provides a practical, fast and robust model for total system design that can deal with a complex mixture of ions. The concise generic form of the equations maximizes their flexibility and utility. While the equations just require dimensioned parameters and iteration, software with physical property packages, modeling of unit operations and virtual plant capability offers the greatest opportunities; it eases generating titration curves and enhancing pH-model fidelity by comparing slopes of the computed and laboratory curves in the control region. The model can be readily set up and modified by simple changes in concentrations and dissociation constants. Here, we look at the improvement of the charge balance to show its final form. We then provide an overview of how to achieve the model fidelity needed for all loop dynamics to increase control system capability, operability and reliability and, ultimately, to boost process performance.

LITERATURE CITED

1. Shinskey, F. G., "pH and pION Control in Process and Waste Streams," Wiley, Hoboken, N.J. (1973).
2. McMillan, G. K., and Cameron, R. A., "Advanced pH Measurement and Control," 3rd ed., ISA, Research Triangle Park, N.C. (2004).

PERSPECTIVE

The charge balance developed by Shinskey showed an insight into how to develop a general-purpose equation not seen in the many publications on electrochemistry. However, Shinskey focused on a single weak acid or weak base with strong acids or strong bases, enabling a direction solution. For complex mixtures of multiple weak acids and weak bases, each with the possibility of multiple dissociation constants, finding the pH that satisfies the charge balance requires a search technique. We employ a simple interval-halving search where midpoint value of the charge balance determines the half of the search range used. (The extreme nonlinearity and rangeability of pH can fool more-sophisticated searches.) Interval halving is guaranteed to provide a solution and is extremely fast because the calculations are so concise. Convergence generally occurs after 10 iterations for a 0–14 pH range, with a resolution comparable to that of the pH electrode (0.01 pH). The specific equations in books on electrolyte modeling usually treat each solution as a special case. In contrast, the general form of the equations using the charge balance provides insight and flexibility to handle complex solutions.

We have improved the charge balance to readily include conjugate salts. While the effect of ionic strength is not currently directly addressed, the dissociation constants (pK_i) can be corrected via the change in hydrogen ion activity with ionic strength per a Debye-Hückel equation. Process streams where the effect on activity coefficients is complex and large, where precipitation occurs, or solvents other than water are used require electrolyte modeling software. The pH models presented here are for dynamic modeling where the focus is on accurately finding and simulating the dynamics of the process response (e.g., process gain, dead time and time constants). What the control system sees is change, so getting the dynamics of the change is the role of these dynamic models for system design, implementation, testing and training. The robustness, speed and conciseness of the charge balance enable running virtual plants in real time and even faster than real time.

SIMULATED TITRATION OF STRONG ACID BY STRONG BASE

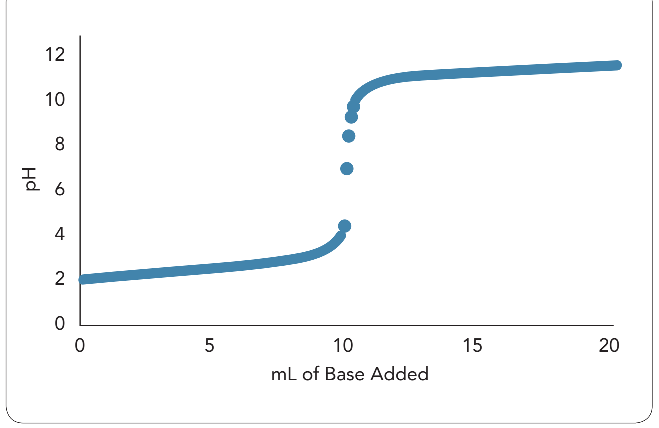

Figure 1. Zooming in on portion of curve from pH 5 to 9 would show that it is not really vertical.

SIMULATED TITRATION OF WEAK ACID BY WEAK BASE

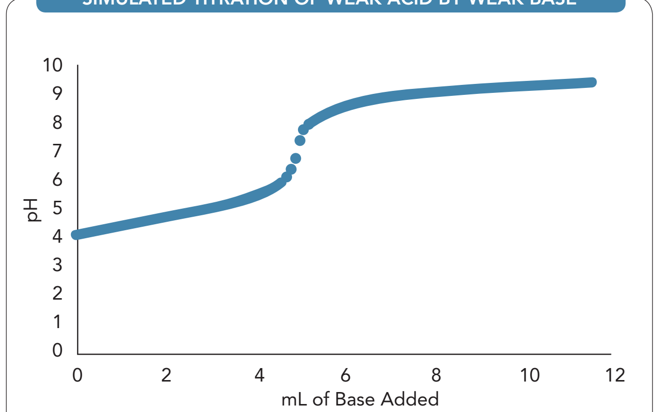

Figure 2. Trace amount of a weak acid or base or its conjugate salt markedly moderates slope.

CHARGE BALANCE

We present here the final form of a straightforward and versatile charge balance for readily simulating the response of an aqueous system for control purposes. By using equilibrium relationships in conjunction with the charge balance, a simple yet robust function appears for rapid convergence on pH. (Details on the derivation of this simple charge balance appear online in Appendix A, while online Appendix B outlines an efficient interval-halving algorithm to solve the balance, and Appendix C provides a checklist of best practices for developing and taking advantage of the model. See: http://goo.gl/0DJErg.)

In many systems, a weak acid or weak base shares an ion in common with a salt present in the system. A system that has an ion in common can exhibit a "buffering" or resistance to changing pH, resulting in a flatter slope to the titration curve. This greatly reduces the local process gain (as indicated by the slope of the titration curve). If the control has a set point in this region, such buffering markedly decreases not only the sensitivity but also the difficulty of pH control. The loss of sensitivity lessens precision in terms of pH being an inference of acid or base concentration, but also diminishes the sensitivity to noise from mixing nonuniformity and limit cycles from valve backlash and stiction. This buffering is readily explained by Le Châtelier's principle. Broadly, it states that a pressure on one side of a reaction (such as increased concentration) results in push in the opposite direction. So, in a system with acetic acid, the addition of sodium acetate contributes additional acetate to the system, driving the equilibrium back towards the undissociated form of acetic acid. With the addition of salt to the system, the effective concentration that appears in the system now depends upon the salts as well as the acid/base present. This appears as the "M" term in the expressions. Equations 1, 2 and 3 suit an acid or base with one, two and three dissociations, respectively:

$$M_1 = [s/(1+P_1)] \times E \tag{1}$$

$$M_2 = \{(2+P_2)/[1+(P_2 \times (1+P_1)]\} \times s \times E \tag{2}$$

$$M_3 = \{[3+P_3 \times (2+P_2)]/[1+P_3 \times (1+P_2 \times (1+P_1))]\} \times s \times E \tag{3}$$

(Strong acids and strong bases have logarithmic dissociation constants that are at the extremes or even outside the normal 0–14 pH scale.)

The factors P_1, P_2 and P_3 are computed as needed per the general Equation 4 where pK_i is the i-th logarithmic acid-dissociation constant (pK_1, pK_2 and pK_3) and s simply is +1 for bases and -1 for acids:

$$p_i = 10^{S \times (pH - pK_i)} \tag{4}$$

The E term, computed by Equation 5, allows including the total effect of the common ions:

$$E = \sum_{i=1}^{n} M_i \times \beta_i + M_{ab} \tag{5}$$

The equation can be formulated for either the i-th anion (for an acid) or i-th cation (for a base) contributing common ions where β_i is the stoichiometric coefficient of the i-th salt's ion contribution, M_i is the molarity of the i-th salt, M_{ab} is the molarity of the acid/base, and n is the number of species contributing common ions.

Ionic species that are not common with an acid or base present in the system appear in the charge balance for the concentration C_S via Equation 6:

$$C_S = \sum_{j=1}^{n} \lambda_j \times \beta_j + X_j \tag{6}$$

where λ is the charge associated with the ionic species for the j-th ion with no corresponding acid (in the case of anions) or base (in the case of cations), n is the number of ions with no corresponding acid and base, β_j is the stoichiometric coefficient and X_j is the concentration of the species j added to the system. (For salts not associated with acids or bases, the positive and negative ions added generally are equal, canceling out the effect on the charge balance. The effect of these salt concentrations mainly is in terms of ionic strength on activity coefficients, most notably that for the hydronium ion and hence the measured pH.)

Finally, the contributions of each M and C_S are aggregated into Equation 7 for total charge balance:

$$0 = C_S + \sum_{i=1}^{n} M_i + 10^{-pH} - 10^{pH-pKw} \tag{7}$$

where pKw is the negative of the base ten log of water dissociation constant.

MODEL FIDELITY

Figures 1 and 2 show the titration curves for a strong acid with strong base and a weak acid with a weak base, respectively. The slope of a true strong acid/strong base changes a factor of ten for each pH unit deviation away from the equivalence point (e.g., 7 pH for water at 25°C). Thus, the pH slope is 10^6 times steeper at 7 pH than at 14 pH; the reagent flow requirement to go from 8 to 7 pH is 10^6 times smaller than that to go from 14 to 13 pH. No straight lines exist, although lab titration curves may give that impression (Figure 1). Zooming in on the apparently vertical line between 5 and 9 pH reveals another S-shaped titration curve. Often titration curves generated in labs lack enough data points to reveal the shape of the curve and the change in slope in this region.

Fortunately, true strong acid or strong base systems are very rare. Just a trace amount of a weak acid or weak base (e.g., 0.01 normality) or its conjugate salt can moderate the slope and, hence, the sensitivity by four or more orders of magnitude (Figure 2). The greater the number and concentration of weak acids, weak bases and their conjugate salts, the more linear the overall titration curve becomes.

Figures 3a and 3b present the titration curve slope predicted by the model for a weak acid before and after the addition of a conjugate salt. As they show, the conjugate salt further moderates the slope of the curve.

IMPACT OF CONJUGATE SALT ADDITION

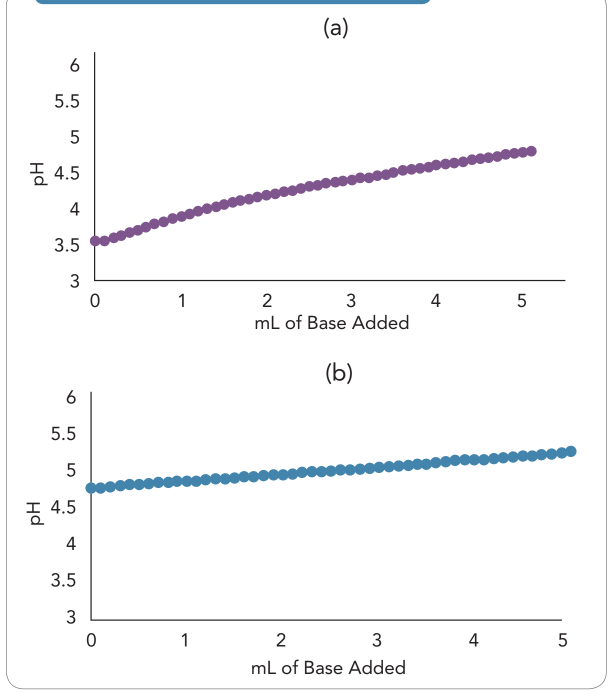

Figure 3. Top graph (a) shows model titration curve slope for weak acid before conjugate salt addition (10 mL 0.005M acetic acid with 0.005M sodium hydroxide incrementally added) while bottom (b) shows slope after addition (5 mL 0.01M acetic acid and 5 mL 0.01M sodium acetate with 0.005M sodium hydroxide incrementally added).

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For these curves and in the charge balance equations, the logarithmic base dissociation constant (pK_b) is converted to an equivalent pK_a ($pK_a = pK_w - pK_b$) for ease of analysis and understanding because of the dramatic effect on the slope for an operating point near a pK_a. The slope of the titration curve, i.e., the process gain, is very sensitive to the concentration of weak acids, weak bases and conjugate salts. The process gain determines not only the controller tuning and linearization requirement but also the precision necessary for the reagent delivery system, regardless of whether it relies on a control valve or a metering pump. You can generate the model titration curve simply by ramping the reagent flow from a starting pH that matches the plant pH when there has been no reagent flow for four or more residence times. You can do this very quickly online with your plant's inline pH control system; because residence time is only a few seconds, generating a titration curve takes only a couple of minutes. Then, adjust model stream composition to match the plant stream composition based on plant samples.

Perform laboratory titrations with the sample at the same temperature as that of the process stream and with the same type of reagent used in the plant. Get at least 10 titration data points in the control region. Put the data points (pH and mL of reagent added) into a spreadsheet and note sample volume and any difference in reagent concentration between the lab and plant. (Labs often use more-dilute reagents.)

Plot the plant titration curve as pH versus a ratio of reagent volume to sample volume for the reagent strength used in the actual pH installation. Also, compute the slope in the pH control region. Then, generate the same type of titration curve using the model and determine its slope in that region. Adjust the concentration of a weak acid or weak base or conjugate salt in the model to better match the model slope to the lab slope. For set points near 6 pH, adding a very small amount of carbonic acid (e.g., 10^{-4} normality) that is a result of carbon dioxide absorption merely from exposure to air often will achieve slope fidelity. While we are accustomed to thinking we exactly know the concentration of a process stream, incredibly small concentrations of ions (e.g., 10^{-6} normality) can affect the pH. Thus, treat the small adjustment of concentrations to achieve process slope fidelity a practical necessity.

How well the primary and secondary time constants and total dead time in the model match the plant also is important. Because most models use perfectly mixed volumes, the modeling of these dynamics involves first subtracting the mixing time (e.g., turnover time) from the total residence time (volume/flow) and then partitioning the remaining residence time into equivalent large and small volumes in series for the primary and secondary time constants, respectively. You can achieve greater fidelity for poorly mixed systems by further splitting the small volume into smaller volumes in series. To model the reagent injection delay, apply to the reagent flow a dead time equal to the injection volume (e.g., dip tube volume) divided by the reagent flow rate.

The model's automation system components must match what is in the plant. The control-valve and metering-pump installed flow characteristic, resolution, dead band and 86% response time must be reasonably accurate. The pH-electrode's 86% response time, which can be large for low velocities and for fouled, aged or dehydrated electrodes, must reflect what can happen in the plant. You also must include transportation delay to the location of the sensor. Introduce noise by adding a fluctuation in process stream component concentrations that corresponds to the degree of uniformity achieved by mixing. The proportional-integral-derivative (PID) controller should have the same form, structure and options (e.g., external reset feedback) as the one used in the plant. Find the controller tuning settings by auto-tuning software and use ratio control for flow feedforward.

NOMENCLATURE

- C_S contribution of salt ions to a charge balance that are not in common with an acid or base
- E molar concentration for a particular acid or base and its common ion
- M_{ab} molar concentration of the acid or base
- M_k molar concentration for the sum of the acids or bases and common ions
- M_i molar contribution of *i*-th ion to the charge balance
- n number of species contributing common ions
- pH negative of the base ten log of hydronium ion concentration
- pK_a logarithmic acid dissociation constant
- pK_b logarithmic base dissociation constant
- pK_i negative of the base ten log of equivalent acid dissociation constant for *i*-th dissociation
- pK_w negative of the base ten log of water dissociation constant
- P_i pH factor for an acid or base with *i* dissociations
- s sign of the particular ion contribution (-1 for acids and +1 for bases)
- X_j concentration of species *j* added to the system

Greek letters

- β stoichiometric coefficient associated with an ion in common with an acid or base
- λ charge associated with an ion

APPLICABILITY

The model can be used to determine the type and degree of mixing, residence time, method of reagent injection, control-valve capacity and precision, and the number of stages of neutralization necessary. The tradition rule of thumb is that a stage of neutralization with a residence time of 20 minutes and a turnover time of less than 10 seconds is needed for every two pH units from the lowest or highest pH to the pH set point. Thus, a strong acid or base with a pH coming in below 1 pH or above 13 pH and a set point of 7 pH would require three stages of neutralization using well-mixed vessels (circular high-axial-agitated ones with baffles and a level about equal to the diameter). Opting for multiple precise valves with valve position control where a small valve is stroked in unison with a large valve, coupled with signal characterization to provide linearization per the titration curve possibly can eliminate one stage. Also, the use of an inline system upstream or in the recirculation line of a volume of any geometry with just an eductor can eliminate the need for a well-mixed vessel.

The model also can provide the details of the control valve and metering pump and reagent piping as well as the location and type of pH electrode. It can show the many benefits of triple electrodes and middle signal selection in terms of reducing the effect of noise and a slow electrode and riding out a single electrode failure of any type. The model also offers a powerful tool for developing, prototyping and testing the control system and operator interface design, including the use of signal characterization, many PID features, ratio control and adaptive control — and then for training the process and automation engineers and operators via a virtual plant.

IMPROVE OPERATIONS

A pH model in a virtual plant not only can help realize a successful pH design but also minimize the total lifecycle cost by increasing the use of inline systems, precise valves and smart control techniques, and enhancing the understanding and training of operators, technicians and engineers. ●

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PLANT QUICKLY BOOSTS PRODUCTION AND PERFORMANCE

Addressing maintenance performance management and behavior issues leads to substantial improvements

By Peter Van Hauwermeiren, Hitachi Consulting

THE GHENT, Belgium, plant of Taminco Corp. manufactures amine-based specialty chemicals for a wide range of markets including crop protection. Prior to its acquisition by Eastman Chemical Co., Kingsport, Tenn., the company was facing serious challenges delivering a consistent level of product quality. This was the result of ongoing diversification of its product slate, which increasingly is shifting from solid formulations to more-complex liquid, multi-component ones.

An assessment of business processes at the site over a four-week period revealed four key issues: a broken performance-management structure; lack of standard ways of working; suboptimal use of asset capacity; and fire-fighting maintenance behavior. To overcome these problems, a 32-week program was launched at the end of 2013 with distinct work streams to deliver improvements in these key areas, with changes implemented over three phases:

1. Stabilization — designing and installing the foundations of a new way of working;
2. Improvement — implementing the new way of working to drive and realize defined improvements; and
3. Preservation — sustaining improvements over the long term.

IMPLEMENTING A NEW WAY OF WORKING

Product changeover represented a key area contributing to losses. To decrease changeover times, the site adopted single-minute exchange of die (SMED) — a lean production method for reducing waste in a manufacturing process. The issue Taminco was facing at Ghent, which many other chemical makers also face, is the need to thoroughly clean equipment before processing different materials; the time required varies depending upon the raw materials involved. For example, consider raw materials in terms of colors: switching directly from black to white would take longer than switching from black to white through gradations of gray. To achieve the most-rapid changeovers, this was factored into planning the running order of changeover operations.

In addition, we analyzed which activities were online versus offline and where efficiency improvements were possible. To ensure that all factors were considered, we physically observed the plant floor during the full changeover period, including preparation time. We also held cross-team workshops to determine how one activity in the production line actually affects another in terms of time on the plant floor. This end-to-end balancing was of significant importance in decreasing line downtime. Fairly simple but key changes — such as ensuring all tools and personnel required for the next step are upfront before switching off the production line, and identifying and working the key path — can reduce changeover times substantially. At the Ghent plant, changeover times fell on average 30–40%. In one line, the time went from 58 hours to only 18–19 hours; in another, it decreased from 81 hours to 41 hours.

A standardized way of working is paramount to delivering world-class manufacturing. Implementing operational excellence tools for the rigorous identification, analysis and management of all losses by cross-departmental teams at plant floor level can yield significant efficiency improvements.

Use of overall equipment effectiveness (OEE) metrics to evaluate a manufacturing operation can provide key insights. For instance, every piece of equipment has maximum possible capacity, i.e., the volume attainable by operating 24 h/d, 365 d/y. Actual capacity achieved, which depends upon the type of industry and planned downtime, as well as other considerations such as major overhauls, frequently does not even come close. Businesses often think it is not possible to impact actual capacity when, in fact, it is. World-class facilities have an OEE of 85–90%, compared to the norm of 40–65%. One of the key ways to reach world-class OEE is by challenging assumptions of actual capacity.

CHANGING THE MAINTENANCE MINDSET

The program's second work stream focused on tackling fire-fighting behavior in the maintenance department. We identified improper prioritization as the problem; it exemplifies a common situation in which changing the workforce's behavior is just as important as having the right infrastructure systems in place.

Before the program, work orders regularly were rated as high importance, leading to an inability to prioritize correctly. Employees thought that labeling work orders as "high priority" would speed up maintenance. Instead, however, this led to a backlog of notifications and poor maintenance planning. In addition, the notifications frequently lacked specific detail on the maintenance work necessary, prompting unnecessary back and forth between departments.

To address these issues, we set clear criteria for the fields that team members needed to complete within the SAP notification system — for instance, the specific type of replacement parts required and their particular location on the faulty equipment. Plant staff also received guidance to help them correctly prioritize maintenance tasks and create maintenance plans. Constructive feedback and coaching on the plant floor for several weeks were key to changing previous deeply ingrained ways of working. Achieving results critically depends upon increasing empowerment and ownership through collaborative change.

PERFORMANCE MANAGEMENT

The program also tackled the siloed nature of the plant's performance management processes by installing an efficient performance management system (Hitachi MCRS) as the backbone. By refining existing key performance indicators (KPIs), creating new ones to build an integrated KPI "tree," and discussing these at all levels in the organization with appropriate frequency, the site achieved a significant shift in focus toward end-to-end performance. To provide maximum value, KPIs must be cascaded from top to bottom, i.e., to show an obvious link to the root cause of an outcome. They also must be complementary; this may seem self-evident but is a real issue when different departments set KPIs without consulting each other. When this happens, it is common to find competing KPIs, which essentially lead to a plant striving for opposing goals, a hugely unproductive activity.

In this case, the fundamentals were in place; the site had a large number of KPIs but was only fully utilizing 50% of them. To address this, we established daily meetings as well as workshops with plant floor staff to identify and discuss issues and root causes. This enabled honing down the roster to key production, maintenance and planning KPIs. These KPIs were designed to interlink and cascade from top to bottom, forming KPI trees. For example, KPIs were cascaded from customer delivery performance level and customer complaints up to schedule compliance. The trees were presented on visual management boards, giving an overview of daily performance and leading to better involvement by the workforce on the plant floor level.

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IMPRESSIVE RESULTS

The project helped Taminco to structurally tackle issues with a clear KPI system that looks for real root causes, and ways of working that analyze and define clear and efficient actions and follow-up.

Overall, the program resulted in 20% volume/output growth. Feeding into this were a 25% increase in OEE and improvements in maintenance efficiency and planning rates. The quality of work order notifications rose to 82% from 32% and, as a result, scheduled maintenance compliance increased to 86% from 43%. The redefinition of planning processes also led to an improvement in planning rates to 70% from 50%.

All of this was made possible by the involvement and engagement of the teams, at all levels, throughout the process. Sustainable change cannot be top-down because significant business transformation hinges on tackling deeply ingrained behaviors starting on the plant floor. Everything within a business is interconnected, so everything within a change program must also link together. ●

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Ponder the Pressure Drop

Readers advise considering the most likely causes of an increase

THIS MONTH'S PUZZLER

At our refinery, the mechanical seals on the pump in the heavy gas oil (HGO) pump-around on the pipe still (figure online at http://goo.gl/XyHAcp) failed about once every two years. The pump manufacturer told us the pump, which delivers 339 gpm, wasn't operating within its most efficient range and would experience fewer problems if we moved the operating point closer to the best operating point. So, a year ago, we trimmed the pump's impeller to 11.75 in. from 12.75 in. We also increased the minimum-flow restrictive orifice (RO) diameter to maintain 194-gpm flow. Before trimming, the 4-in. control valve ran at 50%; initially after trimming, it ran at 67% — but this has been creeping up ever since and now is at 73%. A month back, we started to notice poor distribution in the return line to the crude distillation unit (CDU). The pressure drop across the spray nozzles should be about 6 psi but now reaches 9 psi. Is the trimming causing our problems? Should we go back to the old impeller? Can we increase the RO diameter to reduce wear on the seals even more? What other symptoms should we look for? What's our path forward?

FOCUS ON THE SPRAY NOZZLES

Trimming the pump impeller and increasing the recirculation rate through the restriction orifice will reduce the pump discharge head. Therefore, the extra opening in the flow control valve (from 50% to 67%) is in the expected direction.

Unless metal shavings were left in the impeller in the machine shop, trimming the impeller won't change the flow/pressure-drop characteristics of the spray nozzles. Either damage to the spray nozzles or fluid changes could lead to a change in pressure drop.

Fluid changes include both flow rate and density. It would be unusual for such a large density change. Have you checked your flow rates? For a change in measured pressure drop from 6 psi to 9 psi, a flow rate change of roughly 20% would be required. If the flow meter calibration is off, having a 20% error in the flow rate measurement is possible.

The other source of pressure drop change would be spray nozzle or spray header damage. The most likely source is plugging. Line scale, fouling and solids entering the process are all possible. At a minimum, spray nozzles should have startup strainers installed upstream of them to prevent plugging at startup. If the lines are carbon steel, permanent basket strainers should be installed to prevent scale from plugging them. All piping downstream of the basket strainers should be chrome-alloy (minimum).

One final note: I'd suspect that these spray nozzles have had plugging problems in the past. Five psi is the lower limit of getting a typical spray nozzle to develop a spray cone. Running a nozzle right at this limit normally happens when trying to use the largest possible nozzle for the flow rate.

Andrew Sloley,
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Advisian (Worley Parsons Group),
Houston

HISTORY MATTERS

It's too early to know if the pump manufacturer was correct about trimming the impeller because seal failure only happens every two years. If you have some downtime, you could pull the seals for inspection but this may tell you nothing. Wait and see. Clearly the current problem has nothing to do with seal failure. See Figure 1 a and b online at http://goo.gl/OAwTvV.

Control valves respond by increasing the %-opening because of downstream pressure drop. This increase could be gradual or sudden; it could come and go. You should take some samples from the tower and run gamma log analysis to evaluate tower performance. Temperature profiles won't tell the whole story; some kind of chemistry is going on.

You must look at the equipment most prone to show an increase in pressure drop. Spray nozzles have the smallest opening and will be the most sensitive to fouling. Next, check tubing and, then, the shell-side of a heat exchanger. Chances are any fouling affecting the control valve will appear elsewhere much sooner.

Getting back to the RO: no, don't increase the recirculation flow until you verify the effects of the impeller trimming. Recirculation consumes energy; so, keep it as low as practical. There is another thing to think about: maybe this fouling always existed. Perhaps the engineer who "oversized" the impeller knew about it. Now, you're stuck treading water until you identify the fouling and deal with it.

As for the ultimate cause of the fouling, look to your desalters and crude blending; another concern may be the treatments added to manage fouling. Sometimes, the cure is worse than the disease. HGO tends to foul tower sections; you may want to consider modifying the tower trays if the fouling persists.

Dirk Willard, consultant
Wooster, Ohio

MAY'S PUZZLER

We are experiencing some startup problems in our distillation train, which consists of three towers. When we start up the plant, the product from the reboiler of the second tower is hotter than desired, which delays the overall plant startup. Our condenser load is too high at this time. What is causing these issues and how can we address them?

In addition, during a turnaround, we mixed up the wiring on the three reboiler product pumps. We're now working on a control-system-migration project and need to quickly sort out the wiring problem with the pumps to avoid a long startup. What should we do?

Lastly, we replaced the condenser thermal control valve in the product tower. While doing the final hydrostatic test in-place, we couldn't completely close the spring-open valve. Is there a workaround for this problem so we can get up and running?

Send us your comments, suggestions or solutions for these questions by April 15, 2016. We'll include as many of them as possible in the May 2016 issue and all on ChemicalProcessing.com. Send visuals — a sketch is fine. E-mail us at ProcessPuzzler@putman.net or mail to Process Puzzler, *Chemical Processing*, 1501 E. Woodfield Rd., Suite 400N, Schaumburg, IL 60173. Fax: (630) 467-1120. Please include your name, title, location and company affiliation in the response.

And, of course, if you have a process problem you'd like to pose to our readers, send it along and we'll be pleased to consider it for publication.

Nix Nozzle Nightmares

Don't forget to check nozzle locations when altering towers

Verify that instrument connections will work with the new vessel layout.

MODIFYING THE internal layout of vessels can prompt unexpected problems. For example, after one plant switched the existing trays in a steam stripper from one-pass to two-pass in a quest for higher capacity, the tower didn't work correctly. Several different problems seemed to occur as operators changed operating pressures as well as steam and product rates in an attempt to make the unit work.

In general, at rates equal to the flow capacity of a single-pass tray, the system would work if steam flow rates weren't too high. In contrast, at high liquid rates and high steam rates, the tower would flood. Achievable capacity was roughly 70% of the rate before the modifications, not the 130% intended by the project — which, quite correctly, was considered a failure.

Two-pass liquid trays increase tray capacity by splitting the liquid flow in half. Reduced liquid rates on each tray section decrease weir loading, diminish downcomer pressure losses and cut tray pressure drop. Yet, in this case, the modifications failed to deliver even the same capacity.

Preliminary evaluation of the unit operation didn't clearly identify any reason for the capacity loss. Review of the tray design showed the trays should have worked. The fact they didn't indicates two main areas to check: 1) whether process conditions significantly differ from those expected; and 2) whether the trays as installed aren't what they should have been. Troubleshooting equipment configurations can be difficult on an operating unit. Unless the unit is shut down and physically inspected, what's in the column may remain uncertain.

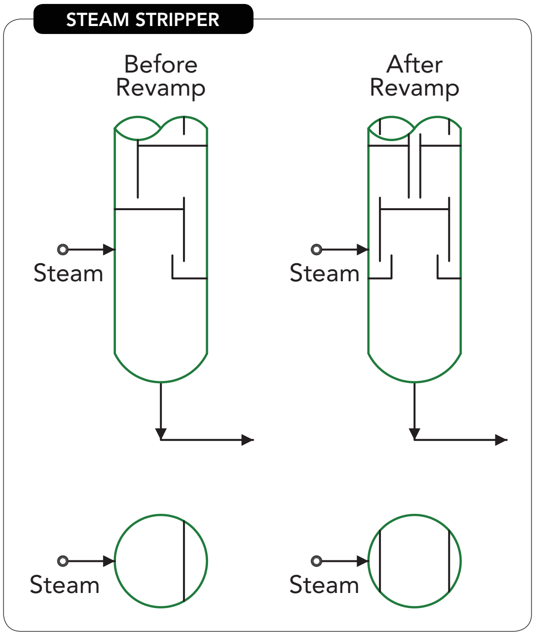

Figure 1. Revamp, which involved switching from one-pass to two-pass trays, cut capacity instead of increasing it.

Figure 1 shows both the original and revamped bottom section of the column. Pay specific attention to the steam injection. Field inspection revealed that, while the trays had been changed, the external piping hadn't been modified. The steam nozzle was putting the steam into the downcomer on one side of the tower.

Steam entering the downcomer reduced its capacity, causing liquid to back up onto the tray above. At rates below about 70% of capacity, the downcomer had enough volume to still allow for vapor/liquid disengaging. At higher rates, the tower flooded.

The revamped unit actually suffered two problems due to nozzles. The second stemmed from the liquid feed nozzle also not being modified or relocated. All the liquid feed was entering on one side of the tower.

Either problem could prompt flooding of the tower. However, only the steam-nozzle problem was seen because it caused the tower to flood first.

So, an effective solution requires further work both at the tower liquid feed (top of the tower) and the tower vapor feed (bottom of the tower).

I have observed other issues with nozzles, including having:

- a feed nozzle in the center downcomer when trays are switched from one-pass to two-pass. This occurs if the nozzle is rotated 90° from the tray alignment line;
- liquid-level measurement nozzles in unusable locations because of changes in internal baffles or collectors; and
- non-usable nozzles after installing strip-lining inside the tower and not cutting holes in the lining for the nozzles.

When modifying vessel internal arrangements, ensure that external feed, product and instrumentation connections end up in the correct locations.

ANDREW SLOLEY, Contributing Editor
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Desuperheaters Enhance Thermal Energy Transfer

A range of desuperheaters designed to offer precise control and reduction of superheated steam temperature helps boost thermal energy transfer, the company says. The desuperheaters provide turndown from 3:1 to 50:1. Carbon steel, stainless steel or chrome moly shell material options withstand temperatures up to 1,094°F. In addition, spray-type, venturi, variable-area, and steam-atomizing desuperheaters can be custom made and designed to meet the exact process conditions. They also recover and recycle waste and residual heat, increasing process efficiency.

Spirax Sarco
800-883-4411
www.spiraxsarco.com

Spectrometer Features Smaller Footprint

The TDLS8000 tunable diode laser spectrometer can quickly make in-situ measurements of gas concentrations in various process conditions. Its laser module includes a newly developed reference cell board that improves the reliability of absorption peak detection, the company says. A large (7.5-in.) LCD touchscreen display replaces the push-button interface used on preceding models, making setting parameters easier and more intuitive. The light source module containing the laser diode is fully sealed and damage resistant. The redesigned spectrometer is just three-quarters the size and weight of the previous model, allowing it to be installed in a greater variety of locations.

Yokogawa Corp. of America
800-888-6400
http://yokogawa.com/us

Top-Mount Positioner Diagnoses Valve Health

Research Control SRD991 valve positioner mounts directly to the top of a control valve with a linear potentiometer. A linear connection mitigates hysteresis between the positioner and actuator by feeding back the actual position of the valve actuator. This provides significantly improved flow control, the company claims. The SRD991 includes an LCD screen, protocols (HART, Profibus-PA and Foundation Fieldbus H1) and two levels of diagnostics. The positioner's device type manager (DTM) displays and configures all diagnostics features. The DTM also provides a complete health report of the valve with full configuration and diagnostics data. Simple installation and setup allow easy upgrade of any bottom-loaded reverse-acting pneumatic positioner.

Badger Meter
877-243-1010
www.badgermeter.com

Level Switch Withstands Extreme Conditions

CleverLevel series has been expanded to include more product variants. The compact level switch based on frequency sweep technology now offers a cooling neck for high temperature applications, a long version for improved level detection in bulk media and a process connection compliant to U.S. and Far East standards. The LBFS product variants are maintenance-free and can endure long-term temperatures up to 200°C (variant-specific) for demanding and hygienic applications. Both 82-mm and 250-mm designs can be installed in tanks with thick layers of insulation as well as in cone-bottom kettles. They can be mounted vertically at the inside tank edge for fill level monitoring.

Baumer Ltd.
860-621-2121
www.baumer.com

Hybrid Mixer Handles Larger Capacities

The PDDM planetary mixer line includes larger working capacities — up to 750 gallons. The multi-agitator mixer features two planetary stirrer blades and two high-speed disperser shafts. Designed for highly viscous and highly filled applications, the hybrid planetary mixer/disperser can quickly incorporate large amounts of dry ingredients into thick or sticky liquid, and

apply intense shear to achieve a smooth, uniform consistency. The PDDM is rated for vacuum operation up to 29.5 in. Hg and includes a jacketed change-can vessel, sight/charge ports on the cover and an automated lift for raising and lowering the agitators.

Charles Ross & Son Company
800-243-7677
www.mixers.com

Sensor Assemblies Keep Operations Running

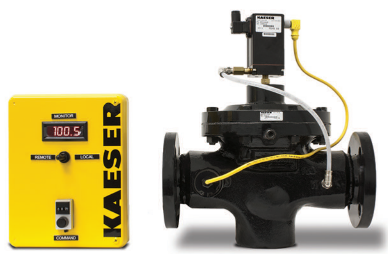
Cleanfit CPA875 and CPA871 sensor assemblies allow installation and removal of pH, ORP, oxygen and NIR sensors during operation, protecting both the process and operating personnel. The CPA875 reportedly is ideal for applications where sensors must be removed for cleaning, calibration

or maintenance on a regular basis, while the CPA871 sensor suits water/wastewater and chemical industry applications. Materials in contact with the process medium are all stainless steel, while seals can be EDPM/FMP or Viton/FFKM, depending on the application. The immersion tube, process connection and service chamber can be stainless steel, titanium, Alloy C22, PEEK or PVDF.

Endress+Hauser
888-363-7377
www.us.endress.com

Flow Controller Reduces Air Loss

Available for system capacities from 250 to 18,000 scfm, the Kaeser Flow Controller (KFC) creates more-effective storage by accumulating compressed air in receivers and only delivering air that is needed for production. The KFC responds to fluctuating demand and actively maintains constant system pressure downstream. More-stable air pressure helps eliminate artificial demand



and substantially reduces air losses through leaks. Further, stored compressed air now can be used to satisfy air demand spikes without pressure drop at the point of use, resulting in higher production rates, reduced maintenance costs, and significant energy savings. The controller can be installed easily in new or existing systems without reconfiguring existing piping.

Kaeser Compressors, Inc.
877-586-2691
www.kaesernews.com/KFC

Transmitter Ignores Vapor and Air Movement

The Pulsar Model R96 non-contact radar transmitter reportedly provides accurate, reliable level control in process applications. Virtually unaffected by the presence of vapors or air movement within a vessel's free space, the two-wire, loop-powered, 6-GHz radar transmitter measures a variety of liquid media in process conditions ranging from calm product surfaces and water-based media to turbulent surfaces and aggressive hydrocarbon media. The transmitter features a measurement range of 130 ft (40 m), advanced diagnostics with automatic waveform capture and data logging, and a device type manager with field configuration and troubleshooting capabilities.

Magnetrol International
630-723-6730
www.magnetrol.com

Fire Valves Work Automatically

In the event of a fire, these fire-safe, fusible link valves provide automatic closure without the need for an operator present. They are available in sizes from ¼ in.–4 in. for the ball valve series and 3 in.–24 in. for the butterfly valve series. All fusible links are FM approved and all valves are API fire-safe approved and available with flanged or NPT ends. They have a temperature range of 165°F–300°F. The valves come in stainless steel, carbon

steel and ductile iron for performance in heavy-duty hazardous locations. Valves also can be operated manually while engaged.

Valtorc International
866-825-8672
www.valtorc.com

Pressure Switches Increase Installation Options

A-Series type-316L stainless steel pressure switches now offer a greater selection of process and electrical connections. With the addition of male and female ½ NPT and 37° flare pressure fittings, both the watertight and explosion-proof versions can be installed in a wider variety of applications, the company reports. Additional electrical conduit fittings improve connection options while NACE-compliant piston seals round out compatibility with sour gas applications. With expanded pressure ranges, the A-Series switch now can control pressure up to 15,000 psi.

Ashcroft
203-385-0635
www.ashcroft.com

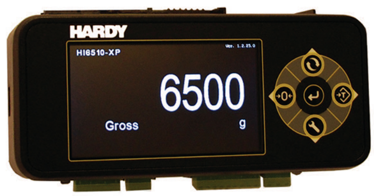
Valve Expands Measurement Modes

Roto-Disc airlock/double-dump valves are now able to feed and measure product into or out of pressure or vacuum environments in four modes. Through the development of the Roto-Disc cycle timer and enhancements to its accumulator chambers, applications now have volumetric and gravimetric measuring capability, in addition to traditional temporal and manual control. Users can switch between any mode almost instantaneously and then return to operation just as quickly, providing measurement flexibility. Load-cell mounts or level sensor ports, both located on the chamber according to the application requirements, support the feeding system. Gravimetric systems include flexible connections on the assembly for accurate weight measurement.

Roto-Disc, Inc.
513-871-2600
www.roto-disc.com

Weight Processor Speeds Processing Time

The HI 6500-XP EtherNet/IP-enabled weight processor for extreme environments can process and output 300 updates per second of processed (stable) weight. A/D conversion, weight processing and the communications port all update at 330 Hz, providing the PLC with the latest processed weight reading every 3 milliseconds. The system results in better product consistency and product yields while reducing processing time, waste time and materials, the company says. It is designed for applications such as batching, blending, filling, dispensing and check weighing where speed and accuracy are paramount to control and quality. A set-up wizard and Rockwell Automation Add-On Profile simplify installation and calibration.



Hardy Process Solutions
858-278-2900
www.hardysolutions.com

Analyzer Fine-Tunes Combustion Process

Using two sensors, the Endura AZ40 analyzer continuously monitors combustion waste gases to measure both excess air and unburned fuel. It provides an unburned fuel measurement in terms of carbon monoxide equivalent (COe). The COe reading supplements the net oxygen measurement to permit further trimming to boost combustion efficiency. The analyzer consists of a sensor assembly, probe with filter assembly, transmitter, and interconnecting cable.

The sensor assembly mounts to a duct or process wall, with the probe extending into the flue gas stream. Available in lengths up to 8+ ft (2.5 m) and suitable for temperatures to 3,000°F (1,650°C), the probe continuously draws in the sample for analysis.

ABB Inc.
800-435-7365
www.abb.com/measurement

Weighing Instrument Features Remote Operation

A new hardware platform with extensive communication capabilities enables the BLH Nobel G5 family of weighing instruments to increase speed and performance, and offer intuitive operation, easy calibration and advanced diagnostics, the company says. The instruments support a range of applications, including process weighing and control, force measurement, factory automation, high dynamic force measurement, and high-speed batching/blending systems. A built-in Web server speeds setup and simplifies parameter changes, enabling remote operation from any PC or mobile device with a Web browser and Ethernet connection. Weight and status are instantly displayed alongside other parameters and diagnostics information via user-friendly operator interface.

Vishay Precision Group, Inc.
484-321-5300
www.blhnobel.com

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Pilot Plant Converts Coke Oven Gas

Process offers competitive-cost output of materials and also decreases emissions

Initial results have been promising.

A PILOT plant installed at the Duisburg, Germany, site of ThyssenKrupp Steel Europe is converting process gases generated during coke production into marketable materials such as fertilizers and chemical propellants. As an added bonus, it also reduces carbon dioxide emissions. The company believes that the plant is the first of its kind anywhere in the world.

The technology involved is the latest development in a collaborative project by the Schwelgern coke plant (KBS) plant engineering company, Duisburg, ThyssenKrupp Industrial Solutions, and Berlin Technical University (TU Berlin).

"There are coke plants all over the world. With this newly developed process we want to give operators the chance to put their process gases to good use and increase the productivity of their plants," says Holger Thielert of ThyssenKrupp Industrial Solutions. "For this we have developed and patented a process that converts coke oven gases into valuable materials in an eco-friendly way. We can market this process worldwide and also retrofit it in existing plants," he adds.

The new process starts with the production of coke, which alongside iron ore is the most important charge material for producing pig iron in a blast furnace.

"For this, coal is 'baked' at high temperatures in the coke plant. The hot gases generated by this process contain a number of substances. The pilot plant uses a complex process to scrub the coke oven gas. Adding carbon dioxide produces ammonium bicarbonate," explains Thielert.

The end products can be put to a range of uses such as nitrogen fertilizers, propellants and foaming agents for plastics or porous ceramics; they can also be used in the food industry.

Following successful tests in the laboratory, two researchers from TU Berlin were tasked with building the pilot plant in Duisburg.

"The key tests can only be carried out under real conditions," notes Sebastian Riethof, a scientist from the university. As part of ThyssenKrupp Steel Europe's integrated iron and steel mill in Duisburg, the Schwelgern coke plant offers ideal conditions for the test phase. "If everything goes to plan here at the coke plant, the new process can also be used on an industrial scale."

Initial results have been promising. The scientists are able to utilize 95% of the ammonia contained in the coke oven gas. Every hour the process produces 15 kg of solid materials from 15 m^3 of coke oven gas and 2 m^3 of carbon dioxide. With this level of efficiency, the chemical products can be manufactured at competitive costs, says Riethof.

If the tests continue successfully, this would be a real breakthrough in productivity and resource efficiency. "Here in Duisburg, almost all process gases are already being recycled efficiently," says KBS managing director Peter Liszio. "If we can now manage on a long-term basis not only to produce marketable products from the coke oven gases for other sectors but also to reduce the carbon dioxide emissions from the mill, it would be real value added with great environmental benefits." Continued positive progress could see this idea and plant type being used worldwide in the future, he believes.

Schwelgern coke plant produces 2.6 million t/y of fuel for the blast furnaces in Duisburg. It is the most modern of its kind in Europe, boasts the world's biggest ovens, and currently employs around 300 people.

ThyssenKrupp also is focused on reducing plant emissions in two other ways. First involves startup of the world's first automated sinter test facility.

During sintering, fine grains of iron ore are mixed with other materials, heated intensely and baked into lumps by fusing the grain edges. The lump shape of the so-called sinter cake is necessary for producing pig iron in the blast furnace. For daily mass production of sinter, the test facility will make it possible within a few hours to predict exactly the optimum mix of charge materials. This will help not only to maintain quality in the final product, but also give better data on the emissions created by the raw materials themselves.

Linked to this is the second emissions focus — precise dust analysis during the entire test process. This will allow lower-dust raw materials to be identified, helping determine the optimum charge mix for each batch.

In addition, the company is constructing a modern fabric filter that it says will capture almost 99.99% of the dust generated by sinter production. The filter is scheduled to start operation in spring 2017.

SEÁN OTTEWELL, Editor at Large
sottewell@putman.net


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