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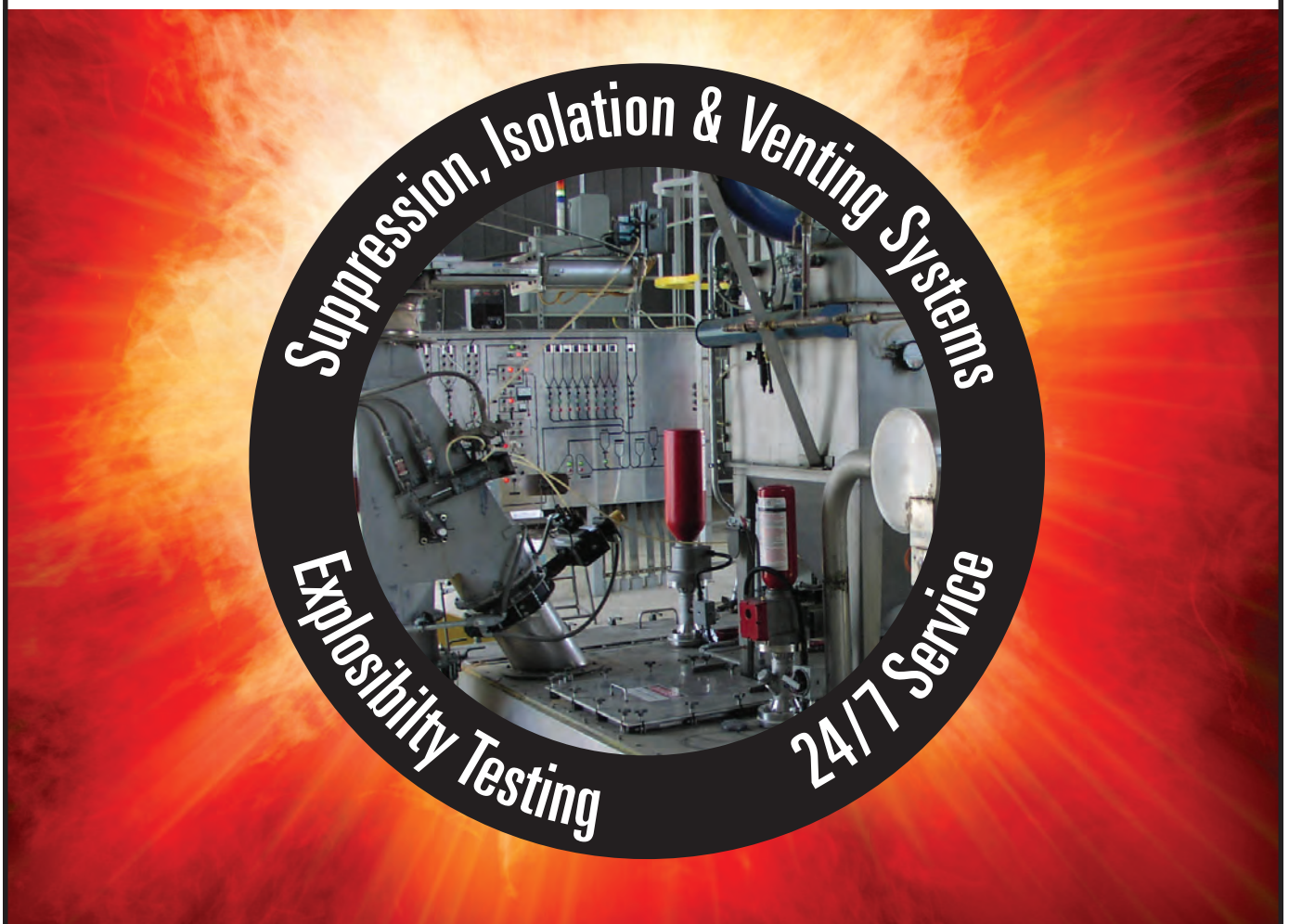

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Chemical Processing (ISSN 0009-2630) is published monthly by Putman Media Inc.,1501 E. Woodfield Road, Suite 400N, Schaumburg, IL 60173. Phone (630) 467-1300. Fax (630) 467-1109. Periodicals postage paid at Schaumburg, IL, and additional mailing offices. POSTMASTER: Send address changes to Chemical Processing, P.O. Box 3434, Northbrook, IL 60065-3434. SUBSCRIPTIONS: Qualified reader subscriptions are accepted from operating management in the chemical processing industries at no charge. To apply for a qualified subscription, fill in the subscription card. To nonqualified subscribers in the United States, subscriptions are $68 per year. Single copies are $15. Canadian and other international annual subscriptions are accepted at $200 Airmail. Single copies are $16. Canada Post International Publications Mail Product Sales Agreement No. 40028661. Canadian Mail Distributor information: Frontier/BWI, PO Box 1051, Fort Erie, Ontario, Canada, L2A 5N8.

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BPA WORLDWIDE

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Folio Editorial Excellence Award Winner

Be an Engineer

That's the theme of a campaign aimed at American youngsters

THE PROSPECTS for the American chemical industry seem better than they have been for quite a while, as last month's cover story, "U.S. Chemicals: The Luster Returns," http://goo.gl/DkX0yl, highlighted. Indeed, the article's author, Thomas Kevin Swift, chief economist of the American Chemistry Council, forecasts that by 2019 the industry will post record trade surpluses.

However, lack of an adequate number of technical professionals such as chemical engineers could blunt longer-term prospects. The growing number of baby boomers who are retiring is exacerbating the situation.

Getting children interested in science, technology, engineering and mathematics (STEM) education certainly isn't a new challenge. For instance, more than six years ago I urged readers to "Convince a Child to Explore Engineering," http://goo.gl/RhYToj.

And, indeed, many efforts to alert kids to interesting and lucrative STEM-related careers are underway. For example, shortly after I wrote that editorial, I wrote another, "Chemical Engineers Crow," http://goo.gl/5tvRBP, about the launch of a website, chemicalengineering.org, by the Chemical Heritage Foundation, Philadelphia, and the American Institute of Chemical Engineers, New York City, that highlights the contributions of chemical engineers. Titled "Chemical Engineers in Action — Innovation at Work," it allows children to explore six key areas in which chemical engineers make a difference.

Such initiatives usually don't get the visibility they deserve. So, I was surprised and delighted to recently see a series of ExxonMobil advertisements on television that promote engineering and science careers. If you missed these ads, you can view them at www.youtube.com/user/ExxonMobil.

As Ken Cohen, vice president of public and government affairs for ExxonMobil, explained in a blog posting: "America has a problem: Not enough U.S. students are pursuing engineering careers.

"…There simply are not enough applicants with adequate skills to fill many of the most promising positions available in the 21st century. This lack of skills is especially acute in jobs that increasingly rely on science, technology, engineering and math.

"This set of circumstances is worrisome for science-based companies like ExxonMobil, of course. But more broadly it is troubling for America's future competitiveness in the global economy.

"To help address this predicament, ExxonMobil has launched a nationwide initiative seeking to inspire the next generation of engineers. Our 'Be an Engineer' campaign aims to highlight the meaningful contributions that engineers make to the world, as well as provide resources to assist young people interested in pursuing the profession."

Besides the television ads, ExxonMobil has launched a website, www.beanengineer.com, that covers reasons to be an engineer, the types of engineering, as well as feats of engineering. The site also highlights a diverse group engineers, ranging from a research specialist at ExxonMobil to the chief technology officer at Xerox to the director of the Applied Biodynamics Laboratory at Boston University. Moreover, it provides engineering-related news items and even includes information on worthwhile courses to take in high school and engineering-related programs for students.

We all should applaud ExxonMobil for its high-visibility efforts to get more children interested in engineering.

ExxonMobil is running television commercials that promote studying engineering.

MARK ROSENZWEIG, Editor in Chief
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Check Out Our Redesign

You'll find the website more intuitive as well as mobile-device friendly

The second navigation bar helps you easily access six key technical areas.

CHANGE IS good. And where technology is concerned, change is often necessary. That's why our design team, programmers and editorial staff have worked behind the scenes for the last six months to re-imagine ChemicalProcessing.com.

We were tasked with creating a new navigation system as well as a new layout for the homepage to put all the important content right at your fingertips. The result is dramatically different from the way the site had been. However, once you've become familiar with the redesign, which hopefully won't take too long, we expect you'll find it even better for fulfilling your chemical processing needs. If that's not the case, you can always email me your questions or concerns and I will address them right away.

For now, here's a quick primer on how to navigate the new site.

Starting from the top you'll see a black navigation bar. This houses six links. The first is **Home** (you can go to our home page from any page on the site by clicking here or on the *Chemical Processing* logo). **Technical Resources** will take you to a page that features eHandbooks, white papers, special reports, reliability-centered maintenance PDFs and a portal to upcoming webinars. Our **News** section focuses on industry news, vendor news and monthly Economic Snapshots. **Columns & Blogs** gives you access to all the monthly columns that appear in the magazine as well as web-exclusive columns and our Chemical Reaction blog. **eNewsletters & Magazine** houses links to current online and print publications, including *CP China*, issue archives, and our editorial staff and editorial board members, and our editorial guidelines. And finally, **Products and Vendor Information** will give you access to products, an events calendar, vendor videos, vendor literature, case studies and industry links.

The second navigation bar is just below the *Chemical Processing* logo. Hover over any of the six categories there — **Automation, Processing Equipment, Asset Management, Environmental Protection, Safety/Security** and **Utilities/Energy** — to get a more-detailed breakout of each section. Hovering over any element of this granular menu shows the most recent story, a short blurb and an image if one is available. To the right you will see other recent content pertaining to that topic.

Throughout the home page you'll see several modules of content. Each is labeled, so it should be pretty evident what you are looking at. Do note that the Editor's Corner is no longer on the top right. It lives down on the left side of the page and is now called **Editor's Take**.

Just above Editor's Take is our monthly cover story. This now gets the prominence it deserves.

The last new feature I'd like to point out — for now — is our "super footer." It appears on the bottom of every page and is what I consider the "Dummies Guide" to our website. Trust me when I say that I will be using this quite often in the beginning of this changeover.

So there you have it — a quick overview of the redesigned site. I encourage you to poke around and let me know if you have any questions or concerns.

TRACI PURDUM,
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Blow the Whistle

Take a stand when you come across a corporate misdeed

Remember, you *will* face retaliation.

EVER WONDER how tetraethyl lead (TEL) was banned from gasoline? The anti-knock additive was developed by chemist Thomas Midgley and introduced by the Ethyl Corp. in 1923. Although regulators had some proof even then of the lethality of TEL, the additive continued in use until phased out as a result of the Clean Air Act of 1970; it was completely prohibited in 1995. Clair Patterson, a geochemist at the California Institute of Technology, led the efforts to ban TEL. Although he was offered lucrative employment to get him to give up the campaign and ostracized for conducting his research, Patterson established atmospheric data showing the connection between increased lead contamination in the environment and in the human body and TEL. Without his efforts who can say where we would be today?

More often, though, it's someone from within a company who raises the alarm — and such whistleblowers often face direct retribution. Consider Mark Quint. Within two days of beginning work for Thar Process Inc., Harmarville, Pa., in October 2010, he found deficiencies in the manufacturing of a supercritical pressure vessel destined for a spice maker. One of the deficiencies he noted was that the vessel did not meet ASME Code or NIST standards because the materials of construction documentation was missing. Quint, a mechanical engineer with more than 20 years of experience, was pressured by his superiors, not once but three times, to falsify documentation. He refused and was fired; he then sued Thor for wrongful termination. It is illegal to coerce someone to break the law. Quint won his case in September 2011.

In 1996, Sally Barnes-Soliz, a chemist at Flint Hills Resources' refinery in Corpus Christi, Texas, was told to falsify her benzene-emissions data, refused and was pressured to resign. She filed a report with the U.S. Environmental Protection Agency (EPA) regarding under-reporting of benzene emissions — 0.61 tons reported versus actual emissions of 61 tons. The company was fined $20 million for under-reporting and failure to comply; it was estimated that compliance would have cost the company only $7 million.

In April 1994, David Cahill, the operations manager at the Asarco/Encycle waste treatment plant in Corpus Christi, Texas, resigned and filed a detailed report on mismanagement at Encycle. He had refused additional waste for treatment. The plant closed in 2005. EPA and state regulators hope to sell the site over the objections of locals who want testing and remediation.

Many whistleblowers keep their identities secret initially but eventually are exposed when the courts become involved. Some manage to take their secrets to the grave: e.g., Mark Feld, aka "Deep Throat," in the Watergate scandal. Occasionally, others come forward to back up the whistleblower.

Not all whistleblowing has been to expose environmental problems; sometimes it's about product safety, or illegal or unethical business practices. Consider the famous revelations about price fixing at ADM: as executive Mark Whitacre told the FBI, there was a saying at ADM: "Our competitors are our friends; our customers are our enemies." Price-fixing and other collusion among competitors is a carefully held secret. In 2004, the *Wall Street Journal* reported on price fixing by Bayer, Dow, DuPont, ExxonMobil and Uniroyal (Crompton). The U.S. Justice Dept. and European investigators granted amnesty to witnesses in exchange for testimony.

All of this may sound hypothetical to you now — but that certainly can change, as I found out. Today, many websites, e.g., http://goo.gl/oE5j9A, http://goo.gl/nLB6nh and http://goo.gl/tQsfKB, can help you decide if whistleblowing is your only course of action and, if so, how you should proceed:

Here's what I learned from my experience as a whistleblower. First, never challenge an issue — initially. Instead, collect information and secure it. Assemble details available electronically and scan paper copies to convert them into digital files; store this information on a thumb drive. Don't worry about so-called theft of intellectual property; that's a small matter. Next, search the websites of regulators like the U.S. Occupational Safety and Health Administration and the EPA for information on how to bring issues to their attention. Consider contacting a whistleblower blog and find a lawyer. Remember, you *will* face retaliation. In fact, one common complaint of whistleblowers is that their employers not only went after them initially but also kept going after them, forcing them to respond.

Becoming a whistleblower takes guts; sometimes, though, you have no other way to maintain your personal integrity. Always heed your conscience.

DIRK WILLARD, Contributing Editor
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Method Converts Methanol at Mild Conditions

Biocatalytic process could cut carbon dioxide emissions and lower production costs

CURRENT METHODS for processing methanol operate at relatively high temperatures and pressures, require expensive catalysts, yield a range of non-specific products and typically result in the release of carbon dioxide into the atmosphere, note researchers at the University of California, Los Angeles (UCLA) Henry Samueli School of Engineering and Applied Science. They have created a more efficient way to turn methanol into useful chemicals, such as liquid fuels, while reducing carbon dioxide emissions (Figure 1).

"Our solution to methanol processing could be a major part of large-scale production that is much lower in cost than current standards," says James C. Liao, chair of the UCLA Department of Chemical and Biomolecular Engineering and lead researcher on the project.

The team synthesized longer-chain molecules at ambient temperature and pressure via a non-oxidative glycolysis pathway modified to convert methanol instead of sugar. They used a set of purified enzymes to demonstrate the biocatalytic pathway, termed the methanol condensation cycle (MCC), and were able to produce ethanol and butanol.

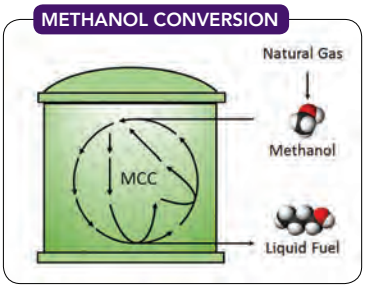


Figure 1. Researchers develop more efficient way to convert methanol to liquid fuel. *Source: UCLA Engineering.*

The process releases no carbon dioxide.

"This is the first demonstration of selectively making carbon-carbon bonds from methanol only under ambient conditions. Thus, it may be cheaper and environmentally friendlier."

In addition to higher-chain alcohols, MCC can be used to produce compounds derived from acetyl-coenzyme A, including fatty acids, alkanes and polyketides, notes Liao.

More details appear in a recent issue of the *Proceedings of the National Academy of Sciences*.

Liao believes the cell-free system could be a viable application for larger-scale production after optimizing the conditions for enzyme and intermediates stability.

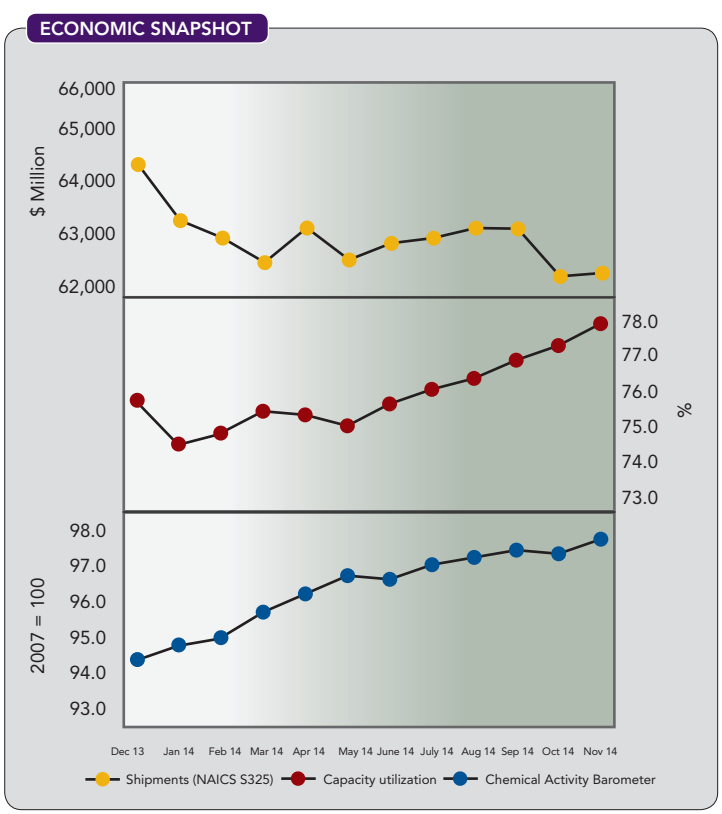
"Cell-free processes can, in principle, achieve 100% theoretical yield, and the production rate is linearly scalable with enzyme activity. It is not limited by the microbial metabolic activity. A cell-free process is closer to a chemical process then to a biological process, and involves less uncertainty."

Liao admits that many challenges remain. "For example, the rates are still too low. We will need to improve the activities of enzymes involved. We will also need to reduce the cost of enzymes, and increase the stability of enzymes, if a cell-free process is to be used. We will need to engineer MCC into an organism, if a microbial process is to be used."

"We will continue to improve the performance of MCC, and then engineer MCC into a host organism. We aim to improve the rate of MCC in vitro and then implement it in one of the common host organisms. Once it is introduced in a host, it can be used to produce a variety of compounds," he adds.

If all goes well, Liao's team expects to conduct trials on a pilot-plant scale within 3–5 years — an "aggressive goal" he says. "However, it depends on the continued funding beyond the ARPA-e [Advanced Research Project Agency-Energy] project," he adds. (The ARPA-e REMOTE program has funded the project since last year and will continue to for at least 6 months.)

Liao says they've received some inquiries from companies interested in cooperating on further development of the technology, and are selectively considering some options.



All three indicators rose slightly. *Source: American Chemistry Council.*

Lactic Acid Process May Cut Glycerol Glut

A TWO-STEP process for making lactic acid (LA) promises environmental and economic advantages over anaerobic sugar fermentation, the method currently used for commercial production of the precursor to polylactic acid (PLA), an increasingly popular biodegradable polymer (Figure 2). The technique uses as feedstock glycerol, a low-value byproduct of biodiesel manufacturing now in growing oversupply as biodiesel output expands, note its developers at the ETH Zurich, Zurich.

Not only is a glut of glycerol developing but also impurities in the byproduct rule out its use in current chemical and pharmaceutical processes, explain the researchers. The material doesn't burn well and so isn't a good energy source, they add.

The new process involves the biocatalytic oxidation of the glycerol to dihydroxyacetone (DHA) followed by isomerization of the DHA using a heterogeneous catalyst, report the team led by Konrad Hungerbühler and Javier Pérez-Ramirez of the university's Institute for Chemical and Bioengineering. The catalyst consists of tin-containing MFI zeolites and is highly active, selective and recyclable, they add.

More details about the cascade process appear in a recent article in the journal *Energy & Environmental Science*.

BIODEGRADABLE CUP

Figure 2. Polylactic acid from renewable resources is finding increasing use for making biodegradable packaging. *Source: ETH Zurich.*

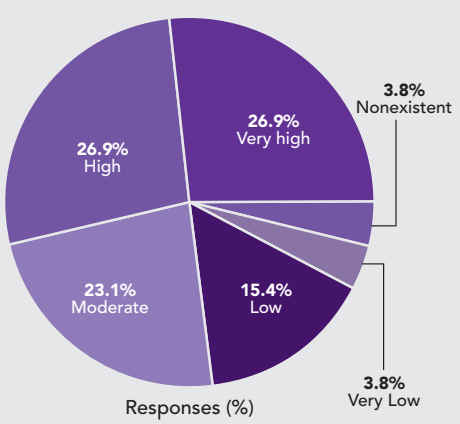
The process cuts overall carbon dioxide emissions by 20% compared to the conventional method, according to the team's analysis. Considering an LA price of $1,800/ton, making LA via DHA isomerization in methanol can provide a marginal profit 15 times higher than that of the conventional approach, the researchers estimate. "Our calculations are even rather conservative," notes team member Merten Morales. "We assumed a glycerol feedstock of relatively good quality. But it also works with low-quality glycerol, which is even cheaper."

According to Pérez-Ramirez, the next steps in the development are scaling up the catalyst for converting DHA into LA; developing a chemocatalytic route with selectivities higher than 90% for making DHA from glycerol; and using DHA as a building block for polymers other than PLA.

Key issues remaining, he says, are assessing the scalability and stability of the isomerization catalyst, determining the impact of glycerol purity on process stability, and piloting the process. One biodiesel producer already has expressed interest in helping to pilot the technology, notes Pérez-Ramirez.

The team now is working to develop a continuous version of the isomerization process. A continuous chemocatalytic process for converting glycerol to DHA would make the two-stage process even more appealing, the researchers add.

HOW DO YOU CHARACTERIZE YOUR SITE'S INTEREST IN USING ADVANCED PROCESS CONTROL?



More than half of respondents say their sites' interest in advanced process control is high or very high.

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Don't Waste Energy with Wastewater

Simple monitoring actions and adopting best practices may lead to significant savings

Energy efficiency and protecting the environment are not mutually exclusive.

IN MOST chemical processing plants the primary objectives of wastewater treatment plants (WTPs) are to meet regulatory requirements and protect public health. Rising energy costs are placing a greater financial burden on wastewater treatment and discharge. Improving energy efficiency at WTPs could help control overall energy costs.

Energy efficiency and protecting the environment are not mutually exclusive. In most plants, energy conservation programs not only reduce energy usage at the facility, but also provide improved control and operation of their unit treatment processes. Hence, this column covers a few tips about controlling and sustaining energy costs in a plant's wastewater treatment operations.

Most water/wastewater utilities need to operate, maintaining the wastewater discharge specifications, while improving their energy efficiency and managing their total energy consumption. The above goals consider both the costs associated with energy use and the plant's reliability over time. With a better energy-management plan and adopting best practices, these goals can be balanced to avoid unanticipated costs, and still improve overall energy efficiency. WTPs also can have energy benchmarks such as gallons of water treated per kilowatt-hour of electricity consumed or kwh/mgd. Some plants are able to sell their treated wastewater back to local communities for domestic use other than potable water. Some communities have separate water service for garden and farm-land irrigation from their neighborhood WTP. A petroleum refinery in southern India recycles 100% of its treated wastewater, saving substantially on its overall utility cost. In addition, due to scarce fresh water, better wastewater treatment and reuse helped the refinery to operate without straining the local authority's water supply system.

Improving overall efficiency of WTPs begins with simple monitoring actions such as leak detection, repairing the water distribution system, or reducing infiltration and inflow to wastewater collection systems.

Water/wastewater treatment is energy intensive mainly due to pumps and electric motors moving large volumes of water. The cost of electricity used in the treatment process is based on two main components: the quantity of electricity used and the peak demand reached in using the electricity. Because the objective of energy cost control is to minimize the facility's overall electricity bill, peak demand reduction is a potential energy cost control opportunity applicable to wastewater treatment. Strategies to lower peak demand include monitoring and addressing the infiltration and inflow, providing additional water storage tanks to flatten pumping demands during peak periods and shifting non-critical loads to off-peak periods, and flattening demand by minimizing the overlap between treatment processes. Considering the sequence of backwash cycles and off-peak backwash times is a common non-critical operation that also can help reduce electric demand.

Reducing the total number of kWh required to treat a given volume of water or wastewater also cuts down the electricity bill. The amount of energy used for water/wastewater treatment consists of various factors, including: treatment unit's capacity, treatment process, type and condition of equipment, and operation and maintenance (O&M) practices. The topography of the WTP also could contribute to higher pumping costs.

In some wastewater treatment units several low- or no-cost opportunities may exist, such as operating only the required level of aeration tanks, installing control equipment based on dissolved oxygen monitoring, idling an aeration tank during low-flow periods, and reducing air flow to the aeration tanks during low-load periods. Regularly cleaning UV lamps is another simple O&M improvement, because lamp sleeve fouling affects equipment performance.

Closely matching pump and motor size to demand also can improve energy efficiency. Most WTPs are designed with excess pumping capacity to cater to peak demands and growth expectations. However, the actual wastewater inflows are lower, due to normal plant operational levels, and conservation efforts at the source units. Hence, if pumps are found operating far from their optimal efficiency point, their energy consumption levels would be higher. If pumps routinely operate outside of their design point for efficiency, then a new pumping solution, such as installing variable speed drives, may reduce energy costs.

In some wastewater treatment units with anaerobic digesters, routing the digester gas to the hot water boilers or using the digester gas to generate electricity using a microturbine can help reduce energy costs. Some microturbines can run on digester gas or bio-gas from WTPs. It's also worthwhile to assess the feasibility of implementing fine bubble aeration at activated sludge treatment facilities, as well as considering supercritical oxidation of wastewater sludge.

VEN V. VENKATESAN, Energy Columnist
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EPA Expands TSCA Rule

Nine hazardous chemicals go on watch list to prevent their import

Benzidine-based dyes can be converted into a chemical known to cause cancer.

ON DECEMBER 29, 2014, the U.S. Environmental Protection Agency (EPA) published a final rule signaling renewed interest in asserting Toxic Substances Control Act (TSCA) jurisdiction over finished goods. The final rule adds nine benzidine-based chemical substances to the existing significant new use rule (SNUR) on these substances, and, with respect to both the newly added and previously-listed substances, makes inapplicable the exemption relating to persons that import or process the substances as part of an article.

According to Jim Jones, assistant administrator for the Office of Chemical Safety and Pollution Prevention: "There must be a level playing field for U.S. businesses — which is why we're targeting harmful chemicals no longer used in the U.S. that find their way into commerce, sometimes through imported products."

The final rule authorizes the EPA to restrict any new uses of these chemicals, including imported goods. It also includes a SNUR for di-n-pentyl phthalate (DnPP) and a SNUR for chloroalkanes, C12-13. Under the rule, anyone who intends to manufacture, import, or process these chemical substances for an activity that's designated as a significant new use must notify the EPA at least 90 days before commencing such manufacture or processing.

THE FINAL SNUR

The EPA states that the final SNUR "closes a loophole" to ensure that nine benzidine-based dyes and products containing them, such as clothing, can't be imported without EPA review and possible restriction. The EPA believes exposure to benzidine-based dyes is of concern to consumers, workers and children because such dyes can be converted in the body into a chemical known to cause cancer. According to the EPA, the nine benzidine substances covered under the SNUR are no longer in use and that it's amending the preexisting SNUR so that the notification requirement also applies to importers and processors of these chemical substances as part of articles, such as clothing.

The EPA is concerned about DnPP because it has been shown to cause developmental and/or reproductive effects in laboratory animals. The EPA states, "[p]hthalates are used in many industrial and consumer products, many of which pose potentially high exposure risks to consumers, workers and children."

The EPA says chloroalkanes, C12-13, are part of a group of chemicals known as short-chain chlorinated paraffins (SCCP), which are used in a variety of industrial applications, primarily as lubricants and coolants in metal cutting and metal forming operations. The EPA notes that SCCPs are no longer in use and "believes that any new uses of SCCPs could cause these chemicals to be released in to the environment and increase potential exposure. Such an increase should not occur without opportunity for EPA to review and control as appropriate."

IMPACT

The final rule is notable for the way it applies to imported articles containing any of the benzidine-based chemicals. The EPA has been working for years to make inapplicable the 40 C.F.R. Section 721.45(f) exemption for articles that otherwise applies to SNURs. TSCA defines "article" as "a manufactured item (1) which is formed to a specific shape or design during manufacture, (2) which has end-use function(s) depending in whole or in part upon its shape or design during end use, and (3) which has either no change of chemical composition during its end use or only those changes of composition that have no commercial purpose separate from that of an article, and that results from a chemical reaction that occurs upon end use of other chemical substances, mixtures, or articles." Historically, articles that contain chemical substances subject to a SNUR that are not intended to be removed and have no separate commercial purpose are generally exempt from TSCA. The final rule on benzidine-based chemicals is broader in that it is not limited to certain articles and for this reason is precedential.

Stakeholders who have an interest in the legal and policy underpinnings of the EPA's treatment of articles should monitor this issue. Given the agency's clear interest in more broadly applying SNURs to articles imported or otherwise, this is an important emerging TSCA issue. ●

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STOP EXPLOSION PROPAG

Choose a suitable method to limit damage elsewhere in the process

By David Grandaw, IEP Technologies

P

GATION

INDUSTRIAL EXPLOSIONS are a constant threat to any facility that handles combustible vapors or finely divided combustible dust. Most organic material will burn in a solid form; if this same material is in a dust or vapor form, under certain conditions it will explode. Combustible dust and vapor explosions happen frequently in the processing industry. Sometimes these explosions remain confined to the process vessel in which they originate. However, more often than not, the initial explosion will result in a secondary explosion with devastating results outside the vessel or through interconnecting ducts or pipes.

Having a comprehensive plan to prevent an explosion from happening under normal circumstances and mitigating the effects of the deflagration under upset conditions is critical to the safe operation of any facility that is faced with this threat. The plan must include identifying where potential for flame propagation exists and a decoupling strategy to prevent this propagation from occurring. This article will discuss various explosion-isolation options.

For an explosion to occur, five elements must be present:

1. fuel, i.e., a combustible dust or vapor;
2. an ignition source;
3. an oxidizing agent, which usually is the oxygen in the air;
4. confinement, which results in pressure buildup during the incipient explosion; and
5. in the case of dust, dispersion into the airstream.

In the chemical industry, vessels typically subjected to this threat include dryers, mills, reactors, air/material separators such as dust collectors, and storage vessels. It is common for the combustible dust to reach its minimum-explosive-concentration level at least locally within these process vessels. All that's needed to initiate the deflagration is an ignition source. The pressure from the incipient explosion travels at the speed of sound while the growing fireball initially propagates at a much slower speed. A typical sequence for a dust explosion includes:

- The dust cloud becomes ignited.
- The deflagration pressure results in rupture of the vessel.
- The shock wave from the ruptured vessel liberates dust that has accumulated on horizontal surfaces in the process area, such as atop beams, ducts, conveyors and even light fixtures, causing the dust to become suspended in the process area.
- The fireball escaping from the vessel ignites the newly suspended dust in the process area, triggering a secondary explosion that can destroy the building.

Figure 1. Highly energetic explosions can occur in connected equipment.

- Flame propagation occurs through interconnected ducts, chutes or conveyors to connected equipment upstream or downstream, prompting highly energetic explosions in these connected vessels (Figure 1).

Ignition control, proper housekeeping to remove residual dust, continuous training of plant personnel on dealing with the dust explosion risk, and management of change to address the effects of a process or product change are all critical to helping prevent an explosion from occurring under normal operating conditions. Unfortunately, abnormal conditions that result in an explosion can occur in any process line. This is why the National Fire Protection Association (NFPA), Quincy, Mass., requires the use of explosion mitigation techniques for vessels subjected to an explosion threat. NFPA 69 [1] lists a number of mitigation methods for dealing with this risk. These methods include inerting with a noncombustible gas or dust, building the vessel strong enough to withstand the pressure from a deflagration (containment), explosion venting and explosion suppression. Except for inerting, these protection techniques don't eliminate the risk of an explosion initiating in one vessel and propagating to interconnected vessels.

EXPLOSION PROPAGATION

The transmission of flame from one vessel to another through an elongated duct results in enhanced burning rates because the turbulence created during propagation increases the mixing of fuel and air. The result can be a flame jet ignition and pressure piling traveling to the interconnected vessel. This often causes a much more energetic explosion in the second vessel than in the source vessel. If explosion protection measures such as venting or suppression are installed on the second vessel, they likely were sized based on a specific deflagration index (K_{ST}). K_{ST} values are determined using two 5,000-joule igniters, or 10,000 joules of energy. The flame jet ignition can produce a significantly higher energy level, resulting in a much more severe explosion than that for which the protection measures are designed.

When left unchecked, flame propagates through interconnected duct from initial flame speeds of around 10 m/sec to a speed where they transition to a detonation, i.e., the speed of sound (343 m/sec). Documented testing has shown risk of this transition occurs in relatively short distances — 40 duct diameters for vapors, 80 duct diameters for dusts. Few explosion protection measures are designed to withstand the effects of a detonation.

The risk and effects of flame propagation are recognized by NFPA in a number of standards related to dealing with explosion risks, such as NFPA 68 and NFPA 654 [2,3]. Section 7.1.6.1 of NFPA 654-2013 states: "Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69, Standard on Explosion Prevention Systems." In addition, the U.S. Occupational Safety and Health Administration's Combustible Dust National Emphasis Program CPL 03-00-008 [4] identifies the lack of explosion isolation as a citable offense under its General Duty Clause.

EXPLOSION ISOLATION

Explosion isolation devices prevent a deflagration in a process vessel from propagating through a connection such as a duct, chute or conveyor to other equipment where it could cause subsequent explosions. The devices work by decoupling the flame propagation and pressure piling between connected

REFERENCES

1. "NFPA 69: Standard on Explosion Prevention Systems," 2014 ed., National Fire Protection Assn., Quincy, Mass. (2014).
2. "NFPA 68: Standard on Explosion Protection by Deflagration Venting," 2013 ed., National Fire Protection Assn., Quincy, Mass. (2013).
3. "NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids," 2013 ed., National Fire Protection Assn., Quincy, Mass. (2013).
4. "Combustible Dust National Emphasis Program," CPL 03-00-008, U.S. Occupational Safety and Health Admin., Washington, D.C. (2008).

equipment. A number of different explosion isolation techniques are recognized as suitable by NFPA 69. These isolation techniques generally are categorized as either active or passive.

Active Explosion Isolation. An active system includes detection components and a control unit as well as the isolation device itself. Detection is performed by either pressure-activated explosion detectors, radiant-energy flame detectors or a combination of these. During an incipient deflagration, the pressure wave is traveling much faster than the flame front, so for energetic deflagrations, pressure-activated detectors will be most useful. This style of detector comes either as a static or fixed-set-point unit, or a dynamic or rate-of-pressure-rise detector. For less energetic explosions that potentially may take a longer time to sense the pressure rise (such as with low K_{ST} dust hazards in larger volumes), the rate of pressure increase is relatively low, so a radiant-energy detection device such as an infrared detector positioned near the mouth of the duct often will spot the deflagration faster than a pressure sensor can. Once detection is achieved with either style device, a signal goes to the control unit. The control unit then activates the isolation device. In addition, as required by NFPA 69, the control unit will have the process controller shut down any equipment that moves product or air through the protected volume.

The active isolation devices are either chemical or mechanical in nature. A chemical isolation device works by rapidly discharging a chemical extinguishing agent, such as sodium bicarbonate, into connecting ductwork to mitigate flame propagation (Figure 2). This is done through a pressurized extinguisher mounted directly to the interconnecting duct. Mechanical isolation options include a high-speed gate valve (Figure 3). Milliseconds after the valve's detectors sense explosion pressure or flame, the controls rapidly deploy a mechanical barrier — closing the valve's gate across the connecting ductwork. Due to their cost, high-speed isolation gate valves are most commonly used in applications where the deflagration dust threat involves a high-value product such as a pharmaceutical dust that can't tolerate contamination from dry chemical extinguishants.

CHEMICAL ISOLATION

Figure 2. Extinguishant such as sodium bicarbonate smothers flame.

MECHANICAL ISOLATION

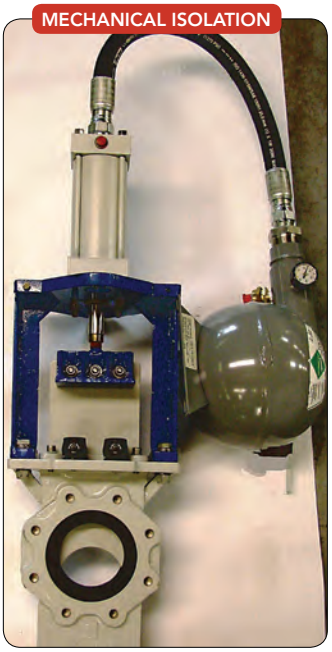

Figure 3. High-speed closing of valve's gate prevents passage of flame.

Determining where the active isolation barrier should be located requires consideration of a number of factors, including the explosivity characteristics of the dust, size of the duct, detection methodology, reaction time of the isolation device to fully create a barrier, and the reduced pressure in the source vessel. Computer modeling often uses these parameters to determine minimum and maximum isolation barrier locations for each specific application.

Passive Explosion Isolation. A variety of passive devices can mitigate flame propagation. NFPA 69 lists the following options as suitable:

1. flame front diverters;
2. passive float valves;
3. passive flap valves;
4. material chokes (rotary valves);
5. static dry flame arresters;
6. hydraulic-type (liquid seal) flame arresters; and
7. liquid product flame arresters.

Deflagration pressure activates the first three devices. Flame front diverters reroute the flame front to atmosphere through an opening such as a rupture disc or explosion door to minimize flame from passing through. These devices only are suitable for use outdoors in an orientation that enables safe flame ejection. Because they redirect but don't completely block flame passage, flame front diverters can't serve as the only means of isolation if the design intent is to completely stop flame propagation (NFPA 69-2014 12.2.1.5).

Passive float valves have internal valve plugs that can move axially within their housings (Figure 4). If an explosion occurs, the pressure wave in advance of the flame front will push and lock the valve

PASSIVE FLOAT VALVES

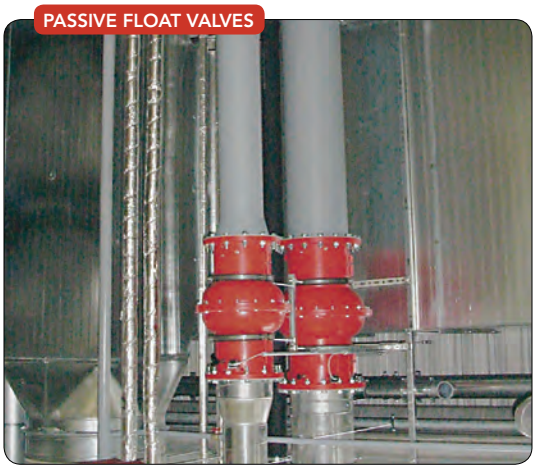

Figure 4. Such units primarily suit light dust loading applications.

KEY PARAMETERS

ISOLATION METHOD	PASSIVE	ACTIVE	DUST LOAD LIMITATIONS
Float-Style Valve	X		X
Flap-Style Valve	X		X
Flame Front Diverter	X		
Chemical Isolation		X	
High-Speed Isolation Valve		X	

Table 1. A variety of factors should be considered when selecting an isolation method.
* Some smaller-diameter flap-style valves are certified for use in ST-2 dust applications.

against the internal housing, creating a mechanical barrier. These valves can be single direction or bidirectional. They typically are used only for light dust loading applications.

Passive flap valves are mounted on the horizontal inlet of the protected vessel, with an interior flap plate held open by the process airflow (Figure 5). When a deflagration occurs, the pressure preceding the flame front causes the internal flap plate to close, creating a mechanical barrier to stop flame propagation upstream. A latching mechanism is required to prevent "bounce" that could allow flame to pass. These devices also must have continuous monitoring for any dust accumulation that may occur, except when there's a documented risk assessment and appropriate internal inspection protocol and frequency that has been approved by the authority having jurisdiction (AHJ).

Each of these passive isolation methods requires testing and certification of suitability for its use as an explosion isolation device by a recognized testing organization acceptable to the AHJ.

A rotary valve intended for use as an explosion isolation valve must meet certain criteria as listed

INSPECTIONS REQUIRED	ST-1 DUSTS	ST-2 DUSTS *	ST-3 DUSTS	VERTICAL DUCT	HORIZONTAL DUCT	PREVENT FLAME PASSAGE	PREVENT PRESSURE PASSAGE
X	X	X	X	X	X	X	X
X	X				X	X	X
X	X				X		
X	X	X	X	X	X	X	
X	X	X	X	X	X	X	X

in NFPA 69. These include design strength suitable for the explosion pressures that could be reached, a minimum of six vanes diametrically opposed, with at least two vanes on each side of the housing in a position of minimum clearance at all times, metallic construction unless otherwise tested and, to ensure no flame passage, external bearings as well as a maximum allowable gap between the internal flights and housing of 0.2 mm.

The last three passive isolation devices — static dry flame arresters, hydraulic-type (liquid seal) flame arresters and liquid product flame arresters — are used specifically for combustible vapor applications and are not to be used for combustible dust explosion propagation threats. NFPA 69-2014 Sections 12.2.5, 12.2.6 and 12.2.7 provide prescriptive requirements for the use and limitations of these devices.

Every explosion isolation method, whether active or passive, needs routine maintenance. NFPA 69 requires inspection at 3-month intervals. This frequency can be modified based on documented operating experience and hazard analysis, with approval of the AHJ and the explosion-prevention-system designer. Inspection records must be kept on file for a minimum of 3 years.

Changes to the process can significantly impact the effectiveness of the explosion isolation method. Some factors that could compromise the explosion isolation system include a change in equipment,

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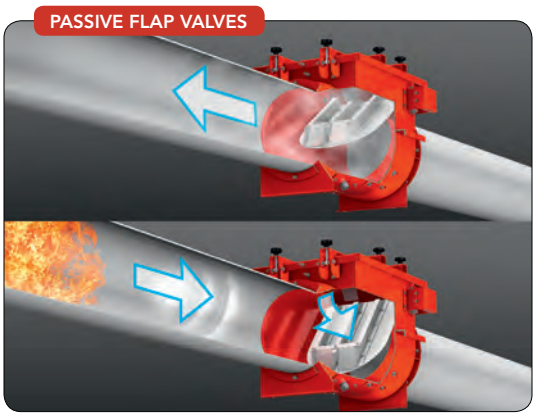

Figure 5. Devices must have latching mechanisms to prevent "bounce" that could allow flame through.

product, operating temperature or pressure, process flow or air flow. It is critical to develop and adhere to a robust management-of-change policy for assessing changes to the process or product that could potentially undermine the ability of the explosion isolation method to perform as originally designed.

SELECTING AN ISOLATION METHOD

Determining a suitable isolation method for a given application requires consideration of a number of factors — including the type of combustible material being handled, the material's propensity for caking or deposits, the impact of product contamination after isolation, initial cost and ease of maintenance. Table 1 gives a snapshot of several key parameters for some isolation methods.

Passive protection often is an attractive option. For vessels with single, smaller-diameter ducts requiring isolation, it's generally the least expensive choice, both in initial investment and ongoing maintenance costs. Post-explosion refurbishment usually is less costly and simpler than for active systems. Moreover, plant personnel typically can perform routine inspection of most passive isolation methods. When considering passive isolation for new applications, discuss its suitability with an explosion protection professional before finalizing on plant component layouts. Duct orientation, dust loading, airflow and pressure drop will impact the efficacy of using passive devices for explosion isolation.

Active explosion isolation usually is a more flexible choice than passive because it can be installed on ducts regardless of orientation or dust loading. The explosivity limitations for active systems generally are much broader than those for passive systems. In addition, because active systems provide no internal obstructions during normal operation, they don't pose pressure drop concerns. The initial cost for active isolation often is more than that for passive isolation; the comparison is very application-specific and depends upon factors such as process configuration and duct size. Active systems typically require more extensive maintenance than that needed for passive barriers, because more components — the detection devices, control unit and the isolation barrier (chemical or valve) — must be inspected.

All isolation methods have limitations. So, it's critical that the isolation method has been tested and approved for the parameters of the particular installation. Work with an experienced explosion protection professional to determine an explosion isolation strategy that's best suited for your application.

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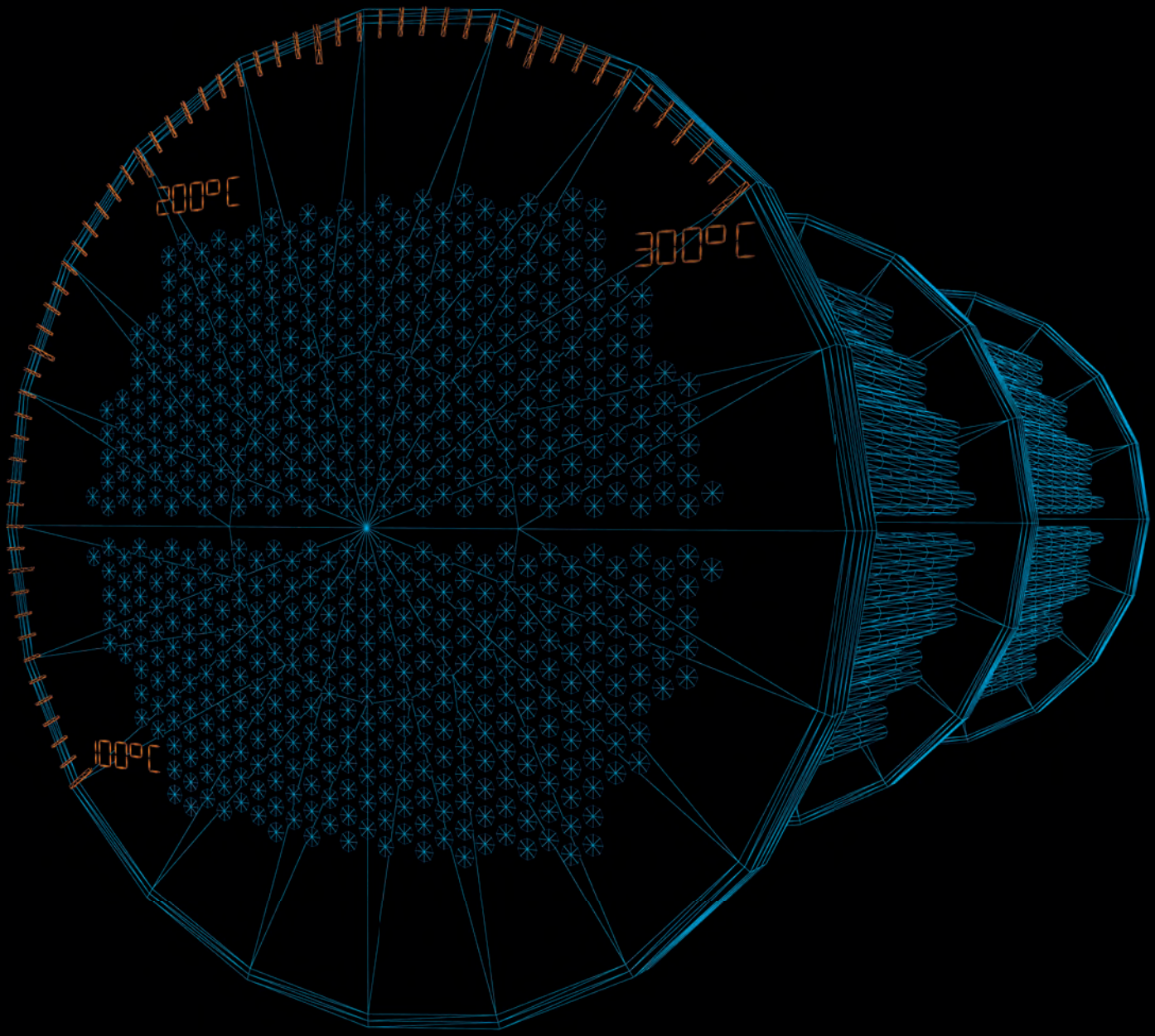

WHEN CONDITIONS HEAT UP DON'T LET CORROSION SHUT YOU DOWN

Whether it's higher temperatures, rising pressures or more acidic media, conditions in oil refineries have never been more extreme. Tube and pipe corrosion are a constant threat, causing as many as half of all major shutdowns. This is why hundreds of the world's most demanding petrochemicals refiners are turning to the next generation of corrosion resistant alloys. Like one German oil refinery, which used Sandvik SAF 2707 HD hyper-duplex heat exchanger tubes to reduce the number of shutdowns from 8 to 1 over a period of four years. The result was massive savings on material replacement. So as your tubes' performance is pushed to new heights, find out how we can help keep corrosion from shutting you down.

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Refrigerant Replacement Rises

Switching to more environmentally friendly materials poses tradeoffs

By Seán Ottewell, Editor at Large

REGULATORY PRESSURES are forcing the phase-out of many widely used refrigeration gases and their replacement with more environmentally friendly alternatives. For example, the U.S. Environmental Protection Agency (EPA) ruled in October that domestic production of R22 (chlorodifluoromethane) should end within five years.

So the industry is turning to alternatives such as ammonia, carbon dioxide and a range of hydrocarbons with low ozone depletion potential (ODP) and low global warming potential (GWP). Such hydrocarbons include: R1270 (refrigerant-grade propylene), R290 (propane), R600 (butane) and R600a (isobutene), together with raft of blends that emulate the performance of existing refrigerants while also providing efficient and environmentally friendly replacements for them.

This offers chemical companies a two-fold opportunity: to improve their own processes by switching to these refrigerants, and to manufacture them to meet the demand. Roche, Basel, Switzerland; and DuPont, Wilmington, Del., are at the forefront of these efforts. However, suppliers such as Versatile Refrigeration, Chemainus, B.C., caution that both the legislation and the technology needed to deal with new refrigerants still are evolving.

AMBITIOUS INITIATIVE

One of the most proactive chemical companies when it comes to replacing old-style refrigeration gases is Roche. The company's Group Directive K6 covers substances affecting the ozone layer and climate and focuses on halons, CFCs, HCFCs, HBFCs, HFCs and PFCs. K6 calls for removal of 90% of these substances from legacy company operations by the end of 2015. Acquisitions will be subject to "appropriate new timeframes."

Roche eventually will ban all these materials from aerosol products manufactured by the company or its affiliates, and from foam products used both for packaging material and new thermal insulation applications. (Existing insulation uses can remain in place until the end of their service lives.) Similarly, Roche will prohibit the gases in production processes; however, it still will permit small-scale laboratory use in certain test methods.

The company is turning to a range of natural refrigerants to help meet these targets — for example, ammonia for air conditioning, carbon dioxide for cold room chilling, and hydrocarbons such as propane, isobutane and ethylene for lyophilization — a freeze-drying process designed to preserve material and make it easier to transport.

NEW CHILLERS

Figure 1. Two R1270 units, each with 260-kW cooling capacity, chill brine at a plant in Orlando. *Source: Versatile Refrigeration Inc.*

As part of this initiative, Roche has designed and installed energy-efficient and environmentally friendly refrigeration systems at sites in the U.S., Ireland and Germany. These use only natural refrigerants, mainly ammonia.

Its Indianapolis site now has a centralized 16,000-m^2 chiller plant fitted with seven ammonia chillers to cool water that then is pumped through a pipe system to individual buildings on site to help keep workers cool. Roche notes that this project required some extra safety features such as ammonia sniffers. As well as being environmentally friendlier than the technology it replaced, the new chiller system is twice as energy efficient, says the company.

A similar project has been undertaken at a site in Ireland, with partial funding from the Sustainable Energy Authority Ireland, Dublin, whose role is to advance the use of sustainable technologies within the country. Here, an almost-two-fold increase in energy efficiency has cut power demand by 925 MWh/y — a savings of 575 t/y of carbon dioxide emissions.

Each ammonia refrigeration system design in Ireland also will incorporate an open flash economizer vessel. Such a vessel allows a considerable portion of the cooling to be carried out at a much higher temperature, approximately -8°C, instead of -22°C or -29°C, saving substantial energy, says the company.

In Germany, a logistics center is using a mixture of natural refrigerants including ammonia, propane and carbon dioxide to provide freezing down to -70°C.

MOBILIZING EFFORTS

Meanwhile, DuPont is urging customers to make R22 an asset and offers advice on recovering and reclaiming it, repairing leaks and maintaining equipment performance. The company also offers its own alternative — Isceon MO99 — as a retrofit to extend the useful life of the equipment.

DuPont also foresees a good future for its new HFO-1234yf refrigerant for automotive air conditioning. A hydrofluoro olefin (HFO), the gas can replace R134a now used as a refrigerant in automobile air conditioning systems. It has a GWP rating 335 times lower than that of R134a.

HFO-1234yf was developed to meet the European Mobile Air Conditioning (MAC) directive that went into effect in 2011 and requires all new car

platforms for sale in Europe to use a refrigerant in their air conditioning systems with a GWP below 150. The U.S. EPA also has issued a proposal that would limit the use of R134a in automotive air conditioning.

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"HFO-1234yf has a 99.9% lower GWP than the refrigerant it was designed to replace, and meets a range of critical performance, sustainability and safety needs. Other low-GWP refrigerants are available for use in complying with the MAC Directive, but most automakers have concluded that HFO-1234yf is the best option. Most of the world's major automakers have already started their commercial transition to HFO-1234yf, and all but one are working to adopt HFO-1234yf," says Kathryn K. McCord, global business director, DuPont Fluorochemicals.

McCord expects the use of HFO-1234yf to grow from three million vehicles at the end of 2014 to seven million by the end of 2015.

DuPont is selling the new refrigerant as Opteon YF, to both automakers and the service industry in the U.S. and Europe. Its manufacturing sites in China and Japan announced capacity expansions last October; the company says further investments could be made if demand justifies them.

"The industry is moving decidedly toward HFO-1234yf because it offers a range of advantages, including cooling power, energy efficiency, safety, materials compatibility, sustainability and total systems cost effectiveness," adds McCord.

She downplays the potential of carbon dioxide as an alternative in automobile air conditioning systems. "While carbon dioxide also was proposed as a low GWP automotive refrigerant, it has been 25 years since the first patent was issued for this technology, yet all indications from the automotive industry are that commercialization of this technology would occur well into the future. Carbon dioxide has low energy efficiency in warm climates, potential for passenger asphyxiation in the event of leaks, and requires a high pressure system that adds weight and size, presenting problems for small car designs and, reportedly, greatly increasing the costs of automotive air conditioning."

In tests, the Japanese Automotive Manufacturer's Association, Tokyo, has determined that under various climate and use conditions, Opteon YF has the potential to reduce the total lifecycle climate potential (LCCP), or contribution to climate change, by 20–30% versus R134a or carbon dioxide systems, assuming global adoption.

REGULATION AND TECHNOLOGY ISSUES

Regulation may the main driver for the move to natural refrigerants, but how the rules are applied varies both within and between jurisdictions. In Canada and the U.S., for example, various codes including the Uniform Mechanical Code (UMC), California Mechanical Code, International Mechanical Code (IMC) and the Canadian Mechanical Refrigeration Code come into play.

"Their intent is very similar — safety and proper installation practices — but each code is set up slightly differently for the jurisdiction it is meant to cover," notes Eric MacGregor, general manager, Versatile Refrigeration Inc.

He cites as an example the recent installation of a hydrocarbon chiller at a U.S. company using the IMC regulations. Another company just ten miles away but in a different county was subject to the UMC regulations (Figure 1).

Then there are the ongoing conversations with the U.S. EPA about what constitutes an acceptable industrial use: "Although the EPA has set out a number of approved end uses, each new use of R290, R600a, R1150, R1270, etc. has to be approved as an acceptable substitute under the Significant New Alternatives Policy (SNAP) program," he notes. Such approvals can be limited to very specific applications, for example centrifugal chillers, absorption systems, chillers for vapor compression with a secondary loop, vapor compression or absorption systems, and vapor compression with a secondary loop.

Moreover, integrating new equipment into existing facilities can raise significant technical issues. Hydrocarbon chillers and other refrigerant-carrying components can pose an extra challenge if they are in certain hazardous areas. For example, a Class 1, Division 2 area normally doesn't have flammable vapors present — but they could arise due to a leak or catastrophic event associated with a chiller. So both the equipment comprising the chiller and the

equipment around the chiller must be intrinsically safe. You also must consider where the refrigerant goes in the event of a release.

"Some regulations require a flare stack to handle possible releases, although this varies by jurisdiction, and we have not seen it required in installations outside the U.S. The new chiller might also face space issues; they are generally smaller than other refrigeration systems but may have larger clearance requirements. Also with the hydrocarbon they may need to be located to a new area due to possible ignition sources," he warns.

Another challenge is training. You need personnel who are fully trained to work with the hazardous new refrigerants — requiring in many cases quite a new skillset, he notes.

Companies also must grapple with coming up with an appropriate strategy for switching to natural refrigeration technology. This can range from retiring existing equipment as soon as possible to running the units until the end of their useful lives before replacing them. MacGregor cautions that, whatever the investment strategy being pursued, calculations must include the costs associated with leak detection, shutdown procedures and new alarms.

MacGregor also notes that with few manufacturers of equipment that use natural refrigerant technology, choice is limited and costs relatively high. This will change as more companies enter the market and competition increases, he believes.

"However, what really impresses potential customers are the figures: a hydrocarbon refrigerant is typically 20% more efficient than a synthetic, so there's a big energy saving to start with. Also, you only need about half the weight of hydrocarbon versus synthetic, depending on the application and the synthetic in question. These are very big selling points," he emphasizes.

"My concerns with all refrigerants are operational suitability and efficiency, as well as refrigerant lifecycle environmental impact from production to destruction. I would like to see more options on the market that offer good efficiency and low environmental impact. Those two attributes have been at odds with each other in the past," he adds.

The option currently favored by Versatile Refrigeration for its refrigeration systems is an R1270, refined propylene.

"We still have to push for more efficiencies and societal acceptance is going to be very important; in the end it's a question of environmental stewardship," MacGregor concludes.

SUCCESSFULLY IMPLEMENT AN OPERATOR CARE PROGRAM

Getting an operator to act as an owner of equipment can provide myriad benefits

By Bill Wilder and Joel Levitt, Life Cycle Engineering

SUCCESSFUL OPERATOR care programs improve reliability, quality and safety. They also enhance job satisfaction. By decreasing unexpected breakdowns, downtime and maintenance costs, operator care programs also boost financial performance.

Such programs aim to have operators act as owners of their equipment. They become full partners with maintenance, engineering and management to ensure equipment reaches operational goals every day. Successful operator care programs:

- improve production;
- provide individual professional development;
- promote reliability and safety;
- reduce waste; and
- decrease training and downtime.

Operator care has four elements, illustrated in Figure 1, that create a hybrid operator who is comfortable in the operations, maintenance and engineering worlds:

KYMP — Know Your Machine and Process. Operators increase their knowledge of their process and their machines. This may go well beyond current knowledge requirements.

P^2 — Prevent or Postpone Failure. Activities to avoid failure include lubricating equipment, hands-on cleaning, tightening bolts and making minor adjustments. We consider this to be basic maintenance work.

D^3R — Detect Defects, Diagnose and Report. Inspections directly resulting from the hands-on cleaning activity identify any deterioration or defects.

CI — Continuous Improvement. The operator always is involved in thinking about how to make the equipment work better. Potential improvements may come from reduced downtime, increased yields and lower utility usage. CI is an adjunctive engineering activity.

IMPLEMENTATION CHALLENGES

You will encounter resistance when launching an operator care program. Success demands proactive steps to address resistance as well as a well-designed learning process. Organizations that simply announce a new expectation and schedule a class but do little intentionally and proactively to manage natural resistance or reinforce the desired change in behavior rarely achieve satisfactory results.

The groups typically involved or impacted by the operator care program are:

FOUR ELEMENTS

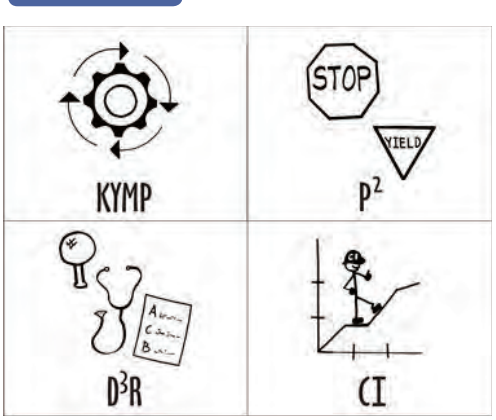

Figure 1. Operator care involves four distinct but complementary aspects.

Figure 2. This proven model involves three stages.

management; operations; maintenance; sales and marketing; and supply chain vendors. People in each of these stakeholder groups will be required to change their behavior.

The stakeholder group most resistant to changes is management, particularly the direct supervisor. This individual also has the most influence over resistance from the operators and other people who must change.

To alter operator behavior to produce the desired results requires integrating the science of change management and learning. This can be achieved by leveraging established models within each discipline. An example is the integration of Prosci's ADKAR model with our 3A learning process.

ADKAR is a model for the five phases or stages all individuals progress through when they change:

1. awareness of the need for change (why);
2. desire to support and participate in the change (our choice);
3. knowledge about how to change (the learning process);
4. ability to implement the change (turning knowledge into action); and
5. reinforcement to sustain the change (celebrating success).

The Life Cycle Engineering (LCE) 3A Learning process (Figure 2) has three elements — align, assimilate and apply.

ACHIEVING AWARENESS AND DESIRE

In the first phase of the LCE 3A learning process, we gain alignment by creating a direct line of sight from individual behavior to organizational goals. This is done through an intentional campaign to establish awareness of the business need for change and a desire to alter behavior. Senior leadership most influences awareness while direct supervisors most influence desire. The supervisors should work with an impact map that connects the desired individual behavior to organizational goals. This learning impact map can be a simple table that has columns for organizational goals, learning objectives, individual behaviors and individual results. The objective is to engage the operators' manager in the discussion and setting of expectations for behavior change following the class. More information on how to implement a learning impact map is given at LCE.com.

Senior leadership will communicate the business reasons for the change. The message should outline the current business environment, including competitor and customer influences. It also should describe the risk of not changing. This communication should make operators and other impacted stakeholders aware of the business drivers for the operator care program.

The supervisor will introduce operator care concepts, pointing out the benefits for the operators' jobs and lives. Operators will prefer to hear from their supervisor about how the change will impact them personally. The supervisor's responsibility includes significant activities that require strong communication, planning and leadership skills to accomplish the following steps in rolling out an operator care program:

- conducting the initial education and pitch for the operator care program (to all hands);
- selecting future leaders for deeper training;
- setting up committees and choosing the pilot area;
- establishing targets for the pilot area;
- creating plans for machines and areas;
- organizing the opening ceremony;
- starting training and implementation in the pilot area; and
- implementing techniques, including reporting, incentives, and external and internal support, to sustain the program.

The supervisor's actions and communications can make or break your program. First, supervisors tend to be the most resistant to change. So, make a conscious effort to include them in the design and deployment of the program. This will improve their willingness to try operator care and act as advocates for the program. Second, supervisors are the most influential people in overcoming resistance and creating desire among the operators. During this align phase of the 3A process, you want to achieve awareness and desire for the operator care program.

CREATING KNOWLEDGE AND ABILITY

The assimilate phase is where the capabilities to implement the change are created. This is achieved by delivering learning events (classes) that:

Assess and access prior experience. Every person comes to the class with unique individual experiences. The facilitator should be able leverage or mitigate these inputs. Failure to do so will lead to disengagement and disruption during the learning event.

Engage participants in activities at least 75% of the time. The event should allow attendees to work with and practice the knowledge introduced. Active participation means the learner is reading, speaking, writing or, in some other way, engaging with the content, not passively listening and watching a slide presentation or video.

Provide relevant application experience. Learning should directly relate to helping the attendees do their jobs or reach a goal. Use examples from the workplace, not textbook case studies.

Offer self-direction in the learning process. Adult learners want to be able to choose how they learn. So, let attendees make decisions about what, how and when they will learn. There obviously are some constraints on this. However, never do for learners what they can do for themselves. Seek out ways to let the participants make decisions.

Typically, such sessions should involve no more than 15 operators.

Even with the best course, the particular class leader makes a big difference. That person should provide a good balance between instructor skills and facilitator skills (Figure 3).

INSTRUCTORS VERSUS FACILITATORS

INSTRUCTORS	FACILITATORS
Content resource (Sage on the stage)	Process manager (Guide by the side)
Share knowledge through writing and lectures	Use knowledge of how people learn to create an active environment
Passive participants	Engaged participants
Control what is taught and when	Access and assess prior experience to encourage sharing of knowledge among participants
It is up to the participant to adapt to learn new skills and knowledge	Learners share and take charge of their learning, benefitting from their unique learning style

Figure 3. The leader of operator care training sessions requires a good balance of skills.

The assimilate phase should include engaging the operators in beginning the operator care process for their equipment. The following exemplifies one approach you could apply. It relies on the 5S process (sort, set in order, shine, standardize and sustain).

1. Observe, interview and evaluate by walking down the area, then audit and score.
2. Obtain any current check sheets, preventive maintenance to-do lists, etc. and scrutinize as a team. Review the maintenance logs for history of chronic failure.
3. Take "before" photos.
4. Establish a quarantine area.
5. Initiate a "red tag" process to identify items that potentially don't demand attention, and sort.
6. Review the red tag log with area team members.
7. Assess what to do with as many red tag items as possible.
8. Determine resources needed.
9. Using the process worksheets, record issues and opportunities.
10. Regroup and discuss what you observed and recorded for improvement. What tasks must be performed? What supplies do we need to do them? Do we need cross-functional support from other work streams?
11. Develop a plan and assign tasks. Obtain supporting documentation for tasks.
12. Review the plan with necessary area workers.
13. Start 5S activities. Simplify. Sweep and clean.
14. Conduct another observation and repeat the audit.
15. Develop the 5S area map with help from the area owner.
16. Implement the 5S board and populate it with help from the area owner.
17. Review and train the area owner on the 5S board responsibilities.
18. Conduct an audit with the area leader, teaching that person what to look for in the audit.
19. Develop an operator-care rounds process per flow and step definitions.
20. Establish or revise operator instructions for the operator round.
21. Review with area workers and adjust as needed.
22. Train steps 19 through 21.
23. Develop coaching cards.

REINFORCING NEW BEHAVIORS

The apply phase is when people begin to attain success. Achieving sustained change in behavior requires reinforcing the new behaviors. When people learn new processes, knowledge and skills, they go through a process that can be divided into three types of learning.

1. *The classroom or formal learning event.* This often is a live facilitator-led session or self-paced learning exercise given during the assimilate phase. However, the reality is that it amounts to only about 10% of the learning process.

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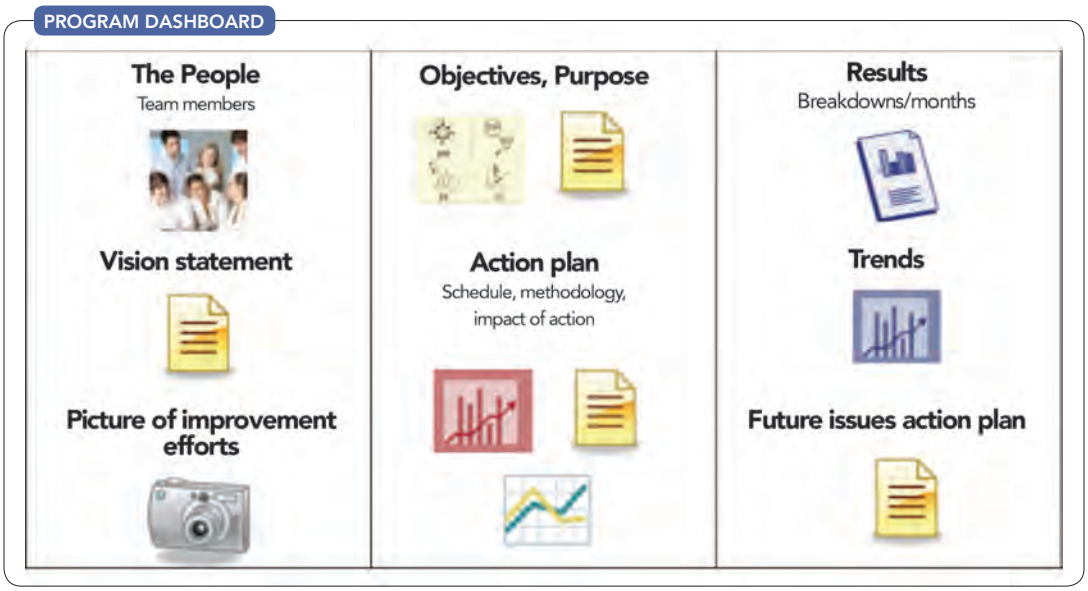

Figure 4. A visual mechanism to show targets and progress can help sustain the program.

2. It is through *coaching and peer support* that operators begin to apply what they have learned. During this application process, they pick the brains of their peers or ask a coach, often the same facilitator who led their classroom session. This learning from peers and coaching represents about 20% of the learning process.
3. The most significant stage of learning is *doing*. Performing actions and learning by trial and error represents 70% of how people learn. Most people gain proficiency in their job by doing it. Yes, formal "book" learning is important, as is the support of peers, coaches and bosses. However, it's the application of the new skills and knowledge learned in the actual work environment that makes the learning stick.

Do not leave this to chance. Ensure the application phase includes all three types of learning. Design specific, challenging tasks that must be completed and documented.

Early success is critical — this spurs people to use what they have learned and make changes. Management support and coaching are crucial for achieving early wins. Managers can run interference and ensure processes and resources are in place to adapt systems and structures. Coaches can provide the mentoring and feedback to help operators apply what they have learned to the work environment. People are naturally resistant to change but coaching and encouragement can help them to adapt. Management and coaching support are important factors in learning retention, as is the individual's commitment to put new knowledge and skills into practice.

To make the new operator-care behaviors "stick," it's a good idea to establish project targets and publish progress on a dashboard. Figure 4 shows suggested components of such a dashboard.

A strong apply phase ensures participants:

- keep goals top of mind;
- celebrate success;
- plan and track progress;
- learn from others;
- receive coaching and mentoring;
- involve their managers; and
- document results.

Some typical mistakes to avoid include:

- not considering both how people learn and how people best adapt to change;
- focusing only on the learning and, therefore, not getting sustained behavior change;
- trying to change behaviors without teaching operators how; and
- training without reinforcement.

TAKE CARE WITH OPERATOR CARE

Achieving success with an operator care program depends as much upon behavior change as new processes and tools. By keeping Prosci's ADKAR model for individual change and LCE's 3A Learning process in mind, you can engage people's willingness and ability to make the change. The end result will be an operator care program that gives operators more satisfaction with their jobs and delivers improved reliability, quality and safety.

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DO MORE WITH MULTIPARAMETER ANALYZERS

Simple-to-implement non-analytical measurements can boost capabilities

By Jim Gray, Emerson Process Management, Rosemount Analytical

LIQUID ANALYZERS have been used for years in industrial applications for pH, conductivity, oxygen, chlorine and other measurements. In recent years, it has become common practice to have line-powered multiparameter analyzers make two or more measurements; using signal cards for each desired measurement type enables a single device to meet the needs of the application. Yet, many users don't realize that adding or changing signal cards gives these analyzers the flexibility to handle new or evolving applications — solving problems beyond their liquid measurement functions quite cost effectively and possibly reducing costs in other areas of the plant as a result.

For instance, inputting non-analytical measurements into a liquid analyzer can improve the accuracy of the main measurement. All the most common liquid analytical measurements require a temperature measurement to correct a measured value to a standard temperature. In some cases, the main sensor may lack a temperature element or may have a very slow temperature response, sometimes as long as 30 minutes. An accurate reading won't occur until the temperature reaches equilibrium. Inputting a fast-responding temperature measurement can improve the accuracy of the main measurement — as well as its efficiency. All the plant operator has to do is add a simple temperature input.

Two common oxygen measurements, % oxygen in gas and % saturation of oxygen, depend upon the total pressure. Changes in the total pressure will cause errors in these measurements if the total pressure isn't measured and corrections applied. Inputting a pressure measurement enables the analyzer to correct these oxygen measurements for total pressure

MULTIPARAMETER ANALYZER

Figure 1. Device provides capabilities for control as well as measurement.

changes. Again, the addition of a non-analytical measurement — pressure — to the multiparameter analyzer saves time and money and improves accuracy.

Non-analytical measurements also can be very useful and provide cost savings by:

- Preventing damage to the analytical sensor. Measurement of sample temperature or pressure can allow diverting sample flow if the temperature or pressure exceeds the sensor's limits.
- Detecting loss of sample flow conditions. Measurement of flow in monitoring and data logging applications can identify when an analytical sensor is out of contact with the sample process, a situation that can lead to false readings and, thus, false alarms.

For multiparameter analyzers used for water treatment, it's often useful to have a flow totalizing capability. This allows observing and logging the rate and total volume of water treated. A flow input signal card can accommodate a low-cost pulse flow sensor as well as any full-featured flow transmitter.

ADDING MEASUREMENTS

Getting readings for pressure, temperature and flow only requires a simple connection of a two-wire transmitter, without the need for an additional power supply. This saves money and reduces complexity while improving the accuracy of the analytical measurement or integrating another needed non-analytical measurement into the application.

A signal card is used for inputting 4–20-mA signals for temperature, pressure and pulse flow. Because multiparameter analyzers are line-powered (85–230 VAC, 47.5–65.0 Hz, 20 W; or 20–30 VDC, 20 W), they not only can receive a transmitter signal but also, if needed, can power the transmitter that provides the signal. All that's required to input a transmitter signal is to connect the transmitter to the powered input of the signal board in the analyzer.

The analyzer software recognizes the presence of the analog input signal card; the only configuration required is to scale the analog input and assign a unit. Once the input is scaled, it becomes an integral measurement of the analyzer, no different than pH or any other analytical measurement. An input measurement can be applied to any of the analyzer features such as HART transmissions, data logging, and discrete and analog outputs. The increased functionality associated with the external measurement incurs only a small increase in cost.

CONTROL CAPABILITIES

Multivariable analyzers can do more than provide measurements. For instance, they can handle a number of traditional water treatment functions and controls, including on/off control, on/off control with delay (to allow time for mixing), interval timer (typically for sensor cleaning), and a date and time signal (sprinkler timer) for routine chemical additions. There's also event-based relay activation, which can be based on totalized flow or the activation of another relay.

In addition, control functions include time proportional control (TPC, duty cycle), using a standard proportional-integral-derivative (PID) algorithm and one or more of the analyzer's relays. PID control also is available using one or more of the analyzer's analog outputs. As is the case with TPC, this relies on a standard PID algorithm; the control variable can be any analytical or input measurement.

The analyzer's discrete and analog control capabilities also make it easily adaptable as a single station controller for applications such as skids, utilities, waste treatment and outfalls that require

basic PID control but aren't hooked up to the plant's distributed control system. Control applications have included PID for pH control, TPC with ORP for chlorine destruction, and differential pressure input for level control. In one case, a multivariable analyzer was used to provide temporary water level control during a plant turnaround. Because the site already had the instrument installed, all it had to do was simply add a 4–20-mA signal card and configure it for level control. The instrument was quickly adapted at minimal cost. In general, the only questions that have arisen in applying the control capability of the analyzer have been whether to opt for direct or reverse control action, a common control question.

Multiparameter analyzers aren't appropriate when you need more than simple single-loop control, e.g., multi-loop control or more sophisticated control algorithms. They also shouldn't be used for control when the control action must be interrelated or interlocked among a number of measurements. Such situations require a programmable logic controller or another more powerful device. However, for a range of straightforward control functions that plants need every day, using the analyzer as a controller can be effective and provide cost savings.

A bad measurement due to a fault leads to bad control output whether it's analog PID, discrete TPC, or even on/off control; the effects of a faulty control signal can cause major process problems. It's important to set a fault value for analog outputs, so the PID control output will go to a safe value during a fault. In the case of TPC, assign a fault relay, which can be used with the TPC relay and a timer relay to provide a safe pulse output.

Multiparameter analyzers also provide data logging capability and can capture primary and secondary measurements, input values, totalized flow and analog output values, including PID output. The analyzers typically can store a month's worth of data taken at 30-second intervals. Events, such as faults, warnings and power on, are written to an event log as they occur. The logged data and an event logger can be downloaded from the analyzer to a memory stick for further analysis or incorporation into plant records.

So, using a multiparameter analyzer for an application such as monitoring pH and totalized flow at a plant outfall ideally would involve only a monthly visit to the analyzer to download data and perform any necessary maintenance. On the other hand, operations and maintenance staffs must be aware of the quality of the measurement and control on a real-time basis, creating a need for communication with the analyzer.

COMMUNICATION

A multiparameter analyzer has a number of secondary measurements associated with each main measurement. For example, a pH measurement involves not just pH but also temperature, glass impedance and reference impedance as secondary measurements. Two pH measurements would have a total of eight measurements available. No matter which digital communication protocol is being used, it's important that all these measurements can be transmitted. In the case of HART, the older revision 5 only can handle four measurements, so it's necessary to use the newer HART revision 7, which can transmit all eight. In the case of the outfall monitoring application, this later revision easily can accommodate all four pH related measurements as well as flow and totalized flow.

However, connecting a multiparameter analyzer to the plant control system requires accessing an input/output (I/O) port for the analyzer's digital signal, which in the case of HART is the analog signal carrying HART. And possibly, the lack of an I/O port near the application is the reason for using the analyzer instead of the plant control system. If this is the case, running signal wire could cost as much as $1,000 or more per foot in some locations.

In such a situation, wireless communication such as Wireless HART can be a lower-cost alternative because it eliminates the need for signal wiring. Making a HART multiparameter analyzer wireless simply involves adding a wireless adapter that can access the measurements and transmit them wirelessly.

The multiparameter analyzer with a wireless adapter securely communicates with a wireless gateway that, in turn, communicates with the control system. This provides a number of ways that all the device variables pertinent to the application can be made available for data logging or alarming based on their values or status, which alerts operations and

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maintenance staffs of problems with the application. The analyzer with a wireless adapter also can be added to an existing wireless HART network. The cost of a wireless adapter and a wireless HART gateway may compare very favorably to running signal wire any great distance.

Beyond simply supplying live measurements and status, the gateway can link to asset management software that will provide detailed diagnostic information on the multiparameter analyzer, analytical sensors and the link between it and any transmitters used with it. In fact, if the multiparameter analyzer is used with a HART transmitter, that transmitter itself can be provided with its own wireless adapter, which makes its diagnostic information available to the asset management software. In this way, all the information on how well the application is functioning is available remotely.

Asset management software also enables configuring the multiparameter analyzer and any transmitter used with its own wireless adapter. In cases where PID or other control is used, control can be tuned remotely because tuning constants are made available to the asset management software.

SEIZE THE OPPORTUNITY

Multiparameter analyzers clearly can do more than simply provide multiple analytical measurements. Their ability to power and input analog signals from other transmitters has made it possible to use them to easily consolidate analytical and non-analytical measurements for low-cost monitoring. The flexibility of multiparameter analyzers allows for quick adjustment of measurements by changing signal cards; the ease and simplicity of configuring the analyzers means a user can quickly adapt them to new applications. Their discrete and analog control capabilities permit the analyzers to handle single station control, not only for analytical measurements but also for virtually any measurement with an analog output. Using wireless HART and HART revision 7 provides a simple, cost-effective means to integrate monitoring and control applications using multiparameter analyzers into the plant control system.

JIM GRAY is an application manager with Emerson Process Management, Rosemount Analytical, Irvine, Calif. E-mail him at Jim-2.Gray@emerson.com.

Pharmaceutical Plant Simplifies REACTOR MONITORING

Bottom outlet valve with built-in sensor obviates new vessel entry point

By Rebecca Dettloff, SensoTech, and Holger Müller, SchuF Chemieventile Vertrieb

THE NEED for process analytical technology (PAT) to optimize pharmaceutical and fine chemical production processes has increased steadily in recent years. Such technology enables real-time monitoring of reactions, providing immediate data on critical process-control parameters. If problems arise during the reaction, the parameters can be modified before the batch is completed. This results in energy and material savings and reduces product sampling. In addition, it ensures optimal product quality.

The manufacturing processes can be monitored with sensors that are installed either directly in the vessel or in the pipeline. If effective process analysis requires sensor installation in the vessel, a suitable entry point must be found. However, modification of existing vessels is prohibitively expensive, involves revalidation and, sometimes, is not even permitted. Entry from the top also can be a problem for low volume batches. So, when a large global pharmaceutical manufacturer wanted to add a sensor to some reactors at a plant in Ireland, it opted for an innovative, cost-effective solution — a bottom outlet valve that incorporates a sensor that quickly and accurately monitors concentrations, phase separations and chemical changes in process liquids (Figure 1). This eliminated the need to modify the existing vessels.

The PAT sensor is an integral part of the valve disc and is directly exposed to the liquid in the vessel. The combination allows an effective inline measurement of relevant parameters without any process connection adapter. It provides a low-cost option for implementing modern PAT in both existing and new vessels.

Because the sensor is located in the bottom part of the vessel, even low-volume batches can be monitored in real time. If necessary, the sensor can be removed quickly between batches without having to extract the valve from the vessel. The valve, made by SchuF of Germany, comes in a wide variety of specifications, including various actuator types, sizes, accessories and materials such as stainless steel, high-nickel alloy, glass or perfluoro-alkoxy polymer lining.

VALVE WITH INTEGRATED SENSOR

Figure 1. Bottom outlet valve incorporates a sensor for measuring concentrations, phase changes and chemical changes in process liquids.

SUCCESSFUL APPLICATION

During product development of the sensor, its maker, SensoTech of Germany, has been working closely with the large manufacturer of pharmaceuticals in Ireland. The valve/sensor combination now is being used successfully at one

of the pharmaceutical firm's plants. It is installed at the vessel bottom of a dissolving station. The maintenance-free LiquiSonic sensor measures the concentration of voriconazole in the vessel at a temperature of 25°C to 45°C. The solvent is toluene. The sensor meets the process requirement for Zone 1 explosion protection and is coated with a high-nickel alloy that allows it to withstand aggressive chemical environments.

Many process liquids are prepared by dissolving solid or liquid substances in a solvent. For producing a homogeneous solution with a defined concentration, the analyzer is used to adjust the flow rates of the main substance and the solvent. Measuring directly in the vessel provides accurate concentration values also during startup and rundown processes (forerunnings and last runnings).

The combined valve/sensor provides a variety of benefits, including:

- exact dosing, which helps to save resources;
- inline concentration measurement to ensure constant product quality;
- process monitoring for online process documentation and traceability;
- direct control of the set formula, which increases operational reliability;
- inline process analysis without a costly process connection; and
- direct measurement in the vessel, eliminating dead space.

The advantages are best summed up by an engineer at the pharmaceutical company: "This relative[ly] simple but innovative valve installation optimizes our process significantly through reduced batch cycle time, improved quality and increased process reliability."

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INTEGRATION INTO THE CONTROL SYSTEM

A LiquiSonic controller displays and processes the measured values. At the pharmaceutical firm, a CAN-bus cable connects the sensor to the controller. The controller can handle up to four sensors. Indeed, at the plant, it gets inputs from another LiquiSonic sensor that monitors concentration in the main pipeline. The controller can store characteristics and records of different process liquids. So if there is a product change, the correct concentration is displayed automatically. The measured values can be read out to do further analyses and create protocols. The clear trend view provides project and technology engineers with a quick overview of the course of the process.

For automatic process control, the measured values can be transmitted to the process control system via fieldbus, analog or digital outputs, serial ports or Ethernet. At the pharmaceutical manufacturer, the data are sent to the process control system via a 4–20-mA signal to enable maintaining constant concentrations during the batch process.

ANALYZER CAPABILITIES

The sensor provides precise data on concentration and density, for example, in alkalis, acids, solutions, emulsions or suspensions. In addition, its technology detects phase transitions, enabling accurate and automatic control of phase separation processes. In a continuous process, the concentration monitoring is used to control the valve. This can offer a significant advantage, for example, where there are fast and exact separations among product, intermediate and carrier phases.

The sensor can continuously monitor even complex reactions like crystallizations or polymerizations. So, process parameters such as degree of saturation, seeding point or crystal content can be controlled in a targeted manner.

The technology is based on the measurement of sonic velocity. An ultrasonic signal is sent through the liquid from a transmitter to a receiver; the travel time is a substance-specific value from which concentration can be determined. The transmitter and receiver are integrated in the sensor and their robust construction makes the sensor maintenance-free. Because the sonic velocity also depends on temperature, two temperature sensors also are integrated in the sensor. Sonic velocity measurement is possible in process liquids with temperatures between -20°C and 180°C.

Unlike with other measurement methods such as refractometers, sealing of the actual sensor element is not necessary.

The sensor offers a measuring accuracy of 0.05 wt % that is independent of deposits in contrast to other measuring methods. (The rounded sensor edges preclude formation of deposits anyway.) The sensor design includes no moving components and complies with the strict hygiene requirements of the pharmaceutical industry. Because of the sensor's extreme robustness, mechanical vibrations or pressure surges have no influence on the measurement.

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Purge the Procedures

Heat exchanger cleaning requires a complete rethink

THIS MONTH'S PUZZLER

We have a simple system for purging heat exchangers at our refinery shop before cleaning them: an upstream high-flow pressure regulator and a pressure gauge, as well as a downstream purge valve and flow meter. We don't bother to vent the exhaust to a flare stack because it's such a small amount. We usually operate the purge at about 1 IWC. Last week, a small fire broke out as one of our welders was cutting away an old lug from a purging exchanger. We reckon a spark set off the fire. It was a hot day, about 100°F. Now, the safety group investigating the incident is calling it a near-miss. Did we do anything wrong? Is there a better way to store these exchangers until we can clean them properly?

DO THE JOB RIGHT

There seem to be serious safety lapses in your shop. It appears that ASME Code Section VIII, Div. 1, and Section III referring to the "N" stamp weren't followed because the shell was cut into. It doesn't sound like a burning permit was issued — normally the safety department issues these. You didn't follow the buddy system and there was no fire watch. In addition, the purge should have gone to a flare stack. I assume N_2 was used for the purge although CO_2, and even water could have been used. Why weren't the inlet and outlet blanked off?

Here's how you should do the purge. Use a calibrated purge flow meter. Test the pressure reading for the gauges and pressure regulator before use. Install an orifice — not a valve — at the outlet; valves can be accidentally shut off. Route a gas purge to the nearest flare and ensure there's a check valve in the line to prevent backflow. If you use water, route it to the correct wastewater-treatment sewer. Tag the purged equipment so that nobody works on it without a permit.

As for the welding or cutting, follow a written procedure. The safety department should review all isometrics and a marked-up process and instrumentation drawing (P&ID) before issuing a hot work permit. Walk through a job plan, ideally on site, before beginning the work — this will improve situational awareness. When you prepare the job plan, make sure you specify the type of heat exchanger and its material of construction. Include the gaskets, the working and design pressures, the planned purge rate, the purge composition, e.g., for N_2, ppm-mass air, the cleaning procedure, and the material safety data sheets and other data on the process fluids going through the exchanger. Lastly, review the work with your mechanical integrity group before the walkdown and review with safety.

William Bohach, president
MP Technologies, LCC,
Savannah, Ga.

COMPLY WITH REGULATIONS

I'm surprised you got away with this for so long. The first problem is with your field cleaning. The exchanger should have been capped, with all connections sealed and airtight, before being moved to the shop for further cleaning and repairs. Purging was unnecessary and risky. However, you've got worse problems.

By U.S. Environmental Protection Agency (EPA) rules, you should have been venting the exchanger to a flare — even a portable flare will do. Some localities require special permits but these can become routine if you fill them out enough. For EPA's recommendation for a vapor recovery system for vessels, see: http://goo.gl/ymrpq4. A heat exchanger is probably too small for this system. In addition, many states require monitoring the concentration of volatile organic compounds.

So, how should you properly blanket a heat exchanger? Keep in mind that the heat exchanger is a vessel. Change the current inerting process to include a sampler inside the exchanger. You don't want to sample too close to the exhaust because the sample there may not be representative. Use an O_2 analyzer; it should be more accurate than a hydrocarbon monitor. Continue purging until the vapor in the exchanger is below 25% of the lower explosive limit. If you're working on an exchanger while it's being purged, monitor the area where the welding is being done.

Continues on p. 41

Resist the Temptation

One option to infer internal flow rate in a column rarely makes sense

Arbitrary offsets indicate a fundamental flaw in the logic of using the HMB approach.

SOME PROCESSES reward close control of liquid and vapor rates inside distillation columns. Conventional control approaches use a variation of flow metering based on either imposing a pressure drop inside the tower or drawing the stream out of the tower, metering it, and returning the stream to the tower (see: "Get Some Inside Information," http://goo.gl/g3DNja and "Ease Measurement of Column Internal Flow," http://goo.gl/Aqq2kJ).

Analysis of system fundamentals might suggest a different approach. Figure 1 illustrates a conventional distillation tower. Any heat and material balance (HMB) envelope must have energy in equal to energy out and mass in equal to mass out. Figure 1 shows the HMB envelopes drawn through the tower. An internal vapor stream and an internal liquid stream both cross the HMB boundaries.

With sufficient data, you can solve the heat and material balances to calculate the internal streams, which, in this case, are the mass of the calculated vapor, M_v, and the mass of the calculated liquid, M_l. You can calculate either stream from analysis of the upper HMB or the lower HMB. The decision to choose between the upper and lower balances depends upon availability of plant data and data accuracy.

The material balance for the upper section is:

$$M_f + M_{cv} = M_{cond} + M_v + M_l + M_{cl} \quad (1)$$

where M is mass flow, f is feed, cv is the calculated vapor stream, $cond$ is condensate, v is vapor product, l is liquid product and cl is the calculated liquid stream.

The energy balance for the upper section is:

$$Q_f + Q_{cv} = Q_{cond} + Q_v + Q_l + Q_{cl} \quad (2)$$

where Q is energy flow, which equals the stream enthalpy, h, times its mass flow rate and allows for substituting $M_i h_i$ for the stream energy flows.

With some algebra, we get an equation for calculating the internal liquid rate, M_{cl}, from the top HMB:

$$M_{cl} = [Q_{cond} + M_{cv}(h_v - h_{cv}) + M_l(h_l - h_{cv}) + M_f(h_{cv} - h_f)]/(h_{cv} - h_l) \quad (3)$$

and an equation for calculating the internal liquid rate from the bottom HMB:

$$M_{cl} = [M_b(h_b - h_{cv}) - Q_{rebl}]/(h_{cl} - h_{cv}) \quad (4)$$

where b is bottoms and $rebl$ is reboiler.

None of these HMB calculations violate any engineering basics. However, while accurate, are they useful?

Most occasions requiring tight control or measurement of internal liquid rates arise from large incentives from either:

- operating at close to minimum reflux; or
- operating at close to minimum or maximum equipment capacity.

Drivers for operation at close to minimum reflux include high energy prices and extremely different values between the overhead and bottoms. When the product value differences are high, the purpose of the distillation column is to remove a trace contaminant but with a minimum slip of the high-value product into the low-value one. This is a process consideration driven by system behavior (relative volatility, compositions, stages available) and economics.

Drivers for operation at close to equipment limits normally are capacity and equipment performance. Flooding sets an upper capacity limit on equipment. For trays, either vapor handling or liquid flow regime on the trays may determine the lower capacity limit. For packed beds, liquid distribution quality at low liquid rates usually establishes the lower limit. This is a hardware consideration driven by the installed equipment (diameter, device type as well as fabrication and installation tolerances).

Let's now consider whether the flow rate equations actually are useful for controlling the stream rates very close to an "optimum" value. Equation 5 summarizes the situation:

Flow rate = (large number - large number)/ (medium number - medium number) (5)

Both subtractions include potential errors in measuring composition, flow rate and temperature.

You must calculate stream enthalpies based on stream compositions, flow rates and temperatures. Calculation of condenser duty and reboiler duty must be based on utility flow rates and temperatures. My experience is that as long as the column products remain on-specification the effect of composition errors is small on the calculation.

In contrast, the effect of flow-rate and temperature measurement errors often is large. Routinely, the possible error exceeds 100% of the calculated value. Often, an arbitrary offset is added to prevent negative flow rates from being calculated. These arbitrary offsets indicate a fundamental flaw in the logic of using the HMB approach.

All control systems that use the difference between two large measured values as a target require high-precision measurement. For example, if the internal liquid rate is 10% of the feed rate and the control objective is to restrict the variation in the

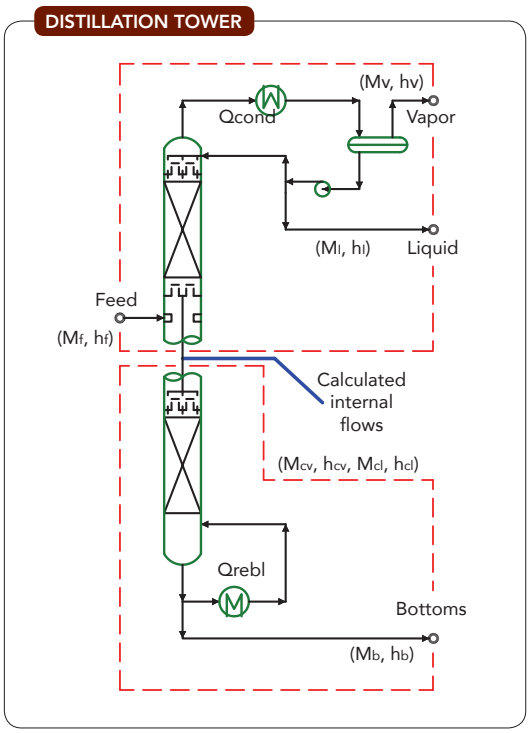


Figure 1. An internal vapor stream and an internal liquid stream both cross the heat and material balance boundaries.

internal liquid rate to 1% of the feed rate, what's the likelihood of success? It's a rare plant flow meter that has a precision higher than 1% of the flow rate. Most standard thermocouples offer roughly 0.75% accuracy. The combined impact of flow-rate and temperature measurement errors makes precise control difficult.

I routinely see controllers with liquid rates targeted at 3.0±0.3% to 5.0±0.5% of the feed rate. The calculations routinely generate negative flow rates. They can't have a relative accuracy of 10%!

The HMB calculation for internal liquid rates obeys the laws of physics. However, the situation that makes knowing the internal rates most important usually is when the rates are very low. This demands extremely precise flow and temperature measurements. Plant instrumentation rarely can meet these requirements. Unless every other choice simply is unacceptable, don't opt for HMB calculation methods to infer internal liquid rates. If you must use them, conduct statistical checks to confirm their suitability and expected value.

ANDREW SLOLEY, Contributing Editor
ASloley@putman.net

PROCESS PUZZLER

Continues from p. 39

The hydrocarbon monitoring should be continuous and recorded.

I have a few more thoughts. How much time elapsed before the welder started cutting? You may want to run a simulation to estimate the "drying" time. Nitrogen will absorb a hydrocarbon. This can take several minutes or many hours depending upon the temperature and process pipe configuration. Because most hydrocarbons are heavier than air, vapors, unless heated, will hug the ground. Avoid welding or cutting near the ground; if you must cut from above, use a fire blanket to isolate the sparks in a canopy.

Some interesting websites germane to this puzzle are: http://goo.gl/wiKB9E and http://goo.gl/Uy55AW.

Dirk Willard, process engineer
A&B Process, Stratford, Wis.

APRIL'S PUZZLER

My company has received an order to build a skid to make a mixed gel, an intermediate for a personal care product. The skid will include an agitated batch reactor where a power is added to produce the viscous gel. This is pumped through a heat exchanger and then blended with a fragrance in a static mixer before going to an agitated storage tank. The skid boundaries were to end with feed to the storage tank but have expanded to include clean-in-place (CIP) and utilities skids; the customer insists this shouldn't affect delivery. We're having trouble defining boundaries between the skids and have received nothing more than some product properties, i.e., viscosity, density and heat capacity at a single temperature. What can we do to ensure this equipment works as desired?

Send us your comments, suggestions or solutions for this question by March 13, 2015. We'll include as many of them as possible in the April 2015 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.

Butterfly Valve Extends Service Life

The Type 578 lug-style butterfly valve offers corrosion resistance with long service life and is available in manual-, electric- and pneumatic-actuated versions. Constructed of a glass-filled polypropylene outer housing with overmolded type-316 stainless-steel lugs, the valve incorporates a double-eccentric design rather than a traditional boot-style design. This enables the disc to completely disengage from the disc seal during operation, reducing friction and component wear to provide longer service life without sacrificing the valve's sealing ability. It also requires only half the operating torque and is not susceptible to elastomer swelling over time, the company says. The truly non-wetted shaft provides maximum protection against leak out and shaft corrosion.

GF Piping Systems
800-854-4090
www.gfpiping.com

Membrane Bioreactor Reduces Energy Use

The Puron MBR ultrafiltration membrane bioreactor series reportedly reduces energy, minimizes downtime, and increases flux in a cost-efficient manner for industrial wastewater treatment applications. Reinforced PVDF (polyvinylidene fluoride) hollow fibers are fixed only at the bottom, eliminating the buildup of fibrous materials that typically clog the upper ends of other modules. Solids and particulates, including bacteria, remain on the outside, while permeate is drawn through the membrane to the inside of the fibers. The system's low energy demands and the robust braided membrane fibers lead to minimal downtime and breakage, says the company.

Koch Membrane Systems, Inc.
888-677- 562
www.kochmembrane.com

Mixer Speeds Up Powder Injection

A high-efficiency charging hopper is now available for the company's line of high-shear mixers with Solids/Liquid Injection Manifold (SLIM) technology. The SLIM is a rotor/stator device engineered for high-speed powder injection into liquid without the need for eductors or pumps. The improved hopper design ensures a steady rate of feed delivery and prevents "rat holes" or bridging of bulk solids. A solenoid-operated multiposition modulating valve maintains a liquid flow rate within 80 to 100% of the 500 gpm design flow rate. Product contact parts are type-316 stainless steel polished to 150-grit (32 Ra) finish. Tri-clamp connections on the liquid inlet, powder inlet and mixture outlet allow for easy disassembly and cleaning.

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

Pressure Transducers Suit Extreme Environments

The 31EP/EA and 32EP/EA Series family of heavy-duty explosion-proof pressure transducers are designed to withstand extreme environmental and pressure conditions. Design of the series incorporates sputtered thin-film pressure sensing technology, all stainless steel wetted parts and an IP67 enclosure. A compact design eases installation within space-constrained hazardous environments. Series transducers are offered as standard with either CSA or ATEX hazardous area approval, along with a selection of pressure ports, electrical outputs, cable lengths and configurations. The designated 32 Series of each group features higher proof pressure specifications. Depending upon selected range, full-scale burst pressure performance can exceed 60,000 psi (4,000 bar).

Gems Sensors & Controls
800-378-1600
www.GemsSensors.com

Level Switch Operates Wirelessly

This float-operated level switch provides a wireless level monitoring system for use on any WirelessHART mesh network. The 1780 level switch uses a float mechanism similar to the one used in the 1710 compact level switch and 2210 side-mounted level switch that moves a magnetic array inside a sealed housing. The movement of the magnetic array is then sensed through the housing by the position monitor via a Hall Effect Sensor. This creates a truly wireless solution with no wires required between the 1780 level switch and the position monitor. The switch also is available with WirelessHART communication only or with an additional pneumatic relay output.

SOR
800-676-6794
www.sorinc.com

Dumper Seals Tightly to Prevent Dust

The Lift & Seal lift and dump drum dumper unit accepts a drum of non-free flowing material and discharges the contents into a hopper at approximately 140 in. above floor level. Unit features a Lift & Seal system for dust-tight operation, Control-Link rotation for 175° dump-carriage rotation, and type-304-stainless-steel product contact surfaces. It also includes a continuously welded tubular steel frame for strength and rigidity, and custom caging with load side light curtain for enhanced operator safety. A gravity roller conveyor base provides easy drum loading and unloading. It is available with discharge heights up to 40 ft and rotation to 180° for any size drum or container.

Material Transfer
800-836-7068
www.materialtransfer.com

Fluid Chiller Minimizes Downtime

A low-temperature fluid chiller, suitable for pilot plants and labs, recirculates heat-transfer fluids at precise temperatures needed to support chemical reaction and recovery applications. The two-stage, cascade refrigeration chiller is capable of reaching -80°C. Designed for 24/7 temperature control, the fluid chiller is equipped with on-board diagnostics that help predict chiller health and avoid unexpected downtime. With a small footprint and choice of water- or air-cooled condenser, the system easily integrates into the production or lab facility. An intuitive touch-screen interface allows for set up of thermal profiles, viewing data and trends and logging diagnostics.

Thermonics Corp.
781-688-2300
www.thermonics-chillers.com

Thermostat Features Failsafe Mode

The Raychem ETS-05 thermostat provides accurate temperature control and monitoring for heat-tracing installations in hazardous areas. An increased terminal size to 6 mm^2 enables power and heat-tracing cables to be connected directly. Available in two versions, the ETS-05-L2-E monitors temperatures up to 199°C and is fitted with a flexible sensor, while the ETS-05-H2-E can be used for temperatures up to 499°C and has a stainless steel sensor. A configurable failsafe mode with LED status indicator shows whether the device itself as well as the heat-tracing cable is switched on or off. It is fully compliant with ATEX and IECEx for use in Zones 1, 2, 21 and 22.

Pentair Technical Solutions
800-545-6258
www.pentairthermal.com

Modular Designs Suits Range of Applications

The Sitrans TS500 product family features new resistance thermometers (RTDs) and thermocouples (T/Cs) designed for universal use in the process industries. The products have a modular design, and come in a large range of sizes and materials, and with a variety of sensors and transmitters. The user can choose a range of process connections, connection heads, sensor types, transmitters and displays to configure individual solutions for a process. The TS500 family supports HART, Profibus and Foundation Fieldbus communication standards, and can be integrated into the operating tools of process control systems, such as Simatic PDM.

Siemens
800-241-4453
www.usa.siemens.com

Temperature Sensor Fits Small Spaces

The AX8 fixed-mount temperature sensor combines thermal and visible cameras along with the company's MSX technology in a small package. Measuring only 54 × 25 × 95 mm, the AX8 is designed to be easy to install in space-constrained areas for automated and uninterrupted condition monitoring of critical electrical and mechanical equipment. The sensor can help detect early temperature-related issues, guarding against unplanned outages, service interruptions, and equipment failure. The thermal imager has 4,800 active temperature points per image, provides streaming temperature data over industry-standard interfaces (EtherNet/IP and Modbus TCP) for easy analysis, has a built-in web interface, and includes analysis and alarm functions that automatically send alerts.

FLIR Systems
866-477-3687
www.flir.com

Steam Trap Monitor Works Wirelessly

The Staps Wireless steam trap monitor is designed to deliver accurate wireless monitoring and reporting of steam trap performance around the plant. The device delivers continuous, accurate monitoring without the need to install cabling. A simple, clamp-on design enables it to fit in areas which previously may have been unsuitable for monitoring equipment, such as remote or awkward locations that prevent installation of long lengths of cabling. The head unit uses 2.4-GHz wireless technology to communicate performance details automatically back to the central receiver, where data can then be interrogated using software installed on the steam user's PC.

Spirax Sarco, Inc.
800-883-4411
www.spiraxsarco.com/us

Camera Captures Fast-Moving Targets

The TiX1000 (with 1,024 × 768 resolution), TiX660 and TiX640 (both 640 × 480) feature up to 10 times the on-camera pixels as are available on standard 320 × 240 cameras. A large 5.6-in. articulating display helps quickly identify issues while still in the field. The cameras deliver highly detailed image quality, advanced focusing options, and the versatility to capture accurate measurements from targets that are challenging, dangerous or moving too fast. The SuperResolution mode feature on the TiX1000 and TiX660 cameras increase image resolution, when viewed in the included SmartView software, four times more than what you get on camera.

Fluke Corp.
800-443-5853
www.fluke.com

Valve Actuator Improves Operations

The EIM Model 500 electric actuator with TEC2 Electronics provides ready information on actuator status and diagnostics that help operations avoid unscheduled maintenance. The Model 500, with its compact size, light weight and advanced electronics, automates small valves used in tight piping configurations and can be utilized with a remote display module for difficult-to-observe applications. With increased stem acceptance, the Model 500 accommodates a variety of valve mounting options. A non-intrusive design that eliminates the need to open control compartments simplifies maintenance and setup. An open network control architecture allows a range of topologies and protocols to integrate into existing or new communication networks.

Emerson Process Management
281-499-1561
www.EmersonProcess.com

Tray Eliminates Clumping

An airslide inlet tray prevents sticky materials from clumping at the entry of vibrating fluid bed dryers and coolers. Installed within the infeed section where material enters the drying system, the airslide inlet tray directs the heated airstream through a series of small openings in the stainless steel plate that face downstream and parallel to the infeed deck. Incoming products begin drying immediately and advance gently and consistently to the primary drying zone while the potential for sticky products to block up the infeed and cause a troublesome cleanup is virtually eliminated. The dryer tray may be easily accessed and removed for cleaning.

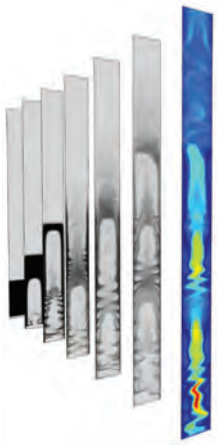
The Witte Company, Inc.
908-689-6500
www.witte.com

Valve Handles Difficult Slurries

Engineered at full-bore with no flow restrictions, the Slurry Knife Wafer (SKW) valve allows abrasive or corrosive fluids to move without compromising process performance, says the company. In addition to its strength and resistance to aggressive slurries, the valve is designed as a full-port fluid-control device that provides a more efficient process, requiring less pumping energy to operate. A cast single-piece body reportedly eliminates any potential leak paths and offers a versatile tower construction that will accept manual- electric-, hydraulic- or pneumatic actuation. When in the open position, the valve's rubber ring sleeves are the only parts in contact with the medium, reducing potential corrosion or deterioration due to wear-and-tear.

Flowrox, Inc.
410-636-2250
www.flowrox.us

Software Features Application Building



Multiphysics software version 5.0 features extensive product updates, add-on products, as well as the new Application Builder. With the Application Builder, Multiphysics is now accessible to everyone through the use of applications. Users can build applications tailored to engineering and manufacturing departments, expanding accessibility to their expertise and to simulation solutions. The Application Builder provides all the tools needed to build and run simulation apps. Version 5.0 also introduces enhancements to the existing functionalities of Multiphysics. New features and updates have been added to the entire product suite, which includes over 25 application-specific modules for simulating any physics including those crucial for the fluid and chemical disciplines.

COMSOL, Inc.
781-273-3322
www.comsol.com

Condition Monitor Boasts Broad Capabilities

Manufacturers can monitor and protect machinery with the Allen-Bradley Dynamix 1444 Series monitors. To protect equipment, the devices measure and monitor a machine's critical dynamic and position parameters, and assure appropriate actions are performed. For general condition monitoring, the monitors offer signal processing and measurement capabilities that help users detect and identify the faults and status across all classes of industrial machinery. Information also can be sent to plantwide and enterprisewide databases for storage and trending. The monitors are rated for -25° to 70°C and 18- to 32-V power, designed for use in hazardous environments, and rated to marine standards for shock and vibration.

Rockwell Automation
414-382-2000
www.rockwellautomation.com

Level Transmitter Offers Two Display Options

The SmartLine Guided Wave Radar level transmitter can measure the level and volume of liquids inside processing tanks up to 160 ft in height. The manufacturer's Application Validation online tool enables users to input technical data about their specific process tank to validate the correct level transmitter application is delivered ready to install out of the box. The transmitter features a choice of a basic alphanumeric display or an advanced graphics display. The advanced graphics display, capable of showing process data in graphical formats and communicating messages from the control room, also offers multiple languages and full integration with the Experion process control system.

Honeywell Process Solutions
800-822-7673
www.honeywellprocess.com

Transmitter Features Small Footprint

The M100 2-wire transmitter offers analytical measurement based on a compact head mount design, and without a local interface. It includes global approvals for hazardous area use, and combines multiparameter measurement with remote access to predictive sensor diagnostic tools over the HART communication protocol. The transmitter covers pH/ORP, dissolved oxygen and conductivity measurements. The company's digital ISM technology enables the sensors to be calibrated away from the process in a convenient location such as a workshop, and quickly swapped in the field. This feature, called Plug and Measure, means measurement point start up is fast and error-free, and can be accomplished without significant know-how, the company says.

Mettler-Toledo
800-352-8763
www.mt.com

Actuator Resists Corrosion

The ECP Series Thermoplastic Quarter Turn Electric Actuators feature an IP-67-rated glass-filled polypropylene housing that provides corrosion resistance and performance in environments and atmospheres considered not ideal for most metal actuators. They are available in several sizes for use with Hayward ball and butterfly valves up to 6 in./DN150 and in torque ranges from 221 in/lbs (25Nm) to 796 in/lbs (90Nm). All ECP actuators feature a manual override, LED status light and Namur-style mounting for solenoids and an ISO5211 mounting base. The product line is available in 115/230V and 12/24V.

Hayward Flow Control
888-429-4635
www.haywardflowcontrol.com

Flow Detector Helps Prevent Contamination

The Flow Detect 2000 is a non-intrusive instrument for detecting flow/no-flow conditions of solids and powders in material handling applications. It prevents downtime caused by blockage, conveyors running empty, no material flow to-and-from a process, or loose slide gates that can cause production loss and equipment failure. The microwave-based device contains the sensing element, power and output connections, and user-adjustment controls in a single NEMA 4X enclosure. The sensor is easy to install through a 1¼-in. NPT opening. The device can be used to prevent cross contamination of ingredients by ensuring flow has stopped before a new material is introduced into the stream.

Bimaster
800-278-4241
www.binmaster.com

Pumps Suit Low-Flows

A range of low-maintenance dosing pumps target high-pressure applications where low-flow, accurate dosing is required. The dosing pumps provide smooth pumping action with no pulsation and very low shear, says the company. With no valve components (reducing the number of wearing parts), blockages are eliminated and the working pump life is extended. Maintenance, when required, can be completed without the need for any specialist skills, thereby maximizing uptime. A modular design allows the four models to cover performance requirements from 0.53 gph (2 L/h) and 1,044 psi (72 bar), up to 330 gph (1,250 L/h) and 174 psi (12 bar).

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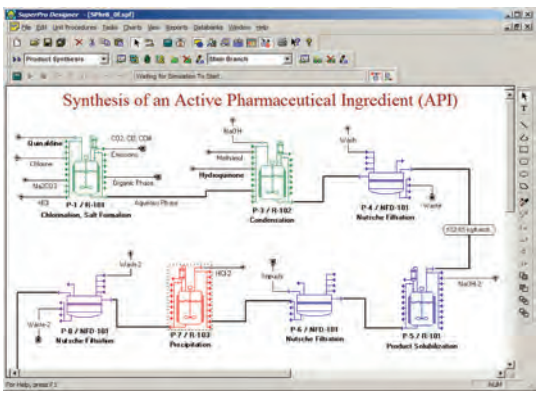

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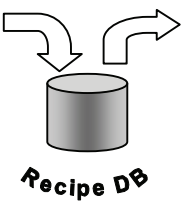

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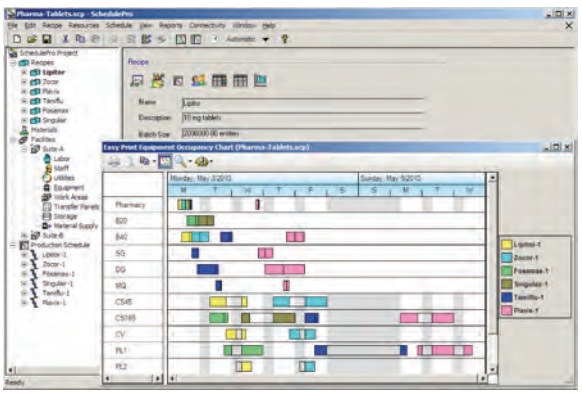

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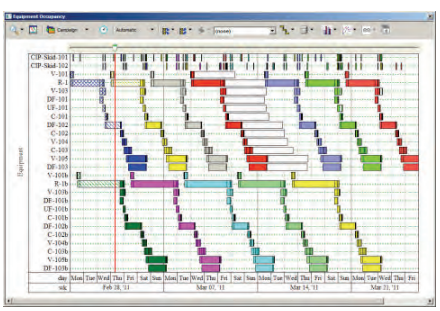

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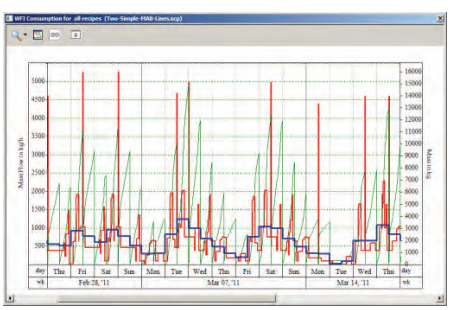
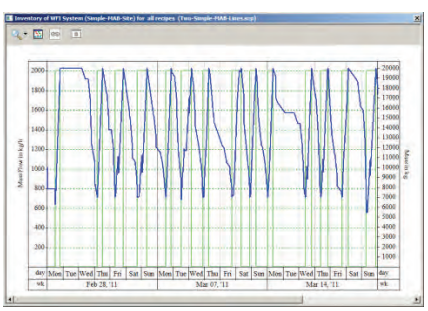


Tracking demand for resources (e.g., labor, materials, utilities, etc.)



Managing inventories for input, intermediate, and output materials

SuperPro Designer is a comprehensive process simulator that facilitates modeling, cost analysis, debottlenecking, cycle time reduction, and environmental impact assessment of integrated biochemical, bio-fuel, fine chemical, pharmaceutical (bulk & fine), food, consumer product, mineral processing, water purification, wastewater treatment, and related processes. Its development was initiated at the Massachusetts Institute of Technology (MIT). SuperPro is already in use at more than 500 companies and 900 universities around the globe (including 18 of the top 20 pharmaceutical companies and 9 of the top 10 biopharmaceutical companies).

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

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ADVERTISER INDEX

Swedish Firm Invests in Bioplastics

A new pilot plant and laboratory will ensure continued expansion in sustainable products

The world bioplastics market could experience 20% growth per year for the foreseeable future.

SWEDISH COMPANY Perstorp, Malmo, has announced continuing investment in its ε-polycaprolactones (PCL) technology, which it markets under the Capa brand. The company says this is to cope with its forecast of 20% growth per year for the foreseeable future in the world bioplastics market.

Among the investments are a new pilot plant in Warrington, U.K. — which is already up and running — and from January increased technical resources and a new laboratory in Malmo. The pilot plant will help to produce new Capa grades for existing customers and support the continued expansion of the Capa thermoplastics product line, while the new lab will become a caprolactone innovation center for application development. This will ensure new formulations are developed and tested to meet the challenges of emerging applications where, says the company, Capa can play a decisive role in enhancing competiveness.

"We are increasing our competitiveness in bioplastics through these investments, which is a core focus area for the Perstorp Group. We intend to take a leading position in the development of new bioplastic products, since Capa thermoplastics add significant value to biopolymer performance and end-of-life solutions," notes Linda Zellner, Perstorp bioplastics manager.

The company is particularly focused on three key bioplastic growth segments — paper coatings, bags, and films and packaging. The current investments are designed to support rapid development of all three, but also to ensure the infrastructure is in place to meet the challenges of new emerging applications.

Perstorp says Capa, in particular, opens up new opportunities for bioplastics such as PLA (polylactic acid), PHA (polyhydroxylalkanoate) and starch by improving their functional properties, especially toughness and flexibility, enabling them to be competitive in film and packaging applications. Its superior compostability also improves the products useful end-of-life, making bioplastic packaging, bags and film environmentally attractive, adds the company. The latest investments are aimed at broadening the sustainable options available to producers and consumers.

"Biopolymer formulators and producers will get a fast response to their specific Capa needs and then have access to a broader range of innovative sustainable options as the bioplastics application portfolio develops," says Zellner.

In addition, speaking in December at the 9th European Bioplastics Conference in Brussels, Zellner outlined the results of a study Perstorp has been involved in to develop a novel biodegradable, compostable waste bag.

Currently, Sweden has three alternatives to organic waste handling systems: paper bags, plastic bags and biobags. All have their flaws. Paper bags, for example, annoy users because they are prone to wetting and breakage. Plastic bags, mostly polyethylene, risk contaminating the anaerobic digestion processes widely used in Sweden. Finally, existing biobags, which are made of starch-based materials, often don't degrade rapidly enough for the same anaerobic digestion processes.

So, Perstorp aimed to develop and evaluate a new bioplastic compostable bag that fulfils the following criteria: user-friendly; no risk of degradation during use; biodegradable in anaerobic digestion chambers; compliant with the SPCR 120 Swedish waste management quality assurance program; handleable by existing pretreatment systems; and environmental performance throughout the lifecycle that corresponds to that of alternative products such as a paper bag and a plastic bag.

The first phase of the three-part study centered on formulating and field testing different types of biobags versus paper bag and plastic bag references. The second step involved anaerobic digestion evaluation of the chosen solution. The last stage, life cycle assessment, found the biobag has a comparable environmental impact to the paper bag and a lower impact than the plastic bag. Users preferred the new biobag, although it did not fulfill all of the set criteria from a project point of view. Problems here included blocking of the pre-treatment step and low levels of biogas generation during anaerobic digestion.

Zellner told the conference that such studies need realistic criteria if they are to support the development of new materials and solutions. Also, it's necessary to consider biogas potential and ease of anaerobic digestion as well as other benefits, including increased collection of organic waste, user friendliness, improved handling in the waste collection system, and better efficiency in raw material use.

"The advantage with this type of study is that general awareness is increased around existing solutions and systems and the need to adapt and improve them further in order to open up the market for new environmentally sound materials," she concludes.

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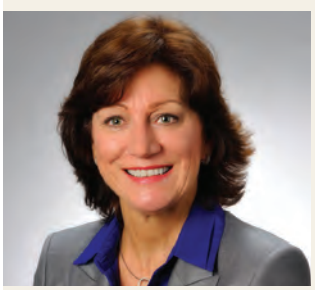

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