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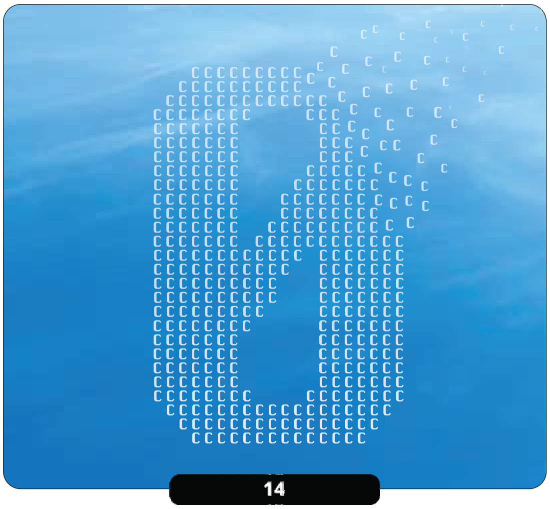

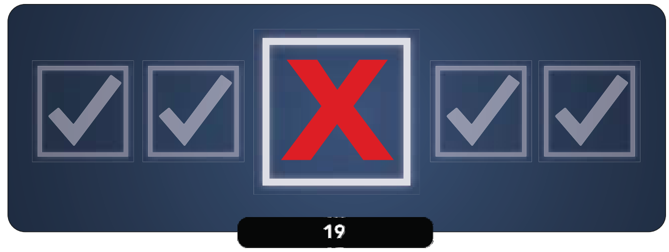

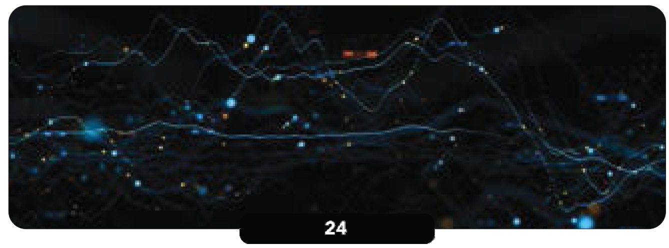

COVER STORY

FEATURES

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DEPARTMENTS

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) 467-1120. Periodicals postage paid at Schaumburg, IL, and additional mailing offices. Postmaster: Please send change of address to Putman Media, PO Box 1888, Cedar Rapids IA 52406-1888; 1-800-553-8878 ext. 5020. SUBSCRIPTIONS: Qualified reader subscriptions are accepted from operating management in the chemical processing industries at no charge. To apply for a free subscription, email putman@stamats.com. 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. REPRINTS: Reprints are available on a custom basis. For price quotation, contact Foster Reprints, (866) 879-9144, www.fostereprints.com. Putman Media Inc. also publishes Control, Control Design, Food Processing, The Journal, Pharma Manufacturing™, Plant Services and Smart Industry. Chemical Processing assumes no responsibility for validity of claims in items reported.

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Remember the West Explosion

Issues revealed by the Texas incident demand ongoing vigilance

No in-place emergency plan alerted people of the need to evacuate.

ON APRIL 17, 2013, the West Fertilizer Co. blending and distribution facility in West, Texas, exploded, killing 12 emergency responders and three other people living close to the site, and causing more than 260 injuries. The U.S. Chemical Safety and Hazard Investigation Board, Washington, D.C., issued its Final Investigation Report in January 2016. That 264-p. report, downloadable at https://bit.ly/3t438zL, remains relevant today. Indeed, the issues identified and the lessons learned from that disaster certainly deserve review at many other plants, and should be shared with those who have entered our industry since then.

The site had a stockpile of between 40 and 60 tons of fertilizer-grade ammonium nitrate (FGAN) as well as an additional volume not yet unloaded from a railcar. Around 7:30 pm, the first signs of a fire were reported to local responders. An explosion occurred only about 20 minutes later. The blast completely destroyed the facility and damaged more than 150 buildings off-site, with about half of them needing complete demolition before reconstruction.

Important conclusions of the report include:

• Combustible materials like wood used for construction offered potential fuel for a fire while provision of limited fire safety features exacerbated risk. The FGAN was stored in bins made of plywood and the facility lacked an automated sprinkler system.

• A previous insurer had dropped coverage because West had not addressed safety concerns identified in loss control surveys. Yet, the insurer at the time of the explosion apparently had not performed its own safety inspections of the facility.

• The local volunteer fire department did not conduct pre-incident planning or response training at the West Fertilizer site, and likely was unaware of the potential for FGAN detonation. Moreover, the responders failed to set up an incident command system, lacked an established incident-management system, did not check safety data sheets, and had not had appropriate training in hazardous materials response. No in-place emergency plan alerted first responders and people in the surrounding community of the need to evacuate at the first sign of a fire in the FGAN facility.

• The location of the facility worsened the off-site consequences of an explosion. The unit was constructed in 1962, and apartments, a nursing home, a school, etc., were built nearby afterward. No local zoning regulations prevented this. (The report notes the West Fertilizer situation is far from unique — many communities nationwide are located too close to hazardous sites.)

• Adoption of inherently safer technology could have significantly reduced risk. (For some pointers on this approach, see: "Use Elegant Design to Bolster Inherent Safety," https://bit.ly/3w0ABNs.)

• Shortcomings in federal regulations existing then led to an underappreciation of hazards, inadequate plant practices and other lapses in addressing actual risks.

The report is somber reading. Unfortunately, many of the points it illuminates still afflict plants today. Some of these issues certainly don't lend themselves to fast, easy or, sometimes even, practical solutions. However, addressing others, such as gaps in emergency plans and dialogue with first responders, may not be as daunting to fix. Indeed, I suggest making a review of emergency plans and first responder preparedness a priority. ●

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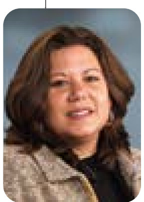
Take Our 2022 Salary Survey

Chemical Processing welcomes your inputs for its annual report on salary and job satisfaction



Has the Great Resignation impacted the chemical industry?

IT'S BEEN a rollercoaster ride for the last two years in terms of job satisfaction and employment. Dubbed the Great Resignation, the number of U.S. workers who quit their jobs reached a new high in November 2021: 4.5 million — up from 4.2 million in October, according to the Society of Human Resource Management. The reason for the exodus is varied but suffice it to say that lower-paying industries are feeling the brunt of the vacancies as workers search for more pay and better working conditions.

So, has the Great Resignation impacted the chemical industry? Our annual salary and job satisfaction survey may provide insights. In its 17th year, we've collected data on everything from salaries and bonuses to job security and hours spent at work. We've also captured candid responses detailing the ups and downs of being in the chemical industry.

In 2005, the inaugural year of the survey, the average annual salary was $85,000 and one respondent advised, "be creative — it ain't the old days. Look to innovate using new trends that provide a very measurable value in the bottom line. Nobody can argue with hard, quantitative dollar results that are a result of creativity and hard work." (See, "2005 Chemical Industry Salary Survey: Field of Greens," https://bit.ly/CPSalary2005.)

In 2021, the average annual salary was $106,000 and respondents were a little more critical of their employers. One person complained: "There was a dramatic reduction in salary and benefits instituted in 2020 blamed on the pandemic. It's a challenge to experience that when there is much inefficient spending, inexperienced people managing projects inefficiently, and lack of experience in the management organization." ("Survey Shows How Job Satisfaction Stacks Up," https://bit.ly/3vNLFxg.)

Over the years we've witnessed fairly stable compensation trends and have always appreciated the candor our respondents exhibit with our open-ended questions about industry perceptions and career advice for greenhorns. We hope you take the time to share your own experiences in the field. The survey is completely anonymous and your input is a valuable resource for *Chemical Processing* readers.

TRACI PURDUM, Executive Digital Editor
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FOLLOW THE QR CODE

Ready to take the survey — scan the code and begin.
https://bit.ly/CPSalary2022

VIE FOR A BONUS

Your time is valuable; so, as a token of our appreciation for completing the survey, you can enter a drawing for a chance to win one of ten $50 Amazon gift cards by including your contact information upon completing the survey. (Your privacy is important to us and we only will use this information to contact the winners.)

EXAMINE DECADE OF DATA

Curious what the last 10 years looked like in terms of compensation and satisfaction?

2021: Job Satisfaction Stacks Up – https://bit.ly/3vNLFxg

2020: Salary and Satisfaction Survive the Pandemic – https://bit.ly/39iASOq

2019: Survey Picks Up Good Vibrations – https://bit.ly/3f8HTD3

2018: Hiring And Salaries Steam Ahead – http://bit.ly/2S6sEQD

2017: It's Not All Roses – http://bit.ly/2mnxZEo

2016: Chemical Engineers Keep On Smiling – http://goo.gl/NOaC4R

2015: Salary And Satisfaction Trends Revealed In The Chemical Processing Industry – http://goo.gl/YtU0xd

2014: Salary Survey Yields A Mixed Bag – http://goo.gl/IroA1C

2013: Salaries Aren't Leveling Off – http://goo.gl/NckQ5c

2012: Salaries Move Ahead — Slowly – http://goo.gl/x00kEt

Master Cold Calls

Honing phone skills with vendors is important

A cold call is meant to inspire contractors to help you.

I REMEMBER my first cold call. I phoned a pump vendor as part of collecting at least three bids per corporate standards. (Now, I know I really must contact five or six because some won't be interested or can't supply the equipment or services I need.) I had calculations and physical properties but was woefully unprepared to answer the questions posed by the inside salesman. I felt embarrassed, as I should have.

Dealing with vendors, constructors, service engineers, and design firm salespeople is something you need to master. As Deck Shifflet (Danny Devito) said about ambulance chasing in the movie The Rainmaker: "Well, you better learn quick or you're going to starve."

A cold call is meant to inspire contractors to help you. So, prepare beforehand. Here's what you'll need: 1) a scope of work (SOW); 2) authorization to implement a project; and 3) a list of qualified companies that can do the work.

An SOW should be simple unless your project is more than $5 million — then you really should hire an engineering firm to write it. If you can't summarize what you're doing in less than 30 pages, you've bitten off more than you can chew; find an engineering firm.

Look over your SOW. Is it understandable to your audience? Does it cover everything a vendor needs without giving away trade secrets or making your company look foolish? Is everything thought out? Have you considered all the intangibles, temporary equipment storage, etc. Don't be afraid to be a little vague if you don't know something that a vendor can figure out easily once on site. After all, you hire a firm because it knows what's needed to do the job. Don't give away the store if you want to test its competence. And most of all, do you have a hook — a lucrative potential contract? Read through the SOW several times.

That brings me to my second part, authorization. You should have your supervisor's permission to pursue the project. Write an engineering report; this will segue into an SOW. Review it with your boss. If the person you report to decides you don't have time for the work, file the SOW, don't throw it away. Things have a way of circling back in our business. (However, keep in mind that a postponed project often requires significant updating, as I noted in June 2021's column, "Keep Cool When Thawing Projects," https://bit.ly/3i7axYI.)

I'm sure you're wondering how to find qualified companies. Websites can help. Check the "Thomas Directory" at www.thomasnet.com. Google and several other sites also are useful. The hard part is reading through the qualifications of a company to determine whether it meets the needs of your project. Also find out which firms are recommended inside your company for such projects.

Once you've identified candidates, create a list on a sheet of paper or spreadsheet: company name, contact, qualification, comment. Comb through websites. Google those firms on your list. Is the company a good match?

With this backgrounding, you're set to make cold calls that are productive for both you and the vendors contacted.

CHECK OUT PAST FIELD NOTES

More than a decade's worth of real-world tips are available online at www.ChemicalProcessing.com/field-notes

Realize, though, that the path to successful recruitment of a contractor generally isn't a straight line. First, you may have to resubmit the SOW more than once to match the capabilities of the contractor you want to hire or you may have to break it up into subcontracts. A detailed SOW may not be possible, so the type of contract may change. Second, you may have to weave through layers of corporate mandarins to finally get to the person who can submit a bid; don't lose these contacts. Third, in some cases, you may have to badger the person to get a bid out. Fourth, your timeline might not match that firm's timeline. By the way, if the company can't handle or isn't interested in your project, ask the contact to suggest other firms worth approaching.

The second time I called a vendor I was much more polished. I had written an introduction and a segue into the SOW. My script even included: "Do you have any questions (Name)?" I also had developed a "Questions and Answers" sheet; this turned out to be very helpful. I did a dress rehearsal a few times. My preparation paid off. The vendor was enthusiastic; we met the next day.

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Greener Biofuel Production Beckons

Novel electrocatalyst-based system operates at mild conditions and produces hydrogen

A RESEARCH team at the U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL), Richland, Wash., has developed a patent-pending system that uses a flow cell bioreactor to turn carbon previously considered unrecoverable from so-called biocrude (aqueous waste streams) into valuable chemicals at room temperature and pressure, while simultaneously generating useful hydrogen.

"The currently used methods of treating biocrude require high-pressure hydrogen, which is usually generated from natural gas," says Juan A. Lopez-Ruiz, a PNNL chemical engineer and project lead. "Our system can generate that hydrogen itself while simultaneously treating the wastewater at near atmospheric conditions using excess renewable electricity, making it inexpensive to operate and potentially carbon neutral."

Waste first moves through a hydrothermal liquefaction (HTL) process. It then undergoes an electrocatalytic conversion in PNNL's flow cell bioreactor, dubbed Clean Sustainable Electrochemical Treatment (CleanSET); there, a catalyst composed of minute metal particles converts the biocrude into oils and paraffin. The treatment simultaneously removes carbon from wastewater, allowing the clean water to be fed back into the HTL process.

"…Traditionally, wastewater treatment requires a way to remove ammonia via high temperature oxidation (if present), then a second step involves anaerobic digestion to convert the organic compounds into methane (and CO_2). Once those steps are complete, a steam reformer converts methane into hydrogen. The CleanSET system does all of those steps in one unit, as it oxidizes ammonia and organic compounds at the anode while simultaneously generating hydrogen at the cathode."

PURIFIED WATER

Figure 1. Juan Lopez-Ruiz poses next to a vial of wastewater purified by a new electrocatalytic bioreactor that also generates hydrogen to help fuel the process. *Source: Andrea Starr, PNNL.*

The researchers shared in *The Journal of Applied Catalysis B: Environmental* how they tested the system for almost 200 hours of continuous operation without losing any efficiency in the process. The trial only stopped because the wastewater sample was exhausted.

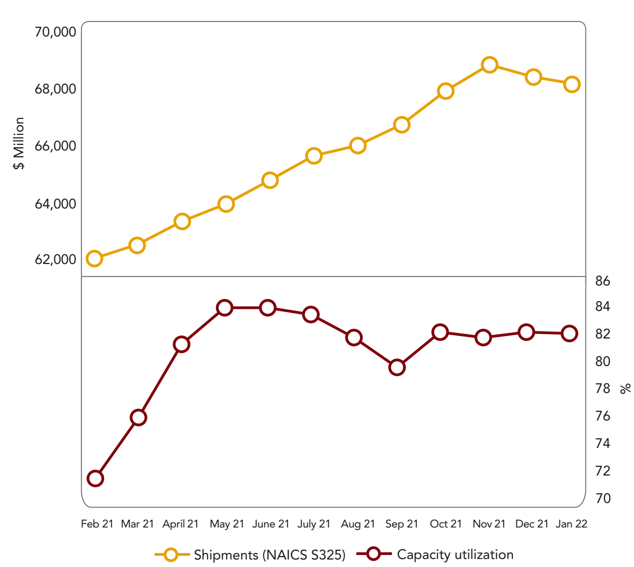
"The reaction rate of the process is proportional to how much waste carbon you are trying to convert. It could run indefinitely if you had wastewater to keep cycling through it," notes Lopez-Ruiz.

"We have already tested the performance of our technology with real biomass-derived wastewater and bio-crude containing sulfur and nitrogen containing compounds (e.g., pyrroles). We didn't see any deactivation for the duration of the experiment, 50 to 160 h. That being said, the system needs to be farther evaluated for thousands of hours to make sure there is not long-term poisoning," explains Lopez-Ruiz.

In addition, evaluation of the electrodes post experiment showed no changes in their micro- and nanostructure. However, Lopez-Ruiz admits further testing under more aggressive conditions and for longer durations will better assess their structural robustness and address potential points of failure.

The team used the same standard catalyst preparation techniques the catalysis and fuel cell industries already use, so, making the electrodes on a large scale wouldn't pose a challenge.

ECONOMIC SNAPSHOT



Both shipments and capacity utilization slipped. *Source: American Chemistry Council.*

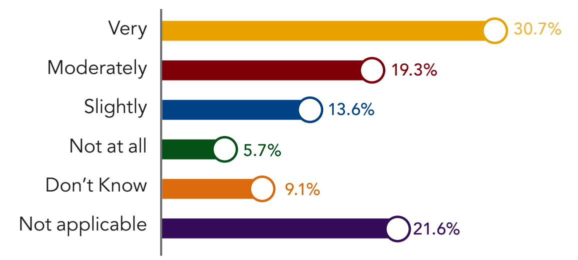
HTL technology is already demonstrated at pre-pilot scale; PNNL has process development units (PDU) available for demonstration of biofuel production.

"The CleanSET technology needs to be scaled-up now to match the processing scales of the PDUs, so we can demonstrate the whole process in series at pre-pilot scale… At this point in the development process, we are seeking a commercial partner or partners to scale up the process to industrial pilot-scale," adds Lopez-Ruiz.

"The next steps are demonstration with different feed-stocks, as that will determine the conditions and electrode compositions we need to use in the electrochemical systems. Once we evaluate that at the laboratory scale, we can move forward with the process scale-up," he concludes.

TO PARTICIPATE IN THIS MONTH'S POLL, GO TO CHEMICALPROCESSING.COM.

How effective do you consider shift handovers at your site?



Far more respondents consider shift handovers somewhat effective or better than slightly or not effective.

Catalyst Eases C-H Bond Functionalization

RESEARCHERS IN Japan have created a high-performance heterogeneous catalyst for the oxidative functionalization of C-H bonds in alkylarene compounds, an essential step in the production of solvents, polymers, surfactants, agrochemicals and pharmaceuticals. The catalyst, made of isolated manganese (Mn) species fixed in a crystalline matrix, requires only mild reaction conditions — 40°C and atmospheric pressure. The work already has drawn the attention of several Japanese chemical companies.

"They are interested in the concepts of a simple catalyst synthesis method and the versatility of combined elements, and we have just started joint research on applying the method to important reactions," confirms research leader Keigo Kamata, an associate professor at the Tokyo Institute of Technology, Tokyo, Japan.

HETEROGENEOUS CATALYST

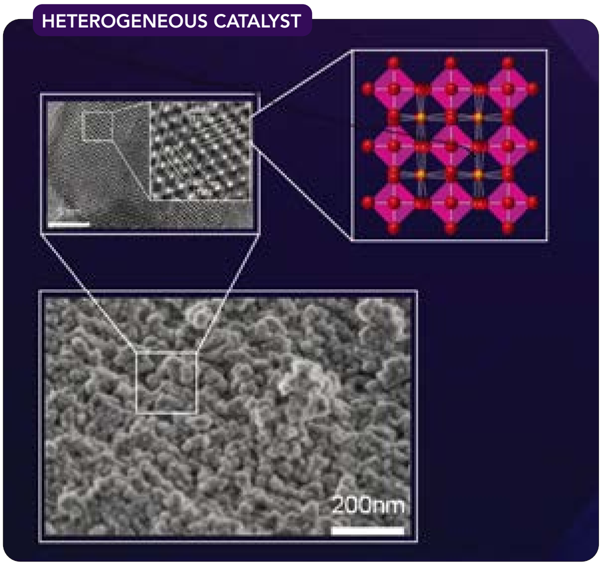


Figure 2. Isolated Mn^{4+} species located in a basic MgO matrix were found to play an important role in C-H bond functionalization. *Source: Tokyo Tech.*

Kamata and his team built on their earlier studies into the catalytic properties of Mg_6MnO_8, a rock-salt structure of magnesium oxide (MgO). However, this time, they used a cost-effective sol-gel process aided by malic acid to create Mg_6MnO_8 with a specific surface area of 104 m^2/g. "That's about seven times higher than Mg_6MnO_8 synthesized using previously reported methods," explains Kamata.

The new catalyst boasts a higher yield than existing Mn-based catalysts and the added benefits of easy recovery by filtration and no loss of activity even after multiple cycles.

To understand why, the team investigated the correlation between the reactivity and acidity of the substrates and the kinetic isotope effects used to determine reaction mechanisms.

These studies, in combination with ^{18}O-labeling experiments, showed that hydrogen abstraction from the hydrocarbon proceeds via a mechanism involving O_2 activation. The structure of Mg_6MnO_8consisting of isolated Mn^{4+} species located in a basic MgO matrix (Figure 2) was found to play an important role in this oxidation process.

Kamata believes this approach is a promising strategy for developing highly efficient heterogeneous oxidation systems with wide substrate scopes and, so, could pave the way to more efficient and environmentally friendly catalysts for organic chemistry applications.

Because the nanomaterials used can be easily synthesized by the simple calcination of precursors, he reckons scaling-up catalyst synthesis is possible.

"On the other hand, however, it is a problem that catalyst pretreatment is required when applying it to the liquid-phase oxidation reaction; thus, the catalytic application to gas-phase reactions at high temperature would be more suitable," Kamata concludes.

Could Chemical Plants Go Nuclear?

Nuclear power has long been recognized as a potential source of low carbon energy

No small modular reactors have been deployed yet in the United States.

I WAS born in the era of Atoms for Peace — President Eisenhower's Cold War strategy to shift the focus from the horror of Hiroshima and Nagasaki to the hope of peaceful, productive and profitable uses for nuclear power. That strategy made some headway. From small beginnings in the 1960s, nuclear power generation expanded rapidly around the world through the 1970s, 80s and 90s. However, safety concerns — punctuated by the Chernobyl disaster of 1986 — together with rapid cost escalation, put a damper on growth. Despite these setbacks, nuclear power today represents 10% of electric generation globally; in some countries — such as France (70%) and Sweden (40%) — the percentage is much higher. (Data from Our World in Data, https://bit.ly/3vT4ZsZ, accessed 01/22/2022.)

Recent events in Eastern Europe have reawakened the specter of nuclear holocaust. However, we are in a new era, where climate change and the pressing need for decarbonization are front and center. Nuclear power has long been recognized as a massive opportunity for low carbon energy, and that includes applications within the process industries. The critical question is, has the technology matured to the point where we can capture this potential both safely and economically? In my view, the answer is — maybe. There have been big improvements; the most promising is the development of small modular reactors (SMRs).

Full-scale conventional nuclear power plants are typically of gigawatt capacity. For example, each of the two South Texas units in Matagorda is rated at 1,280 MW(e). In contrast, SMR designs range from 10–300 MW(e), with a subclass of microreactors less than 10 MW(e). The sizes mean these units can be deployed for relatively small off-grid applications in remote regions, and they also make SMRs accessible for a host of commercial and industrial applications. These new designs incorporate a range of safety improvements, such as high-pressure containment vessels and passive reactor cooling, which dramatically reduce the risk of releasing fission products and radiation. The modules can be substantially manufactured in a factory and installed at the site rather than constructed on-site — a huge cost saving. Also — important for applications in the process industries — most designs include the option of exporting steam, which can be used for process heating and other applications.

One application of nuclear energy that has attracted a lot of attention recently is the production of so-called "pink hydrogen" — hydrogen generated through electrolysis of water by using electricity from a nuclear power plant. However, SMRs open up a much larger range of decarbonization opportunities. A study in 2014 examined ways to provide both heat and power to an oil refinery from light-water SMRs (D.T. Ingersoll, C. Colbert, R. Bromm and Z. Houghton, "NuScale Energy Supply for Oil Recovery and Refining Applications," paper 14337, *Proceedings*, ICAPP 2014, Charlotte, N.C., April 6–9, 2014,). The same study identified a wide range of chemical and petrochemical processes, producing products as diverse as ethylbenzene, terephthalic acid, urea, soda ash, and nylon 6.6 that would be amenable to a similar heat and power system.

No SMRs have been deployed yet in the United States. However, that is about to change. The first U.S. commercial deployment contract was signed in December 2020. The Utah Associated Municipal Power Systems (UAMPS) awarded design and licensing scope to Fluor for the Carbon Free Power Project (CFPP) to build a NuScale VOYGR-6 on the Idaho National Laboratory site. This 6-reactor, 462-MWe (gross) power plant will be approved by the Nuclear Regulatory Commission for construction and operation by 2026, with initial operations in 2029; it should be 100% operational in 2030. Fluor and NuScale have agreed to deliver this plant at or below a levelized cost of electricity of $58/MWh. The U.S. Department of Energy has committed a grant of $1.36 billion to UAMPS for the site-specific design and construction of the CFPP to de-risk this first-of-a kind-reactor deployment. The project economics are aided by advanced nuclear production tax credits (PTCs) that will allow new SMR projects to receive PTCs for the first eight years of operations. Frank Dishongh, president, Fluor Nuclear Project Services, has great confidence in the NuScale technology. He describes it as "a safe, affordable, resilient, carbon-free power source for industries and utilities."

Perhaps your plant could host the first deployment in the process industries. ●

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EPA Commits to Compliance Extension

Manufacturers of articles containing PIP (3:1) now must comply by October 31, 2024

The uproar was so loud the agency issued a rare "no action assurance."

MUCH TO the relief of industrial stakeholders, the U.S. Environmental Protection Agency (EPA) on March 8, 2022, extended the prohibition compliance date for production and distribution in commerce of certain phenol, isopropylated phosphate (3:1) (PIP (3:1))-containing articles, and the PIP (3:1) used to make the articles. The new compliance date is October 31, 2024, along with the compliance date for the associated recordkeeping requirements for manufacturers, processors, and distributors of PIP (3:1)-containing articles. This article explains the rule's implications.

In January 2021, the EPA issued a final rule for PIP (3:1) that prohibits production and distribution of PIP (3:1), PIP (3:1)-containing products, and PIP (3:1)-containing articles, with specified exclusions; forbids or restricts the release of PIP (3:1) to water during manufacturing, processing, distribution in commerce, and commercial use; and requires persons manufacturing, processing, and distributing in commerce PIP (3:1) and products containing PIP (3:1) to notify their customers of these prohibitions and restrictions and to keep records. The final rule established a compliance date of March 8, 2021, after which processing and distribution in commerce of PIP (3:1), PIP (3:1)-containing products, and PIP (3:1)-containing articles were prohibited unless an alternative compliance date or exclusion was provided, which the EPA eventually did. In September 2021, the EPA extended the compliance date from March 8, 2021, to March 8, 2022, along with the compliance date for the recordkeeping requirements. The final rule moves the phased-in prohibition, established in the September 2021 final rule, for the processing and distribution in commerce of PIP (3:1) for use in certain articles, for the processing and distribution in commerce of certain PIP (3:1)-containing articles, and the recordkeeping requirements from March 8, 2022, to October 31, 2024.

The EPA extended the compliance dates to address "the hardships inadvertently created by the January 2021 final rule … due to impacted uses and supply chain challenges that were not communicated to EPA until after the rule was published." As readers may know, shortly after the EPA published the final rule, many stakeholders raised significant concerns about their ability to meet the March 8, 2021, compliance date. Indeed, the uproar was so loud the agency issued a rare "no action assurance" to calm an exceedingly agitated industry. In March 2021, the EPA also requested additional comment on TSCA Section 6(h) final rules for persistent, bioaccumulative, and toxic (PBT) chemicals, which include PIP (3:1). Many makers of consumer and commercial goods were affected by the PIP (3:1) prohibitions, particularly manufacturers of electric and electronic articles.

The EPA evaluated the potential incremental economic impacts of further extending the compliance deadline and determined that extending the date to October 31, 2024, "would reduce the existing burden" of the March 8, 2022, compliance date. By moving the date, the EPA concluded it would result in an estimated annualized cost savings of $1.8 million (from $24.1 to $22.3 million). Reformulation (which can include research and development, laboratory testing, and relabeling) will also be facilitated once an acceptable substitute is identified, given that companies will have more time to gather information regarding the steps involved in the reformulation process. The EPA acknowledges that cost reductions for reformulation are not certain, however, as the time required for the regulated community to identify viable substitutes can be "complex and unpredictable."

In its March 8, 2022 final rule, the EPA states it intends to issue a proposal for a new separate rulemaking on PIP (3:1) and other PBT chemicals in spring 2023. The agency is considering revising the final PBT rules to reduce further worker exposures, promote environmental justice, and better protect human health and the environment. It will then consider any additional information on whether it is feasible for industry to meet the October 2024 compliance date for PIP (3:1).

The extension provides great comfort to manufacturers, importers, wholesalers and retailers of products that contain PIP (3:1). Industry continues to struggle to document that PIP (3:1) is entirely absent in finished goods and replacement parts. As a result, there was a real risk the majority of commercial manufacture, import, and distribution of anything with a wire would have to cease until the very complex global supply chain could provide certified PIP (3:1)-free parts. For stakeholders it will be critically important to comment when the EPA reopens all of the PBT rules in 2023. ●

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Turn Firefighters into Forest Rangers

How digital transformation is people transformation

TIM SYKES
Heavy Industry Machine Health Lead, Augury

Manufacturers are missing their production targets because machines are failing.

WHEN IT comes to machine maintenance, digital tools promise a lot — from improving safety, meeting production targets and eliminating unplanned downtime to filling skill gaps and regulating supply-chain issues. But simply alerting users to machine malfunctions isn't enough to transform your business. To gain insight, Chemical Processing spoke with Tim Sykes, heavy industry machine health lead at Augury, a machine health solutions provider that combines advanced sensors with AI capabilities and human expertise.

Q: Augury sponsored a special report on digitalization with the American Institute of Chemical Engineers. What did you learn in the report and was anything surprising?

A: I don't know that anything was surprising but it was a validation of a lot of the conversations we've had with manufacturers in the chemical and oil refining space over the last several years. We learned that over half of the respondents missed their monthly production targets at least once a year. Half of them say unexpected equipment failures are the biggest risk to missing those targets. And our team has been really focused on helping customers in the manufacturing space to avoid those unexpected failures. Over half — 59 percent — of respondents said that unplanned asset downtime was typically caused by mechanical problems. They want to understand how to get in front of this.

Q: What are the consequences of reactive maintenance?

A: In the chemical processing/oil refining spaces, we have to think of reactive work as dangerous work. These environments in which our manufacturing colleagues and personnel operate are inherently dangerous. The number one goal is to walk out of there with all your limbs attached and all your peers alongside you. When you add into the equation reactive work, that is another hazard in those people's days. Especially for the maintenance crews. When a machine fails unexpectedly, you really don't know what you're going to walk into. What could be in that pump? How could it have failed? What hazards might be there that you otherwise may not have had time to plan for?

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I think the other consequence of reactive work is around the workforce itself. Imagine coming into work each day working in a reactive environment — where your job is simply just to put out fires. That's not a very fun job. We have workforce issues in the industry already. How do you maintain and retain highly skilled talent in an environment where they're getting called in at all hours of the night, on weekends and miss kids' soccer games? This is equally as much a safety issue as it is a worker mental health and human resources retention issue.

Finally, reactive work is almost always more expensive than proactive work. The machine is down unexpectedly, production may or may not have stopped. The machine failure is going to be more expensive to repair than it would have been to prevent.

Q: What about proactive and preventative work?

A: Preventative maintenance has been going on for a while. For instance, it's about having a lubrication program in place for your machines. You need to grease the bearings every so often to keep the friction down and to keep the machine rotating efficiently. It's all typically done on a time basis. If you think about how cars operated 20 years ago, we were changing our oil every 3,000 miles or every three months; that was really time-based preventative maintenance. Now, your car, in many instances, will tell you when it needs an oil change. We're no longer beholden to showing up at the local mechanic once every three months. Now we can go based on how frequently we drive and how hard we use the car — that's condition-based maintenance.

But industry can go even further to prognostic-based condition monitoring. Imagine your car could tell you when it would need its oil changed based on where you want to go. The car would factor in how you drive, how many highway miles you're going to have, how much time you're going to spend driving above the speed limit. Your car would give you a calculation of when you're going to need to change your oil based on how you are running the machine. And that's where the industry can go in the future.

Obviously, you can't go from horse and carriage to flying cars overnight — there's a natural progression. Customers in many cases are still working in this time-based, periodic preventative-maintenance paradigm, and are just starting to get to the point of trusting technologies like IoT sensing devices, artificial intelligence and machine learning to predict when — and even how — their machines are going to fail. As customers adopt these new technologies and begin to trust that the technology is telling them the right thing and predicting the right reasons for failure, customers can then get ahead of these failures, reduce their maintenance costs, increase production and gradually make that shift to condition-based monitoring. It's only then that they have reached a certain level of maturity in their processes and trust in technology that they can take the next step and add additional context to the AI and machine learning. How is the way they run their machines going to affect the machines from a maintenance perspective over their lifetime?

Q: Will we ever get to prognostic-based maintenance?

A: I think we have to get there. Manufacturers are missing their production targets because machines are failing. And we also know that they all have workforce challenges. If we're not preventing production losses, it's a compounding effect from a supply-chain perspective and a workforce perspective. Technology needs to be an aid to the existing workforce, a mechanism to retain talent and augment existing talent.

"It's not about a machine breaking and somebody fixing it — it's about creating a work environment where you're not pulled in a thousand different directions."

Q: How will this approach impact maintenance teams?

A: We need to turn firefighters into forest rangers. And that's really hard to do because firefighters are seen as heroes. If a machine failed and the maintenance technician came in at 2 a.m. to get it back up before the next shift, everybody's congratulating him for doing such a great job. But wouldn't it be better if that machine had never failed at all? It's about shifting the mindset from that reactive to proactive state and to celebrate machines not failing instead of machines being fixed and turned around quickly. From a maintenance technician's perspective, the job now changes from being called at all hours of the night or on weekends to one with more regular hours. It ultimately saves the manufacturer money in terms of repairs as well as lost production.

Augury's Machine Health Solutions combine sensors with advanced AI diagnostics and human reliability experts.

Q: Do you have anything you want to add?

A: I think one of the challenges is that digital transformation is really people transformation. I'm not just talking about making sure the users of a technology platform have solid training and know how to use the platform. If it was just about that, digital transformation would've met its nirvana goals long ago. So, it's clearly about more than training. The key that we found at Augury is to have really a clear definition of success from the get-go.

Once you have that definition of success, it's about highlighting wins. More people in your company are likely to adopt technology as you publicize those wins to your teams and help them understand the impact those wins have on their business overall.

We know AI works. We know IoT technology works. It's really about how do we make sure the people that need to use it take those insights and implement a repair? How do we make them understand the impact they're having on their organization? And how do we begin to celebrate that at all levels of the organization? Because it's not just about a machine breaking and somebody fixing it — it's about their role in helping to increase production, to service customers better and to deliver a safe, fun work environment where they're not pulled in a thousand different directions every day. ●

To access the special report on digitalization, visit: info.augury.com/CEP

NET ZERO EFFORTS ADD UP

Chemical makers launch wide-ranging actions to curb carbon emissions

By Seán Ottewell, Editor at Large

THE EXPERIENCES of Solvay, BASF and Chemours illustrate how chemical companies are refining their strategies to reduce carbon dioxide (CO_2) emissions and, ultimately, become carbon neutral, i.e., have net zero emissions. All aspects of production, from energy generation to global supply chains, are under the spotlight.

Solvay sets out its roadmap in its Solvay One Planet initiative. Here, the Brussels, Belgium-based company outlines strategies to achieve full carbon neutrality by 2040 for all its businesses other than soda ash. By 2050, Solvay expects the entire company to attain neutrality.

The plan contains decade-by-decade goals. Efforts from 2020–2030 will focus on reducing carbon dioxide from energy use and process emissions. Then, 2030–2040 will see energy transition projects including electrification, new energy technologies and process innovations. Finally, initiatives in 2040–2050 will tackle the company's "hard-to-abate" soda ash sites via as yet undefined new technologies and energy sources. As part of this overall strategy, Solvay will use offsets for up to 1 million tons of CO_2, primarily through nature-based offsetting programs in partnership with nongovernmental organizations.

"Solvay plans to invest up to €1 billion [≈$1.1 billion] across all of our businesses, with the exception of the soda ash business, to achieve carbon neutrality by 2040. Specifically for the soda ash business, Solvay plans to provide another €1 billion (≈$1.1 billion) of identified investments through 2040 to pave its path towards full carbon neutrality for the group before 2050," explains Pascal Chalvon, chief sustainability officer.

This decade, the company already has launched 36 emissions-reduction projects based on energy use, together reducing CO_2 emissions by 2.5 million mt/y. Including projects designed to reduce process emissions, Solvay expects to cut CO_2 emissions by 3.7 million mt/y by the end of the decade.

"The success of these early projects has prompted Solvay to upgrade its greenhouse gas [GHG] emissions reduction target from -26% to -30% by 2030," Chalvon adds.

SPECIFIC PROJECTS

Chalvon cites a contract just signed with a local agricultural cooperative to supply biomethane to its plant at Melle, France, as an example of efforts. The cooperative has built a facility to convert waste biomass into 18 GWh/y of energy, which Solvay will purchase as part of its strategy to decarbonize its cyclopentanone unit at Melle. That plant manufactures two grades of cyclopentanone, one for the fragrance market and an ultra-high purity version for the electronics market.

"The same approach now is going to be extended to other sites in Solvay's aroma business, such as our Saint-Fons facility in Lyon," he notes.

The company also is undertaking three major cleaner-energy projects within its soda ash business. One, at its largest European soda ash plant in Devnya, Bulgaria, involves adapting an existing boiler to increase the amount of biomass it can co-combust to 30%. The biomass will come from a variety of sources including locally sourced sunflower husk pellets. When the upgraded boiler begins operating in November of this year, CO_2 emissions related to energy production will fall by 20%.

Similarly, a project in Rheinberg, Germany, should make the company's soda ash plant there (Figure 1) the world's first to be powered primarily by renewable energy.

Meanwhile, refuse-derived fuel (RDF) alone will power a cogeneration plant at the Dombasle soda ash site in France. Two furnaces that will consume 350,000 mt/y of RDF and generate 181 MW of thermal power and 17.5 MW of electrical power will replace three coal-fired boilers. They should begin operation in 2024, and will reduce emissions of CO_2 from the plant by 50%.

Together, these three projects in Europe will cut the group's emissions globally by 8% by 2025.

"The investment focus for the soda ash business is in the energy transition of our plants around the world from coal power to more-sustainable forms of energy. We will also continually improve processes and technologies to make operations as sustainable as possible," stresses Chalvon.

In terms of economics, Solvay doesn't provide a breakdown on how it will split its investments between energy-transition and process-optimization projects. However, Chalvon says they will generate returns well in excess of the cost of capital, with some funds coming from asset-specific financing — enabling the company to continue to invest in its growth areas.

"Furthermore, in 2021 we raised Solvay's internal carbon price from €50 to €100/mt of CO_2 [≈$55–110], thereby ensuring that future investments are oriented towards zero-emission projects. This is therefore input as a cost for every investment project we undertake, allowing us to accelerate our coal exit projects," he explains.

The company is keen to embrace other initiatives that will help meet its commitments, and in the autumn of 2020 joined the Science-Based Targets initiative (SBTi), https://science-basedtargets.org. Founded in 2015, the SBTi helps companies

Figure 1. Project in Germany aims to make the unit the world's first such plant powered primarily by renewable energy. *Source: J. Kefferpuetz, Solvay Deutschland.*

align their GHG emission targets with what climate science shows is required to prevent catastrophic climate change. The organization currently has over 2,500 members.

The SBTi categorizes direct and indirect emissions into three broad scopes: Scope 1 for direct GHG emissions from sources owned or controlled by the company; Scope 2 for indirect GHGs emissions from consumption of purchased electricity, heat or steam; and Scope 3 for other indirect emissions, such as the extraction and production of purchased materials and fuels, outsourced activities and waste disposal.

"The next step for Solvay will be to have our Scope 3 targets finalized by the SBTi later this year. As we continue to advance on our sustainability targets, we certainly expect to continue raising the bar across all three pillars of our Solvay One Planet roadmap: climate, resources and better life," states Chalvon.

He also points to the importance of working with individual governments and local authorities on specific projects. For example, regional investment from the Île-de-France and Nouvelle Aquitaine regions is complementing existing European Union funding toward a new research-and-development pilot line in La Rochelle, France, for advanced inorganic materials used in solid-state batteries. The French state also is providing backing for a €300-million (≈$330-million) capacity expansion at Solvay's polyvinylidene fluoride (PVDF) facility in Tavaux. PVDF is an essential component in electric batteries, too.

SPECIAL TEAM

BASF, Ludwigshafen, Germany, also constantly is investigating ways to improve its sustainability strategies, which include a commitment to cut emissions by 25% by 2030 compared with 2018 and to become climate neutral by 2050.

Its latest initiative, which launched in January, is the Net Zero Accelerator unit. Based at Ludwigshafen, that group is charged with bundling together all of BASF's activities relating to low-CO_2 production technologies, the circular economy and renewable energies.

Led by Lars Kissau, senior vice president, global strategic business development petrochemicals, Net Zero Accelerator reports directly to BASF's company chairman. The unit's initial 80 employees were recruited from in-house experts.

"Net Zero Accelerator is a distinct and cohesive organizational unit and not just a 'virtual' arrangement. All employees now work in a well-coordinated and -orchestrated way under one roof, and additional colleagues are being recruited internally and externally," notes a BASF spokesperson.

Existing initiatives, such as ChemCycling (see: "How Industry Tackles Plastics Plague," https://bit.ly/3pYO5Fn) and methane pyrolysis, are part of the Net Zero Accelerator unit, which currently is focused on scaling up these and other new technologies in the run-up to 2030 before possible commercialization later.

For example, BASF is developing methane pyrolysis technology for the CO_2-free production of hydrogen from natural gas. A pilot plant in Ludwigshafen started up several months ago. Funding for this project was provided by the German Federal Ministry of Education and Research.

Together with SABIC and Linde, BASF is working to develop a pilot furnace for the world's first electrically heated steam cracker (Figure 2). Compared to conventional crackers, it would enable nearly CO_2-free production of basic chemicals. If the necessary funding is granted shortly, the pilot plant could start-up as soon as 2023.

"Some projects and technologies in the scope of Net Zero Accelerator are already ready for commercialization and specific announcements will follow once investment decisions have been taken. Other projects and technologies still require further development. For these, we expect a contribution to our CO_2-reduction targets at a later point in time," adds the spokesperson.

The Net Zero Accelerator unit's purview also includes BASF Renewable Energy, which is responsible for initiating new projects to generate renewable energy and to negotiate long-term power purchase agreements with energy producers.

Already underway are several such projects, including the acquisition of a 49.5% stake in Vattenfall's 1.5-GW Hollandse Kust Zuid wind farm, and a 25-y contract to purchase 186 MW of capacity

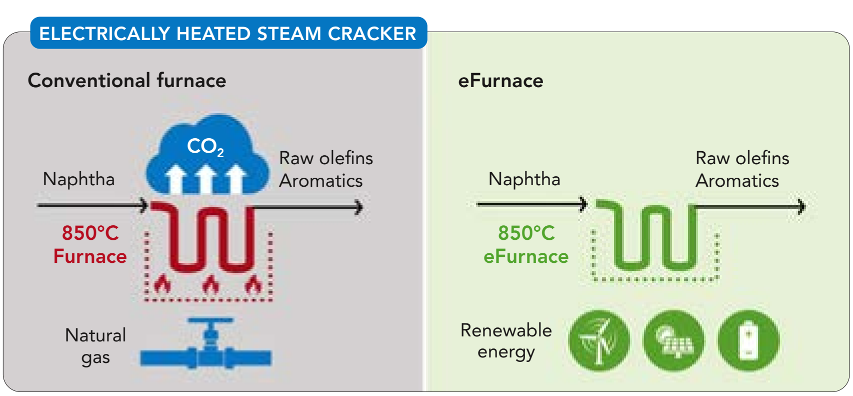

Figure 2. BASF, Linde and SABIC are working towards a 2023 start-up of pilot unit. *Source: BASF.*

from Ørsted's planned Borkum Riffgrund 3 offshore wind farm in the German North Sea.

The unit is reviewing or has initiated other major projects for the generation of electricity from renewable sources in Europe, Asia and the Americas.

"Besides renewable energy from offshore wind farms, we also focus on large-scale solar. For example, together with [German regional energy supplier] enviaM, we have started the construction of a 24-MWp solar park in Schwarzheide, Germany," notes the spokesperson.

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SUSTAINABLE SUPPLY CHAINS

Chemours, Wilmington, Del., has become the 33rd chemical company to join the Together for Sustainability (TfS) initiative, Brussels, Belgium. TfS, https://tfs-initiative.com, was set up to drive and foster resilience, efficiency and sustainability in the chemical industry's global supply chains.

Chemours' own global procurement function involves hundreds of staff and a multi-billion-dollar budget covering everything from energy and gas to transportation services and real estate.

"2020 and 2021 proved to be unprecedented in terms of relentless and impactful supply chain issues. We learned a lot about vulnerabilities and have made substantial progress in assessing risk and developing mitigation plans," notes chief procurement officer (CPO) Michelle Moore.

A key benefit of TfS membership is the ability to collaborate with like-minded procurement professionals in a common industry, says Moore. "In the brief time we've been a member, I have heard CPOs speak of challenges that are remarkably like what we're facing and experiences they have had that will help us avoid similar pitfalls."

To encourage this cross-pollination of data and information, TfS members conduct audits of suppliers. These reports then are shared with both the suppliers and other TfS members. "As a result, we expect improved quality of assessment and audits, and, of course, we all save time and effort through sharing audit and assessment results," adds Moore.

She also is working alongside Chemours' own chief sustainability officer to develop a new vision for responsible procurement.

"A major shift we're making is to embed responsible procurement into our daily work, to drive collective ownership and responsibility for achieving our goals," she stresses.

To help achieve this, the company has drawn together a global eight-member responsible procurement team tasked with taking part in regional TfS networks and developing and driving the company's priority programs.

"Our focus is embedding responsible procurement across our team so that they can drive sustainability at every level and function within Chemours and in our supplier management process. We are looking at it holistically and integrating sustainability criteria in our supplier qualification and performance management processes. To drive ownership at the manager level, we are rewriting our role descriptions to include sustainability aspects as important KPIs, such as quality and cost," she explains.

Success is measured by how well the company can improve the business sustainability score it gets from EcoVadis, https://ecovadis.com — Chemours has received silver certification for two years in a row — and how well responsible procurement ingrains itself in the organization's culture.

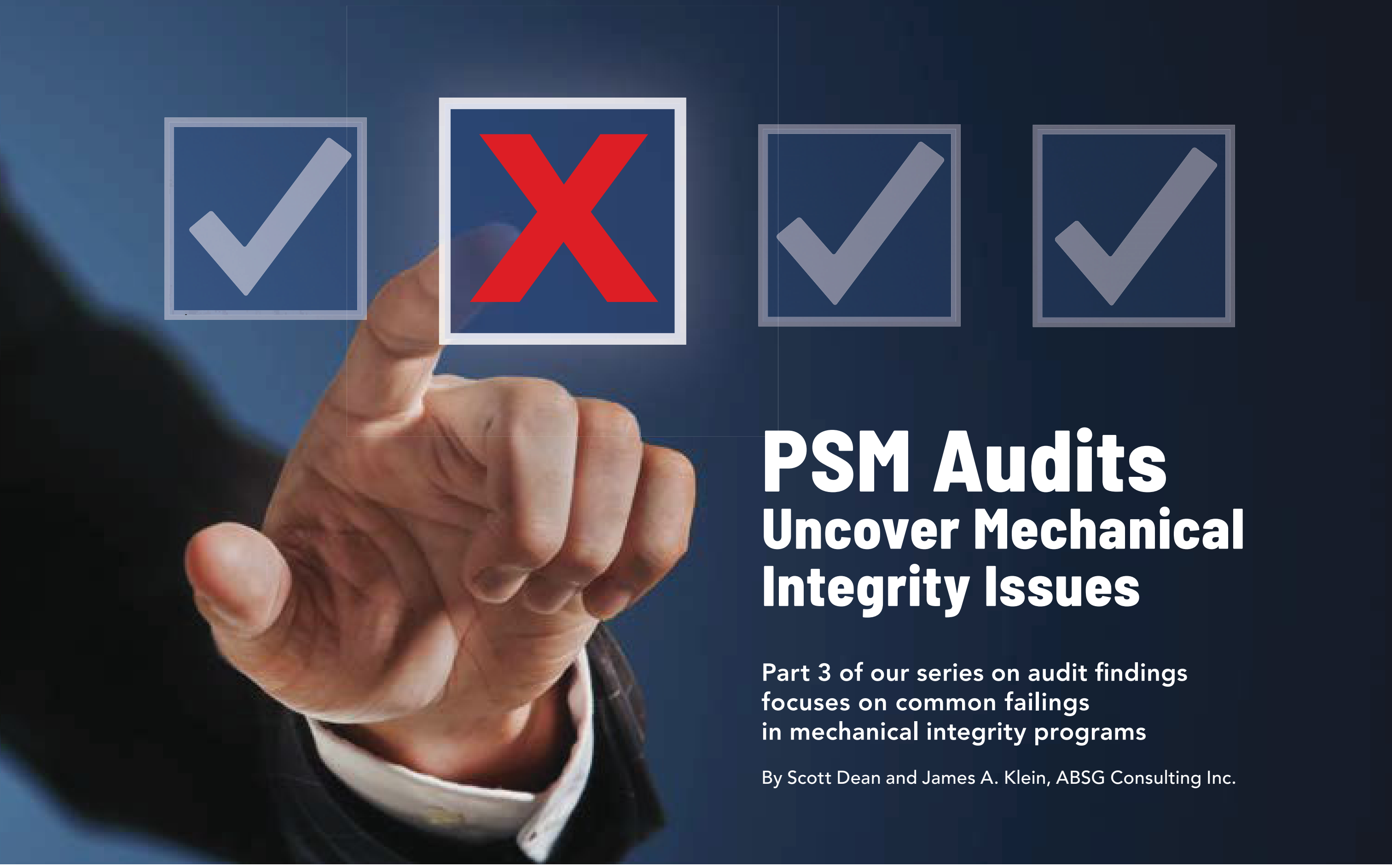
"We're also keen on expanding our supplier reach, so we're tracking the increasing number of suppliers we've assessed. Our membership with TfS should help us move faster in both regards," declares Moore.

While TfS is largely CPO focused, workstreams and regional networks within the organization attract other expertise. One, for example, is devoted to Scope 3 GHG emissions.

"This workstream is of great interest to Chemours to support our climate objectives. So I would not box the work of TfS to only 'procurement-related issues.' We are focused on sustainability issues, too."

Chemours' current goal is to achieve a 60% reduction in Scope 1 and 2 GHG emissions by 2030. It aims to reach net-zero GHG emissions by 2050.

"We belong to many other external forums and networks, and with that may come some great leveraging ideas," Moore concludes. ●



PSM Audits Uncover Mechanical Integrity Issues

Part 3 of our series on audit findings focuses on common failings in mechanical integrity programs

By Scott Dean and James A. Klein, ABSG Consulting Inc.

PROCESS SAFETY management (PSM) audits play a crucial role in evaluating the effectiveness of a company's current programs and identifying potential improvements as well as in complying with relevant regulatory requirements such the 29 CFR 1910:119 Process Safety Management standard of the U.S. Occupational Safety and Health Administration (OSHA) and the 40 CFR 68 Risk Management Program (RMP) rule of the U.S. Environmental Protection Agency (EPA) [1,2]. A facility with a process covered by these regulations must conduct compliance audits every three years.

Previous articles [3, 4] have pointed out deficiencies that audits often find with operating and safe limits, operating procedures, and training. Here, we will look at common audit findings in mechanical integrity (MI) programs.

An MI program [5, 6] should help ensure continued safe and reliable operation of equipment associated with a hazardous process, based on documented design and process safety information (PSI); maintenance efforts consistent with recognized and generally accepted good engineering practices (RAGAGEPs), such as those published by the American Petroleum Institute (API); and the appropriate evaluation and management of process risks. Equipment malfunction or failure and loss of containment can lead to equipment downtime, process upsets, quality problems and, perhaps, significant process safety incidents resulting in personnel injury, equipment damage and environmental harm. This article addresses several of the most frequently observed audit findings related to MI and provides guidance on how appropriate implementation of requirements for PSM elements can improve compliance and ultimately contribute to safe operations and manufacturing excellence.

REQUIREMENTS/BACKGROUND

A company implements an MI program to protect against equipment failure or malfunction, such as leaks from process vessels and piping, that can lead to the release of hazardous chemicals. Loss of containment can cause exposure to toxic chemicals, fires and explosions, significant equipment damage, and environmental harm [7]. Equipment failure, even without loss of containment or other potential hazardous events, also can result in process downtime, productivity issues and supply chain disruptions.

The scope of an MI program typically is very broad, encompassing most, if not all, equipment in a process that contains hazardous materials. So, for example, a large process plant or refinery must include a massive amount of equipment in its MI program. Process equipment in the MI program generally is identified as part of the PSI documentation, which may label equipment "PSM critical" or use some other term to indicate the equipment: 1) typically contains hazardous materials; 2) is a safeguard listed in the process hazard analysis (PHA); 3) is part of another safety system intended to help prevent or mitigate hazardous events; or 4) is covered by RAGAGEP requirements.

The MI program must include inspection or test procedures for all process equipment considered PSM critical.

The OSHA PSM standard specifically identifies certain kinds of equipment:

- pressure vessels and storage tanks;
- piping systems;
- relief and vent systems;
- emergency shutdown systems;
- controls; and
- pumps.

However, this only represents a starting point, with other equipment added as appropriate based on the processes and hazards at the facility.

Important parts of an MI program are 1) developing maintenance procedures, and 2) training mechanics and other maintenance personnel.

An inspection, testing and preventive maintenance (ITPM) plan that identifies the equipment included in the MI program and the inspection and testing requirements, based on RAGAGEPs, manufacturers' recommendations, PHA or other risk-evaluation dictates, or required operating practices should be developed. Figure 1 shows an example ITPM program [5, 7].

COMMON AUDIT FINDINGS

PSM compliance audits often find a number of common issues with MI programs. These failings fall into six general categories: the general MI program; maintenance procedures; maintenance training; the ITPM plans; equipment deficiencies; and quality assurance. So, let's look at each of these.

1. General MI program. Some facilities have implemented preventive maintenance practices but have not developed fully documented MI programs as required by the regulations. In other cases, the MI program may not have identified and included all equipment associated with the covered process. A company may spot gaps in the program by checking the regulatory requirements, auditor review of facility PSI (e.g., equipment files, safe limits tables, safety system and emergency response equipment), or auditor knowledge of RAGAGEPs. In addition, an auditor examination of PHAs may help identify safeguards that have been credited for helping to prevent or mitigate the consequences of potentially hazardous scenarios but that have not been included in the MI program.

Guidance: Broadly assess the covered process, taking into account regulatory requirements, PSI documentation, PHA review, and appropriate RAGAGEPs, to ensure the MI program includes all relevant equipment. Consider identifying "PSM critical" equipment as part of the PSI equipment documentation, based on the potential consequences of equipment failure or malfunction. Document equipment types and the requirements for each in the ITPM plan (see below).

2. Maintenance procedures. In many cases, maintenance procedures have not been developed and documented for equipment associated with the covered processes to ensure ITPM activities are conducted appropriately and consistently by qualified personnel with proper documentation of the results. In some cases, a manufacturer has developed procedures but these are not incorporated. Procedures also may not be provided for common maintenance activities, such as equipment lubrication or calibration, or to address RAGAGEP requirements. Procedural gaps and lack of direction or training for maintenance personnel can undermine inspection, testing or other maintenance activities, leading to higher risk of equipment failure and hazardous incidents. Missing test activities can result in poor evaluation and follow-up on equipment needing attention. Likewise, inadequate or poorly documented historical test data can prevent proper evaluation of reoccurring operating issues and remaining equipment life.

Guidance: Develop maintenance procedures for all required process equipment and work tasks based on manufacturer guidance and any related RAGAGEP requirements. Ensure procedures detail specific inspection and testing tasks, and require proper documentation.

3. Maintenance training. Failure to provide training on an overview of the process and its hazards is a common

EXAMPLE OF AN ITPM PLAN

Equipment/Item	Inspection	Frequency	Basis	Procedure
Reactor 101	External visual	2 years (5 years)	ABC Chemical Procedure XYZ (API 510)	Work Instruction PV-I-001
Reactor 101	Internal visual	10 years	ABC Chemical Procedure XYZ and API 510	Work Instruction PV-I-002
Hi-hi interlock R-101	Functional test	2 years	ABC Chemical Procedure XYZ	Work Instruction INST-I-001
Pump 101 discharge piping	Ultrasonic thickness test	10 years	API 570 for corrosion life > 20 years	Work Instruction PIP-I-002
Pump 101 discharge pumping	Visual	3 years	Plant experience (see PHA 96-03 page A-27)	Work Instruction PIP-I-001

Figure 1. A clear and comprehensive inspection, testing and preventive maintenance (ITPM) plan is an essential part of a mechanical integrity program.

finding. OSHA requirements call for training of maintenance personnel on the hazards related to equipment they are working on as well as the applicable MI procedures. This issue comes up most often with "central" maintenance shops, where all mechanics/technicians are part of one group and are dispersed throughout a large plant to different PSM-covered areas rather than being dedicated to a limited number of processes. Some of the reasons for this include: 1) not receiving all required training when newly hired, 2) the plant has added a new process area but failed to provide overview training to all maintenance personnel, or 3) maintenance technicians, who previously were operators in a particular part of the plant, did not get trained subsequently on other areas in the facility.

Training also must cover maintenance procedures, safe work practices, and use of special tools or equipment as needed. In some cases, specific tests or inspections require certified inspectors per the RAGAGEP; this mandates obtaining appropriate certifications or bringing in qualified external inspectors to conduct the activity. In addition, maintenance personnel should be trained on emergency response plans and management-of-change (MOC) procedures. Although not required specifically by the MI element, maintaining proper documentation of the training is important. Staff also should receive refresher or special skill training as needed.

Guidance: Develop a maintenance training program to ensure training is provided in all required areas. Consider documenting this training, including verifying understanding. Think about making apprenticeship or trade-school training a prerequisite for hiring into maintenance roles; this is becoming increasingly common. Based on required work activities, evaluate whether you need to develop and train internal certified inspectors.

4. ITPM plans. Audit gaps related to development and implementation of ITPM plans often include:

- no ITPM plan;
- incomplete or incorrect ITPM plan (missing equipment types or relevant RAGAGEPs);
- inspection not done or not done on the required frequency;
- inspection does not follow approved maintenance procedure;
- inspection not performed by trained maintenance personnel or qualified/certified inspectors;
- poor documentation of inspection results; and
- no review or follow up of inspection results, including corrective actions or program adjustments.

Let's examine some common audit findings for several types of equipment.

Atmospheric storage tanks. These vessels typically are inspected per "Tank Inspection, Repair, Alteration, and Reconstruction," API Standard 653, 5th ed. (Nov. 2014), Addendum 1 (Apr. 2018). The most common problems found are:

1. No monthly API-653 inspections are being conducted.
2. Thickness readings on tanks ten years and older only are taken on the shell and roof; lack of data on the bottom of the tanks means inspections are incomplete. This leads to retirement dates that only reflect shell thickness.
3. Red-flagged condition monitoring locations (CMLs) are not being reexamined at the recommended interval (established by calculation).
4. Tanks are placed in risk-based-inspection (RBI) status without a proper analysis per "Risk-based Inspection," API Recommended Practice 580, 3rd ed. (Feb. 2016). Many tanks receive RBI status prior to their first ten-year internal inspection, which is not a recommended practice.
5. Major repairs recommended by API inspectors are not done prior to tanks being placed back into service.
6. Proper deferrals are not in place for overdue external, internal and thickness inspections.

Pressure vessels. Inspections typically follow "Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration," API 510, 10th ed. (May 2014), Addendum 1 (May 2017), Addendum 2 (Mar. 2018). The most common problems are:

1. External inspections are overdue.
2. Internal inspections are overdue.
3. Thickness data are on file but no calculation has been performed to determine the remaining life or next inspection interval.
4. Red-flagged CMLs are not being reexamined at recommended interval (as calculated).
5. Nonqualified personnel (e.g., non-API-510-certified individuals without proper training) inspect pressure vessels.
6. Pressure vessels are placed in RBI status without a proper analysis per "Risk-based Inspection," API Recommended Practice 580, 3rd ed. (Feb. 2016). Many pressure vessels receive RBI status at commissioning without baseline thickness readings, which is not a recommended practice.
7. The same pressure vessel out of several similar ones in a given service is inspected multiple times instead of the inspections alternating among all vessels.
8. Proper deferrals are not in place for overdue external, internal and thickness inspections.

Piping systems. Inspections usually follow "Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems," API 570, 4th ed. (Feb. 2016). The most common problems found in audits are:

1. Piping is not properly classified per Table 1 in API 570, 4th ed. Therefore, piping inspection intervals may be set at ten years for all piping circuits, which is not appropriate for any Class 1 and 2 piping circuits present.

2. Piping circuits in the PSM process units are not accounted for in the site test and inspection plan. Those not accounted for are considered overdue.
3. Proper deferrals are lacking for overdue external and thickness inspections.
4. Injection points do not receive three-year thickness inspections.
5. Dead-leg piping is not identified and does not receive proper inspections.
6. Small-bore piping is not inspected.
7. Thickness data are on file but no calculation has been performed to determine the remaining life or next inspection interval.
8. The test and inspection plan does not include buried process piping, including surface-to-air interfaces.
9. Piping circuits over water do not get inspected.
10. The test and inspection plan does not cover expansion joints and hoses.

Guidance: Document an ITPM plan, using approved tests and inspections, to maintain required equipment. In addition, have a process for identifying when RAGAGEP requirements have been changed and for evaluating the needed updates, if any, to the ITPM plan and MI program.

5. Equipment deficiencies. Many sites have not developed a formal program to 1) review equipment deficiencies, and 2) make certain proper steps are taken to respond to issues such as leaks, failed inspections, reaching minimum allowed thickness (T_{min}), operating beyond operating or safe limits, weld failures, etc. These situations must be managed to ensure the integrity of the equipment and safety of personnel. The equipment deficiency program should consider if equipment must be 1) shut down until fixed, 2) run at lower operating rates (temporarily or permanently), 3) possibly bypassed (typically temporarily) until repair or a replacement part is obtained, or 4) replaced. The program also should ensure the proper risk assessments are made, documentation is provided, and appropriate authorization is received. Fitness-for-service evaluations, based on historical operating and inspection data, may be necessary, especially if frequent problems have occurred.

Guidance: Document an equipment deficiency program for responding to equipment operating or inspection deficiencies; it should include proper documentation of the path forward (e.g., bypass authorization procedures, temporary MOC for modifications to allow equipment shutdown/repairs), review and authorization to proceed.

6. Quality assurance. Many sites lack a documented quality assurance (QA) program as required by the MI element. Some may have corporate directives for the site to establish a QA program or that provide additional guidance on particular practices. Often, however, only partial implementation has taken place, or the directives do not address site-specific needs and practices. Documentation that appropriate checks and inspections are being conducted during equipment fabrication and installation frequently is not available or incomplete. Material verification programs are not provided, or are undocumented, or are inconsistent or ineffective. A flawed program to maintain and organize spare parts causes a lack of correct spare parts, sometimes leading to imperfect maintenance and operating decisions when equipment failures occur.

Guidance: Document a QA program for equipment fabrication or receipt that includes inspection, verification and installation procedures, and maintains appropriate spare-parts inventories and controls.

AVOID MI MISTAKES

The scope and requirements related to effective MI programs are complex and detailed. So, unsurprisingly, MI often is one of the elements in a PSM audit with the most findings. In particular, lack of detailed knowledge of relevant RAGAGEPs can lead to poor design of ITPM plans and, therefore, inadequate implementation of MI requirements. Gaps in an MI program often identified in an audit include:

- Some PSI equipment documentation is missing or poorly organized, impacting MI program scope and effectiveness.
- The MI program does not include all required process and facility equipment.
- Maintenance procedures have not been developed.
- Effective maintenance training has not been provided.
- Inspections and tests are not being conducted or are not conducted at the right frequency.
- Program documentation is poorly maintained.

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• Equipment deficiencies are not properly evaluated or addressed.
• A QA program has not been established.

We hope the information provided in this article will help you better evaluate this important part of your PSM program for improved regulatory compliance and continued safe and reliable operation.

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USE ADVANCED ANALYTICS TO BUILD BETTER BATCHES

Cycle time, yield, product quality and workforce efficiency may improve | By Allison Buenemann, Seeq Corporation

BATCH CHEMICAL processes present unique data aggregation, visualization and analytics challenges that may exceed the capabilities of traditional engineering toolsets. For a start, a chronological time stamp of data won't suffice. The relative time during a batch when a datapoint was generated is crucial. This requires the ability to identify the same point within the same phase of a batch of the same product to enable an apples-to-apples comparison and benchmarking. Complex event identification is needed to parse out the necessary data for downstream calculations, statistical and first-principles modeling, and optimization.

In addition, batch processes often store contextual information like batch quality results, along with other identifying metadata, in a manufacturing execution system or batch database. Thorough analysis requires access to all those data as well as their automatic refreshing in a single application.

Effective data visualization is a necessary precursor for performing analytics. Batch process engineers need to calculate metrics, generate statistical profiles, and create process models — with the end goal of optimizing production volumes, product quality, raw material utilization, energy consumption and other factors.

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UPGRADING THE TOOLKIT

Chemical companies historically have used spreadsheets as the preliminary collection point for analyses that require data from multiple different source systems. Because simple time-series trends won't suffice for batch comparison, a subject matter expert (SME) using a spreadsheet may spend hours manually preparing data (or data wrangling), to create even a simple batch overlay chart, and then must repeat this exercise when looking at another product or batch phase. In addition, the spreadsheet approach lacks both the live connectivity critical for long-term data analysis and the easy data visualization necessary for performing analytics.

The seemingly simple task of event identification can spiral into complex logic, one-off scenarios, and knowledge not easily transferrable across the organization.

Spreadsheet-savvy SMEs may be able to hack their way to this point in the analytics process — but what happens when it's time to scale those efforts across different units at different sites in different geographies?

To address these and other issues, a chemical manufacturer needs a robust analytics application that can meet scaling requirements, enhance understanding of relationships among assets, and enable consideration of differences in data sampling frequency, interpolation, and naming conventions. With such advanced analytics tools in hand, SMEs working with data from a manufacturer's production assets can perform these activities to reduce batch cycle times and increase yield, while improving product quality and workforce efficiency.

THE ESSENTIAL BACKBONE

The path to better batch analytics begins by establishing a live connection to each of the source systems (historians, manufacturing execution systems, batch databases, laboratory information systems, etc.) containing data necessary to perform analytics across a selection of site or companywide process units. Modern cloud-based advanced analytics applications address this challenge by connecting natively to the many process data historians, asset hierarchy databases, and structured-query-language-based data sources storing quality data and contextual information on-premises, alongside cloud data sources.

Advanced analytics applications come with built-in visualization options expanding on what's available in traditional

historian trending tools. These visualization capabilities add to an SME's ability to identify time periods of interest. Being able to slice-and-dice a data set into periods of interest enables not only novel visualization techniques (Figure 1) but also powers all downstream analytics. Some modern self-service analytics applications have adopted a new data type of the format [start time, end time, metadata] to complement the traditional [timestamp, value] pairing of sensor data.

These similar events, referred to in the use cases we'll cover as "capsules," enable users to calculate and compare key performance indicators during a particular operation, build variable monitoring limits, calculate golden profiles, and specify model training data. With the calculations performed, the next challenges to address are near-real-time deployment, knowledge capture, and scaling of the analytics to other batch production processes within the organization.

A live data-source connection allows SMEs to configure calculations to automatically update as new data appear in source systems, enabling continuously updating quality models, production forecasts, and maintenance projections. The browser-based nature of these tools permits companywide access to the live updating results, whether by display on a large control room monitor, email notifications behind the scenes when process triggers are exceeded, or other means.

The live data source connections that power modern advanced analytics applications also facilitate near-real-time interaction between producers and consumers of analyses. The ability to annotate features in the data by leaving time-stamped and named notes for later viewers of the analyses helps capture and codify the knowledge of those closest to the process.

Built-in mechanisms for scaling analytics are key to widespread adoption within an organization. Providing connectivity to existing asset hierarchy systems offered by process automation and historian companies, as well as by third-party vendors, is one way that modern applications address this challenge. For organizations without a built-out asset structure, mechanisms for constructing asset groups tailored to specific use cases exist in-application within a point-and-click environment.

SUCCESS STORIES

Digital and analytics leaders in the chemical industry have embraced new self-service analytics technologies to exploit their data investments by solving increasingly complex use cases. Here, we'll look at four that build on the foundational element of advanced event identification and then apply advanced statistics to generate monitoring limits, construct predictive models, and quantify dissimilarity and contribution factors among batches.

DATA VISUALIZATION

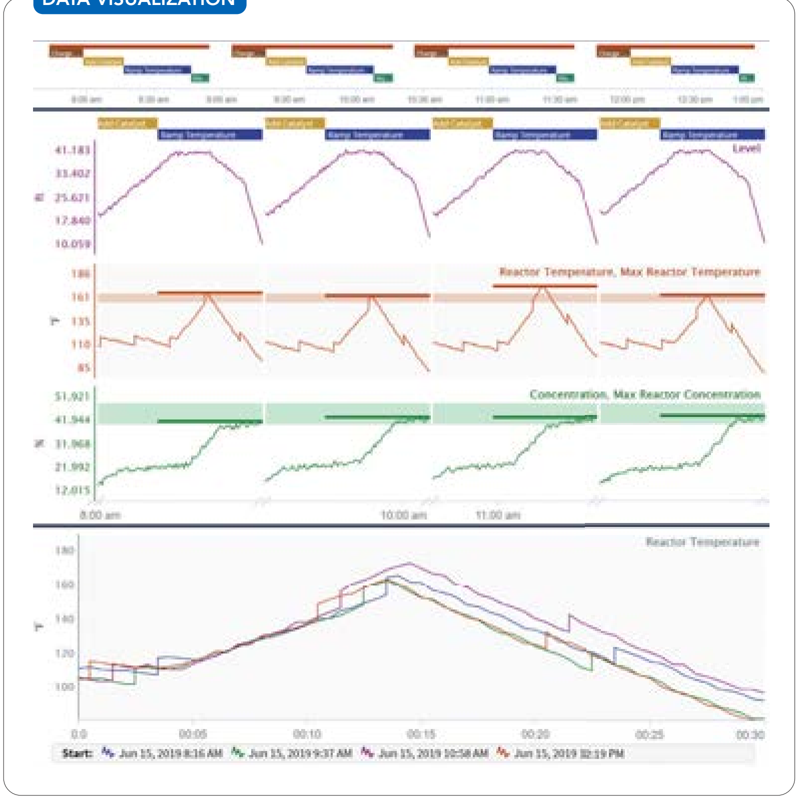

Figure 1. Capsules can provide a Gantt chart of events (top), an end-to-end view of operations (middle), and overlaid signal data during batches or particular phases (bottom).

BATCH DEADTIME

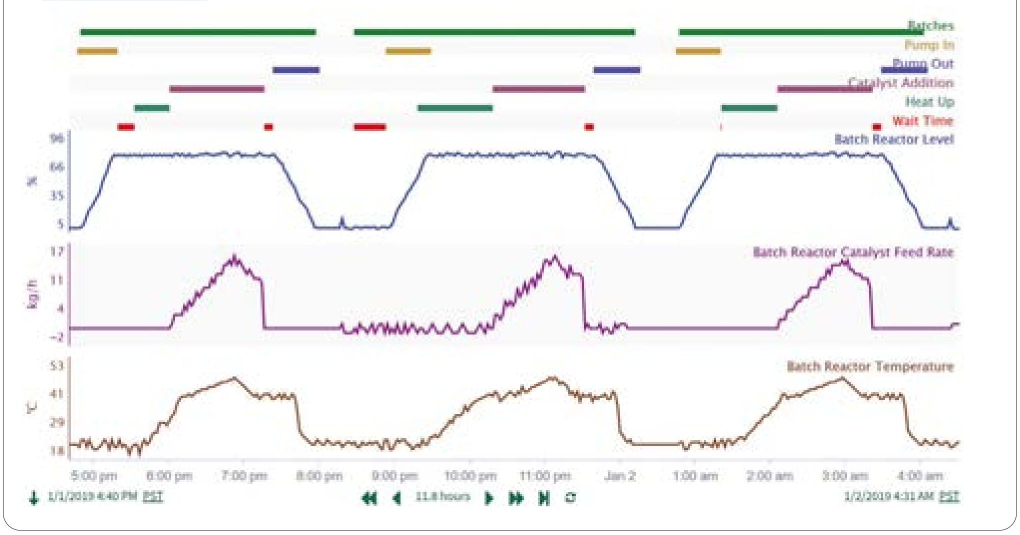

Figure 2. After identifying reaction steps, subtracting time spent on them from total batch time gives overall deadtime.

1. *Batch Deadtime Identification.* A bulk chemical manufacturer wanted to estimate the total production lost each year due to deadtime in batch processes across all its reactors. The company defined deadtime as any time when a procedural step critical to the outcome of the batch wasn't taking place.

The chemical maker used an advanced analytics application to visualize process data from its historian with contextual information about the batch — a capsule with start time, end time, batch identity, and additional quality metadata. These capsules identified the time spent on each operational phase, e.g., charging, heat-up, reaction time and discharge. Phases were identified by increasing or decreasing trend in a signal, values exceeding a threshold, or by looking at a logical combination of other events. Ultimately, the company identified periods of deadtime by subtracting each of the productive reaction steps from the overall batch capsule (Figure 2).

The manufacturer used a single production line to tune the analysis. It then applied a similar methodology to each of the other batch reactors within its facilities. This involved constructing an asset hierarchy containing the relevant batch database events and time-series signals for each reactor. With this asset infrastructure built out, the company was able to quickly toggle the analysis among reactors in a single click, as well as view summary metrics, like the total annual deadtime across all reactors.

With the overall deadtime opportunity identified, the chemical maker put in place monitoring activities and prescribed actions to eliminate deadtime, and then shifted its efforts to minimizing the duration of the productive steps in each batch.

2. *Golden Profile Construction for Batch Quality Monitoring.* For any repeated process, modeling future batches based on successful ones can provide significant value. A manufacturer can define success using a variety of metrics, e.g., a

GOLDEN PROFILE

Figure 3. Because dissolved gas concentration significantly correlated to finished product concentration, profile, shown here for three batches, tracks that parameter.

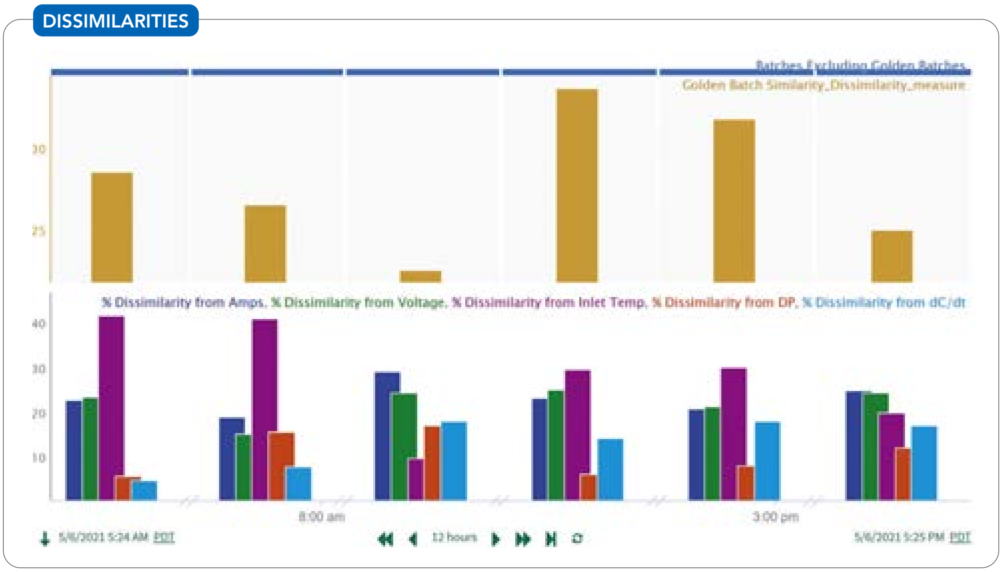

Figure 4. Visualizations of dissimilarity measurements and time-series trends ease identification of root cause of variance and appropriate corrective action.

good quality result from a finished-product lab test, minimal energy expenditure while achieving procedural targets, a short production cycle for a given order quantity, etc. Using metrics from these successful cycles or batches to generate targets and boundary limits for critical process parameters (CPPs) during all events can ensure the success of future runs.

Variability in cycle length or sample frequency can cause difficulties. However, the biggest issue historically has been the static nature of calculated golden profiles. They're built at one point in time based on a set of ideal or optimum cycles — but the golden profile might shift over time with variations in feed composition, sensor drift or process fouling.

Live data connectivity and automatically applied calculations enabled a specialty chemical manufacturer to build dynamic golden profiles for CPPs, with data from newly identified and logically defined golden batches incorporated in near-real-time.

The company identified its golden batches by creating capsules for batches that yielded a high product concentration. These golden batches served as an input into the point-and-click Reference Profile tool in Seeq, which enabled SMEs to calculate average and 3-sigma upper and lower limits for each CPP, including dissolved gas concentration (Figure 3).

The monitoring trends were combined into a dashboard with a date range configured to always show the current batch in production. Flagging of deviations with red capsules at the top of the trend alerted operations staff to take action to keep the batch on specification for the product concentration measurement.

3. *Batch Yield Prediction Based on In-Process Data.* Manufacturers often measure product quality after completion of batches by using lab tests to determine whether finished product is on-specification, off-specification or scrap. Off-spec and scrap products significantly hurt productivity, so maximizing the amount of on-spec product is critical to running a profitable business.

Accurate predictions of future quality measurements can inform process adjustments that help keep the finished product within on-spec limits. However, building suitable models requires knowledge of complex statistics, manual monitoring for deviations, and a feedback loop indicating what knob to turn and to what degree when the model begins to predict an off-spec result.

A specialty polymer manufacturer needed to achieve an average yield above 55% to maintain profitability but below 70% to prevent excessive fouling of downstream equipment. It historically had used a feedback-style control mechanism to keep yield within range, adjusting CPPs like reactor volume, temperature or reactant concentration after an out-of-range yield measurement appeared. At that point, though, unrecoverable raw material losses or downstream fouling already had occurred.

Rather than continue operating this way, the company used an advanced analytics application to build a model to predict the yield of a completed batch based on sensor data as the batch progressed. It utilized point-and-click tools to calculate summary metrics for each signal during each batch, and found that both the maximum reactant concentration and maximum reactor temperature significantly correlated with yield.

The manufacturer developed a regression model to predict yield based on these key performance indicators, and used the coefficients to calculate manipulated-variable control adjustments when an out-of-range yield value was detected. By implementing in-process adjustments informed by the prediction model, the company substantially reduced raw material losses and extended the interval for maintenance to remove fouling from downstream equipment.

4. *Quantifying Batch Dissimilarity from a Golden Batch.* A specialty chemical manufacturer relied on a batch electrochemical process to produce precursors to high-volume synthetic fibers. Specialized equipment inside the reactors often suffered damage when batches didn't run as designed. The

company wanted a better way to spot batches where deviations from established procedures occurred, and to find root causes of the deviations.

It began by using Seeq capsules to identify a few ideal batches. SMEs examined trends of the five manipulated variables in the batch process, looking for the characteristic setpoint changes and ramps specified by the procedure. After differentiating the ideal batches from all others, they took advantage of the extensible tools panel in Seeq to run an advanced algorithm.

The company used the Multivariate Pattern Search Add-On algorithm for Seeq (open source https://bit.ly/3HClgp5) in batch mode to quantify the dissimilarity of each batch from the ideal procedural batches. The algorithm's output included not only the overall dissimilarity percentage but also which signals, and indirectly the execution of which procedural steps, deviated from the ideal.

The algorithm was configured to run on a schedule, updating after completion of each new batch. Visualizations like the one shown in Figure 4 were combined into a report where SMEs could view batch dissimilarity measurements alongside the time-series trends for a particular batch, and then quickly identify the cause of the dissimilarity and correct that step in the procedure before the next batch began.

KEY CONSIDERATIONS

Advanced analytics applications need access to all relevant real-time data sources. These data frequently lack consistent metadata structure and asset association for analysis and, so, require a preparatory contextualization step before analysis. An SME very familiar with the process, in this case batch operations, must perform this data contextualization, even when the advanced analytics application provides some degree of automated data alignment, cleansing and aggregation.

Selecting the right advanced analytics application is important. The wrong tool, in the best case, will add significant time and effort to the analyses; in the worst case, it will yield results that are confusing and break down trust between information technology (IT) and operational technology (OT) teams.

Even with effective data wrangling and a suitable application, finding the best solution in these types of complex analyses often requires an iterative approach that takes time. Also, a company must dedicate one or more SMEs to working with the selected advanced analytics application; these types of experts often are in short supply.

A typical misstep occurs when those unfamiliar with the process use artificial-intelligence or machine-learning algorithms in a silo. Another issue arises when the selected tool requires a high level of IT expertise; this is very hard to find among SMEs.

A better approach is to maximize the productivity of a company's SMEs by giving them a tool that doesn't require extensive IT expertise but does empower them to directly interact with the data of interest in an iterative fashion. ●

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CONTINUOUS LEVEL MONITORING BOLSTERS SAFETY

Guided wave radar transmitters quickly detect hydrocarbon spills and leaks in secondary containment areas at Antwerp site | By Phil Lever and Jimmie Söderström, Emerson

FAILURE TO identify and prevent spills and leaks from large hydrocarbon storage tanks at refineries and terminals can have catastrophic consequences — as the massive explosion and fire in 2005 at the Buncefield oil storage terminal in the U.K. exemplifies. It resulted in more than 40 people suffering injuries as well as extensive property damage. (For details, see: "Buncefield: Why did it happen?" https://bit.ly/3pUnGZh.)

Therefore, it is essential for organizations to implement robust safety measures that minimize risk and comply with the two key global standards relating to overfill prevention. The International Electrotechnical Commission's IEC 61511 standard "Functional safety — Safety instrumented systems for the process industry sector" provides best safety practices for the implementation of a modern overfill prevention system (OPS) in the process industry. The American Petroleum Institute's API 2350 standard "Overfill Protection for Storage Tanks in Petroleum Facilities" details best safety practices in the specific application of non-pressurized above-ground large petroleum storage tanks.

These standards recognize that minimizing the risk of spills and leaks requires employing independent protection layers (IPLs), as depicted in Figure 1. The basic process control system (BPCS), which monitors and regulates the production processes to ensure they are running smoothly, forms the primary layer of protection. If the BPCS is functioning correctly, the other layers will not need to become active. The second layer of protection is the OPS, which must remain separate and independent of the BPCS to provide redundancy. The OPS should stop an overfill from occurring if the BPCS suffers a failure or problem.

The third layer of protection is a secondary containment area, to minimize the consequences should an overfill cause spillage or tank damage result in a leak. When storage tanks are being filled and emptied daily, leaks often can go undetected given the huge volumes of product. However, even a small leak, over time, can lead to a substantial accumulation of hydrocarbons in the containment area; because this accumulation usually is spread over a large area, it can go unnoticed during visual inspection rounds. In the case of hydrocarbon storage tanks, the containment area typically is an underground pit or dike surrounding the tank into which liquid goes to prevent further spreading. In the unlikely event that all these layers fail to prevent or contain an overfill, there is an emergency response layer, which involves alerting the fire department or other appropriate service.

TANK OVERFILL PROTECTION

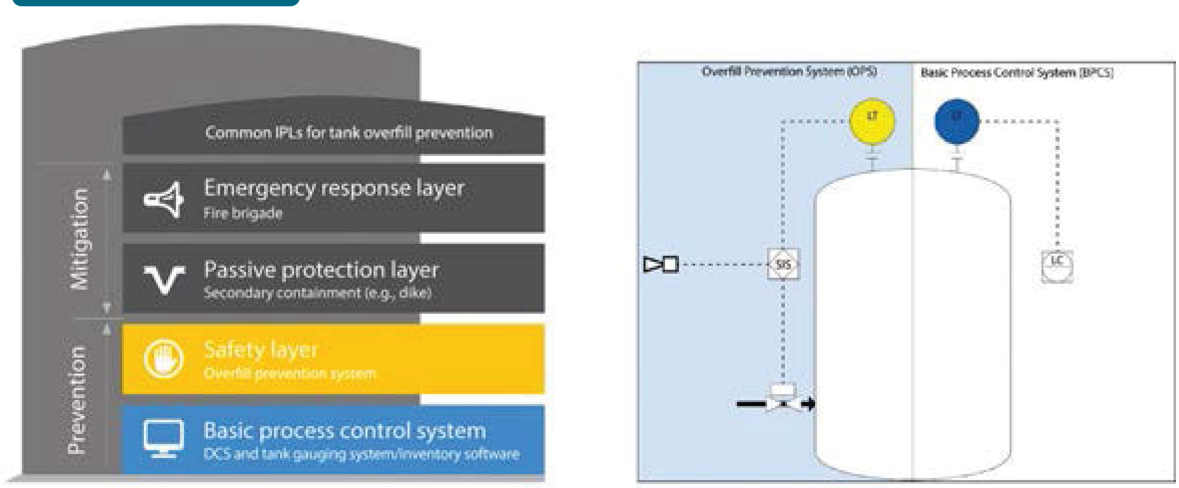

Figure 1. Properly addressing the risk of spills and leaks requires employing a series of independent protection layers (IPLs).

ENHANCED PROTECTION

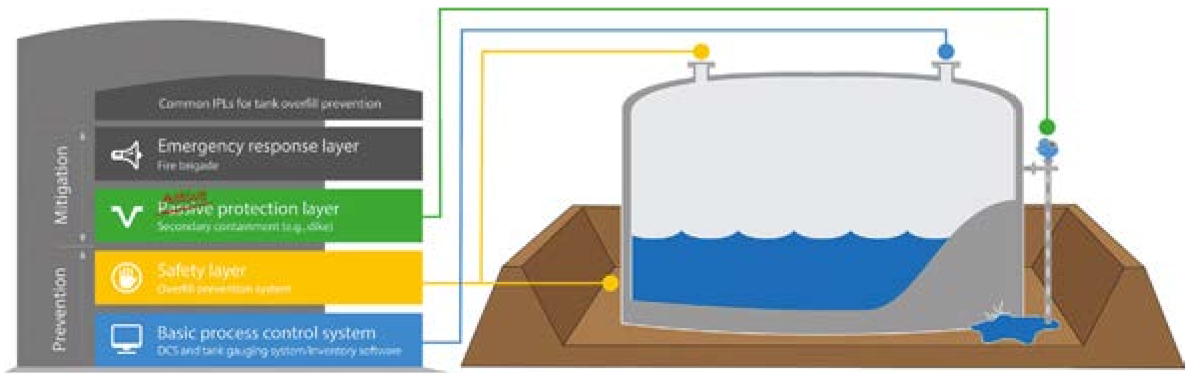

Figure 2. Automated monitoring of secondary containment areas makes this layer of protection active rather than passive.

MONITORING METHODS AND REQUIREMENTS

Historically, the monitoring of containments areas has involved visual inspection by personnel during manual rounds of the site. However, this method is time-consuming, places workers in hazardous areas, and can result in spills or leaks going unnoticed for some time — which then can delay essential repairs and clean-up activities and risks a vapor cloud spreading across the facility and igniting, as happened at Buncefield.

While the IEC 61511 and API 2350 standards cover overfill prevention measures inside tanks, many countries and local authorities have their own codes of practice relating to the containment area outside the tank. The conditions outlined within these codes of practice can vary but typically include requirements relating to the volume of liquid the containment areas must hold as well as the construction materials for them. However, no regulatory requirement forces companies to install level measurement instrumentation to detect spills and leaks through continuous monitoring of containment areas. Nevertheless, some organizations recognize the valuable safety benefits this additional layer of protection (Figure 2) provides and require automated monitoring of containment areas at their sites.

TECHNOLOGY SELECTION

This was very much the case for a global oil and gas company that wanted to install continuous level monitoring in the secondary containment areas around hydrocarbon storage tanks at its facility in Antwerp, Belgium, to fortify its protection against the potential consequences of leaks. The firm sought instrumentation that could detect leaks as quickly and reliably as possible, to increase site and personnel safety. This ruled out basic point-level-detection devices such as vibrating fork switches because secondary containment areas are open to the elements. So, rainwater as well as hydrocarbons can accumulate there; point level detectors cannot distinguish between the two liquids.

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Initially, the company installed hydrocarbon detecting sensors. However, these probes were not sufficiently robust; short circuits regularly caused false fire alarms.

Thus, the firm sought alternatives from several leading automation technology vendors. Its requirements included the capability to cover the full containment area, to measure an interface between oil and water, and to detect hydrocarbons from a thickness of 60 mm. The technology also would have to be unaffected by weather changes in the containment area and be able to operate reliably whether the area was dry, contained one liquid (water or hydrocarbon), or two liquids (water and hydrocarbon, requiring both level and interface measurements). The company also wanted wireless signal capability, due to the limitations of its existing cabling infrastructure, along with the possibility of adding further measurement points in the future.

After considering the various proposals, the company selected Emerson's Rosemount 5300 Level Transmitter, which uses guided wave radar (GWR) technology. In September 2019, it purchased 44 units for use on all secondary containment areas at the Antwerp facility (Figure 3). The installation also included a new WirelessHART network, with each area equipped with an Emerson Wireless 1410D gateway with 781

Field Link antenna, enabling the signal from the measurement points to go directly into the distributed control system (DCS).

THE BENEFITS OF GWR

In GWR technology, low energy microwave pulses are guided down a submerged probe. Microwaves reflected back to the transmitter from the surface enable level measurement. Because a proportion of the emitted pulse continues down the probe, the technology also can detect an interface, which makes it ideal for identifying the presence of oil as well as water in containment areas. In addition, GWR transmitters are very easy to install and do not require compensation for changes in the density or conductivity of the liquid. The technology is practically unaffected by buildup, eliminating the need for recalibration. As there are no moving parts, maintenance requirements are very low, reducing operating costs, while advanced diagnostics ensure quick alerting of operators to any degradation in performance. Although not used in this specific application because of the existing cable infrastructure, the availability of wireless GWR transmitters can help minimize the costs of installation by removing the need for data or power cabling.

GWR transmitters are proven and widely used in interface level-measurement applications. However, the upper liquid layer typically must be between 50 mm and 200 mm, depending on the liquid properties and antenna selection, to enable the device to distinguish between the signals reflected from the two different liquids. With containment areas being very large, that can mean a considerable amount of hydrocarbon leakage would take place before it was identified by the device.

However, an important consideration for the company was detecting the presence of hydrocarbons in the containment area much sooner, to significantly reduce risk and increase safety. This was a key reason for the selection of the Rosemount 5300. Its enhanced functionality permits reducing the minimum detectable thickness of the upper liquid to just 25 mm — thanks to Emerson's Peak in Peak interface algorithm, which allows the transmitter to detect signal peaks that are closer together without having to decrease its signal bandwidth, which would reduce its high sensitivity.

Because containment areas are open to the elements, there always is the potential for materials such as leaves or dirt to get into them, and for buildup eventually to stick to a transmitter's probe, which can affect measurement consistency. To overcome this challenge, the Antwerp installation uses a large coaxial probe with no internal spacers, which makes it more resilient against clogging. This enhancement also provides protection against exposure to rainwater, which can impede the transmitter's signal strength and impair the robustness of the measurement.

A dead zone at the very bottom of the probe typically limits the measuring range of GWR transmitters. This presented a challenge to detecting the presence of hydrocarbons in the containment area when the liquid level did not reach the bottom of the probe. However, a redesign of the large coaxial probe's centering disk has enabled minimizing the lower dead zone in the Rosemount 5300 to just 20 mm for water and 50 mm for hydrocarbons — a 50% reduction from what was previously possible.

INSTALLED LEVEL TRANSMITTER

Figure 3. Site is using 44 of these transmitters for automated monitoring of secondary containment areas to provide greater visibility of potential leaks.

IMPRESSIVE RESULTS

While the company already had an overfill prevention system in place, the automated continuous monitoring of the previously passive safety layer now is providing greater visibility of potential leaks, which previously was not possible. The ability to detect a very thin hydrocarbon layer enables quicker identification of leaks and, thus, doing necessary tank repairs and clean-up activities sooner. This, in turn, reduces emissions of volatile organic compounds, minimizes risk of soil and water pollution, and decreases the chance of a vapor cloud forming and spreading across the facility. In addition, use of automated monitoring means personnel no longer must visit hazardous areas to perform visual inspections and, instead, can focus on value-adding tasks.

The success at the Antwerp facility has spurred the company to explore with Emerson opportunities to introduce continuous level monitoring in secondary containment areas at other sites globally. ●

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Cope With Viscosity Changes

Revised product requires rethinking of both the pump and reactor

THIS MONTH'S PUZZLER

Our research team has changed the flow characteristics of a product. By my measurement, the viscosities of the ingredients now are in the 100-cP range, while previously 30-cP was the maximum. The researchers still are monkeying around with the batch mix schedule, so I don't have a final value on the flow properties.

Thankfully, we use gear pumps for ingredients. The product ran about 20 cP, which allowed us to rely on our old 80-gal/min magnetic-drive centrifugal pump to send the product, which is a weak slurry, to a filter press. The total dynamic head is 148-ft-WC (about 64 psi). This pump is easily cleaned-in-place. Space around the 3,000-gal reactor is very tight, preventing me from installing a new pump off the suction line of the current pump. I also am concerned about the agitation. I have to be ready to change this reactor to the new product within a few weeks. What are your thoughts on the product delivery pump and reactor? Can we successfully make the product?

TUNE THE PROCESS FIRST

Because the problem statement lacks sufficient information about the reactor, potential variation in the product viscosity, and equipment spacing at the site, I only can offer general suggestions. Consider the following issues:

1. Typically, centrifugal pumps are not a proper choice for reliable operation with liquids above 100 cP. For moderate to high viscosities, choices include gear, lobe, piston and progressive cavity pumps. Of course, each of these has pros and cons. For instance, liquids with abrasive particulates would cause wear of gear or piston pumps. If you anticipate wide variations in product viscosity, a progressive cavity pump might be a good option.
2. Because space is limited in the immediate vicinity of the reactor, the suction line to the new pump would be longer. This could cause low suction head at the pump, which, in turn, would be problematic for a piston or progressive cavity pump. A gear pump, on the other hand, is relatively less sensitive to low suction head. In the event of low suction head, see if you can increase pressure in the reactor without affecting product quality.
3. Take into account the flow variability of the product. If you anticipate large variations in the product flow, sustained operation at low flow rates will cause excessive wear of a progressive cavity pump. So, at low flows, consider spillback for such a pump.
4. If you do not expect product viscosity to go significantly above 100 cP, an option worth thinking about is a turbine agitator with high turbulence. Typically, mixing liquids above 600 cP calls for laminar impellers. Because the mixing energy dissipates a short distance from the edge of the blades, these blades would need to extend to a good part of the diameter of the vessel. Also, consider variable speed.
5. In view of the multitude of tasks you need to accomplish in a relatively tight time schedule, get outside help early, including from mixer and pump vendors. Keep the project group and operations and maintenance folks posted on the progress and problems.
6. Note: A *CP* column "Pumps: Get into the Thick of Things," https://bit.ly/3o2Rpyv, by Dirk Willard offers practical pointers on the qualitative aspect of selecting pump types for the viscosity spectrum of liquids.

GC Shah, consultant
Houston

THINK RADICALLY

Given how viscosity increases the horsepower requirements of centrifugal pumps, you have two options: raise the product temperature or dilute the product. Dilution hurts the production rate and increases the utility cost in drying. Besides, it might negatively affect the system downstream from the heat exchanger; assessing this could involve a heat-and-energy balance of the entire process — upstream of the exchanger to the final product.

Raising the temperature might squeak you by if the pump motor suffices. Get some viscosity data at temperature, then discuss these

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Workflows Matter

Effective communications and verifications are essential for project success

Ignoring the cumulative impact of changes leads to many failures.

THE ECONOMICS of chemical manufacturing usually favor production in fewer but larger plants rather than in many smaller ones. Larger facilities require larger organizations and multiple-discipline teams to run effectively. This ratchets up the importance of effective workflows for handing off and reviewing elements of projects. Over-the-fence engineering where work is done in silos with no knowledge or consideration of the actual plant objective can create difficulties. One key contributor to problems are specialists who don't grasp the full impact of their changes. Another common culprit is a rushed workflow that lacks sufficient time for review and verification of the correctness of steps. Every job has a "right" schedule for going from idea to implementation. To understand this better, we must look at the overall procedure used to get from an idea to an implementation.

The idea may range from building a completely new plant to making a modest modification to a current facility. Here, we'll focus on smaller changes, i.e., repairs or replacements to an existing plant. Even minor modifications can involve extensive lead time. Figure 1 summarizes the general workflow for making a change from inception of the project to final implementation and review of how well it worked out. I think four points deserve emphasis.

First, most work, especially in larger and more-complex plants, involves disparate groups: process design (to define what needs doing); mechanical design (for how to build it); purchasing (to buy and determine the expected delivery of necessary components); vendors (to supply these components); constructors (for bringing and assembling hardware and equipment on site); and others. Getting all these groups to work well together hinges on good teamwork.

Engineers whose skills extend beyond their particular area of responsibility can play a key role in making teamwork efficient. Such engineers have the knowledge to successfully balance competing priorities. Skills in overlapping areas don't appear by magic. For example, it takes time for an engineer to get design, operations and construction experience. Likewise, developing expertise on chemical, mechanical and electrical engineering requirements is not a quick process. These more-experienced personnel are critical; they enable changes to meet reasonable schedules because smarter trade-offs are made sooner.

At every step, decisions may change the equipment. So, they need review by groups responsible for previous steps to ensure the alterations remain consistent with the final objectives. Ignoring the cumulative impact of changes leads to many failures. All these feedback-and-check decisions take time. Any work requiring a plant shutdown should have a cut-off date for every step. Management must ensure the cut-off dates for work are adhered to as much as possible. A "good" solution that's on schedule typically is much better than the "best" solution that's late.

Second, as the project progresses, the ability to change the schedule and cost decreases. Once the plant is about half-way along the workflow (Step 4 in Figure 1), the best-case minimum cost

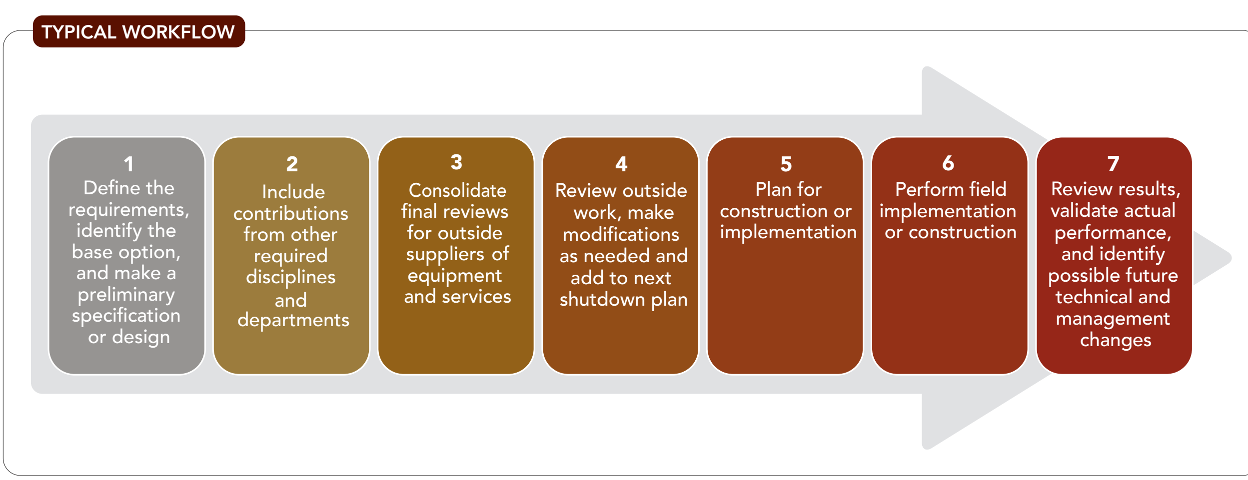

Figure 1. Verifying that changes do not undermine achieving the final objective is crucial.

and schedule is fixed. (The cost estimate still could be wrong, though.)

Third, the largest cost risk occurs once the workflow is half-way through. Poor planning and field execution move costs up from the best case. Extensive analysis shows the largest factors driving cost overruns for an average project are labor productivity and labor costs. Minimizing these risks requires good planning.

Fourth, the final step is validation of upgrades and changes made. (As a plant troubleshooter, I've seen too many problems that remain after multiple "fixes.") This step confirms the required technical result has been achieved. Always remember the most-expensive repair is the one that does not work! Failures often stem from not identifying the real source of a problem or from systemic shortcomings in implementing an effective solution.

Effective teamwork and efficient feedback and review can help optimize workflow and spur project success.

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PROCESS PUZZLER

Continued from p.32

data with the pump vendor, and run a check against viscosity correction curves. You might be alright. If not, you might try air dilution to thin the liquid even more or a booster pump. An air-driven trash pump is more tolerant and might serve as a temporary patch for the problem of moving the product by bypassing the old pump. One word of caution on introducing air to a liquid stream: you gradually will damage the pump no matter how carefully you introduce the air.

Next, let's turn to the agitator. I wonder if the people in research considered this. If you increase viscosity by a factor of three, reaction times will likely lengthen unless you take drastic steps. I assume you have budget constraints; money blows most problems out of the water. Going with my assumption: 1) maximize the shaft speed; 2) if possible, premix ingredients before adding to the reactor, especially solids but also liquids; 3) decrease the reactor temperature to delay the reaction until mixing is complete and then heat up to pump product; ªnd 4) dilute to reduce viscosity and promote mixing.

As usual, R&D boxed you into a corner. This is why engineering has to be integrated into product development. Good luck. If you escape, you're a hero.

Dirk Willard, consultant
Wooster, Ohio

JUNE'S **PUZZLER**

We make an ethoxy compound using a water-based process. Our evaporator is supposed to operate continuously but the operators run batches in manual — with a lot of baby-sitting. The operators complain the level switches and level transmitter don't work as advertised. So, instead, they judge level by looking through three sight gauges. This requires distinguishing wet solids from mere splatter; new operators must learn the difference between actual level and a dirty glass. The design engineer somehow thought a 2-in. pipe made sense for pumping the product, a wet slurry.

I looked at the material balance. Continuous processing is possible, if the flow rate were 10 gal/min through a pipe where the solids settle out at 4 ft/sec — and with working level measurements! Obviously, a 2-in. pipe forces us to dump the product into the dryers in loads measured by estimating the level using the sight gauges.

Temperature control is nearly impossible. Measurements by a resistance temperature detector vary as much as 10°F from sample temperatures and readings with infrared guns.

What can we do to make this a continuous evaporation train? Should we do this? Is there anything we can do to make this process less labor-intensive as a batch process?

Send us your comments, suggestions or solutions for this question by May 13, 2022. We'll include as many of them as possible in the June 2022 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.

Pulse Cleaner Ensures Spotless Valves

The ThinkTop pulse seat clean helps quickly and effectively make drain valves spotless while reportedly delivering savings of up to 95% in cleaning-in-place liquid. A programmable logic controller signal triggers this automated valve-position feature. Short bursts, or pulses, drive the valve cleaning process, activating the valve when shear forces peak. Each position-based pulse takes less than a second, preventing pressure shocks in the system. The pulse creates high turbulent flow as the liquid passes through the narrow gap between the valve housing and valve seat, effectively removing all residuals for spotless drain valves. The unit also verifies that valve cleaning has been completed.

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The CA900 titration analyzer automates routine alkalinity measurement for monitoring, balancing and maintaining alkaline and pH levels in industrial process water applications. Titration analysis calculates alkalinity by dispensing titrant fluid into a reaction cell while monitoring the pH level to its end point. The unit typically performs a single alkalinity measurement per analysis cycle. Its standard program sequence consists of a cleaning cycle, sample acquisition, monitoring of pH, the addition of the titrant fluid, mixing the fluid, calculation of results and data storage. The desired frequency of analysis between cycles can be easily modified to the requirements of the user's process.

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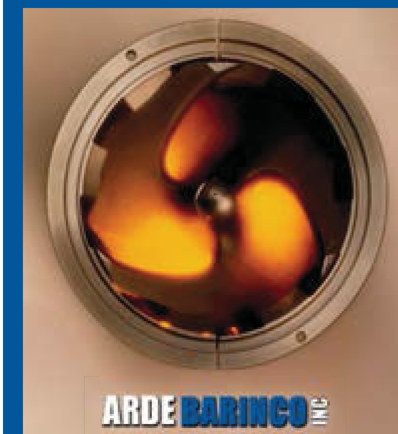

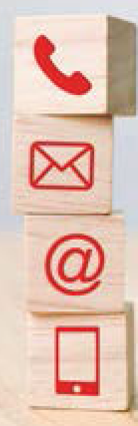

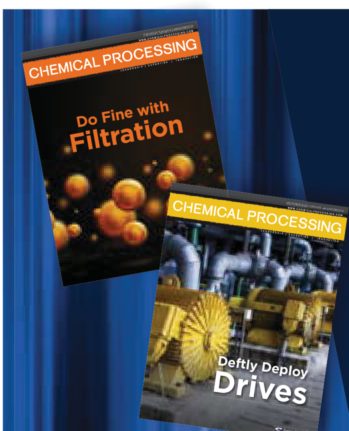

Tool Takes Aim at "Forever Chemicals"

Powerful mass spectrometer is helping identify complex PFAS compounds in the environment

Results show most people in the United States have been exposed to some PFAS.

SOMETIMES CALLED "forever chemicals" because they don't break down in the body, per- and polyfluoroalkyl substances (PFAS) have been used by industry and in consumer products for nearly 80 years. Thousands of PFAS are present in our soil, water, food — plus household cleaning chemicals, personal care products and more.

Concern about PFAS being widespread in both production and use — along with their ability to move and persist in the environment, prompted the Centers for Disease Control and Prevention (CDC), Atlanta, to perform numerous surveys; results show most people in the United States have been exposed to some PFAS.

Most known exposures are relatively low, but some can be high, particularly when people are exposed to a concentrated source over long periods of time. Certain PFAS chemicals can accumulate in the body over time.

According to the U.S. Environmental Protection Agency (EPA), current scientific research suggests exposure to high levels of certain PFAS may lead to adverse health outcomes. The agency says research is still ongoing to determine how different levels of exposure to different PFAS can lead to a variety of health effects. Decreased fertility, developmental delays, increased risk of certain cancers and interference with the body's natural hormones are all possible effects from exposure. (For more on the EPA's efforts, see "PFAS: One Size Does Not Fit All," https://bit.ly/3MNK54y.)

Research also is underway to better understand the health effects associated with low levels of exposure over long periods of time, especially in children.

The EPA Council on PFAS, established in April 2021, has been developing a strategy and associated timelines to protect public health and the environment from the impacts of PFAS. Its strategy includes five principles: understanding the lifecycle of PFAS; getting upstream of the problem by preventing them from entering the environment in the first place; holding polluters accountable; prioritizing protection of disadvantaged communities; and ensuring science-based decision making always is used.

However, health effects associated with exposure to PFAS are difficult to specify considering the sheer number of these chemicals and potentially varying effects and toxicity levels; most studies focus on a limited number of better known PFAS compounds.

Now, researchers at Colorado State University (CSU), Fort Collins, Colo., are using a powerful chemical analysis tool — the 21 Tesla Fourier-transform ion cyclotron resonance mass spectrometer (21T FT-ICR MS) in the NSF-funded National High Magnetic Field Laboratory (MagLab) at CSU's Department of Soil and Crop Sciences — to help unravel the complexities of PFAS. CSU says the 21T FT-ICR MS can differentiate between individual chemical compounds more accurately than any other instrument.

"It's powerful enough to be able to see all of these different PFAS molecules, but it's also powerful enough to pick them out of environmental samples that contain many thousands of natural compounds," says Robert Young, a CSU alumnus and director of the Chemical Analysis and Instrumentation Laboratory at New Mexico State University, Las Cruces, N.M.

The samples analyzed for their recent study came from PFAS-contaminated sites, and each contained about 10,000–30,000 compounds — numerous human-made chemicals against a background of natural organic material. The MagLab's instrument measures mass so precisely the researchers can determine the elemental makeup for many compounds present.

"We're not only attempting to resolve the chemical complexity of PFAS, we're also opening doors for researchers who want to look at treatment, environmental fate and transport, and toxicology," notes Jens Blotevogel, a research assistant professor in CSU's Department of Civil and Environmental Engineering. "This is giving people the strongest possible magnifying glass to unravel these processes."

The researchers also want to study how the compounds change in the environment. Some, they believe, may go from harmless to harmful when they degrade or are mixed with other compounds.

"The long-term goal is to help identify these things so other people know what to look for. As soon as we know what to look for, we can focus on understanding the health and environmental impacts, and prioritize treatment or regulatory solutions," adds Young.

The team is cataloging their findings in a database of PFAS compounds so others can utilize their results. They have published a PFAS library with a report detailing the new analytical method based on their work to date for the U.S. Department of Defense's Strategic Environmental Research and Development Program.

More about their work is published in a recent issue of *Environmental Science and Technology*.

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