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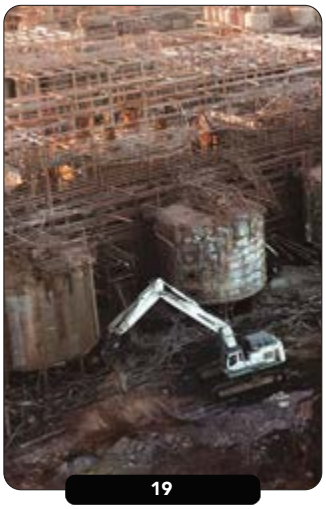
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BPA WORLDWIDE

Please Recycle This Magazine

Folio Editorial Excellence Award Winner

Repurposing Can Make Sense

A former pharmaceutical plant points up the possibilities

PROCESS PLANTS generally operate for many decades, if not longer. However, pressures, either economic, technical or social, eventually doom many sites. The era when a manufacturer could simply abandon a facility without concern for what it left behind thankfully is long gone in the United States and elsewhere. Instead, an operating company faces all sorts of challenges in dealing with these inevitable shutdowns. As this issue's article "Safely Decommission and Decontaminate Plants," p. 19, stresses, properly preparing a site for demolition (or even mothballing if some prospect of a future restart exists) demands careful organization and execution.

While many chemical plants sprawl over large plots and keep most production operations outside, some facilities, including many that make pharmaceuticals, largely locate their processes inside buildings. Such sites, after decommissioning, decontamination and removal of process equipment, may secure surprising second lives.

One such case that comes to my mind is the former factory of Pfizer, Inc., at 630 Flushing Avenue in Brooklyn, N.Y. The company was founded in that area in 1849, and built a massive (about 600,000 ft^2) eight-story complex there in 1940. Pfizer ceased operations at the site in 2008.

The age of the plant undoubtedly undermined its long-term viability. In addition, like many inner-city factories, the surrounding neighborhood had deteriorated over the years before the shutdown. However, the ongoing revitalization of previously blighted areas of Brooklyn has sparked increasing interest in the complex. Acumen Capital Partners, Brooklyn, bought the complex in 2011 and, since then, has fully renovated the space and lured a diverse variety of tenants to the site. Right now, occupancy exceeds 90% and more than 100 tenants call the complex home, says Ashish Dua of Acumen.

For instance, notes Dua, the hygienic features found in certain areas such as laboratories, e.g., washable floors and walls, makes those spaces attractive for artisanal food manufacture. CookUnity, a service that prepares gourmet meals for some noted chefs for direct delivery to consumers across the United States, now occupies about 80,000 ft^2 of former laboratory space for its kitchens.

Also in the complex is Silver Spoon Animation, a firm that does real-time animation and virtual production for films, television, games, etc. In addition, the Trapeze School of New York operates a year-round facility there that offers lessons on flying trapeze, trampoline, aerial hook and other acrobatic activities.

More down-to-earth tenants include Square Roots, an urban farming initiative, and a number of nonprofit groups.

Even the parking lot has gotten a fresh use. Square Roots operates its farming campus there. In addition, Revel, a Brooklyn company focused on electric vehicles, chose the site for the largest universal fast-charging depot in the country. Open 24/7, this "superhub" contains 25 75-kW units that can fast charge any brand of electric vehicle.

Granted, Brooklyn attracts a somewhat more eclectic variety of businesses than other areas, but the success in bringing new life to the former Pfizer plant still shows that repurposing often deserves consideration. After all, reuse not only preserves physical assets but also bolsters the economic vitality of an area by providing new jobs to replace at least some of those lost. ●

Shutdown sites may secure surprising second lives.

MARK ROSENZWEIG, Editor in Chief
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What's New(s)?

Stay up to date on the latest developments and more

Sometimes, you find yourself part of the news cycle.

PART OF covering the chemical industry includes keeping on top of news that impacts our audience. From trends that can help facilities excel to mergers and acquisitions that can potentially impact supply chains and competitive position, we keep our ears to the ground and work to get information posted to our website and included in our enewsletters to best serve readers. (See: www.chemicalprocessing.com/industrynews or sign up for the enewsletters here: www.chemicalprocessing.com/newsletters)

Sometimes, you find yourself part of the news cycle. In late April, we learned the family which owns Putman Media, the publisher of *Chemical Processing* as well as a number of other trade magazines, sold the company to Endeavor Business Media, a large business-to-business publisher based in Nashville, Tenn. Putman Media started in 1938 by publishing its first magazine — the same one we now call *Chemical Processing*. It has been a small-but-mighty company filled with editors, content creators and sales staff who always roll up their sleeves to get things done. Apparently, that's attractive to the likes of bigger publishing companies.

"We are pleased to welcome the Putman Media family to Endeavor Business Media and are excited to expand our reach in the manufacturing market with these highly respected brands and the teams who work on them," said Chris Ferrell, CEO of Endeavor Business Media. "We are committed to growing our information and marketing solutions offerings for the engineering, automation and manufacturing professionals that Putman Media has served for the last 80 years and are honored that Endeavor has been trusted to carry these brands forward."

"The acquisition of Putman Media by Endeavor is an exciting opportunity for these market-leading brands. Leveraging the resources, audience reach and industry expertise across Endeavor's existing portfolio provides substantial growth opportunities so that we may continue to serve our readers and customers with the highest quality of content, information and solutions," added John Cappelletti, now former CEO and owner of Putman Media.

This acquisition will be seamless for our audiences — it's business as usual for us — and the future promises good things with the added resources a bigger company provides.

And speaking of good things, our Process Safety With Trish & Traci podcast has a bevy of fans. Trish Kerin, director of the IChemE Safety Centre and the "Trish" in Trish & Traci, recently presented at the 18th Global Congress On Process Safety. She informs us that many attendees went out of their way to speak to her about the podcast and thanked her for its terrific content. We are on episode 33 and we've covered everything from cybersecurity issues to lessons learned from major process-safety incidents, including Fukushima, the Longford Gas Explosion, Deepwater Horizon and Chernobyl. We also discuss safety indicators, the importance of partnering with first responders and Delta HAZOP among other important topics. You can access the podcasts here: https://bit.ly/CP_Podcasts or you can subscribe to them for free on iTunes, Google Podcasts, Stitcher and Spotify.

Regardless of parent company, our aim will always remain the same: To deliver information that matters to our audience — from articles to webinars and all the news and podcasts in between. ●

TRACI PURDUM, Executive Digital Editor
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Make a Walkdown an Essential Step

Inspecting operations can provide invaluable insights

DOING SOMETHING at a time that will avoid notice is an old ruse. A steel mill I once worked at in Turkey regularly rumbled their coke beds at 4 am. Another company I worked at scheduled startups using new packing during the evening when blowing rust and acid out of the system was less obvious.

Other, not nefarious, activities also benefit from being done at odd hours. For instance, conducting walkdowns, i.e., physically inspecting how a process and equipment are running, between shifts and at unusual times is the best time to catch irregularities in operations.

I strongly believe walkdowns are crucial to keeping on top of maintenance and operations. Such inspections shouldn't be on a schedule or deemed the private turf of a specific department. Typically, I do two-to-three walkdowns a week, taking a total of about four-to-six hours. I carry a flashlight and a smartphone, and use a photo editor and video software. Naturally, some people at the plant won't like recurring reminders about ongoing problems. So, the person doing the walkdowns likely will need a thick skin — and may lose a few friends.

The reaction to a request to conduct walkdowns can be telling. If the idea doesn't get support, I suggest looking for another job. Being told walkdowns are limited to a select few indicates, to me at least, information is siloed for political reasons.

Assuming you get the support you need, what should you do on a walkdown? First, have patience — listen for unusual noises and look for things out of place. I stare at equipment for about a minute and take in the whole scene. Watch what people are doing or not doing. Look up and down. Then, start taking pictures and videos. Videos not only can show movement, such as steam escaping from a failed trap or a swaying unsupported pipe, but also are useful for capturing sounds, like a bearing screaming.

Lighting is important. Typically, I will take photos in room light, first from a distance and then close up. If the photo is grainy, I put the flashlight just outside the frame and reshoot, making sure the photo isn't over-exposed.

Take two shots of important views. The camera may blur one of them. Anchor your wrist on a non-moving wall or something rigid whenever you can. Move around: take shots from the sides, top or even bottom if they clarify the problem. In addition, snap photos of the surroundings, to help later in identifying the location. Ensure the smartphone's clock is set to the correct time; you need to record the actual time a shot was taken. Don't be shy about photographing things the plant got right.

Pictures alone aren't enough. While a picture may say a thousand words, a video paints it across the sky! Nothing shows the problems with a rotating dryer or wash bed like a video. I climbed to the top of a plant in the winter to show all the steam wasted; I zoomed in, resting the smartphone on a handrail to brace it. Hit the pause button and then move the focus to another area. The first frame in the video should center on the equipment you wish to identify; I hold that shot for about three seconds. Then, pause, and move to whatever got your attention. You may have to change position to show the problem in a tighter frame or from a different angle. Use a flashlight if the photo you took earlier appears grainy.

I eventually transfer the pictures and videos to an external drive to free up space on the smart phone and provide long-term storage.

While a picture may say a thousand words, a video paints it across the sky!

CHECK OUT PAST FIELD NOTES

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

So, what should you look for? Here's a short list: 1) steam traps with a continuous flow of steam; 2) poorly supported pipe; 3) equipment vibration and noise; 4) filled sewers; 5) leaks; 6) unplugged valves; 7) broken grounding; 8) unsafe or unproductive practices; 9) poor housekeeping; 10) changes in meter readings; 11) damaged equipment; 12) poor repairs; 13) mislabeled equipment; 14) corrosion; 15) torn-down equipment — never pass up a chance to look at the guts; 16) open manways; 17) impaired infrastructure, e.g., steel, concrete, etc.; and 18) damaged electrical boxes and conduit.

I've worked at companies that required every employee to perform a walkdown. I consider that a great idea.

DIRK WILLARD, Contributing Editor
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Surface Layer Improves CO_2 Capture

Novel membrane method increases selectivity with little reduction in permeability

RESEARCHERS AT North Carolina State University (NCSU), Raleigh, N.C., and SINTEF Industry, an independent research organization in Trondheim, Norway, have developed a new membrane technology that allows for more efficient removal of carbon dioxide (CO_2) from mixed gases.

Their development addresses a longstanding challenge for such membranes — the trade-off between permeability and selectivity; the higher the permeability, the lower the selectivity, resulting in relatively less CO_2 captured.

The research team addressed this problem by growing chemically active polymer chains that are both hydrophilic and CO_2-philic on the surface of existing elastomeric polydimethylsiloxane (PDMS) and glassy polytetrafluoroethylene (PTFE AF) membranes. This increases CO_2 selectivity and causes relatively little reduction in permeability.

To demonstrate the new membranes' capability, the team looked at mixtures of CO_2 and nitrogen, and mixtures of CO_2 and methane.

"In short, with little change in permeability, we've demonstrated we can increase selectivity by as much as about 150 times," says Marius Sandru, senior research scientist at SINTEF. "So we're capturing much more CO_2, relative to the other species in gas mixtures."

More details appear in the journal *Science*.

"The CO_2-selective polyamine surface-grown layer is strongly chemically bound to the substrate surface and becomes an integral part of the PDMS or PTFE AF membrane. This layer is not just simply physically adsorbed or coated to form a new and separate layer, as is the case of conventional thin-film composite CO_2 separation membranes, thereby completely eliminating the possibility that the CO_2-selective layer can be washed away or delaminate. … We performed long-term testing without significant performance drop: up to several thousand hours at various pressures (1.2 to 5 bar), various temperatures (25 to 55°C) and various humidity levels of feed gas," says Rich Spontak, a professor of chemical and biomolecular engineering, and materials science and engineering at NCSU.

Engineering the surface of these membranes to improve selectivity does increase the cost, admit the researchers, who emphasize the modified membranes will still be more cost effective than "premium" membranes on the market. "The high-permeability substrate membranes we selected (namely, PDMS and PTFE AF) are already commercially available at low cost. The surface modification is facile and scalable without requiring expensive chemicals," elaborates Spontak.

The research offers opportunities to explore surface treatments for other separations, but Spontak

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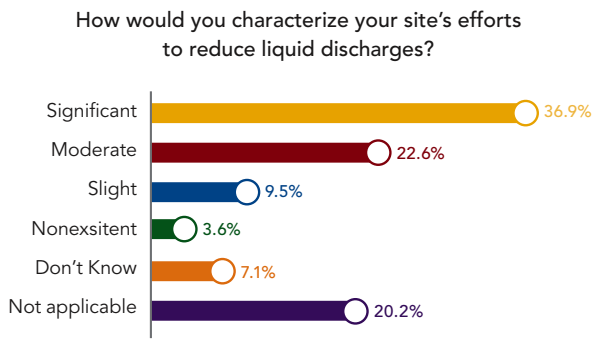
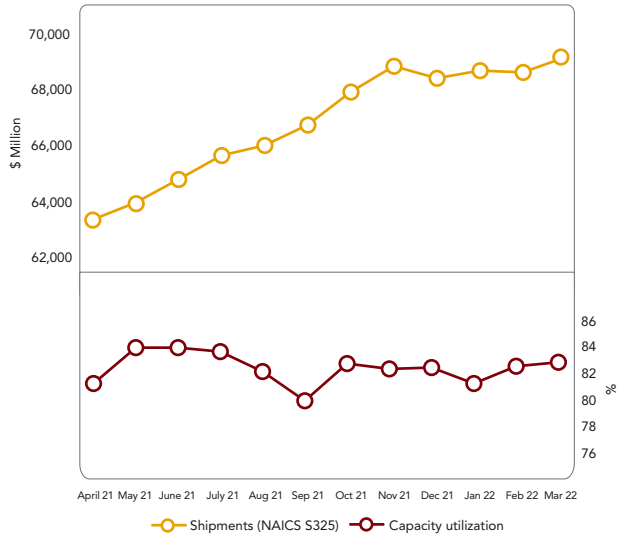


Nearly 60% of respondents termed reduction efforts moderate at least.

ECONOMIC SNAPSHOT



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

says his team is focused primarily on CO_2 separation. "Since good CO_2/N_2 separation typically translates to good CO_2/H_2 separation and with a rekindled interest in an H_2 economy, this is an important direction to consider in the near future," he adds.

"The concept is new and we anticipate it will take time for industry to realize the value of our contribution. We believe the most likely road for commercialization and implementation of these surface-functionalized membranes will involve a large membrane producer to license SINTEF intellectual property or other modalities," reckons Spontak.

To implement the technology on a larger scale, automated industrial production of the surface-functionalized membranes is needed. "Other considerations that must be addressed in next-stage upscaling include membrane module design, packing density and optimum operational conditions. Topics such as these require further investigation and analysis," Spontak notes.

At the present time, Sandru and SINTEF continue the work of upscaling the membranes first for CO_2/N_2 separation from flue gas, as well identification of other suitable CO_2 mixed-gas streams to separate (such as CO_2/H_2). ●

Organic Catalyst Boasts Big Benefits

AN ENZYME-MIMICKING catalyst opens a new route to important organic molecules such as glycolic acid and amino acids from pyruvate, report researchers in Japan. Moreover, the new catalyst is cheaper, more stable, safer and more environmentally friendly than conventional metal catalysts used in industry, they note, adding that it also displays the high enantioselectivity required by the pharmaceutical industry.

"On top of these advantages, our newly developed organic catalyst system also promotes reactions using pyruvate that aren't easily achievable using metal catalysts," says Santanu Mondal, a PhD candidate in the chemistry and chemical bioengineering unit at Okinawa Institute of Science and Technology (OIST) Graduate University, Okinawa, Japan, and lead author of a study recently published in *Organic Letters*.

"Organic catalysts, in particular, are set to revolutionize the industry and make chemistry more sustainable," he stresses.

The researchers use an acid and an amine mixture to force the pyruvate to act as an electron donor rather than its usual role as an electron receiver (Figure 1).

Effectively mimicking how enzymes work, the amine binds to the pyruvate to make an intermediate molecule. The organic acid then covers up part of the intermediate molecule while leaving another part that can donate electrons free to react to form a new product.

Currently, the organic catalyst system only works when reacting pyruvate with a specific class of organic molecule called cyclic imines.

So, the researchers now are looking to develop a more-universal catalyst, i.e., one that can speed up reactions between pyruvate and a broad range of organic molecules.

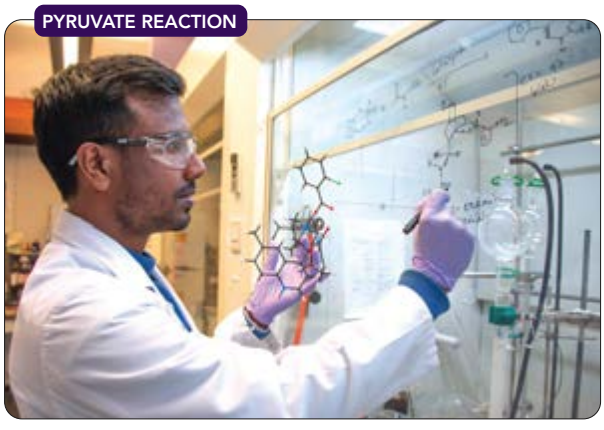


Figure 1. Santanu Mondal sketches out a reaction using a model of newly designed organic catalyst system as a reference. *Source: OIST.*

The challenge here is to try to make the electron-donating intermediate stage of pyruvate react with other functional groups such as aldehydes and ketones. However, different catalysts create different intermediates, all with different properties. For example, the enamine intermediate created by the researchers' new reaction only reacts with cyclic imines. Their hypothesis, currently being investigated, is that creation of other intermediates such as an enolate, if possible, would achieve a broader pyruvate reactivity.

In terms of cost, the researchers note that a palladium catalyst used in similar reactions is 25 times more expensive than their organic acid — which also is made from eco-friendly quinine.

In addition, they believe scale-up of the process for industrial use definitely is possible. However, the researchers caution that the current amine-to-acid-catalyst loading ratio of 1:2 probably would need to be optimized for better results at a larger scale. ●

Get to the Root of Energy Inefficiencies

Reducing energy consumption sometimes requires a deeper look

The truth is a bit more nuanced.

ACCORDING TO Lawrence Livermore National Laboratory, roughly 51% of the energy supplied to industrial consumers ends up as rejected energy (see https://flowcharts.llnl.gov/). This headline number creates the impression industry is an inefficient user of energy and, so, scope exists for major improvements within the sector, especially in the area of waste heat recovery. However, the truth is a bit more nuanced.

Many operations in industry depend on heat cascading from high temperatures to low temperatures. Within the process sector, this is seen most clearly in distillation, the dominant method for separating liquid streams. High-temperature heat is supplied to the reboiler. This evaporates volatile liquids, which then condense at a much lower temperature — often so low the heat is no longer useful, and must be rejected to the ambient environment as a waste.

Various ways to improve the efficiency of distillation columns exist. These include modifications to column internals (e.g., use of various packing materials), which can improve contacting and separation of fluids, and reduce the pressure drop through the column. Other options are based on waste heat recovery; for example, using the hot bottoms stream from a distillation column to preheat the cold feed (feed/bottoms heat exchange), or using the overhead vapor from a high-pressure distillation column, which operates at a high temperature, to reboil a column that operates at a lower pressure and temperature (double-effect distillation).

Interestingly, although these methods do reduce energy consumption, they do not necessarily reduce the percentage of heat that is rejected. Consider double-effect distillation. Let's suppose the two columns require the same amount of reboiler heat, 10 mmBtu/h, and all of the heat passes through the columns, exits in the overhead vapor stream, and is rejected to ambient through overhead condensers. In this case, the heat supplied to the reboilers is 2×10 = 20 mmBtu/h, and the rejected heat is also 2×10 = 20 mmBtu/h. The percentage of the rejected heat is therefore 20/20×100 = 100%.

If we couple the two columns in a double-effect configuration, the high-pressure overhead discharges its heat to the low-pressure reboiler. We only supply external heat (10 mmBtu/h) to the high-pressure reboiler, and we only reject heat (10 mmBtu/h) from the low-pressure overhead vapor. The percentage of the heat that is rejected is therefore 10/10×100 = 100%. What went wrong? Nothing. We simply used all of the heat twice before rejecting it. We, therefore halved our energy consumption, while still rejecting all of the heat — but we used it twice before rejecting it.

Let's now consider the energy impact on a complete chemical plant or refinery unit. Let's assume the plant's energy input is 100 mmBtu/h, and its rejected energy is 50 mmBtu/h, or 50%. The plant contains the two separate distillation columns we just discussed. Each column consumes and rejects 10 mmBtu/h of heat, and these heat flows are included in the plant's total energy input of 100 mmBtu/h and total rejected energy of 50 mmBtu/h.

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If we reconfigure the columns as a double-effect system, we know from our earlier discussion that this reduces both the heat input and the rejected energy by 10 mmBtu/h. The overall percentage of the energy rejected by the plant is now (50-10)/(100-10)×100, or 44.4%. In other words, even though the double-effect arrangement does not change the percentage of the energy rejected by the distillation system, it does reduce the percentage of energy rejected by the overall plant.

This is a highly idealized example. However, the overall concept is sound.

Other options exist that sometimes can achieve greater energy savings. These range from incremental improvements in equipment such as electric motors, to alternative separation technologies such as membrane systems, to radical redesign of processes, including new chemical pathways and new feedstocks. However, as long as a large percentage of the operations in our processes depend on cascading heat, the percentage of energy that ends up rejected will inevitably remain high.

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EPA Targets Asbestos

The proposed reporting requirements are wide-ranging and eliminate exemptions

ON MAY 6, 2022, the U.S. Environmental Protection Agency (EPA) proposed reporting and recordkeeping requirements for asbestos under Section 8(a) of the Toxic Substances Control Act (TSCA). Unsurprisingly, the proposed requirements are extensive and tough. Here is a summary.

The EPA proposes asbestos manufacturers, including importers and processors, must report information known to or reasonably ascertainable by those entities. The term "asbestos" comprises various forms of asbestos, including Libby Amphibole asbestos, native to Libby, Montana, and considered "carcinogenic to humans." The following is a brief list of the proposed primary data requirements:

- **Asbestos domestic manufacturers** (asbestos mine and mill) must provide the quantity manufactured per asbestos type, use, and employee exposure information.
- **Asbestos importers** must provide the quantity imported per asbestos type, use, and employee exposure information. This includes importers of mixtures containing asbestos, articles containing asbestos components, and impurities (in articles, bulk materials, or mixtures, such as in talc and vermiculite).
- **Asbestos processors** (including processors of mixtures or articles) must provide the quantity processed per asbestos type, use, and employee exposure information, including primary processors and secondary processors of asbestos, and situations in which asbestos appears as an intentional or non-intentional impurity, such as in vermiculite and talc.

The EPA suggests mandatory reporting of information on specific asbestos forms, or if specific information is not known or reasonably ascertainable, reporting on "asbestos" as it is listed on the TSCA Chemical Substance Inventory. Reporting would be required related to asbestos as it is manufactured or processed in bulk, as a mixture component, in an article, or as an impurity in bulk materials or products.

The EPA proposes to obtain manufacturing and processing information associated with the different asbestos forms identified, and mandate reporting be completed for each of the forms, to the extent the information is known or reasonably ascertainable. If the specific asbestos type is unknown, a submitter would provide information under the general asbestos form (Chemical Abstracts Service Registry Number (CAS RN) 1332-21-4).

The rule would necessitate reporting on articles containing asbestos (including as an impurity). These data could inform Part 2 of the TSCA risk evaluation for asbestos, where the EPA will determine and then evaluate the relevant conditions of use of such articles containing asbestos. Articles required to report in Part 1 of the risk evaluation include brake blocks for use in the oil industry, rubber sheets for gaskets used to create a chemical-containment seal in the production of titanium dioxide, certain other types of preformed gaskets, and some vehicle friction products.

The proposed rule would result in a one-time reporting obligation. The EPA suggests reporting for persons who have manufactured, including imported, or processed asbestos at any time during the four complete calendar years prior to the effective date of the final rule. The agency anticipates the four calendar years would be 2019 to 2022.

The EPA is voiding the article, impurity, and naturally occurring substance exemptions to Chemical Data Reporting (CDR). The agency did this also under the proposed TSCA Section 8(a)(7) PFAS reporting rule, so we may see this more frequently in the future. As the EPA notes, the existing Section 6 rule on asbestos voids the small business exemption. Stakeholders may wish to comment on all aspects of the proposal, and specifically whether a de minimis threshold is appropriate, as the EPA providing one would help greatly to lessen the reporting burden. Any stakeholder implicated needs to understand the proposal and monitor this space. When a final rule is issued, expect the EPA to take compliance very seriously.

Some expect there will be many potential "first" reporters. These are entities that never had to report because the products they manufacture, import, or process fell under either the article or the impurity exemption. These new reporters will not be familiar with the CDR reporting tool or CDR policies and guidance. Stakeholders, including individual companies, trade associations, non-governmental organizations, and the EPA will need to address these issues to ensure non-traditional reporters are engaged and able to provide information useful to the EPA's analysis.

Expect the EPA to take compliance very seriously.

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Lynn is managing director of Bergeson & Campbell, P.C., a Washington, D.C.-based law firm that concentrates on chemical industry issues. The views expressed herein are solely those of the author.

Digital Solutions Deliver Data Integrity

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MITESH CHHANA
Regional Business Manager
Lab Weighing, EMEA, Sartorius

We must ensure data are correct to make the right decisions.

SAFETY, ACCURACY and reliability are paramount in the development and testing of fine and specialty chemicals. Add to that the need for regulatory compliance, and it becomes clear that proper tools are needed. To understand how lab instruments can complement the process, Chemical Processing spoke with Mitesh Chhana, Regional Business Manager Lab Weighing, EMEA, at Sartorius, a provider of instruments and services for the biopharmaceutical, chemical and food industries.

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Q: Why is data integrity important in the production of raw materials for chemical products and consumer goods?
A: We know that data integrity is important in the pharmaceutical industry. There is also a need for fine chemical producers to concentrate on data integrity because they supply these customers. A lot of companies are now investing in digital solutions. They use electronic lab notebooks (ELN) — Laboratory Information Management Systems (LIMS)— to connect their instruments to manage workflows and get away from paper documentation.

Having correct data also has an impact on how quick companies can increase their discovery or time to market. And the fine chemical and the cosmetic industries are now becoming more and more regulated to be in line with that as they feed into those segments. Some of the consequences: facilities can be shut down, product recalls — so it's cost. Delayed drug approvals — again, cost — and loss of reputation, which is obviously priceless as well.

Q: Based on FDA warning letters, what are the most frequent violations made by chemical companies?
A: The majority of warning letters (79%) are attributed to poor data integrity related to access and role management; i.e., who dealt with the data, or the fact that the lab person wasn't documenting data. The most common example is not implementing controls to ensure that only authorized users can access instruments.

For example, some lab staff are not allowed to use certain instruments if they're not trained. With some instruments, anyone can use them without any traceability. An example of role management is having an administrator on the instrument. Without that control, a lab analyst could change configuration settings, or even delete data, which can lead to manipulation that will be picked up at audit.

Another common problem is data that's not correctly backed up. You need to be able to back up data, all your data, whether it is incorrect or correct from an audit point of view. So, having an audit trail on instruments is key. There are quite a few areas where FDA violations or warning letters [focused] on data integrity.

Q: How can organizations minimize these risks and ensure their data integrity?
A: Data integrity starts with having a quality culture within an organization. Some organizations focus on a particular software or a specific instrument, but this brings a risk of forgetting other important systems or causing integrity problems with data exchange between different systems. Therefore, I recommend a top-down approach to identify GxP-relevant processes and then dive deeper into the sub-processes and individual activities with standalone systems and instruments.

You need to make sure that an instrument has all the features to meet FDA 21 Part 11 CFR compliance or the EU Annex 11, which is for electronic instruments. This should include, as prerequisite, an audit trail, user management, electronic signatures, safe data transfer options for integration into further systems like LIMS or ELN. And this further automates the work process and introduces efficiency, time and cost savings, as well as avoiding violations and manual errors, which would have been incurred beforehand.

Q: Are there instruments that offer this?
A: If we look at the laboratory, there is a half and half split between certain instruments that can, and certain instruments that cannot. And this is really down to vendors investing in having the correct control features to support Code of Federal Regulation (CFR) compliance, but also being able to harmonize and complement connecting effectively and compliantly with LIMS and ELN.

A good example would be the Cubis II® balance. It allows enhancements in connectivity and data integrity, as well as compliance on data handling. But the balance was designed to follow the ALCOA (attributable, legible, contemporaneous, original, and accurate) principles, which is the key concept of good documentation practice and contains all the features to support regulation compliance, as well as the other benefits of cost savings and efficiencies that can be gained from handling data in a digitized form.

Q: How does the Cubis II® support good practice adherence?
A: If we were to work in a paper-based fashion versus an electronic fashion, the only thing that really changes in terms of not taking a printout is basically the user interaction; the balance is pretty much the same. What the Cubis II® balance does is it contains all the technical controls to support the compliance, as well as maintaining all the weighing performance features and benefits and applications that were there anyway. There is no need for additional software. It integrates directly into an overarching LIMS or ELN, which most laboratories will have. These features include the comprehensive audit trails and functions for filtering and exporting for convenient review. You can search on a user or a time or a day. Great for audits and also great for data review.

User and role management can be integrated into your company domain, so it's easy for management, and to support electronic signatures. And one key feature is that we use LDAP (Lightweight Directory Access Protocol), which basically has the same password as you would for all your other Windows passwords within your company. So, it integrates into your IT systems as well, which is fantastic.

Additionally, there are network and time synchronization functions for secure and compliant data transfer. The Cubis II® will give you integration into lab software to a variety of IT interfaces without the need for middleware. This makes things very simple at qualification and reduces operating costs, but maintains compliance. One of the connectivity options featured in Cubis II® is web services. This technology offers bi-directional integration into LIMS and ELN and is very well thought of, especially from a group IT point of view with customers. It makes their life very easy for integration.

The Cubis II® allows enhancements in connectivity and data integrity as well as compliance on data handling.

Q: How do software applications with guided workflows help achieve trustworthy, compliant results?
A: Guided workflows are the real element that gives you not necessarily the compliant benefits but more the real efficiencies and the time savings, and really does lean up your lab processes. So, automated guided workflows eliminate many steps that can lead to mistakes if you were to do it in a paper fashion. It eliminates the risks of transcription errors, just forgetting simple steps along the way.

The user is guided step by step through a workflow, and the process is specified by standard operating procedures from the balance. The workflow application, also within the balance, guides the user through specific parameters, so it has limits and tolerances that are followed. This not only improves the quality of the data but also brings efficiency and control into the entire lab process, and can reduce a lot of lab costs through rework. The cost of your materials that you're using for testing, you're doing them less because you're doing them correct more often. Cubis II® brings workflows onto the balance of small applications in the form of QApps (quality assurance project plan), which can be customized, but we have many pre-built and defined QApps to support many weighing applications.

Having a QApp on the balance means there's no need for additional middleware. We can manage that workflow purely from the balance in a compliant fashion. This allows the user to concentrate on weighing processes, and save space in the lab through not having computers or any additional connectivity required for that.

Q: Are there other balances on the market today that offer digital workflow support without requiring additional software?
A: With regards to within the actual balance, no, this is the only balance on the market that can allow you to maintain full electronic CFR Part 21, Part 11 compliance through all the technical controls it has through audit trail, alibi menu, time synchronization, all these controls are supported within there. All you have to do is connect to your customer IT LIMS or ELN system. There are other manufacturers that offer middleware, but we often see that it can be quite high effort to implement and integrate another software in between an instrument. We can go directly into another customer's overarching laboratory IT system and maintain compliance as well.

Q: Is there anything you'd like to add?
A: We're now seeing more of a drive in chemical segments. Auditors are asking for good data integrity all the time. From a vendor point of view, the Cubis II® solution makes this task of maintaining or improving data integrity very easy and pain-free task through the integration of our balances into our customers' IT systems.

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Open Automation Gets The Green Light

Developments promise benefits at both the control and field instrument levels

By Seán Ottewell, Editor at Large

THE DAYS of chemical companies struggling to integrate multiple, proprietary systems in almost every process plant or facility look numbered. The success of ongoing field trials of open-architecture-based process control systems points to a future of genuine configuration and application portability across components from different suppliers that will reduce system capital cost and total cost of ownership.

To get a sense of where things stand as well as a perspective on the implications for the chemical industry, we got inputs from experts at Endress+Hauser, ExxonMobil, Schneider Electric and Yokogawa.

At the heart of current developments is The Open Group, San Francisco, a global consortium focused on the development of open vendor-neutral technology standards and certifications. Its Open Process Automation Forum (OPAF), http://bit.ly/38HJ89C, now has more than one hundred members drawn from operating companies, hardware and software suppliers, and system integrators. OPAF's efforts focus on developing an open process automation standard (O-PAS).

OPAF member ExxonMobil, an early champion of such an effort, sees a clear need. Such a standard is key, explains Mohan Kalyanaraman, technology acquisition advisor, strategic planning, ExxonMobil Technology and Engineering, Spring, Texas, because working with components from different suppliers can be challenging or subject to

ARCHITECTURE

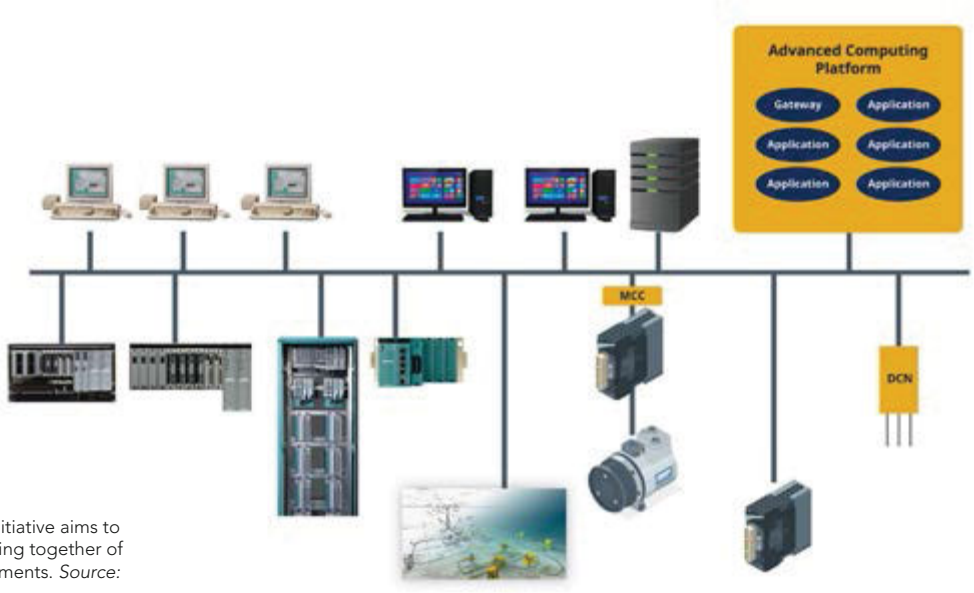

Figure 1. Initiative aims to ease the tying together of diverse elements. *Source: Yokogawa.*

interpretation if the vendor-specific implementations of the standard are not aligned. "However, with robust standards and conformance practices in place, compatibility is no longer an issue," he stresses.

Fellow OPAF member Yokogawa similarly believes that if each part complies with the standard, any issues can be isolated and addressed despite the breadth of model (Figure 1).

"Although availability and long-term stability are not addressed by O-PAS, we would expect various manufacturers to offer products that are differentiated in those regards," says Mark Hammer, global account manager, Yokogawa, Houston. "OPA actually encourages that type of differentiation with cost/benefit tradeoffs while maintaining compliance to the standards. For example, some suppliers could offer high-availability DCNs [distributed control nodes] with integral redundancy or fault tolerance while others could offer lower-priced DCNs without the redundancy or fault tolerance," he adds.

"This topic drives home the need to have an OPA system integrator that has experience with the O-PAS standards and is working with hardware and software suppliers — both OT [operational technology] and IT [information technology] — to design and deliver a true system as opposed to a collection of components," stresses Dave Emerson, vice president of Yokogawa's U.S. Technology Center, The Woodlands, Texas.

INITIAL IMPLEMENTATIONS

The first steps along this road came with a proof of concept (PoC) project completed at a catalyst pilot plant unit in 2018. Here, ExxonMobil, with Lockheed Martin acting as system integrator, demonstrated the attributes needed by an open system: interoperability, configuration portability, and application portability.

"We wanted to answer the question: 'The PoC shows what is possible, but can we deploy this on an actual hydrocarbon service at high temperature and pressure and have operators run it reliably and successfully?'" says Kalyanaraman.

Later in 2018 and into 2019, ExxonMobil built a prototype system to replace a distributed control system (DCS) on a desulfurization-catalyst-testing pilot unit that ran at 600°F and 1,200 psig. The unit had 130 input/output (I/O) devices.

This prototype ran successfully for more than 12 weeks, despite needing more-robust components than those used in the PoC project. Also, because the standards were not fully fleshed out at the time, it required some customization to enable communication and control.

The combined experience gained now is being used in a field trial, one of a handful of OPAF OPA-related projects currently underway. ExxonMobil and systems integrator Yokogawa have started a FEED [front-end engineering design] field trial on a test bed at an unnamed Gulf Coast chemical manufacturer's site.

The single-operator single-console unit has 2,000–2,500 I/O points, 90–100 closed control loops, and includes utilities, tank farms, process operations, finishing and packaging. The OPA components will be aligned with version 2.1 of the OPA standard. Data and information from the field trial process will be integrated with existing business and management systems.

All is going to plan with the test bed, which is central to derisking the associated technologies in preparation for future field trials, notes Ryan Smeltzer, OPA program manager for ExxonMobil Technology and Engineering.

"The test bed has also been a valuable environment to work with suppliers and integrators to evaluate, test, and qualify both commercial and pre-release products for potential inclusion in a field trial. These interactions, coupled with collaborative work on the standards as part of the OPA Forum, have been beneficial to moving the surrounding ecosystem forward," he says.

Yokogawa also is pleased with the progress of the field trial FEED.

"It is going as planned. The overall process reflects the implementation of a SCADA [supervisory control and data acquisition] system rather than a traditional DCS. Like a SCADA project, the selection of the DCNs requires a collaborative effort. The implementation standards, such as graphics, need to be updated to reflect the OPA concepts, and other topics like system availability need to be redefined," explains Hammer.

"The test bed has been a very collaborative effort with ExxonMobil and other suppliers. The concept of open and software-defined control systems is still emerging for most control hardware manufacturers. Getting their products enabled with the necessary infrastructure has been key to making the test bed work," he adds.

While the O-PAS standard is the basis for the test bed and field work, both experts emphasize that significant effort also focuses on building out the full features expected of modern DCSs and providing functionality that goes beyond the traditional DCS.

"As an OPA system integrator, Yokogawa is executing a qualification process on current hardware and software that is being adapted to work in an O-PAS system. This work is expected to lay the groundwork for first-generation O-PAS components from different suppliers. The test-bed process provides feedback to the standards team, and the OPAF team members bring the developments into the test bed. The objective is to have products in the test bed that already meet the standards when released," says Yokogawa's Emerson. Several other end users are discussing possible OPA test beds and field trials with Yokogawa, he adds.

Schneider Electric, Austin, Texas, similarly is enthusiastic about the ExxonMobil field trial. Its contribution is the "plug and produce" software in the form of IEC 61499 runtime and EcoStruxure Automation Expert Soft dPAC management system.

"This represents a strong trajectory towards open process automation systems and the benefits it has for any industrial automation user, integrator, or third-party partners to leverage," notes Nathalie Marcotte, president of Schneider Electric's automation business.

OTHER INITIATIVES

Meanwhile, chemical makers — including BASF, Ludwigshafen, Germany; Dow, Midland, Mich.; and Saudi Aramco, Dhahran, Saudi Arabia — are taking part in other OPAF prototype projects designed to improve knowhow to scale up interoperable systems and foster future process applications.

One includes working with the User Association of Automation Technology in Process Industries (NAMUR), Leverkusen, Germany, on its NAMUR open architecture (NOA) and module type package (MTP) initiatives.

"These standards address different needs and are complementary," explains Hammer. "While the main objective of OPA is such interoperability that allows end users or integrators to deploy systems with platforms from a variety of suppliers, NOA addresses the issue that the vast expansion of smart field devices and the ubiquitous use of IT equipment are generating significantly more data, which could make access difficult within the classic NAMUR automation pyramid. NOA introduces a second network that will not impact the automation system."

In fact, NOA and OPAF leaders have discussed how the two approaches are complementary. Yokogawa expects to see NOA concepts, like MTP, implemented in O-PAS systems along with existing DCSs.

"The NOA goal to support modular process equipment supplied with automation capabilities and access to richer data from field instruments is in line with what end users are asking of OPAF. We expect both to become industry standards," says Yokogawa's Emerson.

The principle of open standards and associated initiatives at the control and field-instrument levels garners support from both suppliers and their customers.

"NOA aims to provide additional data/information from

Figure 2. Unlocking data stranded in instruments and other devices can lead to increased efficiency and reliability. *Source: Endress+Hauser.*

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the field via a separate second channel to do maintenance and optimization without interfering directly in process control. OPA wants to break up the monolithic approach of the automation pyramid. As such, OPA defines [a] much-broader way of interaction in the control-involved nodes and systems," notes Franz Durmeier, team leader IMI marketing intelligence, Endress+Hauser, Reinach, Switzerland.

The results already achieved in various demonstrations seem very promising for the company and its customers, he adds.

The projects listed by OPAF include: a BASF OPA demonstrator with four water tanks and managed control loops using MTP technology based on the NOA program; a Middle East OPA test-bed collaboration between Saudi Aramco and Schneider Electric based at the petrochemical company's Dhahran innovation and research center; and a Dow Chemical MxD open-architecture test bed, which reportedly is serving to explore digital-twin concepts.

ADVANCED COMPUTING PLATFORM

Meanwhile, in parallel with the industrial projects, is a plan to bring an advanced computing platform (ACP) to market. A memorandum of understanding signed in March by Intel, Dell, Schneider, VMWare and Yokogawa commits the companies to this aim, with the ACP allowing the deployment of IT-like technologies into the OT world.

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The ACP uses commercial-off-the-shelf hardware and software to deploy process control applications independent of controller hardware. It allows end users to securely deploy and manage advanced applications — control algorithms — at the lower levels of the stack close to the process edge through key features, including low latency and real-time processing.

"The ACP uses a software-defined approach to deliver OT capability, including the use of containers, virtualization, orchestration, etc. We fully expect there is more than one way to put together the ACP; thus, the focus is on functionality based on user-defined requirements and use cases," explains ExxonMobil's Smeltzer.

Looking further ahead, Yokogawa believes OPA will provide a range of other benefits beyond the expected savings, even before the standard is fully realized.

"The ability to easily test and implement applications, whether custom apps, AI [artificial intelligence], ML [machine learning], or advanced control, will bring more value to users. Users can also use OPA to expand existing systems taking advantage of the lower-cost hardware and virtualized environments," says Hammer.

Then, as the OPA ecosystem matures, Yokogawa envisions end users maintaining a relationship with an OPA system integrator to supply new systems and expand/replace existing DCS/PLC [programmable logic controller]/OPA systems with new components — both hardware and software. OPA also will radically change the way of thinking about automation systems: such systems will become software defined with software components/functionality being deployed to hardware that may change over time.

"Today, end users receive the greatest value from software, not control system hardware — this trend will accelerate with OPA," concludes Yokogawa's Emerson.

For his part, Durmeier believes access to the valuable information found in field-level devices (Figure 2) is crucial to support data-driven services for use cases around NOA.

"Field instruments already have a bunch of data available but most of it is locked in the field level today. Just imagine getting any data of the devices and of the process environment around the devices in real-time to improve processes and work efficiency of maintenance personnel. For field device manufacturers, there are also many advantages if the available field-device data beyond the process value is really used. For example, smart algorithms in the device can create a unique selling point if maintenance of a device can be predicted or prevented. Open and connected systems can provide valuable data at the right place and in the right time," he enthuses.

On the other hand, he points out that companies in the process industries are quite conservative and often reluctant to change the way their processes are run.

Durmeier suggests end users adopting new technologies or standards should start with small evaluations — either in test labs or in plants outside of the core process. Depending on the technology, this might be very important for learning, acceptance, and internal discussions. Device manufacturers and standard organizations can support this with both test devices and expert knowledge about the technologies. Such evaluations can form the basis for creating a rollout plan.

"In general, all new technologies and standards in the context of digitalization have the same goal: increasing the efficiency of the end users," he concludes. ●

Figure 1. Decontaminating and tearing down this aluminum-oxide facility was a complex task. *Source: Frontier Group.*

Safely Decommission and Decontaminate Plants

A number of steps are crucial prior to mothballing or demolition and site restoration

By Barry A. Perlmutter, Perlmutter & Idea Development LLC, and Vinay Devgon, consultant

A PLANT can face shutdown for a variety of reasons, from poor economics due to outdated equipment or no-longer-competitive processes to product obsolescence. The last steps in the life of such a plant are decommissioning and demolition. These steps demand the same manner of organizing and executing as a design-and-construction project with special emphasis on personnel safety and environmental compliance. Figure 1 shows demolition underway by the Frontier Industrial Group at an aluminum-oxide facility in Gregory, Texas. The project to decommission and demolish the plant illustrates the complexity of the task. The environmental remediation, decommissioning, asset recovery and demolition work required 20 months. Frontier utilized barges to ship scrap metals generated during the demolition phase to steel makers in different parts of the country. The company explicitly made workplace safety the project's number one priority.

Decommissioning may occur in preparation for either mothballing or demolition. Mothballing refers to putting the facility in an idle state or temporary shutdown in a manner that allows restarting later when the business environment makes the process attractive again.

Mothballing, while buying time for decision-making, can be surprisingly expensive. Idled assets still need attention from maintenance and other staff. (Remember: "rust never sleeps.") In addition, items such as control systems' hardware and software can become obsolete over time. Mothballing requires its own specialized operating procedures and documentation, safety reviews, etc. Moreover, it can pose significant safety issues, due to manual operation of equipment. For additional information about mothballing, see References 1 and 2.

The alternative to mothballing is decommissioning, followed by decontamination for partial salvage or

demolition to permanently remove the facility. Partial or "surgical" salvage refers to dismantling assets specific to the process but keeping other parts of the facility. For example, the site may decide to tear down specialized solid/liquid separation or drying equipment but retain a reactor that can be used for a different process. During partial salvage, piping reconfigurations as well as control and instrumentation changes also must be considered as these may cost more than a new "normal/standard" installation. The scope definition requires a formal phased project-engineering approach. Any "surgical" demolition is expensive.

Decommissioning in preparation for mothballing can differ greatly from decommissioning in preparation for demolition. For instance, in the case of mothballing, decontamination to strict standards generally is unnecessary because personnel exposure is not an issue. Corrosion, inerting, lubrication, etc., are key concerns.

DECOMMISSIONING FOR DEMOLITION

For demolition, the site is taken "down to the slab" for site restoration. All items, including the structure, are removed, for sale either for reuse or scrap. Expensive alloy items such as those made of tantalum, Hastelloy C, etc., invariably are targeted for reuse. Figure 2 shows the Frontier work at the site in the final stages of the project. In general, plant owners do not get involved with reselling of equipment. Instead, the demolition contractor's cost is adjusted by the estimated value of the equipment (as scrap or recovery), structural steel, etc. Specific spare parts no longer needed also should be salvaged or sold through a third party well-versed in the particular market. In general, recovered values only amount to 10–25% of the new item cost.

When the plant is being demolished, the proper classification of various wastes, their segregation, handling, transport and ultimate disposal are important issues.

A demolition project requires tasks such as abatement of asbestos, lead, mercury and other materials, as well as removal and disposal of lubricants, transformer oils, polychlorinated biphenyls (if present), refrigerants, radioactive materials, etc. Contaminated insulation may be classified as hazardous waste. Strict decontamination standards, based on product toxicity, apply to any equipment to be sent for investment recovery or even sold as scrap. Furthermore, decontaminated scrap going directly to a smelter must have documentation to prove its chain of custody.

For companies without previous experience in these areas, decommissioning and demolition can present serious challenges.

The first stage of a decommissioning/demolition project is planning and cost estimation. We recommend preparation of a formal front-end engineering design (FEL-3 level) document to clearly define the scope, methodology, the detailed schedule and staffing plan as well as a safety and environmental plan for the project. The FEL document should undergo review and critiquing.

The safety and environmental plan should include all information on chemicals and their hazards (flammable, toxic, corrosive) as well as the quantities and types of wastes generated from decommissioning and decontamination efforts. There are many different types of wastes — and these should be classified logically: contaminated, non-contaminated, RCRA [Resource Conservation and Recovery Act], hazardous, etc. Any wastes destined for landfills need planning for their handling, sampling, testing and storage; their shipment involves use of special containers and the keeping of logs. Environmental contractors demand extensive paperwork to ensure proper custody and control of wastes. Compliance requirements for RCRA wastes cover aspects such as handling, storage and disposal (on-site or off-site), and maximum storage duration.

During this stage, developing a staffing plan is important. The decommissioning team includes technical personnel (production, process, project, electrical, mechanical, civil, safety), operators, maintenance staff, the project manager, scheduler, etc. Staffing levels drop rapidly with

Figure 2. Bare ground soon will mark where aluminum-oxide plant stood. *Source: Frontier Group.*

CHECK OUT THE SOURCE OF THIS ARTICLE

This article is based on a chapter is the newly published book "Integration and Optimization of Unit Operations," edited by Barry Perlmutter, which covers all stages from research and development to production. For further details, see: https://bit.ly/37M0erH.

time, so people should know when they can be expected to be "on-boarded" and "off-boarded." Key personnel must be retained for their experience and knowledge. These people can provide details missing in drawings and documentation; this information then must be codified for future records.

A critical step is the selection of contractors. Because operating companies are not highly experienced in decommissioning and demolition activities, it may be prudent to engage a "general engineering contractor" to manage all the subcontractors and be responsible for safety. Depending on the contract, this can afford some limitation of liability for the owner (who might be viewed as having "deep pockets"). The general contractor should be highly experienced in these activities and have first-hand knowledge of the various subcontractors used for abatement, waste transport and disposal, and demolition. The general contractor would be responsible for day-to-day field activity management and subcontractor safety, as well as for compliance with environmental and other regulations.

IMPLEMENTATION

Three main areas require evaluation: decontamination; dismantling and disposal; and site restoration. First, though, you must set the proper direction for the project by considering the future use of the site.

If there are no future activities, the location may become a brownfield site with special environmental compliance needs. Remediation and ongoing costs are an important consideration. A brownfield site invites a high degree of attention from environmental agencies.

Site restoration allows for future functionality. It can include modification or installation of stormwater sewers, sumps, roads, grading and covering with gravel, planting of grass and trees, etc.

It also is important to plan the final production runs before decommissioning to minimize the final inventory of chemicals in storage tanks as well as in-process materials.

The first phase in decommissioning generally is the de-inventorying of in-process and, possibly, raw materials storage. This includes displacement with nitrogen, manual draining of equipment and piping at low points, etc. It is better to remove concentrated waste for disposal because residual chemicals in equipment and piping can contaminate large amounts of wastewater during the washing step; the disposal of this wastewater can pose problems. Pretreatment with temporary carbon beds may be required.

Most chemical suppliers will not take back chemicals due to quality and safety issues. So, disposal of excess chemicals usually is costly and time consuming. You must identify vendors willing to accept the wastes; generally, these vendors incinerate the wastes. You will need to send samples for testing. In addition, you must prepare formal bid documents.

Transporting the chemicals to the selected vendor may call for loading them into tank cars, tank trucks or drums. This may require new, temporary facilities, such as piping and pumps for loading, as well as writing of special procedures, safety reviews, etc.

DECONTAMINATION

This involves removal of contaminants from the system (equipment, piping, structure, waste materials) by rinsing, washing (including high-pressure water washing), heating, chemical treatment and mechanical cleaning. Cleaning of the internal and external surfaces of equipment must take place during this step. Some decontamination also is necessary after dismantling. Special temporary facilities and laydown areas often are needed. The main objectives of any decontamination process are to:

- reduce occupational exposure;
- provide proper waste transport and disposal according to regulations and company policy;
- salvage equipment and materials to the extent possible; and
- restore the site for future use.

The types of contaminants can include solids (residues, products), liquids (left in reactors, tanks, heat exchangers, pumps), vapors (volatile chemicals in pipes, storage tanks), and aerosols (liquid and solid particles suspended in air, powders, dusts). Vent headers where residues may have accumulated demand special attention.

The procedures for final operations of rinsing, decontamination, etc., should be clearly documented and approved before starting. Developing these procedures involves:

- identifying chemicals (solvents, detergents, other cleaning agents) and testing them for efficacy;
- defining and validating by responsible management of cleanliness standards and testing. For example, the

definition of allowable residual levels of chemicals on surfaces should take into account toxicity of the residue and the fate of the equipment. The levels for equipment destined for sale or re-use would differ from that of equipment going to be scrapped and sent to a smelter. For highly hazardous equipment, some companies choose for the equipment to be cut up and sent directly to a smelter.

- picking cleaning methods appropriate for the level of cleanliness or decontamination, e.g., use of spray balls, high-pressure water washing of heat exchangers, etc. Depending on the toxicity of the chemicals, certain equipment, valves, etc., may require disassembly and decontamination.

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Contractors sometimes use a "triple rinse standard," which entails filling and emptying a vessel three times with liquid, thereby diluting by two orders of magnitude. In theory, 1% of whatever was in the vessel may remain each time you empty it; so, a 1:100 dilution with fresh rinse water occurs at each rinse. However, this approach is not suitable for toxic materials, for example.

Cleaning of solids-handling equipment can present special challenges. Such cleaning often relies on agents such as tri-sodium phosphate. Certain equipment needs dismantling for cleaning. High-pressure water washing frequently is used.

DECONTAMINATION STAGES

A structured decontamination process always involves multiple stages. Each stage results in the equipment progressively nearing "clean" status. These stages are:

Primary decontamination. This is the initial cleaning of equipment using water and chemicals, rinsing with water followed by "drying" with steam/nitrogen/compressed air, etc. The level of residual contamination is measured by swabbing (wipe-samples), etc. The residual contamination level must conform to the pre-determined standards defined in the FEL-3 document.

The following illustrates an approach to defining the decontamination standard (i.e., the safe residual level of contamination, SRL (µg/cm^2), for equipment, instruments or other materials to be salvaged:

$SRL = (NOEL \times BW)/(SF \times TC \times H)$

where *NOEL* is no-effect dermal level, µg/kg/d; *BW* is body weight of an adult, taken as 60 kg; *SF* is safety factor, to be defined — a typical value is 100; *TC* is transfer coefficient, cm^2/h, often 1,000 cm^2/h; and *H* stands for the hours of exposure per day, e.g., 8 h/d for salvaged equipment.

Dismantling. The equipment is taken apart to check for the presence of contaminant and for disposal. This is the stage to carry out inspection and testing to ascertain the utility of equipment for future use. For this step, it is critical to examine all the operation and maintenance manuals because each piece of equipment has unique characteristics.

Secondary decontamination. The dismantled parts of the equipment are cleaned with chemicals, water, steam or compressed air, and then the level of contaminant is measured. If the level of the contaminant is high, the process is repeated until an acceptable decontamination criterion is achieved. At this stage, it may be necessary to involve plant staff or service technicians from the original equipment manufacturer (OEM).

Disposal of equipment. After the equipment is declared fit for disposal, it can be sold to a used equipment dealer, another end-user or back to the OEM. The demolition contractor or a third party, not the owner, generally handles this.

Disposal of waste. The process of decontamination generates liquid and solid waste. These wastes must be disposed of in a safe manner, which depends upon the specific rules and regulations for the plant.

For a demolition project, every plant is unique and has its own set of challenges. Figure 3 lists the typical questions and project steps.

PROJECT MANAGEMENT

The goal is to conduct the decommissioning and demolition activities in a manner that minimizes any safety or environmental incidents. The availability of excellent documentation underpins proving compliance and minimizing future liability. Providing such documentation, which can include distributed-control-system data, operating logs, incident reports, etc., requires careful planning, generation, and organization. Consult regulatory personnel for requirements for records retention.

The typical risks during decommissioning and demolition include: exposure of personnel to toxic chemicals; chemical spills; excessive loads on the site waste treatment plant; and injuries to personnel.

To begin the project in the planning phase, gather and file all required documents, such as insurance certificates, permits, and licenses, etc., in both hard-copy and electronic forms. In addition to these documents, you will need process details:

- material safety data sheets (MSDSs) for all chemicals;
- documentation on plant equipment;

- drawings, especially piping and instrumentation diagrams (P&IDs);
- any corporate engineering standards or procedures that detail specific company-mandated decommissioning methodology; and
- operating and environmental permits. Check if special temporary permits are required.

As necessary, plan and conduct audits. These can be by state or federal agencies, particularly if the project involves asbestos abatement, demolition, site closure, surface runoff into creeks, etc.

The next step, done with either internal support or the help of external contractors, is to determine and establish the necessary support services. Typical support services required include: medical service providers (injury treatment and management, respirator clearance, etc.); office trailer and equipment suppliers; equipment fueling and servicing; portable sanitary facilities; tools, safety equipment, and miscellaneous materials; hauling and disposal services; salvage and scrap material transport; and personnel resources, including hiring of local personnel. This also is the time to procure necessary materials and supplies.

After the preplanning is finalized, it is time to begin the work. Typical steps and tasks are:

- performing engineering and hazard surveys;
- completing and issuing for review a site-specific safety and health plan draft;
- establishing and communicating emergency procedures, including minor and serious injury handling, fire protection, and spills/vapor releases;
- determining general task-specific safety requirements and compiling preliminary job-specific safety guidelines;
- conducting site-specific orientation and training;
- finishing final tool and equipment inspections; and
- discussing and finalizing crew work assignments.

Two other specific topics — piping, and storage tanks and vessels — need examination to ensure a successful decommission.

Most process plants have numerous

DECOMMISSIONING STEPS AND QUESTIONS

PLANNING	
1	A description of the decommissioning work plan
2	A work plan for the decontamination of the equipment and support systems
3	A plan for the lockout/tagout (LOTO) of equipments' hazardous energy source(s)
4	Have specific piping and instrumentation diagrams been reviewed or issued?

DECOMMISSIONING PART 1	
1	Have all applicable equipment systems, support equipment, parts and components been properly decontaminated in compliance with the equipment decontamination procedure?
2	Is an "equipment decontamination" label posted on each piece of equipment or component?

DECOMMISSIONING PART 2	
1	Have all affected bulk-chemical delivery lines been isolated, drained and removed, and have the remaining lines been capped?
2	Have all affected waste drain lines been isolated, drained and removed, and have the remaining lines been capped?
3	Have all removed segments of process gas lines, vents, pumping lines, bulk delivery, waste drains and exhaust ductwork been decontaminated, and have provisions been made for proper disposal of all hazardous wastes generated by the removal?
4	Have all inert facilities piping and inert process piping been isolated?
5	Has all electrical wiring been isolated?

DECOMMISSIONING PART 3 (Final Steps)	
1	Has all process-piping labeling been updated to reflect any changes in direction of flow or contents?
2	Have equipment decommissioning and removal been completed?
3	Are all remaining LOTOs, electrical feeds, breakers, junction covers, etc., labeled and secured?
4	Have all wall, floor and ceiling penetrations that were created by the removal of equipment been properly sealed?
5	Has all affected documentation, including drawings, records, etc., been completed and updated?

Figure 3. Decommissioning requires suitable planning and then successful completion of three key phases.

pipelines, both above and below ground. If drawings are unavailable or out-of-date, identifying these pipelines can be a formidable task. Use available drawings to identify and mark all piping. Ensure MSDS information is readily accessible on-site for every fluid within the piping. Develop a plan for recovery of process fluids during final plant shutdown. Piping should be blown into receiving vessels. Determine whether these fluids can be sold, recycled, or sent to the sewer.

Lines containing innocuous liquids, such as lubricating oils, can be drained by cutting and removing piping sections at low points. For draining volatile or hazardous fluids, environmental regulations or good engineering practice may require closed methods, such as installing temporary fittings for line pigging, flushing with cleaning fluids, or draining to vacuum trucks.

Underground lines require special handling. First, you must identify every pipeline grade entry and exit point. At each pipe transition to "below grade," cut out a section of line and suck out the contents using a vacuum truck. Then, rinse or clean the line, and leave it either empty or filled with a flowable concrete mixture. If left empty, blind flanged ends and plug cut ends.

Storage tanks and vessels need draining and cleaning in preparation for demolition. Tank and vessel product heels usually can be sold to a regular customer at a reduced price. Tanks in service for a long time can have a heavy buildup of sludge, resulting in significant difficulties in cleanout and environmentally safe disposal. Underground and above-ground storage tanks always are subject to local, state and federal regulations, so employing a validated contractor to handle these types of tanks is critical.

After tanks and vessels are isolated and cleaned, stencil or affix a label on the side of each tank, near the nameplate, that clearly states "Permanently Out of Service" and also notes the date of closure. Follow the standard color codes used in the demolition industry for markings.

If the plant or unit is to be demolished, the decommissioning phase may include "air-gapping," i.e., its clear, demonstratable isolation. The isolation refers to piping, utilities, power, underground facilities, etc. — anything that enters or leaves the unit. Generally, this involves installing a fence around the unit and performing isolation in such a manner that the demolition phase can proceed quickly. Due to the heavy equipment and the number of personnel involved in demolition activities, interruptions can be costly.

FINAL STEPS

It is necessary to carefully assemble all the final documentation both for the project as well as for any legal actions in the future. A final closure report should document all activities as well as sampling results. All drawings and documents (P&IDs, utility distribution drawings, electrical, underground, etc.) should be updated to reflect the modifications made as part of the decommissioning, demolition, etc. This final project report also should contain any lessons learned that could help engineers in the future.

Remember, a plant closure/demolition usually results from the development of a new process or the building of a state-of-the-art facility. So, the integration and optimization begins again. ●

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DON'T ERR WITH INSTRUMENT AIR SYSTEMS

Compressors and air dryers are among the elements demanding careful attention

By Amin Almasi, mechanical consultant

MANY PLANTS rely on instrument air. This is very clean and filtered compressed air usually specified to stay dry at around -40°C (or sometimes less). It is used for instruments, control and pneumatic systems that typically operate between 6 and 11 Barg. An instrument air supply package generally consists of one or two air compressors, filters and dryers. Such a package plays a vital role in the operation, control, safety and reliability of the plant. This article discusses air compressors, air dryers and their accessories and auxiliaries.

Instrument air as a motive force can provide many benefits. An air-operated system can offer a better power-to-weight ratio than an electrical one. Generally, air-operated devices are more compact, simpler, safer and probably more reliable compared to electrical alternatives. However, pneumatic systems only are around 25–40% as efficient as their electrical counterparts.

Air-operated systems and devices usually serve in applications where other options cannot be used, e.g., due to area classification, or where they can offer significant cost, operational, safety or reliability advantages.

Unfortunately, experience indicates that many plants suffer, at least at first, from undersized instrument air systems. This usually becomes clear at start-up or during the initial period of operation. Avoiding such a problem hinges upon proper analysis of demand during design and sizing.

In some other plants, careless design or risky connections undermine the reliability of instrument air systems, leading, e.g., to uncontrolled leakage, and dirt and debris in the network. Components of the system, connections, and consumers of air require careful checking.

AIR COMPRESSORS

These units fall into two general categories: positive displacement compressors and dynamic compressors. Positive displacement compressors can be further separated into reciprocating and rotary machines. Typical reciprocating compressors include piston and diaphragm types while

rotary compressors are available in many different designs such as sliding vane and dry screw. The most widely used type of positive displacement unit for air services is the dry screw compressor. Dynamic compressors come in two types: centrifugal and axial machines, with centrifugal machines in a conventional configuration or in an integrally geared compressor train most widely used.

It is difficult to give general advice on selection of air compressors. However, for instrument air systems, an inherently dry compression mechanism is a clear requirement. In other words, avoid compressors that add oil or other liquids to the compressed air. While non-dry (wet) compressors have been used in many air applications, these compressors pose great risks to instrument air systems.

Many small applications suit dry-type reciprocating compressors (dry piston compressors). These machines provide oil-free operation by using, for instance, low-friction polytetrafluoroethylene for wearing parts that come in contact with the airstream.

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As a very rough guide, choose a single-stage compressor for pressures of 3.5 Barg or less and a multistage compressor for pressures of around 4.5 Barg or more. A two-stage piston compressor uses less power than a single-stage unit for equivalent output. Piston compressors come in a wide variety of capacities and pressures. Diaphragm compressors use a flexible diaphragm to compress air; therefore, these machines avoid contact between the reciprocating mechanism and the compressed air. However, they are restricted to light-duty, low-capacity and low-pressure applications where economy is a factor. A water-cooled unit generally is more efficient than an air-cooled one; it has lower power consumption but higher initial cost.

Sliding vane compressors only have handled limited applications for air services. In such units, vanes mounted eccentrically in a cylindrical rotor are free to slide in and out of slots. As the rotor turns, the space between the compressor casing and the vanes decreases, compressing the air. These are compact units, well suited for direct connection to an electric motor. However, their efficiency usually is less than that of an equivalent piston unit. They are best used in services requiring small, low-capacity compressors, generally in the range of up to 300 m^3/h and 4.5 Barg, where their low costs and simple configuration may offer some advantages. In recent years, sliding vane compressors have become less popular for air systems.

In dry screw compressors, a pair of close clearance screw (helical lobe) rotors turn together. As air enters the inlet, the rotation of the lobes causes the cavity in which air is trapped to become smaller and smaller, increasing the pressure. Capacity is varied by adjusting the speed of the driving motor, reducing the amount of inlet air, or returning a portion of the compressed air discharged back into the inlet (suction). The outlet piping should contain one or two check valves to prevent air from escaping through the compressor after the unit has stopped. Because of the rotary operation, discharge is almost continuous. This type of compressor is best suited for applications with capacities of up to 30,000 m^3/h and discharge pressure between 6 and 18 Barg. Dry screw compressors have been very popular for air compression systems because of their inherent dry compression mechanism, good reliability, economy and overall excellent operation.

Centrifugal compressors have been popular for air compressor systems; in these machines, rotating blades or impellers impart velocity (energy) to the air, which is converted to increased pressure inside the casing. This type of compressor is best suited for high rates, say, capacities of 700 m^3/h to 300,000 m^3/h. Centrifugal compressors are smaller than similar reciprocating units but use more power. The air delivered is oil free. Such units are considered as the first option for large plants and high-reliability air systems because they offer the greatest reliability and availability among the many different types of air compressors. Some operating companies specify and use only centrifugal compressors for critical air systems.

DRY SCREW COMPRESSORS

These machines cover very broad ranges of capacity and pressure; they are widely used for medium-size applications

but also handle some small services and large applications. Indeed, dry screw compressors are the most popular machines in air and instrument air services. Therefore, from here on, we'll focus on this type of compressor.

Dry screw compressors work on a displacement principle — male and female screw rotors move toward each other while the volume between them and the housing decreases. The pressure ratio of a screw depends on the length and profile of the screw and the form and design of discharge port. The screw system has no valves, so there are no mechanical forces to create imbalance. It can operate at relatively high shaft speed (say, 6,000 rpm or more) and combine a large flow rate with small exterior dimensions. Dry-type screw rotors are not in contact with each other. They are separated by tiny (a few or several micron) clearances. Therefore, high-performance operation requires relatively high speed. Screw rotors are driven by a timing gear system. Most often, conventional induction electric motors (1,500 or 3,000 rpm) drive the compressors, although other drivers, such as various types of engines, may be used.

Many air compressor packages use a two-stage oil-free rotary compressor to achieve a compressor discharge pressure in the range of 9–15 Barg. The packages come with auxiliary equipment such as air filters, intercooler, aftercooler, oil-cooler, enclosure, dampeners, oil filtration and lubrication system, electrical controls, etc. Lubrication oil is needed for the bearings. However, seals, which separate the air compression section from the bearings, prevent lubricant from reaching the inside of the machine where air is compressed. Many applications opt for "1+1", "2+1" or "3+1" compressor configurations, i.e., one or more units running (in parallel for multiple machines) plus a spare.

A dry screw air compressor usually should be provided with vibration probes and other sensors suitable for full condition monitoring. As an example, each bearing should be equipped with X-Y vibration probes. At least one keyphasor and one axial vibration probe should be included for each shaft. In addition, bearings and critical locations need proper temperature sensors (i.e., resistance temperature detectors). Another important consideration is monitoring using operating conditions such as trends of developed capacity, pressure, etc., to evaluate the health and performance of the units.

CAPACITY CONTROL

In a part-load scheme or operation using capacity control, the screw air compressor remains continuously powered. When the demand for compressed air is satisfied or reduced, a capacity control device is activated. This lowers the number of start/stop cycles for electric motors, significantly improving equipment service life with a tiny increase in the operating cost. Such a scheme nearly always is utilized to boost the reliability and availability of air compressor packages and also to provide operational flexibility.

Many different methods allow operation at part-load and capacity control of an air compressor. A well-known method is the bypass loop (recycle line). Here, a portion of discharge air, often air that has gone through the after-cooler, is routed back to the suction. Different sizing guidelines have been proposed for the valve and line — the most common ones are 100% and 50%.

Variable speed drives (VSDs) often make sense for air compressor services needing excellent operational flexibility and capacity control to cover a wide range of capacity/pressure. Due to the limited adjustment in compressor power consumption

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relative to compressed-air output capacity, any form of capacity control usually is inefficient compared to VSDs. However, VSDs generally are restricted to relatively large applications or special services that can justify their high costs.

AIR DRYERS

The air dryer directly impacts the performance and operation of an air supply package. Also, the efficiency of an air compressor can depend upon the air dryer. While different dryer types are available, desiccant-based systems commonly handle air drying. These systems usually use external heat, regenerative-type dual-tower dryers; one tower is online while the other is regenerating the desiccant, which usually is activated alumina. As a very rough indication, the regeneration cycle is approximately 3–4 h, the heating time usually is around 2 h, and the cooling time most often is about 1.5 h. Therefore, a regeneration cycle typically takes 7–8 h.

To maintain the regeneration cycle, the purge air rate usually is around 10–15% of the total package air flow. Compressor sizing always should consider this extra air flow. As a rough indication, air capacity should include a 20–30% margin to account for package losses, purge air, etc.

Two full-sized units (2×100%) should be used for all critical equipment in the dryer package, for example, 2×100% filters, 2×100% dryer towers, 2×100% heaters, etc. The switching to a standby component (filter, tower, heater, etc.) should be automatic. The design, manufacturing and assembling should guarantee the continued operation of an air dryer package in the event of failure of a component, e.g., heater, blower, etc. Many different configurations exist for switching systems. Automatic switchover between beds most often is timer-based with manual change also possible. Any dryer package should include both pre-filter and after-filter systems. In addition, verifying and monitoring the operation of a dryer system requires a moisture analyzer and other sensors.

CASE STUDY

Let's now look at the details of a two-stage dry screw compressor to supply instrument air for a chemical plant. The compressor is a vertically split machine with foot mounting. The package is sized for the rated capacity of 810 m^3/h and rated discharge pressure of 9 Barg. The driver is an induction electric motor with a power rating of 180 kW and nominal speed of 1,500 rpm. The compressor has two screws with speeds of 10,571 rpm and 6,796 rpm; these are driven by a specially designed timing gear system. The maximum and minimum air discharge pressures of the air compressor are approximately 10.5 Barg and around 5 Barg, respectively. The compressor casing is designed for higher pressure, in this case a maximum allowable pressure of 20 Barg. The compressor casing is cast steel with a special coating; screw rotors are made from special alloy steels and have the same coating. All other parts and piping are fabricated from stainless steel. Two compressors are provided, one operating and the other on standby.

The air dryer selected for this application is a desiccant-based system that uses external heat, regenerative-type dual-tower dryers. Each dryer is designed for 12 Barg maximum operating pressure and is protected by a pressure relief valve. Pressure drop in the package is less than 0.7 Barg; therefore, considering all other losses, the rated output pressure of the package is around 8 Barg. The dryer and its piping are fabricated from stainless steel. One tower is online while the other is on standby; each contains around 300 kg of activated alumina. The system employs timer-based automatic switch-over of the towers (from online to regeneration and vice versa). The package also includes pre-filter after-filter systems.

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REFINERY DRIVES ENGAGEMENT IN PROCESS SAFETY

Program gives front-line staff a vital role in enhancing efforts | By Tony Bocek, bp

AS A process operator, I have witnessed the success of a program at the bp Cherry Point refinery, Blaine, Wash., that enhances the site's process safety culture. It specifically addresses workforce issues mentioned in key process safety references. "Guidelines for Risk Based Process Safety" [1] cites workforce involvement as one of twenty essential elements to reduce process safety risks and prevent major incidents. In addition, two of the ten process-safety-culture core principles named in "Essential Practices for Creating, Strengthening, and Sustaining Process Safety Culture" [2] relate to employee participation: empowering individuals and deferring to their expertise as front-line workers. The model implemented at Cherry Point refinery serves both these process-safety-culture core principles. It has enabled the site to establish employee engagement in the process safety program. After decades of practice and development, this process safety management (PSM) model has become a significant driver of the process safety culture at Cherry Point refinery.

The basic structure of the program is built upon three developmental roles staffed by process operators and maintenance technicians. The three roles are: operating area PSM specialists, operations process safety specialist, and reliability department PSM specialists. These are full-time positions that rotate among front-line workers.

Two important points deserve emphasis:

The roles are full-time. Workers, while acting in these roles, do not carry on-shift operations or maintenance responsibilities, aside from training and maintaining their technical skills.

The roles are rotating. There are two reasons for having rotational assignments. First, it allows more workers an opportunity to gain the valuable experience afforded by these roles. Second, it ensures that current front-line workers staff the positions.

Although the duration of the assignments varies, generally assignments last two years, thus, keeping a fresh perspective in the position.

Companies execute employee participation in a variety of different ways. Often operators or maintenance technicians remain on shift, fulfilling their normal duties, while also attending a management-of-change (MOC) review or a process hazard analysis as a peripheral duty. At Cherry Point refinery, on-shift workers may be encouraged, or even required to participate in addition to their day-to-day tasks; however, the positions detailed here are dedicated positions.

Now let's look a bit more at each of the positions.

OPERATING AREA PSM SPECIALISTS

These are operators who are given an off-shift assignment to support PSM compliance for their operating area. The responsibilities of an operating area PSM specialist include (but are not limited to):

- operating procedure writing and review;
- operating manual review and updating;
- alarm management;
- MOC;
- pre-startup safety review;
- operator training;
- hazard-and-operability and layers-of-protection analyses; and
- mitigation plans.

One task to highlight here is updating operating procedures and manuals. The operating area PSM specialists are solely responsible for writing and updating these documents. They confer with engineers, supervisors and other operators, but have ownership of their area's procedures and manuals. It is possible, even with a robust PSM program, that sites may have operating procedures that are outdated, incorrect or unclear. Driving engagement within operations can prevent these issues by having procedures and manuals written by operators with their fellow operators in mind. If a procedure or manual is inaccurate or unclear, an operator can raise that concern directly to the area's PSM specialist, a fellow operator, who has full authority to address it.

OPERATIONS PROCESS SAFETY SPECIALIST

This position is held by an operator who joins the refinery's process safety team full-time, is embedded with the process safety engineers, and provides insight and guidance on the details of front-line refinery operation. A good summary of the concept for this position appears in Ref. 1: "These workers are potentially the most knowledgeable people with respect to the day-to-day details of operating the process

and maintaining the equipment and facilities and may be the sole source for some types of knowledge gained through their unique experiences. Workforce involvement provides management a mechanism for tapping into this valuable expertise." This position allows the refinery to integrate this unique experience into the process safety team. The responsibilities of the operations process safety specialist include (but are not limited to):

- providing insight and guidance to process safety engineers;
- liaising between the operations and process safety teams;
- reviewing and updating site-wide policies and procedure;
- studying and implementing learnings from industry incidents;
- self-verification;
- championing process safety awareness site-wide; and
- implementing standardized PSM practices throughout the entire site.

One example of the work accomplished in this role was an update to the site's demolition and line-cutting procedure. After one turnaround event, it was recognized that an update was necessary. The operations process safety specialist conducted a review of line-cutting incidents throughout industry and identified practices that could prevent the most common errors. After seeking input about best practices from stakeholders including operations, maintenance, supervisors and contractors, the person incorporated these improved practices into the revised procedure. Additionally, the operations process safety specialist developed and delivered training to the site to communicate the changes.

RELIABILITY DEPARTMENT PSM SPECIALISTS

Just as mechanical integrity is essential to the site's PSM program, so, too, is the existence of the reliability department PSM specialists. These specialists are front-line maintenance technicians representing the instrument and electrical shop (I&E technicians), the machine shop (machinists or millwrights), and the general shop (pipefitters, welders and boilermakers). Each maintenance shop has its own PSM specialist. The responsibilities of the reliability department PSM specialists include (but are not limited to):

- managing critical equipment lifecycle;
- training technicians;
- developing and reviewing maintenance procedures;
- MOC;
- hazard analysis;
- root-cause analysis; and
- self-verification.

When the refinery revised its critical equipment lifecycle management program, the reliability department PSM specialists played a vital role. They developed equipment registers, with insight from the process safety team and operations, and updated the preventative maintenance procedures for the equipment. They also developed and provided training to technicians, underscoring the importance of detailed maintenance-event logs.

THE BENEFITS

Now that we have looked at the positions and what they do, let's turn to how the design of Cherry Point refinery's process safety program drives employee engagement. Many studies indicate employee engagement rests upon a few core qualities: ownership; professional and personal growth; and recognition.

Ownership. Operators and maintenance technicians are responsible for delivery of PSM elements, which drives a level of ownership in the program. This ownership, in my opinion, has the largest impact on front-line workers' process safety culture. As well-known author and leadership consultant Jocko Willink succinctly put it [3]: "Ownership is the most powerful compensation you can give a human being."

Professional and Personal Growth. Process safety work provides experience that supports development outside the traditional work scope of operators and maintenance technicians. They also can make a difference and see the value they are adding for their fellow front-line workers. Furthermore, as individuals rotate in and out of these positions, the refinery becomes increasingly staffed with process operators and maintenance technicians who are knowledgeable about the refinery's PSM program.

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Recognition. Because work accomplished within the PSM program is being driven by the front-line workers, there is an opportunity to recognize them, and their departments, for the contributions they have made to process safety. Such recognition increases their sense of accomplishment.

Next, we should list some core competencies. As Ref. 2 cautions: "While empowering others to fulfill their process safety responsibilities is desired, an employee cannot be empowered if they are not competent to carry out their role." Key competencies include (but are not limited to):

- process operator or maintenance technician expertise;
- written and verbal communication skills;

- familiarity with PSM elements;
- critical thinking skills;
- collaborative approach to resolving complex challenges;
- basic computer skills; and
- awareness of different learning styles.

Consideration of these capabilities is an important part of candidate selection.

The U.S. Chemical Safety Board (CSB), in "Safety Digest — The Importance of Worker Participation" [4], highlighted worker engagement as critical to process safety, and discussed how ineffective employee participation was found to be a contributing factor in four process safety incidents. Then-CSB-board-member Rick Engler in a press release about the publication said something that summarizes my personal belief in Cherry Point's process safety program: "Worker engagement is key to an effective process safety program. After all, it's employees who are so often in direct contact with the hazards — and have the experience and knowledge to help prevent them." Several existing process safety regulations already require worker participation. However, I believe basic participation may not be enough. Achieving operational excellence and a strong process safety culture requires front-line workers who are engaged in and take ownership of the PSM program. ●

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Take Some Solid Steps

Improve evaporator level measurement and cut labor intensiveness

REVIEW YOUR INSTALLATION

Consider the following:

1. Numerous technologies are available for level measurement and level switch applications — differential pressure (dP) cell, guided wave radar (GWR), ultrasonic and others — with each technology having pros and cons. Favor technology that could be implemented without a long shutdown and without having to do many mechanical modifications to the evaporator (e.g., adding extra nozzles). You also should also consider signal transmission (HART, Fieldbus, etc.) to make sure it is compatible with your current distributed control system.
2. If you are using a dP cell system, slurry tends to clog impulse lines. Changing to a capillary system (with diaphragm) will help minimize clogging of the impulse legs because it replaces impulse legs with a capillary system. Slurry still could coat the diaphragm, though. Good agitation near the diaphragm will reduce fouling of the diaphragm.
3. Other non-contact technologies such as GWR or ultrasonic could offer significant relief from the slurry (coating) problem but would require nozzles in the top of the crystallizer.
4. Slurry coating of the probe and interference from vapors would be key considerations for level switches as well. Modern technologies offer diagnostics and compensation for coating.
5. You indicated that resistance temperature detector (RTD) readings are off by as much as 10°F; this could cause problems with temperature control. Tuning (proportional, integral, derivative settings) could be another issue to consider. Slurry may be coating the RTD thermowell. Provide better agitation near the thermowell or relocate the thermowell to a spot that has better agitation and is representative of the process. Avoid dead-legs.

GC Shah, consultant
Houston

THINK UNCONVENTIONALLY

Without level control, you can forget about automatic control, let alone continuous control!

You also should forget about some technologies for level that others have tried unsuccessfully: nuclear, radar and contact.

Nuclear, being a non-contact method, will at least report the level — but it will be wrong. Solids splattered on surfaces will show up as level because they absorb radiation.

Radar also is a wave-based method, which means it will suffer the same fate as nuclear.

The various contact level switches available won't work because they can't detect the difference between solids in solution and solids splattered on the switch.

Weigh cells might tell you the level if you can keep track of the residual product left between batches. You may want to deploy a second, check

THIS MONTH'S PUZZLER

We make an ethoxy compound using a water-based process. Our evaporator is supposed to operate continuously but instead the operators run it in manual — with a lot of babysitting. 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?

scale downstream and programming to track the residual. The trouble is that weigh cells are expensive.

Perhaps you need a more radical approach. Could you use cameras? You could place these either outside the evaporator, looking at the sight glasses, or even inside the evaporator. The operator could look at the feed to decide what the level is. Periodically, the camera lens would require cleaning but this could work. Cameras won't make the system automatic but can reduce operator involvement to a minimum; their cost might be competitive with retrofitting weigh cells to the evaporator. Someday, software may even be available to operate the system in true automatic fashion.

As for the pipe size issue, I see two solutions: a different type of pump, or a smaller discharge pipe. Take this to the laboratory to determine if you can replace the current pump type by one with a larger motor to handle the smaller pipe or go with a progressive cavity or lobe pump; get the vendor of the new pump to provide pressure drop data for changes in the pipe diameter.

CHECK OUT PREVIOUS PUZZLERS

To see all the Puzzlers that have been published over the years, go to: www.ChemicalProcessing.com/voices/process-puzzler/.

Remember, accurate sampling and storage are crucial if the sample is to represent the material being pumped.

Temperature control of a slurry always is difficult. It is best to pick a sample point and build the product quality control around it. Try several points to determine which is best for control. Ensuring accuracy in temperature measurement calls for an approach opposite to that for pressure readings: for temperature you need mixing; for pressure you require an established, steady but representative positioning — elbows for temperature instruments, straight pipe for pressure ones.

Dirk Willard, consultant
Wooster, Ohio

AUGUST'S **PUZZLER**

A safety review has discovered serious flaws in our relief valve vent system and electrical area classification. The reliefs for our ammonia compressors vent on to the roof of a busy area in our plant. In addition, the compressor building lacks an exhaust fan, which makes it a Class 1, Div. 1, Group D zone.

I designed a 4-ft diameter scrubber with the relief vents going to a basin. I proposed 10% sulfuric acid. The superintendent doesn't like operators working with acid. He also complains the scrubber will be ignored: the ammonia alarm goes off about six-to-ten times a year (when someone actually takes note of it). The safety director gripes about having to resize the relief valves for the pressure drop: it's a 300-psig system! He's also concerned the ammonia relief flows will blow right through the basin without being captured. The project group is troubled over the cost of the scrubber because of material selection.

Now, the superintendent has talked corporate into the idea of using the scrubber to handle the formaldehyde and methanol that escapes our storage tanks when we do inspections and repairs. We have a thermal oxidizer but it only captures about 90% of the vapor from the plant.

Are there any options other than sulfuric acid that would lower the project cost? How much of a concern is resizing the relief valves? Can you suggest other ideas to meet the scope of this project?

Send us your comments, suggestions or solutions for this question by July 8, 2022. We'll include as many of them as possible in the August 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.

Don't Say "What Were They Thinking?"

Hindsight doesn't account for the human factors behind a choice

Understanding how bad decisions get made can reduce their frequency.

"EVERYONE SHOULD have realized that won't work the way they wanted," is a refrain heard all too often. However, engineers are not machines that convert an input (information) into an output (decision) based on purely objective factors. How we make decisions also counts.

Understanding how bad decisions get made can reduce their frequency. The psychology of decision-making, which already is used in safety analysis, provides insights. So, let's look at some elements to see how they can influence design choices, maintenance criteria, control system design, and other areas. All these elements involve cognitive biases — factors that can affect decisions without us noticing or controlling them.

Anchoring is the process where the first idea or piece of information presented becomes the reference point for comparing all other ideas. Anchoring gives undue weight to the first information you have available. One example is where the initial proposed design choice for equipment becomes the favored option automatically, even if it was simply a throwaway idea mentioned casually.

Availability is the ease of keeping a particular choice in mind. The adage that every problem has a simple, easy-to-understand, wrong answer underscores the availability problem. If you're not familiar with a topic, an uncomplicated analysis and solution requires less mental effort than more-complex proposals. The simple proposal is easier to keep in mind, so tends to be favored.

Framing is a response to how a question is asked. People vary from risk takers to risk avoiders. For example, in evaluating a new, but not identical, replacement part, the risk can be stated as "99% chance of working" or "1% chance of not working." These statements represent the same probability but the risk-averse person is more likely to think a decision that has "99% chance of being right" is better than one that has "1% chance of being wrong," even though that's not true.

Polarization is a group decision problem where the group talks itself into a choice that is more extreme than anything a single individual would select. The extreme choice could be in any direction. One case is where participants in a design review intended to cut cost (a value-improvement meeting, for example) talk themselves into cutting project scope to a point well beyond where any individual would agree is realistic.

Habit is a reflexive response to a familiar situation. We'll use a specific solution like a particular control configuration because we've always handled the situation that way. Even when the habit gives a valid technical answer, it can lead us to miss better solutions.

Representative failure is similar to habit. When we have a choice, we often make decisions based on how similar the situation looks to something we've already encountered. For example, we may have used a shell-and-tube exchanger in a "very comparable" service before, so let's opt for the same type of exchanger now. However, perhaps we missed a difference that significantly affects the performance. It's often difficult to judge the importance of small variations when we're convinced the situation is similar.

Selective memory also can contribute to problems. Over time, we may forget how difficult a particular supplier is to deal with or why we don't buy those cheaper parts anymore. In other situations, memories can combine or points be forgotten. We think we're doing the right thing but have mixed together multiple previous experiences and aren't making as good a decision as we believe.

Deference to authority can undermine making good choices. Are you working on something your boss did when in your job? Does your company's "expert" on the topic favor a specific option? Both of these can short-circuit a critical analysis of a decision. The authority of some people involved may overwhelm doubts others have.

Conformity is another name for peer pressure. Everyone else thinking something is a good idea can make you believe your doubts are unfounded. Mention any doubts you have and at least get them discussed.

These factors represent only some of the reasons poor choices get made. No one has a magic cure for any of these. The best decisions come when reasonable time is available and all involved are willing to evaluate the possible risks and advantages of specific choices. With effort, you can minimize a future engineer's hindsight criticism of your own work.

ANDREW SLOLEY, Contributing Editor
ASloley@putman.net

Pump Reduces Maintenance Time and Costs

The FTI Air FT025 ¼-in. non-metallic air-operated double diaphragm (AODD) pump is manufactured from unfilled polypropylene, unfilled polyvinylidene fluoride, or conductive carbon-filled polypropylene. Santoprene or polytetrafluoroethylene diaphragms provide maximum chemical compatibility. The pump offers 5.8 gal/min (22 l/min) maximum flow. Its simple, lube-free non-stalling air valve requires no separate or mechanical pilot valve. The air valve contains fewer parts than other options on the market, reducing maintenance time and costs, the company says. The pump works with fluids including acids and bases, plating solutions, wastewater and solvents. It is quiet, rated at only 65.3 dB(A), and has versatile suction and discharge connections.

Finish Thompson Inc.
814-455-4478
https://ftiair.com/

Filters Clean Up Gas Streams

Dollinger series GP-146 high efficiency filters are designed to remove dirt, pipe scale and other contaminants from process air and other gases. Acting as the last line of defense against particulates that could contaminate the end product or damage expensive equipment, the filters deliver reliable filtration over extended periods while reportedly lowering total cost of ownership. An efficient radial-fin filter element provides the largest filtration area for a given element size. It offers operational integrity up to a differential pressure of 50 psid as standard, with special designs available for applications which demand higher differential capabilities.

Celeros Flow Technology
800-344-2611
www.celerosft.com/

RTD Probe Accommodates Older Plants

The Guided Wave resistance temperature detector (RTD) insertion probe with single-sided transmission (SST) reportedly is ideal for continuous process monitoring applications. The combined RTD-SST probe provides additional temperature data along with near-infrared (NIR) measurements. Easily installed in a pipe or reactor through a single access port, it is compatible with most analyzers, as well as older chemical plants or reactors without access ports for additional process analytical tools. The new design also suits applications that benefit from high-accuracy temperature and NIR measurements being completed at the same location; for example, temperature-sensitive measurements such as methanol in water.

Process Insights
713-947-9591
www.process-insights.com

Valve Positioner Offers Maintenance Insights

The TopWorx PD Series smart valve positioner provides 100% control over valve position and integrates communication via a 4–20-mA loop signal and HART protocols. Users can extract

feedback through this intelligent communication and can monitor for trends that offer predictive maintenance insights to help prevent costly downtime. To maximize reliability, the unit uses Hall-effect contactless position detection. Two PNP alarms configured throughout the full displacement range help improve plant productivity and safety in any process application. It also is designed to withstand a variety of environmental conditions, and is available in two models to address either general purpose applications or explosive atmospheres.

Emerson Automation Solutions
888-889-9170
www.emerson.com

Software Simplifies Industrial Analytics

TrendMiner NextGen brings operational insights to anyone in an organization, regardless of their level of analytics training. Users now can do anything from basic trend viewing to advanced diagnostic, predictive, and prescriptive analytics using machine learning and artificial intelligence. The industrial analytics software enables production experts to visualize and analyze production performance using sensor-generated, time-series data in combination with contextual event information. The 2022.R1 release features an easy-to-use method of searching through thousands of sensor readings over years of data. The software is said to give instant answers to know what has happened, how often, and why. Searching, filtering, coloring, switching, and comparing trend views offers a quick production performance overview.

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Studies Link Socioeconomics to Pollution

"Mined" wastewater reveals impact of industrial chemicals and medications on environment

Correct disposal does not include flushing or trashing.

RESEARCHERS AT the University of Bath, Bath, U.K., "mined" wastewater for biophysico-chemical indicators (BCIs) and found a direct link between the size of a city or town and the quantity of harmful chemicals and biological agents released naturally into the environment after passing through people's bodies, or directly discharged via various activities such as showering and dish washing.

The researchers studied five cities and towns in the country's southwest, each with very different characteristics including population size, industry presence and socioeconomic status. They looked for BCIs in rivers and wastewaters associated with each location to determine their impact on the environment. The researchers particularly focused on industrial chemicals such as bisphenol A found in plastics; personal care products, including UV filters and preservatives in cosmetics; pesticides, illicit drugs; lifestyle chemicals such as caffeine and nicotine; prescription medicines; and genetic material such as antibiotic-resistance genes.

"We found that wastewater represents an excellent fingerprint of a city's use of a complex mixture of substances of biological and chemical origin," says Barbara Kasprzyk-Hordern, professor in the department of chemistry and lead researcher on the study.

The biggest offenders identified were painkillers and medications used for heart disease, mental health conditions, and epilepsy; antibiotics — known to contribute to the prevalence of antibiotic resistance; lifestyle chemicals such as caffeine; and substances produced when these compounds are broken down by the body.

"Each of us needs to start considering our lifestyle as a factor contributing to deterioration of environmental health," she advises. "First, we need to acknowledge that we are responsible, through the way we live, for water contamination, and then we need to start finding solutions," she adds.

"It's often more sustainable to remove the problem at [the] source, for instance via social interventions, than to invest in end-of-pipe, energy-intensive wastewater treatment processes that do not necessarily help reduce society's carbon footprint or provide wider environmental benefits," counsels Ruth Barden, director of environmental solutions at Wessex Water, Bath, U.K., which collaborated on the research.

The researchers hope the study's findings, recently published in the *Journal of Hazardous Materials*, will give local governments the impetus to establish policies that will better support the health and resilience of their city environments; they suggest several social interventions to target pharmaceuticals — for example, awareness campaigns to highlight the correct disposal of unused pharmaceuticals, which does not include flushing or trashing, but instead returning medicines to pharmacies. Green prescribing is another. Here, if several medicines of equal therapeutic benefit exist, doctors prescribe the one with the least environmental impact. Another alternative is social prescribing in which doctors refer patients to local, non-clinical services offering activities known to improve health and wellbeing; patients considered not-at-risk are prescribed medicine as a last resort.

"Most of us are unaware of this impact because each use of a product results in small parts-per-billion quantities of toxic waste that can't be seen with a naked eye, but when taken together, these tiny quantities create a complex chemical cocktail in our rivers that might have detrimental effects on the wider environment, especially aquatic creatures," emphasizes Kasprzyk-Hordern.

This latest study builds on research conducted by the same group and published last year in *Environmental Science & Technology*. It concluded down-the-drain disposal of pharmaceuticals remains an overlooked and unrecognized source of environmental contamination that requires non-technological "at source" solutions.

In this study, 31 pharmaceuticals were monitored over seven days at five wastewater treatment plants (WWTPs) serving the same five towns and cities in southwest U.K. It revealed down-the-drain co-disposal of six pharmaceuticals to three WWTPs: carbamazepine and propranolol in city A; sildenafil in city B; and diltiazem, capecitabine and sertraline in city D.

The study also revealed a one-off record co-disposal of an estimated 253 pills (40 g of carbamazepine) and an estimated 96 pills (4 g of propranolol) in city A which accounted for their ten-fold and three-fold respective increases in wastewater daily loads over that of "normal" bodily-excretion-only days.

As a result, the researchers urge reducing these down-the-drain disposals, noting such disposals were double that of a previous study performed in 2005.

SEÁN OTTEWELL, Editor at Large
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