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Keep Up with Evolving Codes

Knowing the changes between new and previous versions is important

Identifying revisions and their impact isn't always easy.

TECHNOLOGY AND practices change with the times. Indeed, in our industry, virtually nothing stays static except fundamental relationships set by nature. Some design methods considered state-of-the-art not that long ago now seem outlandishly outdated. Equipment termed cutting edge a couple of decades back get dismissed as ancient relics. Operating and safety practices deemed acceptable in the past might cause considerable consternation today.

In response, recognized and generally accepted good engineering practices (RAGAGEPs) evolve. Sometimes, particularly for consensus codes and standards, this takes a while, which reflects the deliberate consensus-based nature of the updating and approval process.

Relying on an outdated version, unless regulations or jurisdictions require its use, doesn't make sense. However, especially for people who don't routinely reference such a document, knowing what revisions appear in the latest version and understanding their significance isn't always easy.

So, *Chemical Processing* sporadically publishes articles that cover the changes and their impact.

For instance, this issue contains just such an article: "Understand the Key Changes in NFPA 30," p. 23. It clarifies what's new in the 2021 edition of the National Fire Protection Association's "Flammable and Combustible Liquids Code." It covers six adopted technical changes and also two proposed changes that ultimately were rejected but address issues businesses still should consider.

An earlier article — "Understand the Changes in API RP 754," http://bit.ly/2IchCok — explains the important revisions in an update to a key recommended practice for process safety issued by the American Petroleum Institute.

Still another article — "Safety Instrumented Systems: Bridge the Gap," http://bit.ly/2Jrraie — discusses significant changes in the second editions of two key process safety standards issued by the International Electrotechnical Commission — IEC 61508: "Functional Safety of E/E/PES Safety-Related Systems," and IEC 61511: "Functional Safety — Safety Instrumented Systems for the Process Industry Sector, Part 1."

"Does Your Existing SIS Get the Job Done," http://bit.ly/2MbQ7zj, looks at a revision in the second edition of IEC 61511 that affects the grandfathering of in-place safety instrumented systems.

Another article — "Dust Explosion Standard Gets Significant Revisions," http://bit.ly/2U23Tpq — details the implications of updates to NFPA 654.

Changes in government regulations also can have profound impact. The situation in the United States at the moment is particularly fluid because of the Biden Administration's markedly different attitude to that of the Trump Administration. This is fostering a lot of revisions as well as reversals of prior policies. Fortunately, our monthly "Compliance Advisor" column provides a way to keep up on actions significant to the chemical industry. For instance, August's column focuses on changes proposed by the U.S. Environmental Protection Agency (EPA) to reporting rules for per- and polyfluoroalkyl substances: "PFAS — Is Anything Not Reportable?" https://bit.ly/3rX8c6N. The June column covers changes in toxic release inventory reporting — "EPA Expands TRI Reporting Requirements," https://bit.ly/3lCG3Ri. To see the full roster of columns, go to https://bit.ly/CP-Compliance.

Expect more such content from *Chemical Processing* in the future. ●

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Probe Particle Size Distribution

Lack of uniformity in a material can complicate processing and handling

What size are we talking about?

READERS OF this column know that I emphasize physical properties as the first step in understanding the behavior of a material or a piece of equipment. Color, hardness and shape are some simple examples of elusive properties that have clear definitions and ways to measure. However, a number of other properties can be confusing or very difficult to pin down. For instance, while we would like particle size to be a specific number that we can rely on, chemical manufacturers rarely deal with materials containing just a single size. So, we must characterize a material by its particle size distribution (PSD) to ensure we are making or buying the correct stuff. Unfortunately, such a characterization is not that simple. The size may represent an average of the mass, volume, surface area or some other physical property.

In one common PSD description, we use an average along with a range of sizes (i.e., 50% below the mass average of 50 micron, 10% below 10 micron and 10% above 100 micron). That sounds specific enough — but it really isn't.

So, we use graphs to show how the particles are distributed. Most people look at these graphs and convert them back to the simpler description as described above. However, the shape of the curve tells a lot about your material — but seldom gets sufficient attention. For instance, a PSD that follows a Fibonacci series is less likely to attrite than one that is log-normal because the finer particles cushion the larger particles from wear and impact.

Another misuse of graphs is in conversion of the mass PSD to surface area. This requires a shape factor; it usually fluctuates with size. I reviewed a research program that was having problems producing the same product even when the starting chemical hadn't changed. The team had PSDs that appeared to be consistent. However, they hadn't examined the chemicals with a microscope. The crystals varied from batch to batch in shape but gave the same PSD as the composition changed. The problem was a polymorph that appeared when the starting solution's concentration was too weak. You always want pictures of your particles to avoid this embarrassing situation.

You can obtain a PSD in many ways but results seldom agree. So, it's important that you and your customer are on the same page. Help ensure this by sending a graph along with details on your procedure and equipment. The most common method to get a PSD is screening. Many different procedures (shaking time, frequency and even the use of media to prevent screen blinding) can be used along with a variety of screen shapes and materials of construction. Unfortunately, this method is time consuming and seldom makes sense for highly reactive or hazardous materials for obvious reasons.

Looking at particles with a microscope not only gives the size distribution but also the shape. By using a scanning or transmission electron microscope, you additionally can find chemical composition.

EXPLORE ISSUES POSED BY SOLIDS

Check out previous Solid Advice columns online at www.ChemicalProcessing.com/voices/solid-advice/.

Many laser-based devices will give a PSD and, sometimes, even shape information. These devices offer the advantage of producing the graph and can be used off-line as well as integrated into the process.

You must pair the PSD with the method of analysis and how the sample was obtained. In my May 2016 column "Prevent Problems with Fine Particles," http://bit.ly/2DvaVOx, I cited a problem in using thief samples made worse due to the short travel distance of the tanker truck. Our customer would grab a sample upon receipt of the tanker and claim it was too fine. Its sample didn't represent the whole of the tanker. In addition, the customer was using grounded metal screens to check the sample while our plant was employing nylon screens. We fixed the sampling problem with a drop-through blender and the chute remained clean. The blender collected any fines; these were pushed out at the beginning of the next fill, solving the problem from our end.

Particle size distribution is what you make of it and how you use it. Be sure to select the most appropriate method of obtaining PSD and communicate details to your customer.

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Utilities Pose Underappreciated Safety Risks

Air, water, steam and gas systems may harbor some unpleasant surprises

Too many sites have discovered the risks the hard way.

IN FEBRUARY 1999, a boiler blew up at a car factory. The boiler was shut down for cleaning and then purged with nitrogen. However, because of faulty controls and poor isolation, gas flowed to the burner from a gas line that was left open. After 90 seconds, the boiler exploded, setting off a coal dust explosion that killed six workers. This accident was one of the most expensive in history. (For more details, see Trevor Kletz's "Still Going Wrong! Case Histories of Process Plant Disasters and How They Could Have Been Avoided," 1st ed., p. 105.) The U.S. Occupational Safety and Health Administration keeps a record of steam boiler accidents, which happen more often than you might think.

Yes, I know your insurance company requires annual inspection of boilers. How much can an inspector look at, though? Does the person check your procedures or determine if safety equipment works or has been set up correctly? Probably not.

Now, consider your other utility systems: compressed air, nitrogen, water supply, refrigeration, cooling towers, natural gas and electricity. How many times have you considered safety, let alone reliability, of these vital services? What would happen if you lost compressed air? What about water or fuel gas? Too many sites have discovered the risks the hard way!

In December 2015, a loss of fuel gas to a boiler made the flares fail at a California refinery, leading to a reportable environmental event. (A few other times, the loss of boilers resulted in a shutdown of the refinery.)

In another incident, a paper mill closed its water line for repairs, but someone forgot to check with the powerhouse. Deprived of cooling water, oil in an air compressor overheated and exploded, killing one worker and injuring four others. A review later showed the temperature controls weren't functioning but I'm sure there's more to it. Given the poor maintenance of piping and instrumentation diagrams (P&IDs) and other drawings in plants, especially those for utility systems, I wonder if anyone knew how to properly isolate piping for maintenance. By the way, while many think that isometrics are appropriate for utilities, I've observed that P&IDs will do if they include sufficient mechanical details and orient the pipe network so it's spatially correct.

Roy Sanders cites an exploding compressor jacket caused by loss of cooling water on p. 148 of "Chemical Process Safety," 3rd ed. At one plant I worked at, the motors for two water-cooled compressors burned up in the summer two years in a row. Kletz, on p. 8 of "Still Going Wrong!" blames badly marked pipe for an accidental break in a 100-psig air line; the pipe fitter was lucky that time. Poor documentation often underlies an incident. I wonder how many accidents plants could avoid if better documentation improved inspection and allowed better leak detection.

In February 2009, a gas line leaked in the powerhouse of a Pennsylvania steel mill. The line exploded, killing one laborer.

Not all powerhouse accidents involve gas, steam and air. In July 2018, two workers were burned from handling lime in a Kansas City water plant. In August 1976 and again in January 2003, explosions occurred in handling ion exchangers as part of uranium separation. This type of accident involving ion exchangers that use nitric acid or other corrosives in the backwash was so common years ago that equipment manufacturers often warned about the risks.

At another plant I worked at, a welder was slightly injured when his torch lit off a hydrogen cloud in the chiller room. Hydrogen results from acid leaking into a closed chilled water system. I actually was in the process of updating the P&IDs when the incident took place.

Recently, I recorded another near-miss because fouled cooling water threatened to trip our ammonia refrigeration relief valves. Fouled exchangers are a common issue at plants. Funny how the little things get overlooked.

Completing and maintaining P&IDs, isometrics and equipment files of utilities will help you identify additional elements to monitor in your plant: e.g., pressure vessels, thermal expansion, and material incompatibilities. For example, after creating a P&ID for the compressed air system at one plant, I discovered several operating and design issues that badly needed attention. I wonder what I would have discovered if I looked at the fuel gas system? ●

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Cheaper H_2O_2 Production Beckons

Palladium-gold catalyst delivers high selectivity and uses less-toxic materials

TRADITIONAL HYDROGEN peroxide (H_2O_2) production depends upon a complicated, multi-step process that requires large facilities and involves chemicals derived from fossil fuels, making H_2O_2 difficult and costly to produce. Now, a team of researchers from the University of Illinois, Urbana-Champaign (UIUC) have improved upon an existing palladium-gold nanoparticle-based catalyst for more-efficient, environmentally friendly H_2O_2 production.

"This 'direct synthesis' method was known to synthesize 80% water and just 20% hydrogen peroxide," notes David Flaherty, a professor of chemical and biomolecular engineering at UIUC.

So, the researchers began tweaking the arrangement of palladium and gold atoms needed in the nanoparticles to increase selectivity to achieve higher hydrogen peroxide output and less water. They found that a catalyst with a ratio of one palladium to 220 gold atoms generates almost 100% H_2O_2, which is about the point of diminishing returns.

In addition, the catalyst remains stable over many days of service, continuously achieves high selectivity, and uses clean water as a solvent, which avoids the problematic and corrosive additives often relied on for this chemistry.

"We tested the catalyst for ~100 h on-stream and found minimal deactivation over this period with no loss of selectivity. The catalysts do not appear to sinter or leach to any significant extent during this time…. While it is true that gold is an expensive metal, it is actually less expensive permol than Pd or Pt. Additionally, since we do not observe any significant amount of leaching, the catalysts can be recycled at the end of the lifetime to recover the precious metals," notes Tomas Ricciardulli, a graduate student in chemical and biomolecular engineering at UIUC.

The atoms' organization within the catalyst also matters, the researchers say. They discovered palladium atoms touching one another favor water formation, while those surrounded by gold favor H_2O_2 formation. An article in the *Journal of the American Chemical Society* contains more detail.

The team is pursuing development of nanoparticle catalysts with new compositions and reactors to enable hybrid chemical-electrochemical methods for this reaction. "Our ultimate goal is to develop feasible technology for distributed production of H_2O_2, which would open doors for many sustainable alternatives to traditional chemical processes," believes Flaherty.

"H_2O_2 can be used in place of a number of other more hazardous or atom-inefficient oxidants like HOCl and Cl_2, but is currently too expensive. Industrial H_2O_2 is almost always sold as a mixture with water and water is expensive to transport, which means that most of what you pay for when you buy H_2O_2 is actually the transportation and purification (i.e., removal of water). If we could produce and consume H_2O_2 at a relatively small scale in the same facility, the cost of it would be significantly decreased. However, the current indirect H_2O_2 synthesis process (anthraquinone auto-oxidation) is only feasible at large scale, which motivates research into direct H_2O_2 synthesis," adds Ricciardulli.

The researchers first must address a few challenges before the process can be industrially implemented and profitable. "The most important hurdle is to prevent decomposition of the H_2O_2 product. There are two possible routes for H_2O_2 decomposition: disproportionation ($2\ H_2O_2 \rightarrow 2\ H_2O + O_2$) and reduction ($H_2O_2 + H_2 \rightarrow 2\ H_2O$). These reactions are somewhat nebulous and not well understood. So far, the research from our group has focused on shutting down the direct water ($2\ H_2 + O_2 \rightarrow 2\ H_2O$) formation pathway, and this study highlights an effective strategy to that end. Now that we have done that, we can turn our attention to better focus on these side reactions.

"In addition to addressing the decomposition reactions, ongoing work within our research group is aimed at increasing the catalyst productivity and decreasing the Au requirement for selective catalysis. To that end, we are investigating the effects of nanoparticle size, nanoparticle morphology, active metal identity, support material and solvent. My first follow-up paper will be published later this year and we hope to have appropriate answers to our research questions within the next few years," says Ricciardulli.

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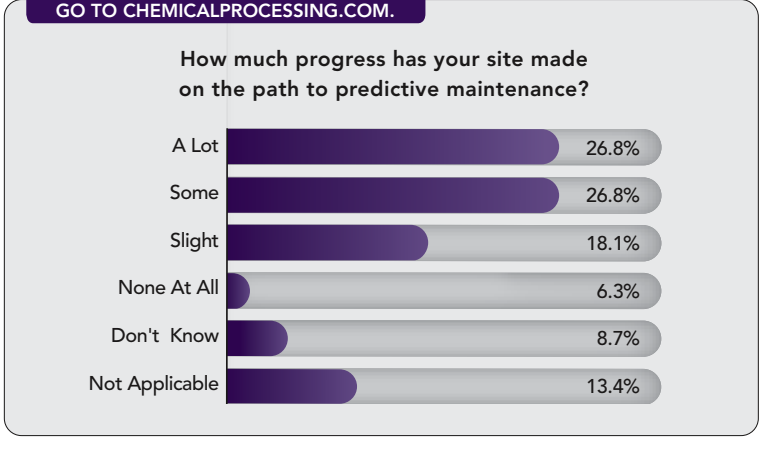


More than half of respondents report at least some progress.

Tweaked Molecular Sieves Spur Mixture Separation

FINE-TUNING THE thickness of super-thin carbon molecular sieves (CMSs) can enhance the efficiency of separating and purifying different gaseous mixtures, report researchers at the King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia, who have developed a way to tweak the thicknesses.

Creation of CMS membranes involves depositing a layer of carbon-rich polymers onto a suitable support and then applying heat to convert the polymer into a microporous CMS film. The KAUST researchers found that membrane thicknesses of 50–300 nm contain "sweet spots" that the researchers believe can be optimized for separating different gaseous mixtures.

Currently, the team produces the membranes as laboratory-scale single-fiber modules (Figure 2); its immediate target is to develop multi-fiber modules with 10–100-cm² active membrane areas.

The membranes show permeances after several months of around 500 GPU (gas permeation units) for H_2 and CO_2, and 100 GPU for O_2, with O_2/N_2, CO_2/CH_4 selectivities of 6–7 and >40, respectively.

"Importantly, we are developing promising, scalable modification ways to boost membrane selectivities at only a minor expense of permeance," says group leader and professor of chemical engineering Ingo Pinnau. The challenge in scaling up the membranes predominantly lies in maximizing the achievable performance of the module versus the fabrication reproducibility of individual fibers.

"We need to consider whether we would want to use as small as possible fibers to pack a large membrane surface area into the module at the expense of increased risk of defects," he adds.

Pinnau notes that the work is continuously guided by the understanding of the underlying physics of thin and ultra-thin separating layers — something that is particularly important when dealing with microporous amorphous materials that undergo an extended process of decelerating collapse, i.e., physical aging.

One conclusion already very clear is that opting for excessively thin layers is strongly counterproductive, points out research scientist Wojciech Ogieglo.

"Such thin layers turn out to collapse at an exponentially accelerated rate, which often renders them practically useless for efficient separations. Going to thicker layers seems much more beneficial as it also helps in dealing with unavoidable defects," he explains.

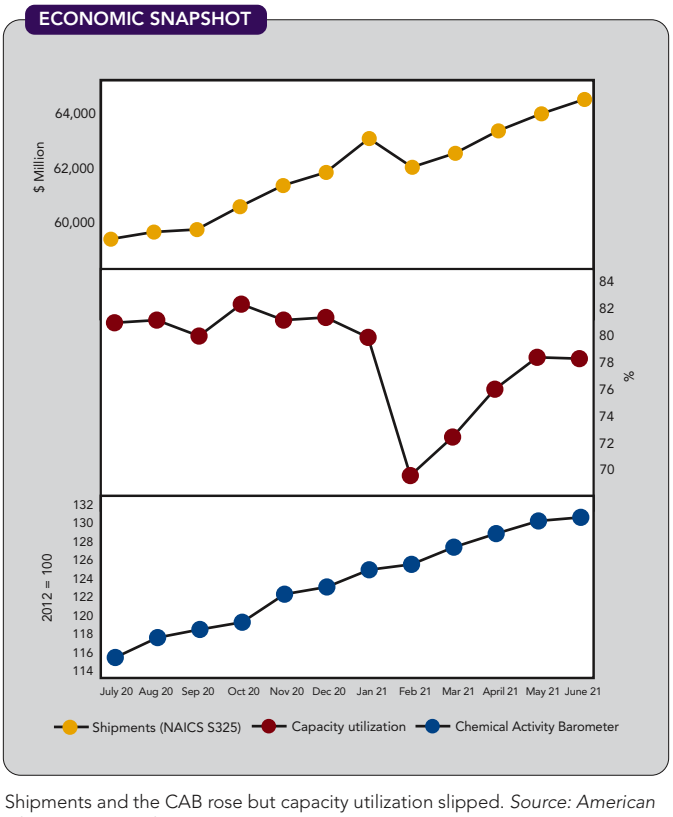
"Next to carbon membranes, we are also exploring novel polymers of intrinsic microporosity, which are a relatively new class of very promising membrane materials," reveals Ogieglo.

MEMBRANE RESEARCHERS

Figure 2. Chemical engineering professor Ingo Pinnau (left) and Wojciech Ogieglo (right) hope to scale-up production of their membrane to test its performance and long-term stability. *Source: KAUST; Anastasia Serin.*

Current funding comes from KAUST's Advanced Membranes and Porous Materials Center, which promotes projects with clear scale-up potential. Both researchers believe that industrial involvement could happen as their work progresses.

ECONOMIC SNAPSHOT



Shipments and the CAB rose but capacity utilization slipped. *Source: American Chemistry Council.*

Behold the Impact of Human Behavior

Saving energy starts with conscious effort and corporate awareness

Behavioral changes often lead to technological changes.

WHERE SHOULD we look to find opportunities to save energy in our industry? The engineers among us, including me, tend to turn immediately to technical options, such as new process designs, more efficient equipment, and more sophisticated control systems. However, many of the best savings come from behavioral changes. These can take many different forms. At a very basic level, do you routinely turn off unneeded lights in your house, or when you leave your office? If you do, you are acting on your awareness of the need to save energy. This awareness can readily be transferred to other areas of your life and your work — for example, by turning off process equipment when it's not needed, or thinking through operating strategies, or even making physical changes in the plant that will result in energy savings. In other words, behavioral changes often lead to technological changes. The two approaches are complementary; they do not — or should not — compete.

Appropriate strategies within companies can harness and multiply positive behaviors. At the highest level, most companies have energy policies intended to integrate energy efficiency into the corporate culture. The policy then flows down to various departments and disciplines in the company for implementation. This can lead to a wide range of new practices and behavioral changes, both on a corporate and individual level; for example:

• Engagement of executive level support for corporate energy-efficiency activities.

• Enhanced data collection and analysis to support the development of energy strategies and the deployment of energy management systems.

• Engineering standards and procurement rules that require premium-efficiency electric motors, enhanced insulation, and other measures that minimize energy use in new plants and revamps.

• Allocation of funds specifically for energy efficiency projects, or allowing a lower rate of return for projects that reduce energy consumption than for other types of projects. These measures can result in implementing energy-saving projects that would not otherwise meet the company's financial rules.

• Implementation of site energy audits, pinch studies, and other programs designed to identify and implement energy-saving opportunities.

• Employee awareness programs (e.g., energy fairs and competitions) designed to raise interest in energy and environmental matters.

• Training of existing personnel, recruitment of new personnel, and/or use of contract labor, to support energy efficiency priorities. This can include specialized technical and engineering personnel, maintenance staff, and others.

• Making energy efficiency an evaluation criterion for executive compensation and employee bonuses.

• Identification and sharing of best practices.

• Use of external resources. This includes, for example, resources from commercial entities, government agencies such as the U.S. Department of Energy, the Environmental Protection Administration, and the ISO 50001 international standard for energy management systems.

Energy policies often are accompanied by energy goals, either in the form of absolute energy savings or improvements in energy intensity. For example, in 1995, the Dow Chemical Company set a goal to reduce its energy intensity by 20% in ten years. They bettered the goal, achieving a 22% reduction by 2005.

The company then set an even-more-aggressive goal in 2006 — to reduce energy intensity by a further 25%. This goal has proved elusive; Dow is not alone in this struggle. A combination of factors, including economic slowdowns and market instability, extreme weather conditions, and the Covid-19 pandemic, have all resulted in periodic production cuts over the past few years; this has adversely affected energy efficiency. In addition, U.S. natural gas prices have declined significantly since peaking in 2005, making it more difficult to justify projects that save energy. Nevertheless, corporate energy-saving goals serve a useful role in drawing attention to an important target. Without that focus, energy intensity across the industry would almost certainly have deteriorated. As discussed in a recent column ("Drive Energy Efficiency with Decarbonization," July 2021, https://bit.ly/35YKCwk), energy efforts now concentrate on decarbonation, which is part of an even larger ESG (environment, social and governance) movement in the industry. However, energy efficiency remains an important piece of the puzzle, and continues to be a priority.

For further information see, Alan Rossiter & Beth Jones, "Energy Management and Efficiency for the Process Industries," AIChE/John Wiley & Sons, Inc., Hoboken, New Jersey, 2015, pp. 25–55.

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Is FDA Food Safety Revision in Our Future?

Bill aims to reassess the chemicals used in food

FOOD SAFETY comes in many forms. Years ago, Congress passed the Food Quality Protection Act, amending the nation's pesticide law to ensure a safer, more reliable food supply. Consumer groups have urged Congress for years to modernize the nation's food chemical law, the Federal Food, Drug, and Cosmetic Act (FFDCA), to address often-stated concerns with chemicals in food. Thus far, those concerns remain largely unaddressed by any legislative effort. Things may be changing. On July 26, 2021, Representative Jan Schakowsky (D-IL), chair of the House Energy and Commerce Subcommittee on Consumer Protection and Commerce, introduced the Food Chemical Reassessment Act of 2021 (H.R. 4694), which would require the U.S. Food and Drug Administration (FDA) to study and reassess chemicals used in food. This article summarizes the measure, and speculates on its likelihood of passage.

More than ever, consumers and other stakeholder groups are intensely interested in ensuring the foods we consume, and any chemicals added by food processors and others, are safe. Over the years, legislative efforts have arisen to modernize the FFDCA in ways similar to the modernizing of the Toxic Substances Control Act in 2016. For reasons not entirely clear, however, these efforts haven't succeeded. With Congress energized on many fronts and a Democrat in the White House, this could change.

The Food Chemical Reassessment Act of 2021 would amend the FFDCA to create an Office of Food Safety Reassessment within the FDA's Center for Food Safety and Applied Nutrition. Its purpose would be to reassess the safety of food additives, food contact substances, GRAS (Generally Recognized as Safe) substances, and prior-sanctioned substances or classes thereof. Beginning in 2022 and at least once every three years, the office would reassess the safety of at least ten of these substances. The office would determine whether a substance is "safe" within the meaning of FFDCA Section 409 and establish conditions, if any, for safe use of the substance.

Under the bill, the first ten substances for reassessment include: perfluoroalkyl substances and polyfluoroalkyl substances (PFAS); ortho-phthalates; tert-butylhydroquinone; titanium dioxide; potassium bromate; perchlorate; butylated hydroxyanisole (BHA); butylated hydroxytoluene (BHT); brominated vegetable oil (BVO); and propyl paraben. Several of these substances, including titanium dioxide and PFAS, are high-profile chemicals already under global scrutiny and no strangers to controversy.

The bill would also reestablish the Food Advisory Committee. The committee would counsel the Secretary of Health and Human Services on the standards for reassessments and the process and methods necessary to complete the work.

The Environmental Working Group, Environmental Defense Fund, Consumer Reports, Center for Science in the Public Interest, Healthy Babies Bright Futures, Breast Cancer Prevention Partners, Defend Our Health, and Earthjustice all endorse the bill. Other groups are expected to support the measure in the months ahead.

Some believe food safety reform is a goal whose time has come.

DISCUSSION

Congress plainly is in overdrive these days with precedent-setting infrastructure, voting rights, and police reform legislation, to name a few. Because H.R. 4694 was referred to a busy House Energy and Commerce Committee for action, and with no Senate companion legislation introduced to date, there's a very good chance this bill will not move forward any time soon. This much is clear.

What also is clear, however, is calls for FFDCA modernization to continue to build, along with increased awareness about the chemicals in our food. Creating a new FDA Office of Food Safety Reassessment would be a significant undertaking for the agency, but some argue an essential addition to ensure the public's confidence in food safety. Reestablishing a Food Advisory Committee is a less controversial step, and is not expected to encounter significant resistance.

Proposals to "reform" the GRAS-listing procedures are not new, and some contend the concept has outlived its utility

Stakeholders in this space are urged to monitor this effort carefully. Some believe food safety reform is a goal whose time has come. ●

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Coriolis Meters Measure More Than Flow

VANESSA KLEKAR
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ABB Measurement & Analytics

Looking at instrumentation in general, there's hardly any other device where you can get more data. And that provides you with a window into the process.

FLOW IS fundamental to the operation of any chemical plant. The newest kid on the block, relatively speaking, is Coriolis flow metering — it first appeared on the scene 35 years ago. Coriolis flowmeters not only address their own performance but also track broader process issues and deliver improvements across plant operations.

To understand all the benefits of Coriolis flowmeters and the robust information they provide, *Chemical Processing* spoke with Vanessa Klekar, U.S. technical sales specialist manager, Flow Products, at ABB Measurement & Analytics.

Q: What was used before Coriolis flowmeters?

A: Mechanical, electromagnetic and differential pressure (DP) flowmeters. There were many issues with mechanical meters — including parts that wear out, causing downtime and high maintenance costs. With DP, you have limitations in accuracy. The big advantage with Coriolis meters is they provide direct mass flow measurement.

Q: What makes Coriolis flowmeters more accurate?

A: It's mainly the principle of operation. You have vibrating tubes and any flow going through the tubes generate a phase shift between the inlet and the outlet of the meter. It's almost 10 times more accurate than the older technologies. And the whole principle is directly related to mass flow instead of volume flow. You get an additional benefit for accuracy by getting rid of any kind of pressure and temperature compensation or by recalculating any volume flow measurements into mass flow.

The Coriolis meter is a direct mass measurement and it also measures the density directly. And in many chemical applications, the density of the product is directly related to quality. It's not just the accuracy, it's also improving performance.

Q: Can you explain the different Coriolis designs?

A: Coriolis meters come with a little bit of a difference in their design, especially the mechanical part of it. There are larger, U-shaped designs and slightly bent tube design like ABBs. You also have straight tube designs. And they all have pros and cons. But I would say most of the Coriolis meter designs have developed into dual-tube design. This means the process flow is equally split between the slightly bent tubes when going through the meter. This design has proven to provide a very high accuracy, reliable measurement with little sensitivity to challenging process conditions, or installation effects.

Q: What are they best used for?

A: Anywhere you need accurate measurement. Coriolis meters are used in measurement of ingredients going into reactors to ensure the proper mixture and a safe chemical process. Some ingredients are really expensive, so our customers need accurate measurement to meet a quality specification while minimizing the use of the most expensive components. And so that's where accurate measurement truly becomes important. Coriolis meters are also used after the batching process to measure the mixture of products. This is where density measurements indicate quality. They're also used in measuring the gas that is going to incinerators and exhaust systems for environmental compliance. Coriolis meters have a built-in verification, therefore, they provide users confidence in their performance while minimizing downtime. If you need to verify that the meter is performing within its stated accuracy, these verifications do this. Therefore, you don't have to take the downtime to remove the meter, take it to a lab to get it calibrated. The online diagnostics can do that for you.

Some recent applications also are in custody transfer when you're loading a truck or a barge. It's popular because of their accuracy and the fact that you can measure in pounds; in mass and you don't have to account for the change of temperature and pressure on the volume of the product itself.

Q: What needs to be considered when selecting Coriolis meters?

A: Things such as flow rate, density and process fluid need to be considered to make sure the tube material is compatible with the chemical and process conditions. Temperature is also important. There may be some things we need to do like remote mount transmitters, if it's going to be a really high temperature. Pressure needs to be considered as well, it is critical that the process connections and tubes are rated to meet the design requirements.

Also, how accurate does it need to be? There are different tiers of Coriolis meters in our offering. If this isn't a custody use, maybe a utility meter will do; in the competitive petrochemical industry, these product tiers allow customers to get the benefits of Coriolis technology without paying the price for the highest level accuracy.

Q: Is there ever a case where a Coriolis meter is not required or the best choice?

A: There are definitely places where a Coriolis meter is overkill. If you just need a general idea of what's going on or an indication that there's some type of flow happening in the line, you wouldn't need a Coriolis meter. If you put a Coriolis meter at every measurement point, you could definitely build a chemical plant so expensive that you would price yourself out of the market.

Coriolis meters are also limited in size. If you have a really large pipeline, a Coriolis meter wouldn't work.

Another area where you don't use Coriolis is steam measurement. Or for simple water — freshwater or wastewater treatment plants usually don't use a Coriolis simply because it would be overkill.

Q: What about fluid factors like entrained bubbles?

A: At ABB we have done a lot of research in that area. We think it's one thing to specify accuracy in the data sheet in lab situations, but it's another thing to increase the accuracy when it really counts in the field. And gas bubbles are one of the most frequent reasons why Coriolis meters have additional errors or do not meet their accuracy specs. We have come out with a new solution called Enhanced Coriolis Control (ECC.) The software puts intelligence into the meter to control the vibration of the tubes in a much better way and countering any effect coming from gas bubbles; by doing so, this increases the accuracy significantly. And the great thing is it's not something mechanical or hardware-related. It's simply software. And by applying the latest algorithms coming from research into that controlling area, you can gain a lot of benefits and a lot of accuracy.

For older meters, you simply need to update the firmware of the meter.

CORIOLIS FLOWMETERS

With no up or downstream piping requirements the compact Coriolis flowmeters can be installed in the tightest spaces, enabling applications not possible before.

Q: What sort of issues can Coriolis meters detect?

A: The whole density feature is like a built-in analyzer into a flowmeter with all the benefits that come with it. You can measure concentrations. You can control online the recipe of a chemical mixture. The other point, of course, is that with these vibrating tubes, Coriolis meters can provide you with so much data from the process that you can detect sediments or you can detect abrasion to the tubing, any kind of coating, any kind of gas phases. You can detect gas bubbles in a way that you can prevent pumps from running dry. Looking at instrumentation in general, there's hardly any other device where you can get more data. And that provides you with a window into the process. For example, if a valve is not closing down 100%, you can see that from the data of a Coriolis meter. You have to know how to look for it and how to interpret the data, but there is a lot of potential.

Q: Are there maintenance issues to consider?

A: If you have any kind of corrosion, erosion or coating issues with the tubes, you need to be careful that the tubes are fit for the purpose and that they are not affected by the application. Most manufacturers, ABB included, provide some sort of software solution that monitors the health status of the meter.

We like to be involved with applications upfront because there are some things that we can recommend. If you have a highly abrasive fluid, we would want to recommend keeping the velocity down to a certain level in the meter. So maybe you would go a meter size up. As far as general maintenance, these meters truly are as close to maintenance-free as you can get. They don't have moving parts that wear and tear.

If you can prevent anything affecting the tubes, the lifespan is pretty long.

For more information, email Vanessa Klekar at vanessa.klekar@us.abb.com or visit www.abb.com/coriolis.

Industry Raises Its Shield

Efforts expand to fend off cybersecurity threats

By Seán Ottewell, Editor at Large

RECENT MALWARE attacks have targeted supply chains, a strategy that has focused the cybersecurity efforts of the chemical industry, its vendors and even the U.S. government.

Chemical engineers must stay on top of a lot of things today, with the most important being to really understand their cybersecurity risks, stresses Eric Byres, founder and chief technology officer of cybersecurity company aDolus, Victoria, B.C.

"The problem here is that a lot of security systems are little more than check lists. They are all about compliance and nothing to do with risk reduction. So, the first thing chemical engineers need to do is get a handle on the big risks and what they can do to mitigate them. Of course, the biggest risk now is from ransomware attacks — often on supply chain systems with weak authentication and lousy access management," he explains.

It's also crucial to understand attackers' motivations. China's focus is on obtaining state secrets and intellectual property while North Korea aims primarily to steal cash and attack anyone who criticizes the regime there, he notes.

"It's essential that the chemical industry knows and understands the motivations for these different actors, because your defenses will need to be adjust[ed] for the threat actor you are most likely to be exposed to," Byres cautions.

aDolus's own technology to tackle supply chain malware is its Framework for Analysis and Coordinated Trust (FACT), a software and firmware validation service. The idea here is companies that develop software or manufacture products containing software subscribe to the aDolus service. Then, users of these products can validate new software patches and upgrades before installing them in critical equipment.

In effect, vendors certified by aDolus pass digital fingerprints of their legitimate software and firmware to the FACT server (called the Trust Repository); fingerprints then go to an analysis engine to check the sub-components to determine if they contain any vulnerabilities or malware.

"So we ask two questions: is the digital fingerprint of the package correct, and are all the components in that package authentic and safe to use? The driving force here is that people don't know if the software they are loading is safe. Even if it is legitimate, how can you be sure that it's the right version and that it doesn't contain any back doors? The challenge is to improve the trustworthiness of software they are loading," Byres emphasizes.

Back in 2017, he realized that to do the trust analysis part of FACT would demand generating a software bill of materials (SBOM) — a technology that many today believe is critical to security following the 2020 SolarWinds attacks. Indeed, underscoring its importance, President Biden's Executive Order (EO) 14028, "Improving the Nation's Cybersecurity," now requires SBOMs for all U.S. government purchases of "critical software." This has left suppliers scrambling to be able to produce SBOMs.

"The EO has a specific mention about a standardized model for SBOMs and I think a number of standards will emerge which will then be implemented by industry, too," says Byres.

As an example of how this process could work, he cites ongoing work with real-time-data-management company OSIsoft, San Leandro, Calif., now part of AVEVA.

"OSIsoft submits all its released software packages to FACT, where we generate SBOMs. We then analyze the components uncovered by the SBOMs for vulnerabilities, potential malware and code-signing issues. OSIsoft uses this data to ensure that they are shipping secure software to their customers. They also offer FACT as a way for their clients to validate all OSIsoft software before loading it into their ICS [internet connection sharing] servers."

Nevertheless, a number of issues, including notifications, still require consideration, notes Byres. "Software needs continuous monitoring to make sure that it has the latest patches and versions, for example. A control valve is tested as part of its manufacturing process, but you don't just leave it operating on the plant for years without ongoing monitoring and maintenance, would you?"

Unfortunately, things may get worse soon because ransomware attacks are where the money is now, he warns. "Having your ransomware distributed to tens of thousands of companies gives a colossal return on investment. I'm also really worried that ransomware supply-chain attackers will join up with security system attackers at some point, although the two currently operate independently. It's essentially the cyber wild west out there."

A ROLE FOR PEOPLE

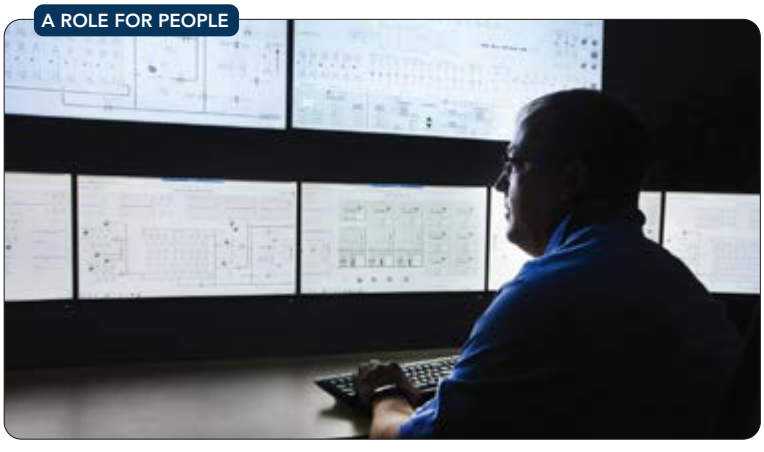

Figure 1. Trained and available personnel are key to maintaining cybersecurity protection levels. *Source: Emerson.*

TAKING A FRESH LOOK

Its spin-off from DuPont in July 2015 gave Chemours, Wilmington, Del., the opportunity to review its existing cybersecurity program and transform it with an eye to the future of the business and chemical manufacturing, according to chief information security officer Reginald Williams. "As our business has evolved, so has our cybersecurity posture, including how we've made changes to our environment to improve security and better enable remote work," he says.

"For example, we've made a concerted effort to increase cybersecurity awareness among our employees and contractors. While we continually test their ability to identify potential attack vectors, last October we held a month of employee cybersecurity training that was very successful at driving engagement and building cyber awareness," he adds.

Chemours participates with peers in forums such as the cybersecurity subgroup of the American Chemistry Council, Washington, D.C., to discuss common cybersecurity issues. "These

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conversations are somewhat anonymous and offer a safe, secure place to have a sounding board and learn from what others are experiencing," notes Williams. The company also is looking to expand its partnership with the U.S. Department of Homeland Security.

So, for example, while Sunburst malware didn't impact Chemours, this strategy allowed it to review how the attack happened and run scenarios to determine how the company would react and what the impacts would be.

"We took the lessons learned from analyzing the attack to improve our ability to monitor and detect threats within our environment. It also prompted a contract review to ensure our partners, vendors and suppliers are also taking the appropriate measures and have short notification timelines if they were to ever be impacted," Williams remarks.

This goes hand-in-hand with use of undisclosed "best of breed" technologies to spot potential threats. Similarly, Williams is confident that Chemours already has in place or is adhering to most of the guidelines mentioned in the EO.

However, the term "digitalization" is becoming a nebulous concept, he cautions, so each enterprise must define what the term means for its own business: "Companies need to start working with their vendors in a way that brings them into that digitalization conversation and discussion as it relates to your cybersecurity strategy. Have your vendor share how they can help you achieve your goals."

Additionally, companies must more closely monitor what their vendors or third parties are placing in their environments. "For example, an IoT [Internet of Things] vendor may install a device intended to support one function, but it could end up causing problems for you if you don't know about it and don't have the ability to monitor it," he warns.

At the same time, basic cybersecurity steps, such as not leaving basic or default passwords in place, sometimes still are overlooked. To prevent attackers from using these and other basic controls as a foothold, he advocates adhering to the SANS Institute's CIS Controls, https://bit.ly/3fG5my5, plus regular audits to identify areas that need improvement in the face of emerging cyber threats.

A KEY ALTERATION

What must change is how we view cybersecurity, stresses Alexandre Peixoto, product manager for DeltaV with responsibility for cybersecurity and network products, Emerson, Round Rock, Texas.

"The business needs to connect OT [operational technology] to IT [information technology] systems will not be going away, but we need to focus more on minimizing risk to operations and less on cybersecurity driven by convenience. For example, air-gapping seems easier to deploy

and maintain, but it is simply not effective for today's digitally enabled operating environment," he warns.

The answer is to design security into the system architecture and maintain that security throughout the system's lifecycle, he says.

As a minimum, designing for security typically means securely pushing data out to business systems, and restricting or highly scrutinizing what data need to come back into the operations environment.

"For many end users, the need to minimize operational risks comes as a corporate directive to ensure incidents like recent ransomware attacks do not happen, but these directives often do not come with sufficient funding. To address this and other cybersecurity issues, Emerson strives to educate end users on how they can improve their entire operational cybersecurity posture by using existing solutions more fully, and by understanding gaps in their operations," Peixoto explains.

"At the same time, it's become abundantly clear to everyone that end users need to validate their suppliers all the way to the original manufacturer in a full supply chain," he adds.

One approach taken by Emerson is to incorporate industry guidelines such as ISASecure Secure Development Lifecycle Assurance (ISASecure SDLA), https://bit.ly/37uhOwc, which is based on the IEC 62443-4-1 cybersecurity standard, into new product development for distributed control systems (DCSs).

"Standards bodies and third-party accreditation help ensure the strongest protections within our products, and this includes advanced strategies like threat modeling and mitigation techniques during the development processes," he notes.

Highly visible malware incidents coupled with more information-sharing requirements and standards have significantly increased awareness beyond client cybersecurity teams to their corporate executives, he adds. "It feels like today the whole organization is considering cybersecurity in some way, shape or form."

However, turning awareness into results requires investment, which has been slower to appear, Peixoto cautions.

"Organizations that do understand the difference between security as an essential feature and security as an

investment are driving projects with cybersecurity in mind. These companies recognize that secure operations require technological advancements coupled with personnel training. With cybersecurity, overall protection is only as strong as the weakest link. In other words, having all cybersecurity products and solutions implemented but not managed by trained and available personnel will result in an overall low cybersecurity protection level [Figure 1]," he concludes.

LEGACY VULNERABILITIES

Matt Malone, ICS cybersecurity consultant for Yokogawa, Houston, also sees upticks in both cybersecurity awareness and interest from chemical industry clients — and he anticipates they will continue to expand their current cyber-defense postures. For its part, Yokogawa is urging all its clients to continue building and improving their cybersecurity programs.

"When addressing attack vectors, it's important to keep in mind than many of these sites use legacy systems. These systems were built to last decades and many have a patchwork of automation solutions that also span decades. This means that older attack vectors are still vulnerable until they have been addressed," he explains.

One of the common strategies for industrial cybersecurity is to adopt the zero-trust model. If you take this strategy to its logical conclusion, then the operator should not trust a single technology, including air gapping, Malone points out.

"The defense-in-depth model for applying industrial cybersecurity applications goes hand-in-hand with the zero-trust strategy because the end user can have overlapping fields of protection by using multiple, and differing, types of cybersecurity solutions" he adds.

That's why Yokogawa has adopted various cybersecurity applications within its portfolio, including reducing the risk of cyberattack within an industrial control system network by implementing several approaches tailored for any DCS or supervisory-control-and-data-acquisition system.

At the same time, the company has adopted a secure-by-design methodology for its automation equipment and submits its DCS and safety-instrumented-system equipment for

RANSOMWARE VICTIM

Figure 2. Saudi Aramco reportedly faces a $50-million ransom demand. *Source: Saudi Aramco.*

third-party testing and certification. "These certifications provide bona fides to our clients that we take the integrity of their systems very seriously," Malone notes. Moreover, they put Yokogawa ahead of the SBOM curve before the EO was released, he believes.

"An attestation of this, and our commitment to manage the security of our products through their lifecycles, is the 62443-4-1 SDLA security certification for both of our product development centers in Japan and Singapore, including internal process and procedures to manage each SBOM," he explains.

Meanwhile, the cyber wild west, as Byres describes it, continues, with Saudi Aramco, Dhahran, Saudi Arabia, (Figure 2) becoming the latest victim as of press time. The company has confirmed an indirect release of a limited amount of company data that was held by third-party contractors; it says the release wasn't due to a breach of its systems and didn't impact its operations. The hackers reportedly are demanding a $50 million ransom for information they claim covers project specifications, unit prices, business agreements, company clients and invoices.

Understand the Key Changes in NFPA 30

The 2021 edition of the code contains six important revisions | By Mike Snyder, DEKRA

SINCE 1913, the National Fire Protection Association (NFPA), Quincy, Mass., has published "NFPA 30: Flammable and Combustible Liquids Code." This document has served as the leading information source for safe handling and storage of flammable and combustible liquids. It is a recognized and generally accepted good engineering practice (RAGAGEP) that's widely used in the field of risk management and applied by government authorities, emergency responders and end users to ensure safe storage and handling of liquids. Most state and regional codes are based on NFPA 30.

Proper use and application of NFPA 30 is a key part of an effective loss control engineering program that ensures:

- correct selection and use of containers for storage of liquids;
- appropriate and effective fire protection for storage areas;
- safe practices for dispensing, transferring, handling and use of liquids; and
- sound methods for tank storage and piping systems, including bulk loading and unloading operations.

NFPA 30 is updated through an open, consensus-based process that occurs approximately every three years. Each revision cycle proceeds according to a published schedule and offers several opportunities for the public to provide input and commentary for changing, updating and improving the standard [1].

WHAT'S NEW

In 2021, NFPA adopted an updated version of the code; it can be viewed online at www.NFPA.org/30. The new edition retains the structure and chapter architecture of the 2018 standard. To address continued challenges in liquid risk management and resolve technical issues presented by new containers and storage configurations, the code incorporates six technical changes. Two additional significant changes were proposed but reversed during the consensus process. Details of the adopted and proposed/reversed changes follow, starting with the six adopted changes.

1. *Flammable and combustible liquid nomenclature.* Throughout NFPA 30 (2021), any liquid that has a flash point is termed "ignitable (flammable or combustible)." When referring to a specific type of ignitable liquid, NFPA 30 uses liquid class to denote boiling point and flash point ranges.

This nomenclature change decreases the use of the terms "flammable" and "combustible" to reduce confusion of terminology arising from the varying definitions applied by agencies and the globally harmonized system (GHS). For example, the U.S. Occupational Safety and Health Administration (OSHA) sets 140°F (60°C) as the delineation between flammable and combustible liquid classification, whereas NFPA specifies 100°F (37.8°C). Use of liquid class provides consistency in evaluating any liquid with a flash point. Because any liquid with a flash point can burn given a sufficient ignition source and, therefore, can be termed an ignitable liquid, the classification (e.g., Class I, Class II and Class III) provides perspective on the relative ease of ignition.

2. *Treatment of beverages, medicines and other consumer products containing not more than 20% water-miscible liquids.* The 2018 edition of NFPA 30 excluded from coverage any beverages, medicines, foodstuffs, cosmetics and other consumer products containing not more than 50% by volume of water-miscible flammable or combustible liquids so long as the remainder of the product consisted of components that do not burn. This exception applied to liquids in containers not exceeding 1.3 gal (5 L) [2].

Additional fire testing data were presented to support the reduction of this exclusion to not more than 20% by volume of

water-miscible liquid. The 2021 edition provides specific protection coverage or the storage can be treated as unprotected.

3. *Improvements to application flowcharts and new fire protection design options*. Chapter 16 (Protected Storage) provides specifications for the design and configuration of automatic fire protection systems for all inside storage of ignitable liquids in containers, intermediate bulk containers (IBCs) and portable tanks that are used in accordance with the container requirements specified in Section 9.4. Liquids protected in accordance with the requirements of this chapter are considered protected storage. Protected storage allows for virtually unlimited quantities in the protected configuration.

Commercial use and development of liquids continues to drive the need for new containers and configurations of storage, which require careful evaluation with regard to effective fire protection design.

Significant additions to this chapter include:

- Three new protection schemes for small (<1 gal; 3.7 L) containers of alcohols and 50/50 alcohol/water mixtures now appear in Section 16.5.
- New sections 16.5.2.13 and 16.6.5 add in-rack protection criteria for Class II liquids in metal containers using K25.2 extended coverage sprinklers.
- New section 16.5.2.14 provides new fire protection criteria for liquids with flash points less than 200°F (93°C) in cartoned, 2-oz plastic bottles.
- New sections 16.5.2.15 and 16.6.4 give sprinkler protection criteria for liquids with flash points greater than or equal to 450°F (232°C).

4. *Flammable liquid cabinet self-closing doors (Section 9.5.3)*. All new flammable liquid storage cabinets must have self-closing doors. This update is not retroactive, applying only to new, not existing, cabinets. It resolves conflicts with other model fire and safety codes.

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5. *Anchoring of tanks (Section 22.5.3)*. This section was added to specify the conditions where anchorage of tanks is required, making the consideration method for anchorage explicit and detailed.

6. *Metallic/non-metallic composite piping (Section 27.4.7)*. An added subsection covers such piping, which has been in use for 20 years with a variety of flammable liquids. The composite piping system consists of an inner metallic liquid-conducting tube and an outer non-metallic tube that contains any leakage from the inner metallic tube. Monitoring the space between the inner and outer tubes for pressure can provide a way to detect leakage.

PROPOSED BUT NOT IMPLEMENTED

Two significant changes were reversed during the consensus process:

1. *Composite intermediate bulk containers (Chapter 9)*. The fire risks presented by composite IBCs storing combustible liquids are well documented in the literature [3]. Additional restrictions on the use of composite IBCs were proposed but subsequently removed, with requirements reverting to those in the 2018 edition.

The current requirements for use and storage of composite IBCs are:

- Composite IBCs are not authorized for the storage of Class I liquids, except in specific limited situations detailed in Section 9.1.4.
- Composite IBCs containing a Class II or Class IIIA liquid must be listed and labeled. Units not listed and labelled are prohibited.
- Addition of requirements for conducting a hazard analysis and implementing a lower threshold for maximum allowable quantities that can be staged to Section 18.5.4.1, which details allowances for storage of liquids in incidental-use applications. It reduces the number of composite IBCs that can be temporarily staged in an operational area.

2. *Exhaust ventilation credit reductions (Section 17.11)*. During the first revision, a decrease to 50% from 75% in the maximum credit possible for required ventilation available from local exhaust ventilation (LEV) was proposed based on concerns about ventilation compromise that could exist by improper use of LEV equipment. This was reversed during the Technical Committee's work on the second draft, restoring the maximum 75% credit.

WHAT DOES THIS MEAN FOR MY OPERATIONS?

While NFPA 30 is a widely used RAGAGEP, local and state adoption of the code varies extensively. Often, the adopted version is from previous revision cycles and is augmented by local amendments.

When faced with a local adoption of NFPA 30, it is essential you have access to both the relevant edition of NFPA 30 as well as a copy of any amendments. This information is necessary to ensure compliance of current operations and new projects. Typically, when a jurisdiction has adopted an older version of NFPA 30 and you desire to use features from newer editions, variance procedures exist.

OSHA 1910.106 (Flammable Liquid Standard) is based on the 1969 edition of NFPA 30. In 1995, OSHA produced

a letter of interpretation that allowed facility owners to use a more-current version in lieu of the older requirements in 1910.106 [4]. OSHA states it will accept later editions of consensus codes, such as NFPA 30, when those editions set forth requirements that are as protective as the current requirements in the standard. In such situations, the company has the burden of proof to demonstrate the measures implemented are equivalently protective.

The two changes proposed but not adopted address issues that businesses should consider. If combustible liquids are stored in composite IBCs, a review of the literature and the proposed technical changes is warranted. Also, assess whether ventilation deficiencies may exist as the result of improper use of LEV equipment.

Work already has started on updates for NFPA 30, 2024 edition, which will feature additional advancements in ignitable-liquid loss prevention. All stakeholders in the industry are encouraged to review proposed updates included in the first draft of the next edition of NFPA 30(2024) by visiting www.NFPA.org/30 and clicking the "Next Edition" tab. The First Draft Report, including final actions taken on the public inputs, is scheduled for publication by March 22, 2022. Public comment on it is due by May 31, 2022. ●

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Consider Chain Conveyors

Such devices offer advantages for moving solids over short distances

By Amin Almasi, mechanical consultant

MANY CHEMICAL makers overlook chain conveyors. That's not surprising because published information on them is sparse. Yet, these strong and rugged conveyors ideally suit applications such as special feeding units that call for slower transportation speeds over short distances and at moderate inclines. The angle of incline can exceed that usually used for belt or other conventional conveyors — even steep and varying angles are possible. Chain conveyors generally operate at relatively high discharge rates in applications that need great flexibility and pose load variations.

The devices usually have a lower profile and lighter design than other conveyors and, thus, offer benefits in applications with limited space or requiring a compact/low-weight unit. Moreover, chain conveyors often operate better with sticky materials and in challenging services than other conveyors such as rubber belts (which tend to retain sticky materials that even multiple cleaning stations might not effectively remove).

A chain conveyor consists of a trough or bed (bottom of the conveyor casing) on which run continuously driven chain(s) with pendants, flights or attachments. These pendants, flights or attachments scrape the bulk material over the trough, moving solids forward to the discharge point. The chain is driven via sprockets (wheel teeth).

The chain is specifically designed for conveyor service. It usually consists of a series of journal bearings held together by link plates or something similar. Many design alternatives exist. In a popular one, each bearing comprises a pin and a bush on which the chain roller revolves. Commonly, drop-forged chain, also known as scraper chain, is used. Other options include hollow-bearing-pin, solid-bearing-pin, deep-link, forked, round-link and box-scraper chain.

Attachments are fitted to a conveyor chain to adapt it for a particular application. Each attachment typically is made from single piece of steel.

Many different variations of chain conveyors are possible, depending on type of chain, attachment details, and their configuration. In one model, known as a pitch ladder chain conveyor, two side chains move ladder-type attachments. Another model, the pitch loader chain conveyor, features a centrally located chain and extended attachments to both sides.

Each type of conveyor chain comes in a range of pitches. The need for adequate wheel tooth strength usually dictates minimum pitch while the rigidity of chain plate determines the maximum. Strengthening the chain with bushes between the link plates (or other means) may enable exceeding the maximum pitch so long as there's still enough clearance with the sprocket.

As a very rough indication, chain conveyor width typically ranges from 0.2 m to 1.5 m and length runs from a few meters to 30 m.

DRIVERS AND TENSION CONTROL

Electric motors (usually with gear units to convert the speed) or hydraulic motors drive the sprockets. Most sprockets are made from special grades of steel. The sprockets typically have an odd number of teeth (preferably a prime number), although a composite or an even number sometimes is used. Modern sprockets are specially designed to spread the load across more teeth (at least three), ensuring maximum contact surface between the chain links and the sprocket teeth during operation. This results in lower wear and extended life of the sprocket and the chain. Sprockets in double pitch configuration also are available. Double sprockets offer larger pin/journal area, greater pull strength and increased bearing area. They wear evenly and offer a longer service life and lower noise than standard sprockets. They often find use in critical and high reliability services.

Chain conveyors require overload protection; different means and devices can provide this. A simple solution often is to use shear-pin sprockets that break when overloaded, stopping the chain conveyor and saving considerable expense and downtime. Another option is to measure the slip of each gear unit; a chain stall then triggers the switching off of drivers. Alternatively, clutch(es) can be used, with a suitable control unit opening them when required. You can employ two or more methods simultaneously to increase overall reliability and safety.

Suitable chain tensioning and tension control is extremely important. Tension should be adequate for proper operation — and adjustable. Wear increases if chain adjustment is too tight or too loose, allowing chain to flog.

CONSTRUCTION MATERIALS

High-quality chain conveyors usually use specially selected high-strength low-alloy steels that can withstand abrasion and other wear as well as corrosion. Correct heat treatment nearly always is necessary for good characteristics and optimum wear resistance. (Chain conveyors manufactured from plastic and non-metallic parts do find use in small and limited applications.)

Wear is a major concern for chain conveyors. Achieving optimum wear life requires consideration of many different aspects such as the selection of material, drive arrangements, the speed, etc. Long-lasting chain with case-hardened pins and large bearing area in journals reduces wear.

Special coatings for steel parts such as urethane coatings — if compatible with the service — can reduce wear, noise and metal-to-metal friction. Before opting for such a coating, check prior applications and seek successful long-term operating references.

Correct lubrication of the chain's bearing surfaces will minimize power absorption, wear rate, erosion, corrosion and noise. For normal conditions and operating temperatures, a quality mineral oil with medium viscosity may suffice. Self-lubricating chains that require no additional lubrication are available for certain applications.

There is a link between smooth and low-noise operation and system reliability and long life. The key is to prevent excessive metal/metal friction and damage mechanisms. These adverse effects can create noises, inefficiencies and reliability issues. Not surprisingly, the most productive and reliable chain conveyors also are the quietest, smoothest and longest-lasting ones.

A useful concept for ease of maintenance of large, critical chain conveyors is separation of wear and structural parts. This enables easily replacing the very hard materials used for wear parts while making the structural parts of high-strength steel expected to last for many years.

OPERATING ISSUES

Many different parameters — such as the details and layout of the chain conveyor, the chain speed, involved frictional coefficients, details of bulk materials (particle size, etc.) and others — affect efficiency and performance.

The chain's speed is a major parameter; mass flowrate changes significantly with variation of chain speed. Frictional coefficients involved also are important; they can affect mass flowrate, consumed power, and wear of parts.

The average wear depth depends on operating parameters, the chain speed and the characteristics of the bulk material (such as its particle size, abrasiveness, etc.). Higher chain speed and larger particles often lead to more wear of various components. However, the relationship between the speed and wear is highly nonlinear and complicated.

Some chain conveyors have generated high noise that could lead to permanent hearing loss. This noise stems from the interaction between different moving parts (conveyor flight components) and fixed parts. Traditionally, the most important noise control measure has been the application of proper coatings (such as urethanes).

Areas where impacts and heavy friction occur, such as where the chain changes direction at the discharge end, require careful consideration during design, manufacture and installation. Such impacts, heavy friction, etc., often result in excessive noise, high maintenance and low reliability.

Material being handled may suppress noise caused by the chain conveyor system by dampening impacts that occur between the conveyor flight parts, conveyor trough/deck, etc. Therefore, the noise during empty or low-load operation often exceeds that of full-load operation.

Sometimes, resonance has occurred between chain system and trough assembly. This resonance not only undermined the smooth operation of the chain conveyor system but also became the main cause of noise generation and damage. Therefore, a critical chain conveyor requires a full vibrational study. Such a study also would help to improve overall structure and reduce stresses and deflections.

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WEAR AND RELIABILITY

The metal parts in chain conveyors are prone to wear and tear in long-term operation. The damage and degradation mechanisms depend upon the nature of the particular part. The life and reliability of a chain conveyor is determined not only by these damage and degradation mechanisms (pitch elongation, etc.) but also by the wear of each component part and the weakest link in the system. So, thorough periodical inspections and ongoing condition monitoring always make sense.

Mutual friction between different parts such as outer link plates and inner link plates creates wear. When the amount of wear exceeds 25–30% of the thickness of the original part (link plate, etc.), the strength of the chain decreases considerably. So, ideally, replacement should occur before parts reach this degraded stage.

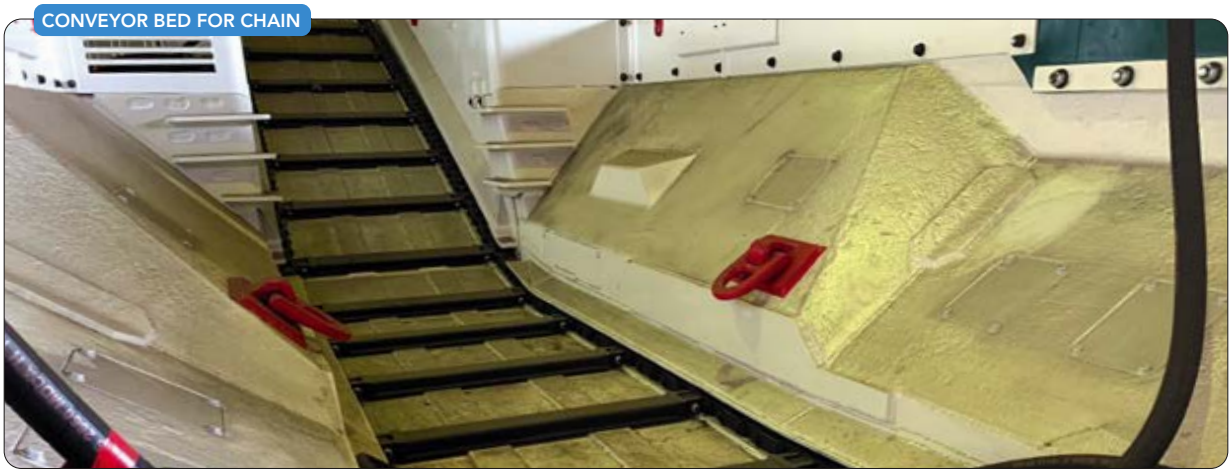

Figure 1. This application includes a pronounced change in angle of incline.

In many configurations, the chain is installed and moved on a conveyor trough (deck or bed — Figure 1); this trough/surface is prone to wear by both the chain and the bulk materials handled. The wear mainly concentrates around the chain unless delivered materials are significantly abrasive. Wear of the accelerating area is more serious than that of the stable (constant speed) area.

Pin wear generally occurs when chain engages with sprocket teeth and each link articulates around the sprocket. Bush wear arises when it contacts the track and the load is supported by the pin and bush. It also can occur when contacting the sprocket tooth. Chain usually should be replaced when the bush has worn through to the pin.

Because sprockets are under considerable loads, stresses and continuous/repetitive contacts, they often suffer wear and damage. When a sprocket is worn out, chain clings to it and tends to cause a vibration when coming out of the sprocket. While giving a general value for allowable wear of sprocket is difficult, as a very rough indication, don't allow the wear to exceed 2.5-mm depth.

DEGRADATION

Elongation of chain pitch is a common degradation mechanism. It usually occurs when the chain engages with the sprocket or runs along the track. The flexing of the chain around the sprocket causes wear between the pin and bush, thus allowing the pitch to stretch. As this stretch increases and the pitch become longer, the chain tends to climb the sprocket tooth. To check the pitch, take the average of measurements of 10–20 pitches under operating tension. Then, calculate the elongation by comparing the original pitch when new against the measured pitch of the worn chain. As rough general guide, replace the chain when pitch elongation approaches the limit of about 103–105% of the original pitch.

The wear mechanism of the trough (bed or deck) under the chain and moving materials usually is micro-cutting. This mainly relates to abrasive conditions. Such a complex wear process also may involve corrosion depending on the type and characteristics of the bulk materials. In challenging services, the wear mechanisms mainly have been micro-cutting and corrosive wear accompanied by fatigue fracture.

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Open Process Automation Moves Ahead

Work is advancing on a standard, conformance certification and product prototypes | By Don Bartusiak, Collaborative Systems Integration

END USERS in the chemical and energy industries now must contend with and integrate multiple proprietary systems in almost every process plant or facility. With industrial control systems, end users experience several major pain points: (1) lack of interoperability and inability to reuse their control applications between systems from different suppliers; (2) excess cost during system upgrades due to close couplings between components; and (3) barriers to introduction of new technology. These pain points result in elevated capital costs on new projects and high total cost of ownership through the asset lifecycle, especially in operation and maintenance.

To address these pain points, the Open Process Automation Forum (OPAF) of The Open Group, http://bit.ly/38HJ89C, an international forum of end users, system integrators, suppliers, academic institutions and standards organizations, is working to develop the specifications for open-architecture-based process control systems. OPAF's goal is to enable more open and modular systems that support integration of best-in-class components.

This architecture will provide both configuration and application portability across components from different suppliers, thereby reducing system capital cost and total cost of ownership. The vision is a standards-based, open, secure and interoperable process control architecture that lowers the cost of control system upgrades and replacements, removes barriers to technology insertion, and has adaptable cybersecurity designed in.

This article, which is an adapted, updated version of a keynote presentation at Yokogawa's "Y-NOW 2020: DX Solutions for Tomorrow" event, outlines the progress of the Open Process Automation initiative, the Open Process Automation Standard (O-PAS), and the status of industry prototyping. It also briefly addresses key end-user issues such as cybersecurity and long-term control system migration.

DIGITAL TRANSFORMATION

In meeting the challenges presented by the "new normal" business environment, the chemical industry rapidly accelerated the adoption of digital transformation. Many years of planning and implementation were consolidated into a matter of months. As digital transformation efforts continue, it is clear that the role of process control systems will loom large in the industry.

Digital transformation requires the low-cost implementation of change — which is the ability to make rapid, iterative and data-driven innovations in plant operations — at a fraction of the cost previously possible. This demands overcoming the restrictions to innovation created by closed, proprietary systems. Since its origin in the 1970s, process control architecture has continued to include significant proprietary hardware and software elements despite the wide adoption of a variety of de facto and industry standards.

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Major global industrial and chemical companies are collaborating with leading process automation suppliers and system integrators to accelerate a revolutionary change in automation through the adoption of O-PAS, a standard of The Open Group. O-PAS provides a critical standards framework to address these issues and many more.

O-PAS STANDARD UPDATE

The focus of O-PAS is to reduce the cost of control system upgrades and replacements and enable increased value generation by removing barriers to inserting technology.

OPAF also plans to achieve adaptable cybersecurity that is designed-in to our systems. Figure 1 shows the scope of this activity; it includes the distributed control system (DCS), programmable logic controllers (PLCs), input/output (I/O) modules associated with the DCS and PLCs, and the layer of supervisory control above the DCS. Out-of-scope are field devices and communications to them, the safety instrumented system (SIS), and the business systems that are shown below in the figure.

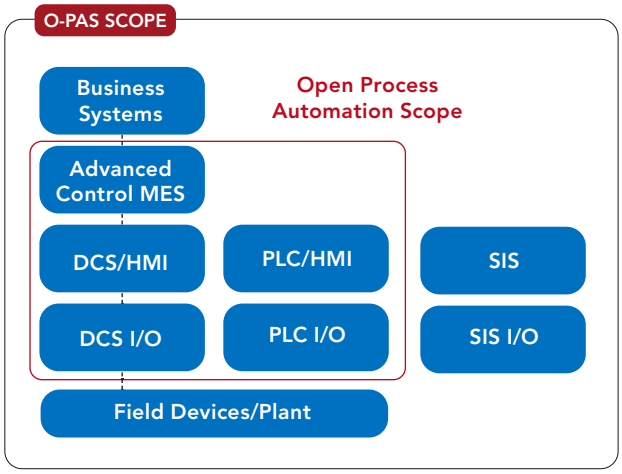

Figure 1. The initiative focuses on the five elements within the box.

The vision for the solution to the business problem is to transition from closed, proprietary control systems to a standards-based, secure and interoperable open process automation (OPA) architecture. Figure 2 depicts the reference architecture we would like to achieve. In contrast to the current state-of-the-art, which is based on the Purdue reference model and its 1970s-vintage computer-integrated-manufacturing heritage, we now see an architecture that more closely resembles an Internet and information technology (IT) style reference. Its architecture has three basic distinguishing characteristics: an edge device, an industry-standards-based communication network, and a supervisory computing platform.

We refer to the edge device as a distributed control node (DCN). It features configurable I/O, the first touch of computing, and interfaces to existing equipment, such as those depicted by the blue boxes in the figure.

The second distinguishing characteristic, the industry-standards-based communications network, is the O-PAS connectivity framework.

The third distinguishing characteristic is the on-premise supervisory type of computing platform that takes advantage of technologies already used in IT and telecommunications. The reason for the on-premise location is to provide the availability and low latency required for the types of applications that will run here. The OPA reference architecture supports communications to all sorts of field devices, both wired and

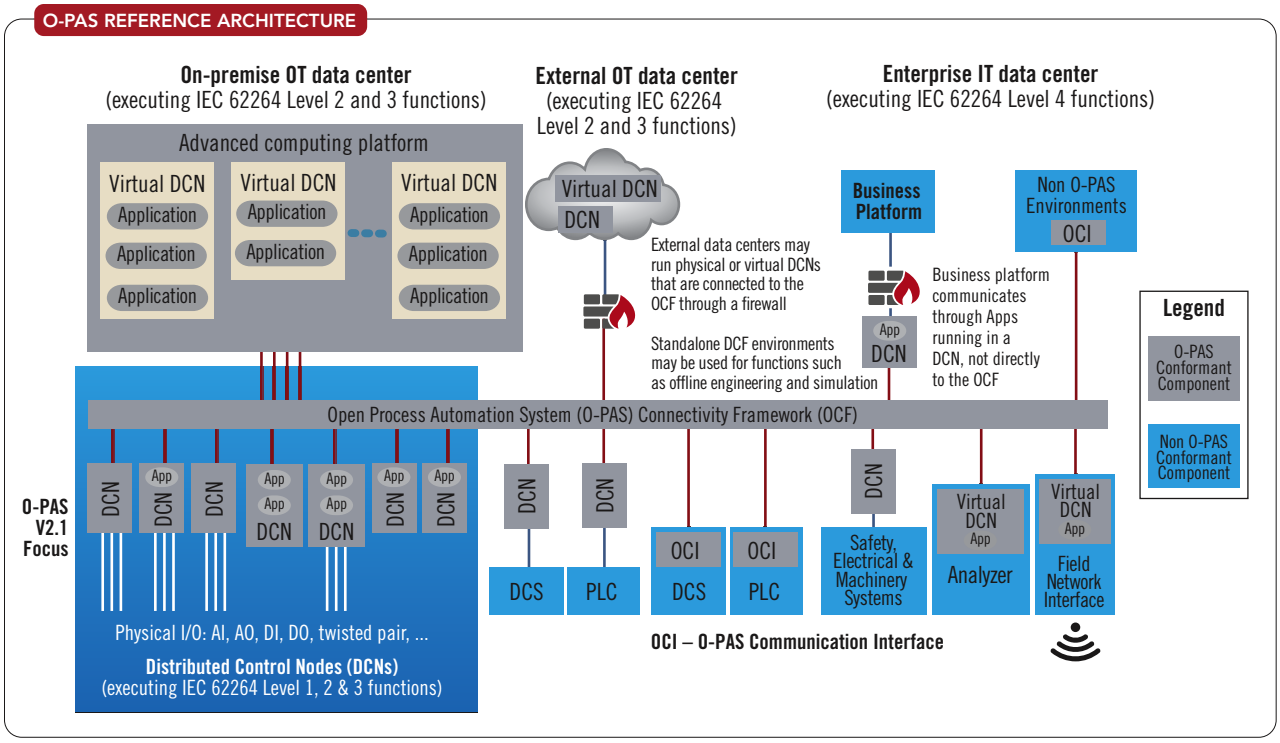

Figure 2. The distributed control nodes, connectivity framework and on-premise computing are key distinguishing characteristics.

wireless. It also provides data pathways to either a company's internal, higher-level compute capabilities or public or private Cloud platforms.

TECHNICAL STANDARD

The standards that drive the OPA vision are the product of the OPAF. OPAF was founded in 2016 and, at present, has 102 member organizations. These include 22 operating companies representing five different industry vertical sectors, six of the seven major control system vendors, including Yokogawa, which is a very important contributor to this effort, and a large number of hardware/software suppliers and systems integrators.

In OPAF, the development of the technical standard is occurring in parallel with efforts to address the business ecosystem required for the successful commercialization of the vision. We also are bringing forth the conformance certification process in phase with the development of the technical standard. When we set forth the design for the standard in 2017, we defined three steps in the initial development versions, with each taking approximately a year to a year and a half. Version One (V1) addresses interoperability, Version Two (V2) configuration portability, and Version Three (V3) application portability across the full spectrum of the business problems that we want to solve.

We refer to the concept as a "standard of standards," which means that if an existing standard is fit for purpose, the idea is to incorporate it into the OPA standard. Figure 3 shows how we intend to leverage some current standards — for instance, ISA 95 (IEC 62264) for technical architecture, and ISA 99 (IEC 62443) for cybersecurity. OPAF also references OPC UA and others in this standard of standards.

In June, OPAF published O-PAS V2.1. (Again, the theme for V2 is "configuration portability.") This includes a specification for the file formats for import and export between various software products and where that file format leverages the AutomationML standard. OPC UA's information models comprise a key portion of the data interface that enables interoperability. The specification describes how to do alarming, provides for a basic set of function blocks that are at the root of industrial control systems, and details how O-PAS leverages the IEC 61499 and IEC 61131 standards. It also broaches new

STANDARD OF STANDARDS

O-PAS Part	Subject Matter	Referenced Standards
Part 1	Technical architecture	IEC 62264 (ISA 95)
Part 2	Security	IEC 62443 (ISA 99)
Part 3	Profiles	n.a.
Part 4	Connectivity framework	IEC 62541 (OPC UA0
Part 5	System management	DMTD (Redfish)
Part 6	Information and exchange models	IEX 62714 (automationML), IEC 62682 (ISA 18), IEC 61131, IEC 61499
Part 7	Physical platform	"whitespace"

Figure 3. O-PAS leverages a number of relevant existing standards.

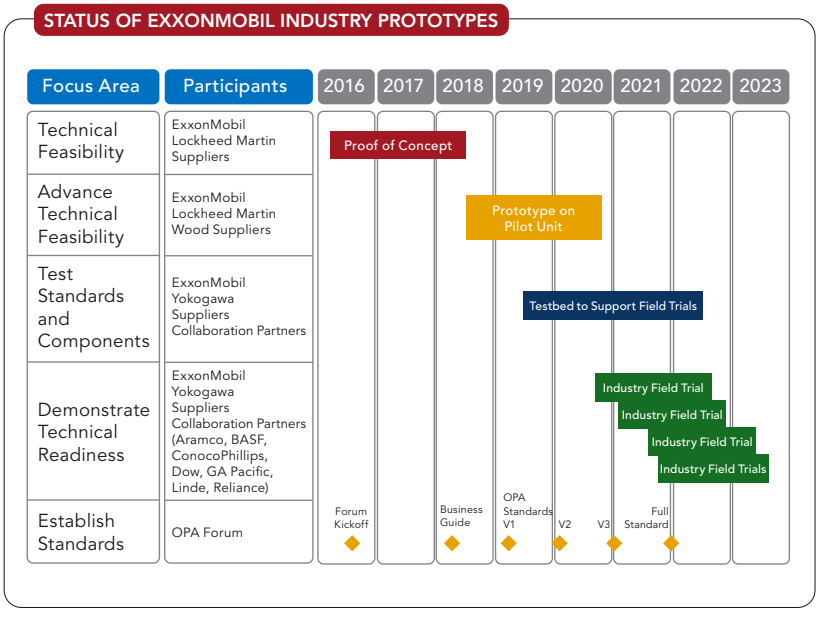

Figure 4. Work has progressed from proof of concept to prototype on pilot plant and now to testbed to support field trials.

territory, i.e., the physical realization of the DCN that we call the "physical platform." Part 7 of the O-PAS standard specifies the physical platform.

In addition to the technical work, the business and enterprise working groups are addressing how to promote industry adoption, manufacturing of products, and deployment of those products by end users. We held an Industry Adoption Workshop on October 29, 2020 and an End User Caucus on July 20, 2021 where O-PAS V3 contents were discussed to understand end-user priorities and needs. The business and enterprise architecture working groups are assisting in defining requirements for O-PAS V3. The conformance working group is very active starting-up the first phase, which we refer to as "Wave One" for conformance certification. It addresses Part 5, which is the specification for systems management, as well as Part 4, the O-PAS connectivity framework. Meanwhile, the technical working group is busy defining the V3 requirements, where the key themes are going to be application portability and orchestration technology.

INDUSTRY PROTOTYPES

Several operating companies now are conducting prototype tests of O-PAS-based systems. Figure 4 summarizes the three major OPA system building projects that ExxonMobil has completed or has in process. The proof-of-concept was a demonstration against a simulated plant. The prototype was an O-PAS-based system in Clinton, N.J., that controlled an actual pilot plant. It is a hydrocarbon-containing unit for catalyst control operating at 660°F and 1,200 psi with 130 I/O points. Lockheed Martin and the Wood Group served as systems integrators. ExxonMobil found that the prototype, like the proof-of-concept before it, demonstrated the quality attributes of interoperability, interchangeability, configuration portability, and application software portability.

Now, the company has built a testbed facility in The Woodlands, Texas, just up the road from ExxonMobil's campus. Yokogawa is the prime systems integrator for this testbed; it is the staging location for a set of industry field trials. ExxonMobil also has established a collaboration partnership with seven other operating companies, as listed in the figure. They are sharing information about their findings as each company begins to conduct its prototyping or testbed activities.

Other operating companies also are working on prototypes. For instance, BASF has produced a portable demonstration of an O-PAS-based system that can be exhibited at trade shows. It includes a water tank, two heaters, four coolers and 12 valves. The key results BASF has reported are conformance to the OPA standard and demonstration of the Namur Module Type Package and Namur Open Architecture concepts.

In addition, Georgia Pacific has just completed what it refers to as a "demo display board," which is a portable instantiation of an O-PAS-based system. Siemens is the systems integrator. Saudi Aramco is building an OPA testbed in Dhahran with Schneider Electric as the system integrator. In addition, Petronas has announced plans to build an OPA testbed in Malaysia.

MIGRATION TO O-PAS

Naturally, control system end users wish to avoid completely replacing their existing systems and, instead, phase-in open architecture. That's completely consistent with the low-cost implementation of change OPAF considers to be a cornerstone.

As with any significant technology transformation, it will take time. We view migration in terms of ten- and 20-year horizons. Within ten years, we expect many existing facilities to incorporate O-PAS-based systems as they replace components. This will result in hybrid systems with mixtures of existing DCS and PLC technologies and O-PAS-compliant ones. Naturally, the initial uptake will comprise innovators and early adopters; their systems should go far in building credibility for O-PAS. In addition, some suppliers that are investing very heavily in the OPA concept, Yokogawa for example, will be at the leading edge of that transformation.

Over the same timeframe, we expect a healthy share of new installations to deploy O-PAS-compliant systems. Those systems will make immediate use of the Industrial Internet of Things and other technologies emerging today. Their architectures will exemplify the OPA reference and will resemble far less the hardware-defined segmented arrangements such as the Purdue model.

Within 20 years, we expect industrial control systems to look much more like the OPA reference architecture engines — in contrast to the current DCS and PLC configurations — and to embody the OPA business ecosystem.

INTEGRAL CYBERSECURITY

A key O-PAS principle is that, as technology transformation occurs, no compromises will be made in terms of requirements for reliability, availability and cybersecurity. For cybersecurity, O-PAS, Part 2 leverages the IEC 62443 standard. The conductivity framework of the O-PAS standard that uses OPC UA takes full advantage of certificate-based message authentication and role-based access control as fundamental technologies for cybersecurity. The IEC 62443 concepts involving zones and conduits to segment a network limit the scope of failure and provide adjustable layers of security. In the Yokogawa testbed, ExxonMobil has incorporated technologies such as the latest firewall from Palo Alto Networks and is experimenting with anomaly detection inside the control network.

A key point of the O-PAS standard is to define the interfaces to achieve the quality attributes of interoperability, interchangeability and portability, particularly for the end user's software applications. We consider cybersecurity a foundation for this.

COMPELLING BENEFITS

Open process automation offers advantages to both end users and suppliers. Among other things, end users will gain:

- easier application reuse;
- designed-in safety and security;
- elimination of system integration issues; and
- reduced total cost of ownership.

Meanwhile, suppliers will get benefits including:

- access to new markets and customers; and
- efficiency improvements from dropping non-differentiated products.

A key to success is a demand for change from a critical mass of end users. Based on the efforts to date and how far we have progressed in terms of commercialization, OPAF feels that we are nearing an inflection point when end users begin requiring O-PAS conformance in their bid specifications and suppliers announce roadmaps for O-PAS-conforming products.

DON BARTUSIAK, who recently retired after 33 years with ExxonMobil, is president of Collaborative Systems Integration, Austin, Texas, and co-chair of The Open Process Automation Forum. Email him at don.bartusiak@csi-automation.com.

Plant Benefits from Augmented Remote Operations

First commercial implementation of prepackaged system showcases its value

By Christine Craig, Honeywell Specialty Materials, and Colin Hams, Honeywell Process Solutions

PLANT MANAGEMENT at the Honeywell Specialty Materials' polyethylene wax production facility in Orange, Texas, wanted to maintain business continuity for manufacturing operations while abiding by social distancing policies. The plant was faced with pivoting its operational practices rapidly to deal with the challenges of today's ever-changing environment.

The Orange facility had gone to a split-shift arrangement where half of its engineers were at the plant and the other half worked from home. The site needed a way for personnel to stay connected to process operations while working remotely. The goal was to limit the interaction between engineers and operators who were on site in the central control room.

Plant engineers conferred with remote operations specialists from their sister division, Honeywell Process Solutions, and decided to implement Experion Augmented Remote Operations (ARO) to enable, if needed, off-site locations to control the Orange plant.

PREPACKAGED SOLUTION

While the setup of a dedicated remote operations center can take years to plan and commission, drop-in deployment of ARO requires only about a day's time and no re-engineering. Users can employ the same human/machine interface (HMI) displays, configurations and menus as their control room station. Pre-built ARO virtual machines can be downloaded and deployed in virtual infrastructure and configured on site to meet the needs of a specific facility.

With the ARO approach, a dedicated server augments the plant distributed control system (DCS) and provides remote operations capabilities to authorized users. A single ARO server can host multiple concurrent users of control room stations, enabling the performing of operational support activities from a different area on site, from another operations center, or even by users working from home who access the system via a secure virtual private network connection to the corporate information technology network.

Engineers or operators working remotely have the same integrated user experience as if they were in the actual control center at the site. They can view the process in real time by looking at the same graphics and warning signals they normally see in the control center. The system is configured to require credentials to view certain processes or to allow the same control of the process as the operator in the plant.

ARO provides high levels of cybersecurity restricting unauthorized access to the system. This allows for more secure remote plant operations — not just remote engineering like homegrown or customized remote options. The ARO platform includes safeguards such as digital certificate authority records, encrypted https communications and multi-factor authentication. Access permission can be granted to authorized personnel on a per-user basis. Users can be restricted to read-only access for monitoring capabilities or granted read-write access for full remote operations tasks.

The applications for augmented remote operations can extend beyond monitoring or operating control systems — including, for instance, to bringing in video virtual support from off-site experts or via virtual or augmented reality. Likewise, personnel can pull in digital information to enhance

a process. In addition, use of digital twins to replicate all physical assets can enable engineers to remotely work on plant projects in a cloud data center using a software representation of the physical equipment.

Furthermore, augmented remote operations can help to improve efficiencies across areas on the same site or different ones. Users can repurpose equipment such as existing engineering and training stations at other locations or utilize operator consoles that may be available at these facilities. The ARO approach also allows multiple sites to securely share their operations with other control centers or operational staff working from another office location or home.

INITIAL IMPLEMENTATION

This project, the first commercial implementation of ARO, began in late March 2020 and was completed in less than two days. The ARO package consisted of a virtual server containing software and remote desktop gateways, which were connected to the plant DCS to augment the existing process control scheme. The virtual server was located on the demilitarized zone network between the process control and business networks to afford expanded monitoring and control capabilities. This approach provided additional stations that personnel outside the main control room can access remotely, when appropriate.

By leveraging remote desktop technology, the use of ARO allowed the plant to have DCS clients on its business network without the installation of any control system software whatsoever.

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The ARO software setup took approximately 10–15 minutes for each user and was easy to accomplish. A single person was designated to coordinate setup activities with all the stakeholders on site. This individual served as a dedicated resource who scheduled meetings with each shift supervisor, engineer and leadership team member. Having such a clear roll-out plan helped everyone see the benefits of ARO more quickly.

Control system engineers and process experts can use ARO to monitor production processes and provide operational support from outside the control room. A remote operating station, set up in an administrative building conference room, replicates the control room console HMI and allows temporary control of the plant during emergencies when evacuation of the main control room is necessary. The remote workstation currently is being used for incident investigations and process hazard analysis. This capability has been very useful for workers in the administration building. The control system HMI is accessible for designated users from anywhere on the business network.

Thanks to the availability of ARO technology, management at the Orange plant could restrict access to the control room to minimize the potential exposure of board operators to health hazards. In the past, operations staff and engineers went into the control room multiple times a day to get control system information. The use of ARO allowed enactment of strict social distancing measures.

ADDITIONAL BENEFITS

ARO also has proven valuable for operational troubleshooting and collaboration between engineers and operators. A large project implemented over three phases added the technology for each reactor train on site. The first weekend after implementation of ARO, the lead project engineer was called because the site had an unexpected shutdown on one reactor train. A board operator was attempting to start up the unit and needed help to get it running. The lead project engineer logged in to the ARO dashboard and, while on the telephone, walked the board operator through both the outside and inside steps to get the unit restarted. This saved at least four hours of downtime on the reactor by allowing immediate troubleshooting collaboration between operations and engineering.

The knowledge that remote operation of the Orange facility is possible during an emergency has given plant leadership a certain peace of mind. Previously, security was the main concern with remote operations and, consequently, the technology never was used at the site. The ARO system provided enhanced security that allowed for the implementation of new software and hardware to make this capability available.

ARO also promises to reduce emergency response time at the plant by enabling process experts to quickly access the control system HMI when offsite to provide rapid troubleshooting assistance.

The initial deployment of ARO technology at the Orange plant was seamless and non-disruptive. Installation activities were completed within a few days with the help of a dedicated implementation leader, who provided troubleshooting assistance and helped individual operators and engineers become familiar with system log-in, start-up and other aspects of the new remote capabilities. As this was the first installation, ARO deployment at future sites likely should take less than half a day. ●

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Sort Out a Scale-Up Snafu

Various factors that could reduce reactor performance need investigation

TUNE THE PROCESS FIRST

The problem description suggests scale-up issues. As far as I can determine, the batch processing capacity has gone up by 70% while reactor volume has doubled. Because some components remained the same, you need to check if they are the bottleneck. (Given the change in batch recipe, comparison with earlier batch recipes may not be helpful.) Start by looking at smaller, easy-to-change items first. If they can't help in increasing the processing capacity, you will need to have a careful look at big-ticket items, which could require a major overhaul.

1. Because you have trouble starting the reactor, check % opening of the steam valve. (I assume you're getting temperature progression.) A valve open, say, above 75%, would indicate it's undersized for the new application. Check steam supply and make sure all condensate is effectively removed from steam entering the heating jacket. On the other hand, consider that superheated steam provides lower heat transfer than saturated steam.
2. Because you have trouble cooling down, check for possible fouling of the spiral heat exchanger. Also, check the speed of the lobe pump to ensure you have adequate flow to the spiral cooler.

After you exhaust all possible quick-and-easy fixes, look at big issues that could require a major overhaul and coordination with Operations and Marketing to minimize business interruptions. These include:

1. Estimate heating (and heat progression) and subsequent cooling requirements of the new recipe to see if you have adequate capacity to do the job. If the jacket is too small, consider a separate heater to augment jacket heating.
2. Check agitation. When you say agitation went up by 30%, I assume you mean power went up by 30%, not necessarily the extent of agitation. Because you can process a smaller batch size (30% less), issues to address include agitation and/or dead pockets (e.g., removal of baffles). Because you have a different recipe, estimate power and agitation requirements for the new setup. Correlations for agitation and power requirements based on Reynold's number and Froude number exist in the open literature. Also, get help from the agitator vendor.
3. Review relief valve pop. The figure shows no pressure control system. Check trends and the historian to determine the time and stage in the batch at which the relief valve popped. A mis-step in batch processing possibly could have caused high pressure. On the other hand, if you find that, at a certain stage, the batch pressure could get so high to lift the relief valve, see if you can up the set point on the relief valve. Increasing the set point obviously will require you

THIS MONTH'S PUZZLER

I'm a new process engineer hired to sort out a botched expansion. The plant tried to increase production by replacing our reliable pressurized batch reactor with a vessel with double the capacity. The new system (figure online at https://bit.ly/3CUwSSy) has operated for three months but isn't performing well.

In the new setup, we boosted the agitation by a factor of 30% but kept the same heat exchanger because, according to corporate, it was oversized by a factor of two — now, the capacity matches the theoretical heat load. In addition, we increased the pump motor size and added a variable frequency drive — before the scale-up, the pump ran at the bottom of its curve. We retained the steam control valve; the cooling water is on an open-closed valve. We got rid of the bottom shell baffle and also the pre-batch tank, which our researchers believe we don't need. We largely duplicated everything else. The previous plant owners left scant records, so we had to go by modeling. The designers didn't bother talking to any of the operators; it was a hostile takeover so the old managers and engineers aren't cooperating.

I inspected the old vessel in the boneyard and noticed the bottom baffle was added later; the code stamp agrees. The agitation nozzle appears to have been beefed up, perhaps afterwards as well. I checked the motor and it's always been in the same bucket.

Currently, we're having difficulty starting the reactor. We also are having trouble cooling it down between batches. The relief valve on the vessel has popped twice in the past month — an operator told me that never happened before. The valve sticks open when it relieves. The viscosity is lower than expected, about 180 cP, suggesting a reversal of the reaction or incomplete reaction, and the temperature spikes above 180°F at the reactor outlet. I had the operators reduce the batch size by 30% and we seem to be making good product with the process in control.

Further complicating my troubleshooting, the new management changed the batch ingredients. The surviving laboratory technician from the old days says the viscosities and densities are higher.

What was done wrong? How can we get this process producing at the desired rate?

to carefully check relief valve sizing and pressure limitations of all components of the system and its supports. Among many other industrial guidelines, API-620/521 has guidelines for a systematic check for these systems.

You mentioned the hostile nature of the takeover rules out communication with the original company. As we know, due diligence is a pivotally important first step in takeovers but one that wasn't done well here. Your company is relatively lucky — because potential environmental and safety liabilities and possible litigations could leave you with problems with long-term profitability, compliance and corporate image.

GC Shah, consultant
Houston

[Another response appears online, see: https://bit.ly/3szBA38.]

NOVEMBER'S **PUZZLER**

We've been operating a soil remediation process for about three months. It takes in chloro-compounds like polychlorinated biphenyls and dioxins. The solids-handling part of the process works flawlessly but biological fouling problems with the solvent extraction circuit began to arise about two weeks after start-up.

We take in soil from places a hundred miles away or so. There's little quality control — we accept almost anything. However, our operators know to reject loads with logs, gravel, concrete and asphalt chunks. One truck delivered a stop sign! Our screw conveyors seem to handle what we take in.

We get our solvent, toluene, from pharmaceutical plants when they're not burning it in their thermal oxidizer. Originally, we planned to source it from refineries but we can't compete with the price the aviation industry pays.

We first noticed the problem in the vacuum systems drying the soil; then, it affected the flocculation in our settler and, finally, the extractor itself. I found a similar pond scum in our recycled solvent tank.

Other challenges for me are the rapid decrease in the quantity of recovered solvent as well as odor complaints from our neighbors in the industrial park. I think we may have to put in a scrubber system that we can feed back into our solvent recovery train.

Did we miss a treatment step? What could the residue be? What can be done about this?

Send us your comments, suggestions or solutions for this question by October 8, 2021. We'll include as many of them as possible in the November 2021 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.

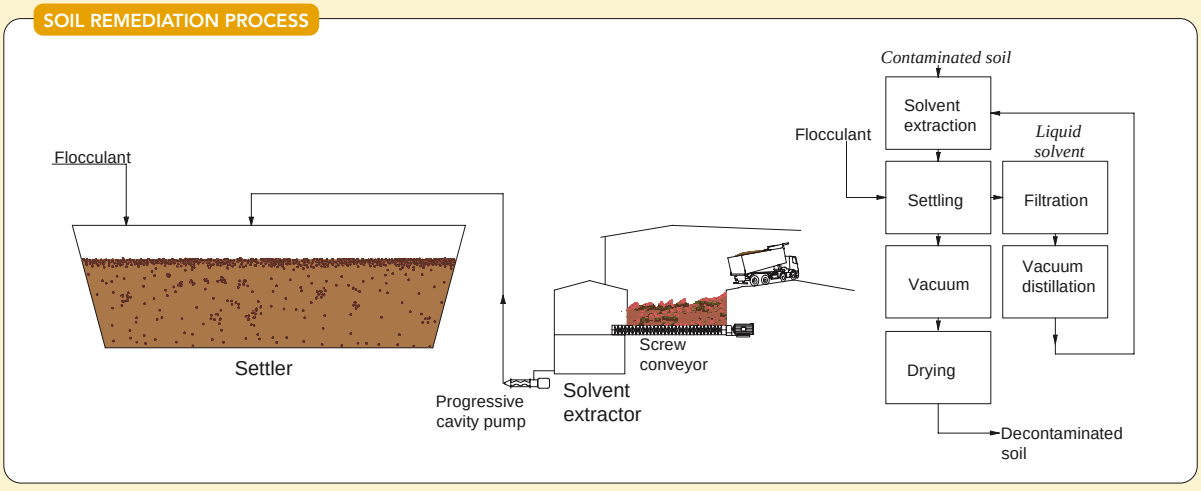

Figure 1. Liquid extraction circuit suffers from biological fouling.

Do More with Mass Balance

Tracking a change in inventory can result in important insights

Simple analysis can lead to powerful trouble-shooting techniques.

MASS BALANCE is critical for understanding unit performance and troubleshooting. What goes in must come out. In simple equipment like drums or tanks, this is straightforward. However, in more-complex situations such as with reactors, creating a full mass balance may be a challenge. Nevertheless, all components, including trace ones, must mass balance.

Mass balance also includes an accumulation term. The difference between flow in and flow out shows up as a change in inventory. This simple analysis can lead to powerful troubleshooting techniques.

One example is understanding trace amounts of water in non-aqueous systems. Many systems have water boots that may drain either continuously or intermittently. Often, this is a small waste stream that doesn't get carefully measured, particularly if it's one that flows intermittently. Data on flow rate may be captured but not the frequency of the flow. Also, many times local flow instruments handle intermittent flows, and the readings don't go to a historian.

One simple method of estimating a small flow rate in this type of system is to track the change in level over time. First, block-in the downstream flow from the water boot (for example). Then, measure the change in level in the boot over a defined time to get an average flow rate.

FIND MORE GREAT INSIGHTS

For more troubleshooting tips, check out previous Plant Insites columns from Andrew Sloley online at www.ChemicalProcessing.com/voices/plant-insites/.

This approach even suits verifying flow rates for larger streams. For instance, many plants rely on a day tank to ensure a constant feed rate to an operation. If the feed tank can be isolated for a reasonable period, such as a day, checking the change in level and calculating the volume can serve to double-check flow meter readings. Of course, this requires knowledge of the density.

Blocking-in flow can reveal other issues as well. Two common findings are (1) tanks aren't truly cylindrical, and (2) valves leak.

Large tanks, in particular, deviate from true cylinders. They can have a tilt and swell out under hydrostatic load. Their bottoms, if sitting directly on the ground, can flex. While the flex usually amounts to millimeters, in two extreme cases I've seen a tank exhibit a bottom flex of five inches when completely filled.

Problems are more common in older tanks constructed under no-longer-accepted standards. To account for this, tanks often have strapping tables that correct for volume based on height and fluid density rather than just assuming a cylindrical shape. Additionally, a tank may have suffered damage or not have been a cylinder in the first place.

Valves can leak. In one troubleshooting assignment, plant staff insisted that no water contamination was entering a process. Operators pointed out they never had to drain water from a water boot on a drum. However, given the upstream feed came from a drum with a boot that did contain water, the feed had to have soluble water in it. The products out of the unit were completely dry. So, where did the water go?

Mainly to humor me, the operators agreed to close a second isolation valve on the line from the water boot. We waited after closing the second valve. Within the hour, the boot showed a water level, with the level increasing over time. Just opening the isolation valve, without opening the official drain valve, made the water level drop and disappear. The manual drain valve was leaking.

By measuring how fast the level dropped, we estimated a leak rate. It exceeded the entire water rate expected. In normal operation, the drain valve was leaking a small but constant flow of hydrocarbons into the water treatment system. This hydrocarbon flow was the problem we actually were trying to find.

Replacing this apparently minor valve with the plant running was impossible. This is a common problem with many valves often seen as of minor importance and serving more of a utility function. Resorting to some special procedures eventually enabled adding a new drain valve in series with the existing one. The existing (leaking) valve then was fully opened and the new one used instead. After this modification, the water treatment system operation greatly improved.

Mass balance is a critical concept often important in troubleshooting, as these examples illustrate. Never forget that mass balance must apply to both bulk and trace components.

ANDREW SLOLEY, Contributing Editor
ASloley@putman.net

Pressure Gauge Expands Device Communication

The MAN-LC digital pressure gauge with an integral transmitter features a large digital display, multiple programmable features and IO-Link. The 24-Vdc-powered unit's liquid crystal display contains a backlit screen, which combined with large display characters, provides clarity traditional digital barrel transmitters cannot provide, the company says. The unit includes 2× configurable outputs and may be programmed as desired. Analog and frequency, plus alarm outputs are standard; an optional pluggable relay module with 2× potential-free SPDT contacts is available either factory assembled, or as a retrofit kit. A variety of flanged and diaphragm seal process connections extends the application reach to many industrial applications.

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Fungi-Infested Plastics Pose Health Threat

Better waste management of disposed plastics could prevent spread of pathogens

Wind can transport plastic particles in the topsoil over long distances.

A NEW threat to human, animal and plant health from microplastics has emerged, with the finding that they have become a habitat for pathogenic fungal species. The work, carried out by researchers at the German universities of Bayreuth, Hannover and Munich, shows that microplastics both host and accumulate fungal pathogens in terrestrial ecosystems.

The researchers say this is the first time such accumulations have been observed and, in a recent issue of *Scientific Reports*, urge policy makers to classify plastic debris as a potential threat to human health.

Using high-throughput methods, the researchers analyzed fungal communities in soil samples taken from a marketplace, a dump site, a roadside, and a courtyard near human settlements in western Kenya.

"We were able to observe all stages of fungal biofilm formation on the microplastic particles recovered from the soil samples. In doing so, we were able to demonstrate that fungi not only grow, but also reproduce in the so-called plastisphere. The data we obtained from microscopic examinations and DNA analyses supports the assumption that fungi systematically colonize microplastics in the soil," explains Gerasimos Gkoutselis, of Bayreuth's Department of Mycology and lead author of the study.

"Moreover, they provide evidence that microplastic in soil accumulates certain pathogenic fungal species. Some species dangerous to humans, including black fungi and cryptococcal yeast fungi, are present on the surfaces of microplastic particles in higher concentrations than in the surrounding soil. Our study therefore justifies the presumption that microplastics in soil are a potential source of fungal infections," he adds.

The researchers also found potentially human pathogenic fungi previously linked to plastic colonization in other contexts, including: *Fusarium oxysporum* and *Alternaria alternata* which form biofilms on indoor and landfill plastics; members of *Cladosporium*, *Phoma* and *Curvularia* which have been isolated from environmental plastic particles; and the *Rhodotorula* species which can colonize plastic catheters in hospitals.

The study also detected a significant association with microplastic by several opportunistic pathogens, such as *N. difuens*, a cryptococcal yeast known to be able to cause subcutaneous pathologies in humans, and *P. herbarum*, a filamentous species causing a spectrum of infections in humans — especially in those with suppressed immune systems.

Infections of humans by plastic-associated fungi already have been observed in Kenya and other parts of Africa, with *Fusarium oxysporum* causing keratitis epidemics and *Rh. mucilaginosa* causing fungemia in hospital patients. Both fungi were found among the dominant or enriched species on plastic waste.

The study notes the impact of pathogen-infested plastic waste may be particularly critical in tropical regions, which receive massive influxes of plastic waste due to underdeveloped waste management.

"Aggravatingly," they write, "fungal pathogens are most abundant in tropical and subtropical soils. Thus, microplastics in countries such as Kenya could contribute to the already extremely high fungal infection-related mortality and morbidity of the population. Due to the longevity of most plastic types and the fact that fungi can thrive and most likely proliferate within the plastisphere, the pathogen load on its surface is likely to increase over time and may result in an enhanced pathogen-carrying capacity of ecosystems."

In this scenario, say the authors, shifts in the structure and functionality of soil mycobiomes are likely to occur, eventually culminating in biodiversity losses and extinction of local species. Wind can transport plastic particles in the topsoil over long distances, which may result in habitat expansion of attached fungi. In this way, pathogens will become invasive or directly transmitted to unprotected hosts.

If colonized plastic fragments enter a long-range, fluctuating cycle of transport and fallout during the plastic cycle, spill-over events and epidemics could increase in frequency, with microplastics serving the function of artificial "super-spreaders," they caution.

The researchers note that Kenya has a progressive strategy to deal with plastic waste, especially single-use plastics. The country has joined an alliance to impede import of plastic waste from industrialized countries.

"The fact that we discovered numerous potentially pathogenic fungal colonies in the soil samples from Kenya is a clear indication of the urgency of the problem in tropical regions in general, where the rate of fungal infections is already high," says Gerhard Rambold, head of Bayreuth's Department of Mycology.

"Our study shows that measures to prevent plastic waste from entering the environment and to further develop waste management are urgently needed globally," he concludes. ●

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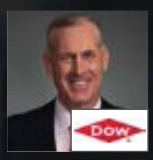

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