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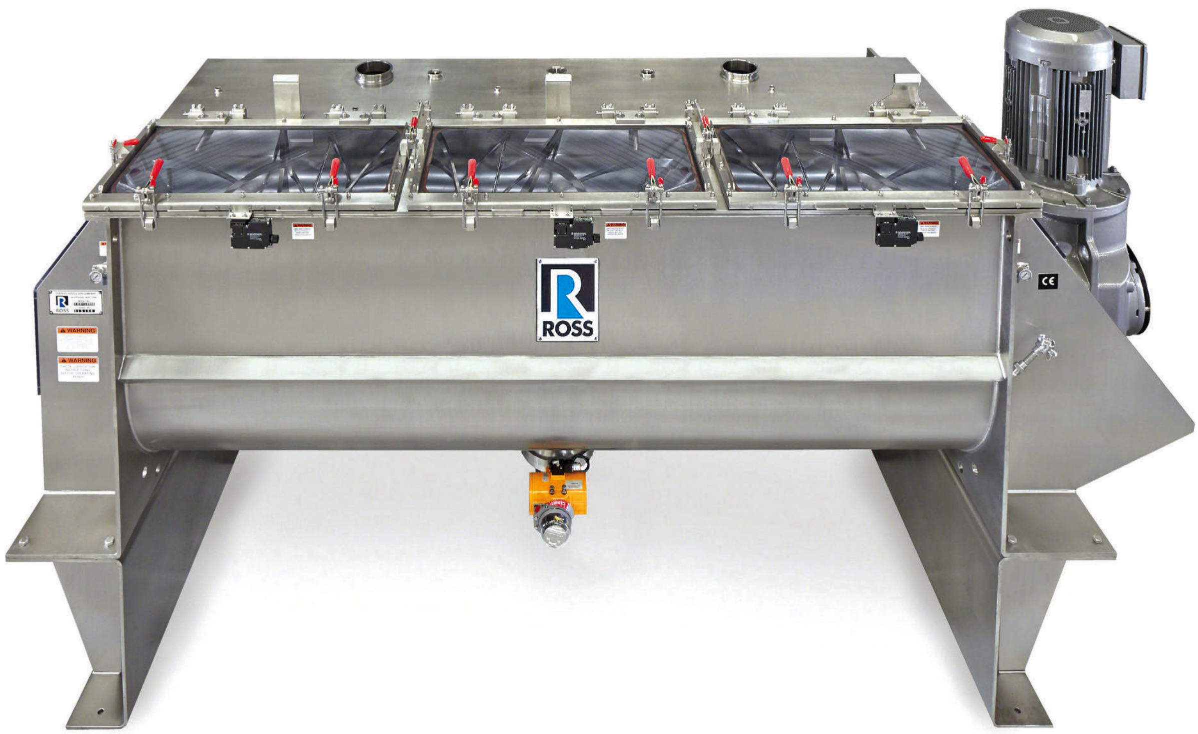

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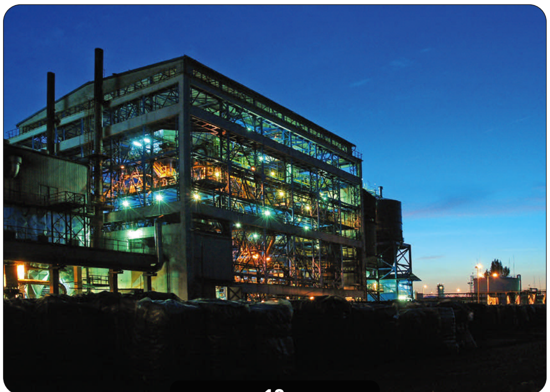

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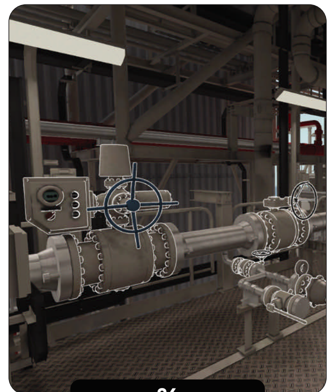

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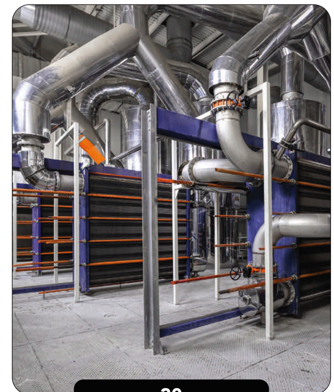

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Exercise Ethical Engineering

When faced with dilemmas, stand firm in your convictions

Ethics is a particularly challenging area in any profession.

"**…. IN** the presence of these my betters and my equals in my calling, bind myself upon my honour and cold iron, that, of the best of my knowledge and power, I will not henceforth suffer or pass, or be privy to the passing of, bad workmanship or faulty material in aught that concerns my works before mankind as an engineer, or in my dealings with my own soul before my maker."

In 1922, Rudyard Kipling wrote those words to accompany Canada's oath of an engineer ritual. Countries around the world have similar oaths. Indeed, the first American ceremony took place on June 4, 1970, at Cleveland State University's Fenn College of Engineering.

I went down the rabbit hole of ethics ceremonies after a recent episode of Process Safety with Trish & Traci (chemicalprocessing.com/33007224). Trish Kerin, director of the IChemE Safety Centre, and I discussed transparency and the need for professionals to exercise ethical judgment.

"Ethics is a particularly challenging area in any profession," Kerin stated. "That's because it's about doing what's right, not necessarily doing what's easy or what's cheapest or what's financially better for the company at the time."

Kerin knows what it's like to be on the receiving end of a career-limiting consequence. "It hasn't harmed my career long-term, but at the time, it was devastating," she said.

Alison Fraser, a chemical engineer with Actalent, a talent group specializing in engineers and scientists, took an oath of ethics as well when she participated in the Kipling-inspired ceremony after graduating from McGill University with a master's degree in chemical engineering.

She says she's been fortunate not to face significant challenges that would conflict with that oath but working in regulatory compliance, she has run into situations where clients want to take an action that is legal but, in her professional opinion, not ethical.

"I've had clients ask if they can move production to a lower-cost country with laxer regulations, so they can keep using a carcinogenic product rather than changing the designs so that a non-carcinogenic product can be used instead. This is legal, but if a chemical is a carcinogen in Europe, it's a carcinogen everywhere in the world. So ethically, this is a non-starter since workers, and potentially the public, are being put at risk unnecessarily."

In these cases, she points out the long-term drawbacks and higher costs of the non-ethical approach. "I make it clear that I will never sign off on anything that goes against my professional ethics. Make sure to be consistent no matter how important the client or project is. When you're consistent, you'll gain people's respect."

It's that kind of fortitude that Kerin champions. "A company is defined by its people," Kerin said. "We need our people to be ethical. We need them to be standing up for what's right. And we need to support them with processes that encourage the right behaviors and discourage the wrong behaviors."

Fraser agrees. A few years into her career, the importance of ethics became personal for her when she lost a relative to a workplace-related health issue. "Whenever I make a decision related to professional ethics, I like to think I could be saving at least one family from going through what mine did. It's so important for us to remember, as engineers, what an important and positive impact we can have." ●

TRACI PURDUM, Editor-in-Chief
tpurdum@endeavorb2b.com

RESEARCH

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Problems Predicting Particulates

Working with particulate solids requires both theory and practical experimentation

THE CORNERSTONE of chemical engineering is based on the application of theoretical models and fundamentals. We have faith in these because they have been shown to be repeatable and, for the most part, infallible. We trust our theory will prove to match our real-world observations in practice. Otherwise, when we design a unit operation, how do you know what to expect?

But working with particulate solids opens many to challenge our faith in theory. Solids have too many degrees of freedom. We seldom work with one particle size but, instead, a distribution of not only size but shape and surface texture. An example is the treatment of slurries that usually appear as a dense liquid. This will satisfy energy and residence time concerns but not the interaction between the solids and settling characteristics.

I recall a slurry that appeared to be well-mixed as it came out of the crystallizer, but a subtle change in handling segregated the particles during centrifugation. In the original process design, the centrifuge processed the slurry as it came out of the crystallizer. To scale up the operation, more crystallizers were added. However, it was not possible to locate a centrifuge by each crystallizer. The designers decided to use a larger centrifuge in another building. This also allowed the process to be semi-continuous, which allowed the plant to be more efficient in response to customer demand.

Each crystallizer would discharge its slurry to the centrifuge feed tank. The system worked quite well until demand dropped. The feed tank had an agitator that only kept solids off the bottom of the tank. The centrifuge would produce larger particles at first and then finer particles later at low-crystallizer use. Some settling also occurred in the pipeline. The solution was to recirculate the slurry in the feed tank to avoid settling and tap off that line to run the centrifuge. In this case, the theory was correct, but it was not applied properly to account for the particle distribution.

Predicting the behavior of slurries is complicated by reactions and physical processes such as attrition. Friction or impact during handling may generate fine particles due to secondary nucleation. The fine particles are more reactive due to the increase in surface energy. This problem is noticeable in crystallizers, causing excessive nuclei that hinder growth and can give a different morphology to the crystals. We had a product with a very fast nucleation rate and generally made a mush-like slurry. However, after the size reached about 15 micron, nucleation dropped off, and growth increased. Theory would not predict this behavior, as crystallization is imagined as more of a continuous process. However, this is where seeding becomes an option if the meta-stable solubility range is reproducible. (Working with solids is a lot of fun.)

Solids have too many degrees of freedom.

In theory, there are two major outcomes of attrition and a lot of gray areas between these two outcomes. One is the formation of only fine particles due to friction; the other is abrasion and breakage or splitting of the particles. Attrition seldom happens at these two extremes but exhibits a continuum of outcomes. To grind a chemical below the desired size requires repeated impacts and often produces more fine particles than desired. An elutriator could separate these fines but may require additional work before being salable. Why couldn't we just break the size to our desired size?

The first answer I usually get focuses on the fundamental properties of hardness, elasticity/brittleness, Young's modulus, as well as the undefined micro-cracks that allow breakage to occur along fault lines caused by chemical variations in the solid. An example is the crushing of coal. While the objective is to make the finer coal burn faster, the finest particles are those released along the fault lines and are the non-combustible components of coal (i.e., calcium, iron, ash.)

The second answer is that we really have no way to predict how a material will attrite based on physical properties. Instead, we must rely on experimentation and theories that relate energy used to the formation of surface area based on the elasticity theory of brittle solids (Kick, Bond, Rittinger.) There is a reason why the operators are always adjusting the fan on their hammer mill. The particles are constantly changing their physical properties.

There's a saying that sums up working with solids: In theory, there is no difference between theory and practice; however, in practice, there is.

TOM BLACKWOOD, Powder & Solids Columnist

Prepare for the Worst

Plan for the unexpected, and have mitigation steps in place

This is where training and exercising emergency response skills paid off.

SEVERAL YEARS ago, I fulfilled a lifelong ambition of learning to scuba dive. My path to certification wasn't smooth, but it makes for a great story of endurance and overcoming adversity. I was working at a refinery at the time. It was a high-stress role, and I was looking for an escape. I took a vacation to Fiji for a week and decided to learn to dive while I was there. I did my theory work and all my confined water sessions. It was all going well, and I was looking forward to my first open-water dive of the course. We got our kit together and headed to the boat. There was a gentle swell of about 3 ft. We would be diving on the reef just offshore from the resort. Three of us were on the boat: the boat driver, my instructor and me.

Whenever you undertake a higher-hazard activity, you must ensure you have planned for the unexpected and have mitigation steps in place. In the workplace, this is like having emergency-response plans and emergency equipment on standby. For example, during hot-work activities, you have a fire watch in position with firefighting equipment. You need to train and exercise your employees on emergency response so their response is second nature.

So, how does this relate to me learning to scuba dive? We set out from the dock and to the outside of the reef. The gentle swell was no concern. We were getting ready to dive, so my instructor and the boat driver were at the bow preparing the dive flag. I was sitting quietly at the back of the boat with all my equipment on: buoyancy control device with tank and regulator, weight belt, mask and fins. I was thinking about the dive brief and the skills I needed to show the instructor. Something made me look out the back of the boat. I saw a wall of water coming at me. I had to look up to see the top of the wave; it was almost 12-ft. high. At that moment, all I had time to do was put my arms over my head as the wave engulfed the boat. I was washed up to the bow as the boat capsized, and I became entangled in some ropes inside the rope locker. My mask, while still on, was full of water, and I had no air.

This is where training and exercising emergency response skills paid off. I was able to use a little bit of air from my lungs to clear the water from my mask – I could at least see. This helped me find my way out and kick to the surface for a much-needed breath. However, I was still tangled in ropes. My instructor surfaced nearby and came over to me, located my regulator and put it in my mouth so I had air available, then started to untangle me. I wanted to remove my weight belt to get more buoyancy, but he said no, we might need to descend to swim away from where the waves were breaking. As he continued to untangle me, the next wave struck; I was dragged across the top of the reef and my fins were swept off. We were finally able to descend and swim away from the waves, though I had no fins and was bleeding from coral cuts all over my legs and feet. A nearby fishing boat came to our rescue. I arrived home a few days later, determined not to be beaten by my experience. I went on to qualify as a diver, become a scuba instructor and a cave diver (there aren't any waves in caves).

I had been trained in clearing my mask of water, managing my buoyancy and weight belt and the importance of breathing through the regulator. All these skills were taught to me, and I practiced them until they were second nature. It was these skills that saved my life that day. What are the critical safety skills your workforce needs to prepare for and manage the unexpected? How are you training your people? How are they practicing their skills? One day, it might mean the difference between life and death. ●

TRISH KERIN, Safety Columnist

Bio-Route Cracks Carbene Chemistry

Environmentally friendly process could lead to sustainable production of advanced biofuels

A TEAM of researchers in the United States has developed a scalable, microbial platform capable of carrying out carbene transfer reactions.

Carbenes are highly reactive carbon-based molecules containing divalent carbon atoms and used in the manufacture of chemicals, fuels and pharmaceuticals. However, this use has been limited because of the expensive and often toxic chemicals needed to drive their reactions.

What the researchers from Lawrence Berkeley National Laboratory and the University of California, Berkeley have done is replace these chemicals with natural products produced by an engineered strain of the bacteria Streptomyces (Figure 1).

Based at the U.S. Department of Energy's Joint BioEnergy Institute (JBEI), the researchers observed the engineered bacterium as it metabolized and converted sugars into the carbene precursor and its alkene substrate.

Streptomyces also expressed an engineered enzyme that used those chemicals to produce cyclopropanes, high-energy molecules that could potentially be used in the sustainable production of novel bioactive compounds and advanced biofuels.

"We can now perform these interesting reactions inside the bacterial cell. The cells produce all the reagents and the cofactors, which means that you can scale this reaction to very large scales for mass manufacturing," explains Jay Keasling, principal investigator, senior faculty scientist at Lawrence Berkeley National Laboratory and CEO of the JBEI. "All you need to add is sugar, and the cells do the rest," he adds.

While Keasling acknowledges that the conversion efficiency for the integrated carbene-transfer reaction and the final product titer are not high, he believes they are sufficient for proof of concept: "The work demonstrates a new type of chemistry in the cell, along with production of the precursors for that chemistry."

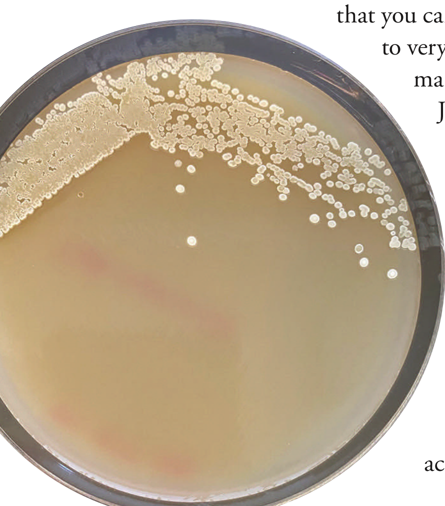
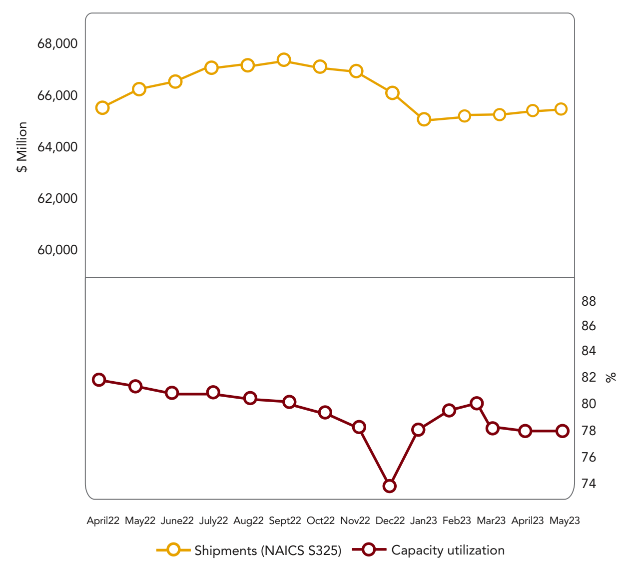


Figure 1. Researchers at the Joint BioEnergy Institute observed an engineered strain of the bacteria Streptomyces producing cyclopropanes, high-energy molecules that could potentially be used in the sustainable production of novel bioactive compounds and advanced biofuels. *Source: Jing Huang/Berkeley Lab.*

ECONOMIC SNAPSHOT



Shipments rose and capacity utilization decreased slightly.
Source: American Chemistry Council.

Writing in a recent issue of *Nature*, the researchers note this fully integrated system can be envisioned for many carbene donor molecules and alkene substrates.

Nevertheless, while the researchers may have developed a scalable platform, its commercialization is still far off.

"We would need to increase the titer, rate and yield of the production process. This would involve extensive engineering of the host bacterium's pathways to produce the precursors as well as the enzyme that catalyzes the reaction," shares Keasling. "We don't have plans to do this work. This might be something that a company would want to do if they were to scale the process," he notes.

For now, the researchers are examining other types of similar precursors to see if they can diversify the substrate and product ranges.

Catalyst Converts Methane To Formaldehyde

A NOVEL catalyst derived from tungsten trioxide has achieved near 100% conversion of methane to formaldehyde under 420-nm light irradiation and at room temperature.

Researchers from chemistry and chemical engineering departments at University College London, the University of Hong Kong and Tsinghua University, Beijing, China, collaborated to develop the material, which features a dual-active site comprising copper and tungsten atomic species that work in tandem to ensure an effective and selective conversion process (Figure 2).

Mechanistic analysis found that the tungsten trioxide substrate provides the visible-light responsive activity for methane conversion, while the atomically dispersed copper acts as an effective electron acceptor.

"Further research will be focused on improving the catalyst's efficiency and selectivity," said Zhengxiao Guo, professor of chemistry and mechanical engineering at the University of Hong Kong and corresponding author of a recent paper describing the work in *Nature Communications*. "Tasks include enriching the atomic active sites during catalyst synthesis and scale-up and to design innovative reactor systems, for example, to enhance solar/catalyst interactions and to achieve multi-pass reactions."

Guo also notes that the dual-active site strategy developed here can be applied to other chemical reactions that involve multiple electrons to complete the process, such as water-splitting hydrogen generation and carbon-dioxide conversion into other chemicals.

"It extends the scope and flexibility for fine-tuning of the local microenvironment, so that reaction rate and pathways can be tailored to maximise productivity and improve selectivity," he added. We are applying similar design strategies for other chemical reactions — with very promising discoveries in the pipeline."

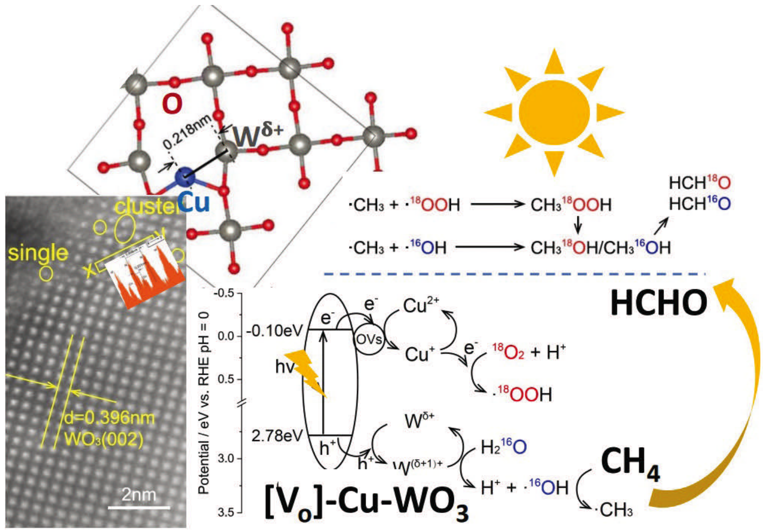


Figure 2. The selective conversion of methane to formaldehyde, a valuable commodity chemical. *Source: the University of Hong Kong.*

In terms of commercial potential, Guo says that one of the key challenges is to control the synthesis conditions and to tailor them for large reactors in scale-up reactions so that reproducibility is maintained for the catalyst performance. "Another challenge is to improve further the durability of such catalysts," he said. "Both are also common issues with catalysts in general. We are working on ways of tackling those."

The team is actively seeking industrial partnerships for continued development of the catalyst system and its practical applications. Guo says it is important to note that even the low concentrations of formaldehyde generated during the reaction can be applied in household, commercial and medical products. "Such low concentrations can be readily produced and applied on demand and on site, offering great flexibility for product design in the supply chain," he concluded.

Oxyfuel Combustion Paves Way to Net Zero

The technology, when paired with an electrolyzer, can be an economical option

Recently, I discovered an interesting opportunity to use oxyfuel in a refinery.

IN MY June column, "Develop Your Decarbonization Roadmap," chemicalprocessing.com/33005104, I discussed steps to reach a net-zero footprint in your process plant. The first focus should be on Scope 1 emissions, which are emissions from boilers and furnaces on-site, and Scope 2 emissions, which are indirect emissions from imported energy. This column will cover a practical pathway toward zero emissions through oxyfuel combustion.

CCUS SPARKS DECARBONIZATION

For many plants, a common method to eliminate Scope 1 emissions is through "post-combustion CO_2 removal." Carbon capture utilization and storage (CCUS) often is used. This complex system uses amine absorbers and regenerators, which carry both high capital investments and high variable costs for power and steam consumption.

Pre-combustion technologies can help avoid low-concentration CO_2 production in the flue gas. These technologies include hydrogen firing, ammonia firing, electrical heating and oxyfuel combustion. For now, I'll discuss oxyfuel combustion in more detail.

OXYFUEL DRIVES DECARBONIZATION

The purpose of oxyfuel is to use pure oxygen instead of air to fire a furnace. Pure oxygen offers the advantage of producing only CO_2 and H_2O during combustion. Removing water through condensation and drying creates a pure CO_2 stream, which is then compressed and sent to sequestration, shipping or utilization for other products.

Another advantage of oxyfuel is its efficiency. Traditionally with combustion air, 79% of the air in the form of nitrogen is heated for no reason in the furnace, resulting in inefficiencies and higher fuel consumption. Oxyfuel uses less fuel because the recycled flue gas is already at an elevated temperature. It should be noted that using oxygen directly in a burner is difficult. Therefore, part of the furnace's flue gas must be recycled to the burners to keep the oxygen concentration below the limits to ensure safe combustion.

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CCUS OR OXYFUEL?

In traditional oxyfuel configurations, an air separation unit (ASU) produces the oxygen. The ASU is a high capital investment and very costly to operate due to the cryogenic distillation needed to produce the oxygen. Nonetheless, ASUs tend to be more economical for larger units. Consequently, you must decide whether an ASU unit is more economical than a CCUS unit for pre-combustion or post-combustion CO_2 removal.

Recently, I discovered an interesting opportunity to use oxyfuel in a refinery.

OXYFUEL COMBUSTION SUCCESS STORY

Increasingly, companies are producing green hydrogen in electrolyzers and using renewable power to drive the electrolysis process. These units, installed on an industrial scale, reach 100 megawatts (MW) or more. For example, Shell in the Netherlands is installing a 200-MW electrolyzer in the Port of Rotterdam, coming on-stream in 2025. It reportedly will produce 60 tons of green hydrogen/day. This hydrogen can be used for automobile hydrogen fueling stations, hydrotreating, hydrocracking or as a fuel to reduce Scope 1 emissions through pre-combustion removal of CO_2. Pure oxygen is a byproduct of this process. Because hydrogen and oxygen have different molecular weights, 60 tons/day of hydrogen equals the production of around 480 tons/day of pure oxygen. This is enough oxygen to fire a 69-MW or 237-MMBTU/hr furnace, similar to an oil refinery's large furnace or boiler.

OXYFUEL COMBUSTION IGNITES OPPORTUNITY

The bottom line: Oxyfuel offers a significant advantage by saving money and reducing emissions. The oxyfuel firing with oxygen from an electrolyzer does not require an ASU. The electrolyzer's waste oxygen stream directly serves this purpose. Now, you can decarbonize a major furnace in your plant simply by installing a blower for recycling flue gas, new furnace ducting, cooling water exchangers to cool down the flue gas, flue gas dryers, and modifying the burners to handle the new combustion mix of CO_2, oxygen and fuel. Visit https://bit.ly/44zVmOc to see how a 237-MMBTU/hr furnace will now avoid 120 $kTCO_2$ per year of CO_2 emissions, about 5% to 10% less than a typical refinery's emissions. ●

MICHIEL SPOOR, Energy Columnist

EPA's Plastic Waste Pains

New proposal targets plastic waste-based feedstocks used to make transportation fuels

The rulemaking reflects a level of EPA discomfort.

ON JUNE 20, 2023, the U.S. Environmental Protection Agency (EPA) proposed significant new use rules (SNURs) under the Toxic Substances Control Act (TSCA) for 18 chemicals subject to premanufacture notices (PMNs). The rulemaking reflects a level of EPA discomfort with certain new chemicals derived from plastic waste. This article explains the significance of this proposal.

Earlier this year, the EPA issued a draft of its National Strategy to Prevent Plastic Pollution and, together with its National Recycling Strategy, identified how the agency will prevent plastic waste and reduce, reuse, recycle and capture plastic from land-based sources. The former strategy includes several goals, one of which is to eliminate plastic waste release and other waste from land-based sources by 2040. The EPA does not view activities that convert non-hazardous solid waste to fuels or fuel substitutes (plastics-to-fuel) or for energy production to be "recycling" activities, such as pyrolysis. The EPA intends to require companies submitting new pyrolysis oil chemicals for review under TSCA to conduct testing for impurities that could be present in the new chemical substance prior to approval and ongoing testing to ensure no variability in the plastic waste stream is used to generate the pyrolysis oil.

Based on these pronouncements, the proposed SNUR is unsurprising. It reflects the EPA's new approach to plastics-to-fuel chemicals. The 18 chemicals at issue are made from plastic waste-derived feedstocks. The proposed SNURs would ensure they are contaminant-free before they can be used to make transportation fuels.

The EPA approved the plastic-based feedstocks in 2015 and 2019 but says it now knows more about their impurities. The proposed SNURs would require EPA review before the manufacturing or processing of the chemicals using waste-derived feedstocks that contain any amount of these chemicals: heavy metals, dioxins, phthalates, per- and polyfluoroalkyl substances, polybrominated diphenyl ethers, alkylphenols, perchlorates, benzophenone, bisphenol A, organochlorine pesticides, ethyl glycol, methyl glycol or N-methylpyrrolidone.

According to the Federal Register notice, the orders require no manufacture, processing or use of the PMN substances other than for processing and use as a fuel, fuel additive, fuel blending stock or refinery feedstock; use of personal protective equipment where there is a potential for dermal exposure; and establishment of a hazard communication program. Additionally, the proposed SNURs would designate certain activities as significant new uses, including manufacturing PMN substances using feedstocks containing any heavy metals or chemicals noted above.

This SNUR, if promulgated as proposed, could prohibit the manufacturing of all PMN substances, which presumably include some variations of pyrolysis oils or products derived from pyrolysis oils based on the public information available. The proposal is noteworthy for several reasons. First, the new SNUR provisions do not relate to the PMN products, byproducts formed with the PMN substances or impurities in the PMN substances. Instead, the SNUR specifies that PMN substances may not be manufactured from feedstocks that contain a list of specified substances. The EPA does not explain why it views these substances as a potential risk when present in feedstocks.

Second, EPA provides no de minimis level below which the SNUR does not apply. This is problematic for any manufacturer of any PMN substances because a manufacturer will have to document the absolute absence of all the specified substances in all batches of all feedstocks used. Even if a company could test all the feedstock it uses, one can only detect down to an analytic level of detection.

Third, the EPA is departing from its long-standing practice and has proposed regulating existing chemicals (the specified components) as new chemicals. A manufacturer of any of the PMN substances could produce the PMN substances from pristine feedstocks with no problematic byproducts or impurities and subsequently blend any of the specified problematic substances into the product and distribute that mixture for further processing or use.

In past pyrolysis oil cases, the EPA required testing for the presence of dioxin in the products. The agency may have a reason to broaden its concern to other halogens (fluorine, bromine), but the better solution is not to focus on the feedstock but rather the products. Doing so would maintain the commercial prospects for safely repurposing waste plastic to produce waste-derived transportation fuels. ●

LYNN L. BERGESON, Regulatory Columnist

Lynn is a lawyer specializing in chemical industry regulations.
The views expressed herein are solely her own. This column is not intended to provide, nor should be construed as, legal advice.

Alternative Fuels Pose Flow-Metering Challenges

FRANK FLOW
Head of analyzer products and chemical industry, Flexim Americas Corporation

"We've been measuring gases for a long time, and we've done a lot with pure hydrogen."

THE PHYSICAL properties of hydrogen differ highly from other gases. Plant operators are therefore faced with major challenges due to the necessary adaptations that need to be made. To help us understand the challenges and options available, Chemical Processing spoke with Frank Flow, head of analyzer products and chemical industry at Flexim Americas Corporation.

Q: Let's set the stage in terms of alternative fuels. Can you give me an overview of what it means for your area of expertise?

A: Whether hydrogen, ammonia or biodiesel, chemical facilities and the market in general are using alternative fuels. It's a little bit different from mass flow applications that we saw in the past, so we have to address how to measure those fuels.

Q: What challenges are there with Hydrogen (H2) gas measurement?

A: From the non-invasive ultrasonic standpoint, we've been measuring gases for a long time, and we've done a lot of flow measurement with pure hydrogen. Because it is a lighter molecule and because we're on the outside of the pipe — and the standard pipe that we're seeing is usually carbon steel or stainless — we need more pressure on those applications for that gas to be compressed to make the measurement.

If we're doing an existing application where somebody's moving to hydrogen, we have to ensure that we have enough pressure on that application to make a measurement.

We know where our limitations are. We know what some possible solutions are for it, so we are prepared from that standpoint. As people use hydrogen blends, they're using the available hydrogen, which is great because this is a clean, pure-burning fuel. It makes sense for them to use it from a regulatory and financial perspective. As you start dosing in hydrogen to a natural gas stream, there are several things that happen. The molecular weight of the gas changes, and this changes the compressibility factor of the gas. So now you have a dynamic change in the calculated mass flow, and it changes the BTU value or the energy content of what's flowing through that gas.

So as that mass for the molecular weight changes, that can be accounted for by using sound speed measurement along with pressure and temperature. If we can identify that the properties are changing and we can correlate this back to a percent hydrogen that's changing, we can dynamically correct for compressibility and for the BTU value just by using the inherent values that come out of the ultrasonic meter. So not only are you getting a volumetric flow, but you're also getting a mass flow that's able to adjust for the properties of that gas. And the biggest factors that are going to impact our users are things like compressibility and energy content.

Currently, a customer must use several different devices to do that. In addition to a flow meter, the customer needs an analyzer for the gases. This information is calculated in an external controller along with the flow to provide mass flow and energy value. This information is required for managing combustion.

Q: What issues and limitations are there when using clamp-on ultrasonics?

A: On steel pipes, I would say the bottom of the pressure threshold right now with clamp-on-transit-time is 10 bar, 150 psi, and that's really kind of stretching. Ideally, you would be at 20 bar, 300-ish psi. Having that much pressure ensures robust signal strength and diagnostics. The great thing about transit time is that you're not really going to find a limitation on the velocity in most cases. So, you can have extremely high velocities down to low velocities because hydrogen application will require a larger turndown to meet the same energy requirements. If you've got a smaller pipe with a thicker wall, you're going to need more pressure, and you tend to see more pressure on those applications, but it's one of those limitations to be aware of with clamp-on. Depending on the pipe size and the velocities, you must be prepared to use different waveforms or frequencies.

There are going to be some limitations usually impacted by the pressure since it is a low-weight, small molecule — it's hydrogen, it's atomic number 1. So, when we get to other solutions that we're doing noninvasively, we're starting to use plastics or other pipe materials that allow us to get down to lower pressures. The lowest pressure that we've tested is about one bar, and that would be using a plastic pipe. The issue with ultrasonic is this impedance relationship, and that's where the steel requires more pressure. That's why we can work noninvasively on lower-pressure gases, by using different pipe materials.

Q: How are customers dealing with traditional hydrogen blending applications, and what new methods are being employed with ultrasonics?

A: Customers are taking some type of gas analyzer and calculating the properties using their DCS or a flow computer. Many people are using differential pressure technology. It's been around for a long time; it's understood. So that technology's out there. Newer customers or newer plants might use Coriolis technology, but that must be installed when the process is shut down. These technologies create a pressure drop, and there are going to be some limitations on the velocities and the pressure. Coriolis needs some pressure as well to make that measurement.

Q: Ammonia as an energy carrier is starting to take shape. What experience and problems with ammonia flow can clamp-on meters offer?

A: We're seeing ammonia more from the producer side. So, I haven't measured ammonia in an application where I knew that it was being used for combustion. However, I've measured ammonia when it's been used for other processes, whether it's at a chemical plant that's producing it or somebody that's using it for power generation to control emissions. So, from that standpoint, we've got a fair amount of experience measuring ammonia both in a gas or a liquid state. On the liquid side, it tends to be colder and more pressurized, and that's no problem for us being outside the pipe. If the transducers are insulated, you keep a moisture barrier and the ultrasonics work really well on ammonia. It's a straightforward measurement.

You want to be quick about how you do the installation because it does want to build up ice, especially in the south, because there's enough moisture in the air that it'll create ice on the surface of that pipe quickly. Obviously, it's a toxic gas, so you want to limit your leak points; it's a no-brainer from the standpoint of not creating a leak point.

When we move to the gas side, it's easier because it's a denser fluid. For steel pipes, we don't need as much pressure on that; typically, around 100 PSI is fine. Unless we get into a smaller pipe with a thicker wall, that's going to be your exception there. The one thing to watch out for is if you have a two-phase, so if the liquid's turning into a gas or vice versa, this would be a problem for ultrasonic technology and a problem for most flow technology at a certain point.

Q: Bio Diesel is another developing green energy. What are you seeing that's unique to this process, and are ultrasonic meters a viable means of metering for some of these processes?

A: Biodiesels are taking waste products or plant-based oils, and they're producing a diesel product with it. Throughout that entire process, ultrasonics work quite well, even though there are changing properties and constituents. If the fluid properties are changing enough, the mass balance aspect gets challenged with ultrasonic technology, but you still get volumetric flow and an indication of what's going on in the pipe. The temperature in these applications is usually higher, so if you've got a means of making a measurement noninvasively, it makes sense because now you're not exposing your maintenance workers to a possible safety issue.

The other side of that is we're seeing corn oil, soybean oil and other things like that that are used for diesel. These are friendly for ultrasonic technologies, and most of the processes work quite well for clamp-on.

Flexim gas flowmeters: Dynamic Gas Master – non-invasive clamp-on measurement of gas properties

Q: Is there anything you'd like to add?

A: The basics of what we're still seeing, even in some of these new processes, are our traditional utility measurements, which the clamp-on ultrasonic technologies are proven. On the emerging side are things like CO_2 to diesel or e-diesel, I think that's earth-changing; people are capturing their CO_2 and they're repurposing it back into a fuel.

And that would be the one thing I would touch on for ultrasonics too. Our gaseous CO_2 at this point is still not something that we can do with a clamp-on transit time technology. There are some in-situ ultrasonic technologies that look like they can handle that measurement. Clamp-on can work reliably on supercritical gases – where the pressure and temperature are above the critical point – and on liquid-dense CO_2. Supercritical fluids have some of the same issues with Equation of State calculations mentioned in the above hydrogen blending. Again, sound speed becomes a beneficial auxiliary measure that can provide value in calculating mass flow.

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BEYOND GREENWASHING

By Jonathan Katz

Sustainability designations like ISCC Plus can authenticate efforts to reduce carbon footprint

CORPORATE SUSTAINABILITY claims are facing their moment of truth. In February, Shell Plc joined a growing list of organizations accused of embellishing their environmental wins. A climate group called Global Witness filed a complaint with the Securities and Exchange Commission (SEC), alleging the company engaged in greenwashing by classifying natural gas as renewable energy.

Investors, regulators and buyers have certainly upped the ante for carbon transparency, leaving chemical companies with the challenge of validating their environmental statements. Increasingly, chemical manufacturers are seeking third-party certifications to back their carbon-reduction statements. When it comes to material inputs, ISCC Plus is one of the more common certifications that chemical firms are pursuing.

ISCC stands for International Sustainability and Carbon Certification, a system designed to verify the use of sustainable, bio-based and recyclable materials in the supply chain. The ISCC Plus designation is a voluntary standard for markets and sectors not regulated by the European Union (EU) Renewable Energy Directive II. This includes plastics, chemicals, food and feed markets. It also applies to biofuels outside the EU and the United Kingdom.

The global standard is based on the mass-balance accounting approach that allows chemical manufacturers to use a mix of fossil fuels and recycled or renewable materials in their products. It's a preferred method of sustainable accounting for the chemical industry because it's designed to trace the flow of materials through a complex value chain.

As ISCC explains, physical segregation of recycled content is often impractical since chemically recycled or bio-based feedstocks are typically blended in the manufacturing complex. The mass balance approach makes it possible to track sustainable characteristics of a material in the value chain and attribute it based on verifiable bookkeeping.

Chemical manufacturers say the standard helps them meet market demand for more sustainably sourced products. Even so, the process is not always straightforward. The ISCC website includes hundreds of pages of guidance documents. The process involves sophisticated bookkeeping methodologies and internal training to ensure employees understand the steps and rules.


Orion Engineered Carbons has received ISCC Plus certification at three sites, including this one in Jaslo, Poland. *Source: Orion Engineered Carbons.*

WHY PURSUE ISCC PLUS CERTIFICATION?

For Brazilian polyolefins producer Braskem, ISCC Plus certification aligns with the company's commitment to a carbon-neutral, circular economy, says Susan Gluodenis, Braskem's director of global quality. The company is looking to increase sales of its recycled content product portfolio to 1 million tons of green ethylene, produced from sugarcane ethanol, by 2030. The designation helps the company demonstrate to customers its commitment to meeting sustainability targets, Gluodenis says.

Braskem first received ISCC Plus trading certification in 2021, allowing the company to sell its sustainable products. In January, the company received ISCC Plus certification for all five of its U.S. polypropylene production facilities.

Orion Engineered Carbons received ISCC Plus certification in November 2022 for multiple grades of carbon black, a pelletized or powder material used in high-performance applications, including tires. The Spring, Texas, subsidiary of Orion S.A., Luxembourg, began its pursuit of ISCC Plus certification in 2022 to increase visibility of new products derived from sustainable material, says Dirk Roller, vice president of global quality and reference laboratories for Orion.

Orion uses oil derived from waste streams, such as pyrolysis oil from end-of-life tires and a byproduct of wood pulp manufacturing. The certification provides Orion with guidelines to gradually bring sustainable products to market, in line with its goal to reach net-zero greenhouse gas emissions by 2050.

"2050 is still far away, but we must start now, even with smaller steps," emphasizes Roller. "There is not enough sustainable raw material on the market to immediately replace 100% of our feedstock. ISCC Plus provides excellent tools to start with a lower amount of sustainable material, while compositions can be changed over time to reflect the expected increasing availability of sustainable feedstock to meet our production requirements."

Mesbah Sabur, co-founder and CEO of Circularise, a company that provides certification traceability solutions, concurs, saying the ISCC Plus mass-balance methodology is a first step toward more extensive conversion to sustainable feedstocks.

"There will be a tipping point, and it might be different per organization and their skill and type of manufacturing processes, but once this tipping point is reached, it becomes much more realistic to step away from a mass-balance system," he explains.

AVOIDING CONFUSION WITH CONVERSION

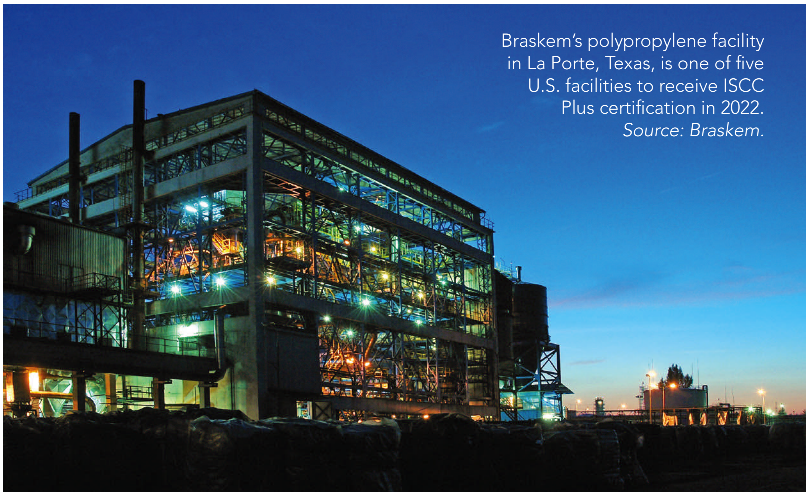
The certification process requires planning and collaboration. As Sabur explains, the ISCC guidance includes 200-plus pages of documentation. The certification also involves independent audits, which means organizations must keep detailed records. The mass-balance approach becomes even more complex when allocating amounts of sustainable materials to finished products.

For example, if a process has inputs of 50% sustainable and 50% virgin material, then the products produced will be certified as a 50-50 split of materials. But mass balance includes a credit system that allows organizations to allocate a larger proportion of sustainable material to some products, while lowering the content they claim in others.

Companies with rudimentary accounting capabilities or minimal internal resources dedicated to the program can quickly become overwhelmed. "A lot of the companies that we encounter, they've set up their initial bookkeeping with some sort of an Excel sheet, and then business starts booming and they have more and more transactions, and they realize this is not going to work," Sabur says. Circularise has developed a platform designed to automate mass-balance reporting and help chemical producers navigate the ISCC Plus process, Sabur adds.

Cepsa Química, the chemicals division of Spanish petroleum company Cespa, has received ISCC Plus certification for its circular phenol and acetone products as well as renewable and circular linear alkylbenzene (LAB). For example, the company is substituting some of the benzene produced from crude oil in its refineries with benzene purchased from suppliers that use recycled plastics, used cooking oil or wood as a feedstock.

Having a leader dedicated to the process is an important first step toward achieving ISCC Plus certification, Sabur says. At Cespa, that person is Arturo Castro Ramirez, the company's product stewardship technician. Castro Ramirez attended a two-day training session hosted by ISCC in Germany to learn the basics of the program. He administers the training internally to employees responsible for various tasks to complete the program requirements. These functions include managing the mass-balance bookkeeping, forwarding the sustainability declaration and calculating the conversion factor (sustainable inputs vs. outputs).



Braskem's polypropylene facility in La Porte, Texas, is one of five U.S. facilities to receive ISCC Plus certification in 2022. *Source: Braskem.*

"The key point in mass balance is the conversion factor," Castro Ramirez explains. "For example, here at Palos de la Frontera (Spain), we start our process with benzene and propylene that is oxidized and then we obtain phenol and acetone. So, there is a ratio between how many tons of benzene you need to produce for, say, 1 ton of sustainable phenol."

The conversion factor is critical because plants must prove during the external audit that they are not selling more sustainable product than the amount of sustainable raw material they have received, Castro Ramirez adds.

Orion also trained employees on ISCC requirements related to their specific work functions. The company initially considered using outside consultants to support it during the application process, but experts were booked for weeks and couldn't meet the company's three- to six-month timeline for certification, Roller says.

Like Castro Ramirez, Roller assumed the role of project lead and onboarded the Orion team on the ISCC process. Roller consulted with an ISCC-approved auditor to address questions during the preparation process. "Although we only had a few hours support, this helped us to understand the basic things and to get immediate questions answered," he says.

Phillips 66 received ISCC Plus certification at its Sweeny refinery in Old Ocean, Texas, in mid-2022 to process pyrolysis oil from hard-to-recycle waste plastics into cracker feedstock to produce circular polymers.

The company relied on scientists and engineers at its research center in Bartlesville, Oklahoma, to analyze samples of feedstocks to ensure they were compatible with process units, says Brandon Polander, an emerging energy technology specialist at Phillips 66. Refinery personnel also evaluated the refining processes to identify any potential engineering concerns prior to pursuing ISCC certification at its facilities, he adds.

PLAN FOR THE UNEXPECTED

At Braskem, the company encountered some unforeseen challenges when calculating the conversion factor in its U.S. plants. The company, which already had received certifications at its Germany and Brazil facilities, tried to apply the same calculation formula at the five U.S. operations, Gluodenis says. But the U.S. facilities had different configurations in their processes that the company had to factor into the equation, making the certification effort more complex. The company had to build different models, work with the plants' engineering teams, and consult with the auditor who evaluated previous ISCC Plus-certified plants within Braskem to accurately calculate the conversion factor, Gluodenis elaborates.

ISCC PLUS AND MASS BALANCE FAQs

WHAT CAN BE CERTIFIED?

Under ISCC PLUS, all types of agricultural and forestry raw materials, biowastes/residues and fossil materials contributing to the circular economy and bioeconomy can be certified.

WHAT ARE THE DIFFERENT RAW MATERIAL CATEGORIES UNDER ISCC PLUS?

- Bio Feedstocks – materials derived from virgin biomass products from industries such as agriculture and forestry.

- Circular Feedstocks – Reuse or recycling of waste materials at the beginning of the supply chain. Includes bio-circular products that are waste and residues of biological origin from agriculture, forestry and related industries, including fisheries and aquaculture, as well as biodegradable industrial and municipal waste, such as food.

- Renewable Feedstocks – Using renewable sources, such as wind and solar, to produce materials of non-biological origin. The input feedstock must not contain usable energy. The renewability of electricity can be proven via renewable energy obligations, renewable power purchase agreements or via a direct connection/link of the processing unit with the respective unit producing renewable electricity.

HOW DOES MASS BALANCE WORK?

According to Circularise, the mass balance approach is a chain-of-custody model that allows chemicals and plastics operations to incrementally transition to using sustainable feedstocks without setting up separate production lines for sustainable products. The process is guaranteed by third-party certification, creating the need for bookkeeping and reporting throughout the supply chain.

HOW DO YOU ENSURE MASS BALANCE MATERIAL IS ACCURATELY ALLOCATED?

As Circularise notes, organizations need a documentation and reporting system. They also need an independent third party to conduct an audit, including the certification of the bookkeeping system, materials used and reporting system to ensure the integrity of the material allocation process.

The organization must report the overall balance periodically to prove that output credits do not exceed the input credits for that bookkeeping period. "Credits for sustainable materials can then be allocated to an output material, as long as the net proportions of material characteristics are preserved. When materials are traded between companies they must be accompanied by a certificate for that material (a sustainability declaration), corresponding to its sourcing and a declaration of its sustainability profile," Circularise notes on its website.

The company did not use outside consultants because the organization already had significant internal experience handling various types of certifications. "We have, on any given day, somewhere between 20 and 25 certifications within Braskem as a whole, so the five for the U.S. were added to the mix," she explains. "So, we already had a good knowledge base within Braskem."

Braskem's experience is not unusual. "There are always some exceptions or edge cases that you need to solve," says Sabur. "You're not going to decide to get certified and be ready in two months. It's a process."

Understanding the process is among the top obstacles Sabur encounters when he meets with companies seeking ISCC Plus certification. He even sees it within large organizations. "We work with companies that generate more than a couple billion dollars of revenue a year, and there's huge amounts of confusion within the organizations, within different departments," he says.

Companies will ask questions about what they can or can't do and how to execute the process, he says. Considering the sometimes-onerous nature of the program, Sabur recommends that organizations give themselves plenty of time to prepare for the certification process.

"Definitely start early, earlier than you might think otherwise and you might be comfortable with," he says. "You will be much more prepared for the moment because there is quite a learning curve. It's not a very simple thing to install in an organization." ●

Process Monitoring Maintains Productivity, Mitigates Downtime

AMANDA TYNDALL
senior product manager, Veolia Water Technologies & Solutions

"You could make a decision on a hunch, but that adds risk."

ANALYTICAL EQUIPMENT needs to be robust, reliable and responsive when monitoring industrial processes in order to detect change and enable corrective action. It also should be easy to use and provide high uptime.

When considering process organics monitoring, there's a lot to unpack. To help make sense of all the capabilities, Chemical Processing spoke with Amanda Tyndall, senior product manager for Sievers Instruments at Veolia Water Technologies & Solutions.

Q: Why is process monitoring important?

A: Monitoring industrial process water and wastewater is critical for process control, quality assurance, asset protection as well as regulatory compliance. Water is used in a variety of processes and products within a facility, and wastewater is also generated that needs to be cleaned up before environmental discharge or potential onsite reuse. Process monitoring helps identify contamination, either from the source water or from process fluids. On the wastewater side, there are discharge guidelines as well as sustainability targets to reduce a company's water footprint. Ultimately, process monitoring aims to maintain productivity and avoid downtime while maximizing revenue, minimizing costs, and supporting sustainability goals.

Q: What are current pain points with process organics monitoring, and how can they be overcome?

A: The goals of process monitoring are first to establish a baseline, detect a change from that baseline and then take corrective action. When a user can't accurately set a baseline or pick up that deviation, there's no ability to take data-driven action.

One of the biggest challenges is when users can't detect what they're looking for, so they are unable to determine root cause of the contamination event.

You could make a decision on a hunch, but that adds risk. If that decision wasn't right because the data were unreliable, then it's hard to justify the action and resulting monetary expense. In some cases, an instrument may not detect a process upset because the technology isn't able to capture the change, or in other cases, an instrument may face complex and lengthy maintenance that keeps it from operating correctly at the time of critical need. This is the other big process-monitoring pain point, high maintenance and complex processes. Modern analytical instruments often have modular designs making it easy to maintain, troubleshoot and get back online if there is any issue.

There are several considerations that can help decision-making related to process instrumentation. These include analysis time, complexity of technology, reagents or consumables needed, maintenance, ease of troubleshooting, moving parts that could fail, data management, automated features and diagnostics. These last three have really allowed users to be more hands-off, trust their data, and make data-driven process improvements.

Q: There are different TOC analyzers out there – how do they differ?

A: Total organic carbon (TOC) is a critical tool for process monitoring; it's a direct way to measure complete organic contamination. While many discharge permits for wastewater are still written for historical biological oxygen demand (BOD) and chemical oxygen demand (COD), these measurements take two to three hours for COD with often hazardous reagents, and BOD takes five days. BOD and COD can also suffer from interferences that are common in water streams, such as nitrates, chlorides, sulfides and disinfectants.

TOC analyzers oxidize organics in a sample to carbon dioxide and then measure that carbon dioxide. Different TOC analyzers use different oxidation techniques or different detection techniques depending on what is being monitored or what features are needed for a certain application.

For oxidation, common technologies include UV light, UV light with an oxidizing agent, heat with an oxidizing agent, combustion at different temperatures (with or without catalysts), two-staged advanced oxidation and super critical water oxidation involving pressure and temperature. These are listed in order of increasing sample complexity. For pure streams, UV light can oxidize the small amount of organics present. For complex streams with salts and solids, super critical water oxidation, two staged advanced oxidation and combustion are designed for those harsher conditions. It is important to consider the goals whether speed, accuracy, robustness, complete oxidation of carbon, etc.

For pure samples, the goal of monitoring is really to measure nothing - or to confirm there aren't any contaminants in the water. Here accuracy, precision and stability are driving factors.

For process, utility and even source water, TOC technologies aim to capture all the organics to determine quality levels and detect leaks. For source water, this includes natural organics matter like humic acids. For utility water, key organic contaminants are glycol or other cooling fluids that could breakdown to form organics acids and cause corrosion. The goal is to provide robust and responsive operation to fully capture and continuously monitor processes for quality and control.

Finally, for wastewater, the analyzer must be fit for more rigorous demands like salts, solids and high organics loading. Additional applications in chemical processing and refining could require operation in a hazardous environment where data is critical to process continuity and plant safety. In these cases, automated features like rinsing, calibration and predictive diagnostics help provide uptime and simple troubleshooting to stay in compliance and optimize treatment processes. Additional data management tools now allow businesses to drive processes and trend data over time to enable efficiencies.

The TOC-R3 uses high-temperature non-catalytic combustion across a broad analytical range. It features automated calibration, self-cleaning and check standard capability, allowing for low system downtime. Its rapid cycle time and optional leak detection mode and wide-range detection support a variety of applications.

Q: Do they stand up to the harsh environments you suggested?

A: They do if they're built right for the application. For example, a pure water analyzer wouldn't handle a wastewater stream. When we think about harsh environments and complex streams, combustion has been an industry staple for organics monitoring. There are, however, different types of combustion at different temperatures and with varying oxidation aids. Catalytic combustion uses a platinum catalyst where the catalyst efficiency can vary with organic compounds and catalyst activity diminishes as active sites fill up. Catalytic combustion is used in the lab and online, but needs more frequent calibrations and exchange of the catalyst to provide trustworthy data at the target range.

On the contrary, high-temperature, non-catalytic combustion offers full complete oxidation of tough samples that can be relied upon for comprehensive organics analysis. This simple technology makes it easier for operators to trust data and avoid unnecessary downtime from maintenance or consumables replacements.

Q: What are the main applications, and are there other uses?

A: Organics analysis helps industrial users track water quality, control treatment processes and maintain regulatory or corporate compliance. Common applications include tracking organics removal from source water to point of use, whether that water is used as an ingredient, in boiler feedwater, condensate return or cleaning processes.

Oftentimes, industries are aiming to maintain productivity, maximize profitability and protect assets, whether those are equipment assets such as boilers and condensing treatment or water treatment equipment like biological systems or membranes. Protecting assets from fouling through proper pretreatment or rapid and sensitive detection of leaks can prevent downtime, repairs, early replacement and shutdown.

A growing application is from users thinking about overall water footprint and finding opportunity to reuse. By 'following' water from source through treatment to use instead of automatically discharging treated wastewater, process monitoring can indicate if a stream is able to be reused. Each of these must meet a quality target, and they're not all the same; with organics monitoring, users gain the ability to make decisions that impact sustainability.

Q: Anything that you would like to add?

A: When we think about what's changing and how we can overcome pain points, some exciting developments are around automation features and predictive diagnostics. These features help prevent downtime, lower maintenance requirements and provide trustworthy data. Automation features can include check standards, calibration and rinsing, which help with challenging samples. In addition, status monitoring of what's going on inside the analyzer provides usage information and health of the analyzer.

We want to design instrumentation with robustness, reliability and responsiveness to establish a baseline, detect a change and make corrective actions. An analyzer with high uptime, simple operation and low maintenance helps operators optimize treatment processes, maximize profitability and find opportunities for sustainability.

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Visualize VR Blessings & Burdens

Careful consideration of training objectives and challenges is necessary to maximize the benefits of virtual reality technology

BY SEÁN OTTEWELL

DOW, AIR Liquide and Chevron were early adopters of virtual reality (VR) as a training tool.

Now they are leveraging it to further improve training, both in their process and business activities, by working closely with specialist vendors and start-ups.

For example, Dow, based in Midland, Michigan, is establishing several innovation centers around the world. The first, at the company's Zhangjiagang site in China (Figure 1), focuses on environment, health, safety and sustainability functions.

One of the main challenges with traditional safety training programs is an overreliance on non-interactive tools, such as video and slides, that don't involve critical and quick-thinking skills, Dow noted in a March 8 news release.

"The available learning technology has created challenges in ensuring understanding of the nuances between existing safety and sustainability standards and the guidelines governing them when issues play out in real life," the company said.

So, the plan at Zhangjiagang is to use VR technologies to close these gaps and decrease risks.

In a similar vein, Paris-based Air Liquide has opened a smart innovative operations (SIO) center in Kuala Lumpur, Malaysia, to accelerate troubleshooting, improve local operations and give access to expertise across borders. The center leverages a range of digital tools, including some developed with start-ups.

VR-based immersive training is a cornerstone of the SIO's efforts. Air Liquide believes that exposing employees to real-time training in a simulated environment that mimics the layout and operations of an actual plant is a vast improvement on traditional theoretical studies.

Additionally, this training method improves employees' technical understanding of on-site operations without incurring the typical cost of an on-site training program — or training-related injuries, the company notes. The approach is particularly helpful in improving productivity in complex environments, such as air-separation units, according to the company.

"Since VR has advanced to a stage where it is able to produce a virtual replica of the plant operations, employees can train as many times needed — generating a pool of highly skilled employees," notes the company.

OTHER DIGITAL EFFORTS

Chevron also has begun working to improve its digital capabilities.

In May, Motive.io announced Chevron had selected the company as part of the Chevron Technology Ventures Catalyst program. A long-standing and early adopter of immersive technologies, Chevron uses the program to identify new technologies with the potential to enhance its process and business activities. Its latest investment round involves US$90 million.

Motive.io designed its XR management system (XMS) to help users create, edit and deploy VR training modules faster. The system's authoring tool allows users to create and

Figure 1. Dow's first innovation center is at its Zhangjiagang site in China. *Source: Dow.*

edit VR training without having to write code and integrates with a customer's own learning management system (LMS). This works with both the Sharable Content Object Reference Model and xAPI software packages out of the box, with no changes needed. The platform also includes a conversational AI component.

"I am very bullish on AI in general; however, it's hard to say at this stage exactly how and where it will impact immersive technology," says Motive.io CEO Ryan Chapman.

One possibility is the use of fully conversant digital agents to enhance training. "Training scenarios often benefit from the ability for the learner to ask a professional for guidance if they are unsure of what step to do next," he explains. "An AI-powered agent could fill the role of an adviser if a real trainer isn't available."

AI may also be useful in the development of 3D scene and asset generation, as well as training simulation scenarios.

The use of VR and other immersive training technologies grew steadily during the pandemic as companies sought new ways to train and engage their remote workforce, Chapman says.

That said, he notes that use and deployment challenges remain. "A negative first experience with a poorly designed application can turn off many users," he cautions. Also, the cost to create and manage the content can quickly become prohibitive.

"The best deployments we've seen focus first and foremost on the business problem that the training is solving," Chapman says. "These have a much better track record because they can demonstrate a very clear ROI to the stakeholders and the ultimate decision-makers."

C-level sponsorship is another critical component of a successful VR training program, notes Luca Vezzadini, co-founder and CTO of software company Kairos3D. He also suggests that chemical companies considering VR technology take time to identify their specific training needs and consider whether they want to prioritize a learning program for onboarding newcomers for high-risk activities, emergency response protocols or equipment handling.

"Also, the involvement of subject matter experts is always critical for the creation of effective training simulations," Vezzadini adds.

Kairos3D, which counts several petrochemical companies as customers, specializes in creating 3D digital twins, with a focus on training process industry field operators (Figure 2).

"Such experiential, simulation-based learning is the most effective way to give the workforce the situational awareness needed to make the right choice in every scenario," Vezzadini says.

One scenario involves integrating its 3D technology with training programs based on LMS. Here, trainees initially engage in conventional theoretical online lessons, and once they successfully complete this part, they gain access to the company's immersive 3D modules. Within this environment, they encounter increasingly complex scenarios and must achieve a minimum score for each scenario to advance.

Figure 2. Using proprietary technology, Kairos3D focuses on training process industry field operators. *Source: Kairos3D.*

"Not only does this approach support the learning process for newcomers, but it also provides value for seasoned operators who need to review rarely used procedures, acquire novel practices or gain proficiency in specific emergency situations," notes Vezzadini.

This methodology allows quantitative analysis of users, such as scoring and facilitates the monitoring of workers' readiness for the wide range of operations they will be required to perform in the real world.

"In fact, asset managers and HR managers are supported in their decisions from the system's automated dashboards, which provide insights into the theoretical and practical preparedness of operators across various procedures and practices they must execute in the field," he explains.

A second common application involves integrating the 3D platform with traditional operator training simulators (OTS). These dynamic process simulation tools address the learning needs of board operators.

Using an agnostic interoperability layer that allows bi-directional integration with the OTS, trainees can then maneuver the equipment in the 3D model and experience the simulated reaction of the 3D virtual representation of the plant according to the values computed by the OTS process model.

The 3D-OTS integrated training system can be used with the assistance of an instructor or in unattended mode.

A third common application involves projects where VR simulations are used in standalone mode, neither connected to OTS/process models nor integrated with LMS. Here, trainees select the scenario they want to exercise and are then driven by the system to familiarize themselves with and execute the tasks that build up each training procedure.

"This translates to a risk-free, cost-effective approach to train field operators for what awaits them in the real world through experiential learning. Major benefits include a significant reduction of logistic costs, a higher knowledge transfer without pulling SMEs away from their work and a safer, more effective performance of industrial facilities," notes Vezzadini.

IS VR REALLY THE ANSWER?

Questions remain as to VR's future within the chemical industry. It could be a solution looking for a problem, cautions Dave Strobhar, chief human factors engineer at Beville Operator Performance Specialists.

"The attitude in the industry seems to be 'This is great. Now how can I use it?'" he says. But Strobhar believes that, without proper training objectives, VR technologies run the risk of mirroring the early evolution of simulators in the process industry.

"I don't think there's enough honesty about what happened," he reflects, pointing out that while everyone was keen to buy them up when they first came out, many ended up in back rooms covered in dust or cannibalized for spare parts.

"The senior management of one company I worked with thought it was a great idea to put their simulator in the control room and that the operators would simply go over and do something with it if and when they got a chance. There was no thought put into how they were ever going to use the simulator — and they never came with any training curriculums from the vendors in those days, either," Strobhar adds.

While that situation has improved, with learning plans and objectives much more defined now, his experience is that training departments often still don't realize they have a problem in the first place.

For example, he cites a Center for Operator Performance project, which looked at training programs carried out by different refineries. One took a week to get an operator onto the unit, another took eight weeks. Both were happy they were turning out operators as good as they could be. "So everybody thought they were doing a good job. Obviously, there's something wrong here," he suggests.

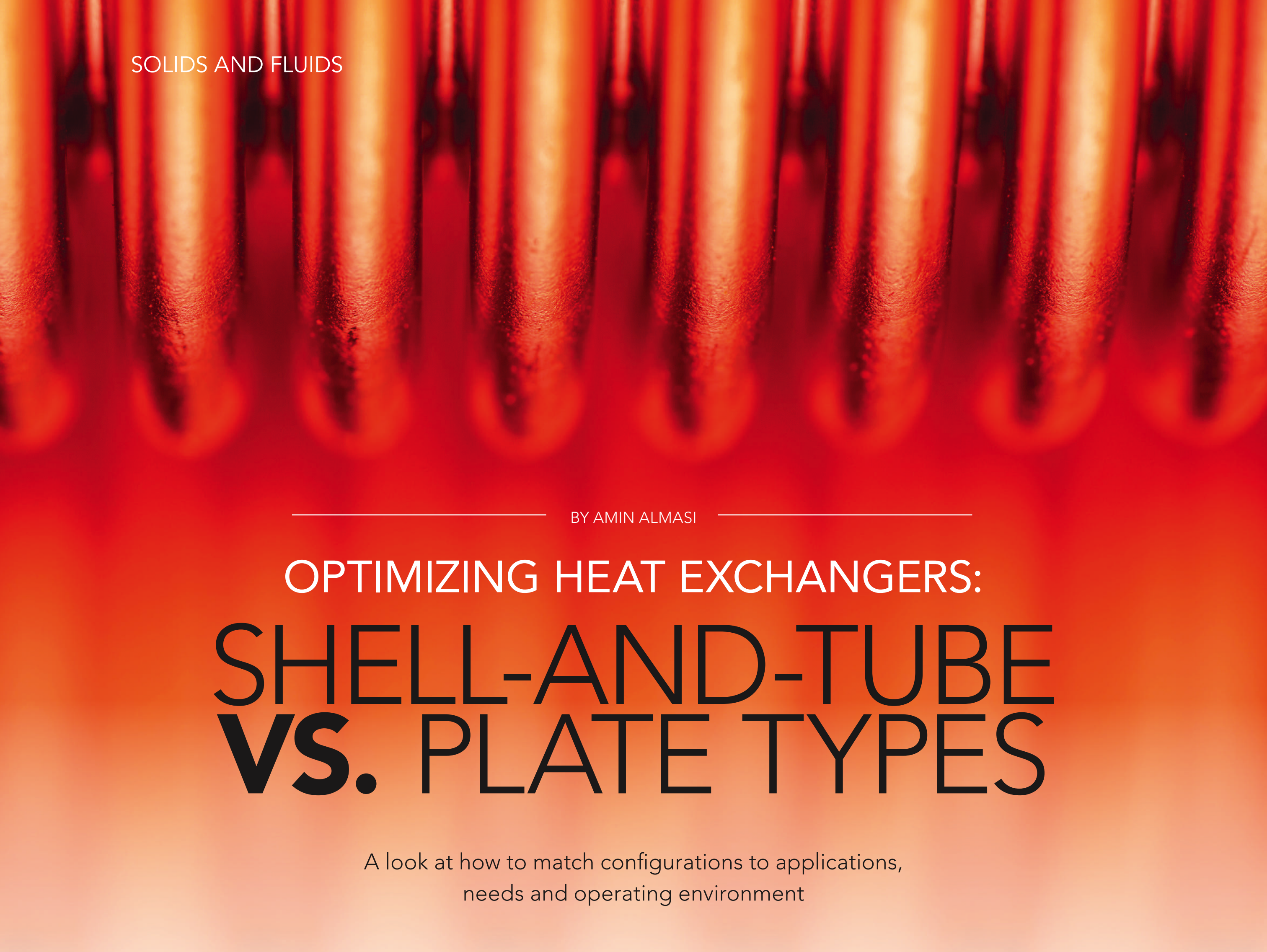
Even stranger, when an operator moved from one refinery to another — within the same company — he failed the training program at the second despite being fully qualified at the first. "Something's surely amiss in all of this," he says.

He wonders, would VR technology be used effectively in this situation or any other where the training departments don't fully understand their own challenges?

On the other hand, Strobhar notes that the ability of VR technologies to allow field operators to practice something they couldn't do on a live plant, such as starting up a compressor, would have benefits. Those gains could be even more significant if VR could mimic the sort of muscle memory involved in changing a particular piece of equipment, such as a pump.

However, he believes the best experience is always gained by being out in the plant.

"The point is not to spend extra money where you don't have to," he says. "If it's just walking around a unit, with full access to a facility, I can do the same thing without any snazzy VR technology."



BY AMIN ALMASI

OPTIMIZING HEAT EXCHANGERS: SHELL-AND-TUBE VS. PLATE TYPES

A look at how to match configurations to applications, needs and operating environment

HEAT-EXCHANGER SELECTION plays a critical role in the efficient operation of chemical processing plants. Shell-and-tube and plate-type designs have emerged as go-to options for process operations. But they come in many different configurations, models and sizes for various applications and services. Understanding the intricacies of each type of heat exchanger and their ideal uses can help chemical operations optimize thermal performance, improve productivity and enable more sustainable practices. Here's a closer look at the different selection alternatives and their suitable uses.

SHELL-AND-TUBE HEAT EXCHANGERS

This design provides a low-cost, reliable, effective and operational-friendly method of heat exchange. Shell-and-tube models (Figure 1) consist of numerous tubes encased in an outer shell or housing that may vary in diameter and flow path. The tubes come assembled together in a tube bundle. The unit transfers heat by distributing the heating or cooling medium through the shell, and heating or cooling the liquid through the tube, or in rare cases vice-versa. Many types of shell-and-tube heat exchangers are available, usually distinguished by the head and tube-sheet configurations. Common, widely used options include the U-tube removable bundle and straight-tube heat exchangers.

U-tube, removable bundle designs: The U-tube consists of straight-length tubes bent into a U-shape (Figure 2). Depending on the fluid outside the tubes, the bundle comes with tube supports or flow baffles along its length. The tube bundle assembly that fits inside the shell includes the tube-sheet, tubes, tube supports and flow baffles. For small heat exchangers, the shell can be a length of pipe that contains inlet and outlet connections and a flange at one end to insert the tube bundle. The other end of the shell comes with a cap or head. For large heat exchangers, the shell is a properly fabricated pressure vessel. This is to contain the fluid on the outside of the tube bundle. A head assembly is usually bolted to the shell flange to complete the heat exchanger. This contains the inlet and outlet connections for directing the fluid (usually liquid) into the tube bundle.

The head assembly contains one or more pass partitions. This also affects the tube-side heat transfer coefficient and pressure drop. The tube bundle should usually have tube supports along its length. When condensing vapor is a possibility, the provisions are needed for proper flow and drainage of condensate out of the shell. When a liquid circulates outside the tube bundle, flow baffles are necessary to support the tubes and direct flow across the bundle. In this case, the number and spacing of the flow baffles control the shell-side heat transfer performance and also its pressure drop. The nature of the U-tube construction allows for large temperature differences between the tube-side and shell-side fluids with the U-tubes expanding or contracting independently of the shell assembly. In addition, the tube bundle assembly is removable for easy and cost-effective replacement of the heat-transfer surface should a failure or leak develop in the bundle.

U-tube type heat exchangers have some limitations and disadvantages. First, because of the U-bends, the tube-side fluid/liquid always makes multiple passes down the length of the equipment. This may not be economical on close temperature approaches, and there might be high-pressure losses associated with it. The U-bend also prevents mechanical cleaning of the heat exchanger when the tube-side fluid/liquid is dirty or prone to scaling or fouling. U-bends may also be more susceptible to failures, cracks and problems, though these issues have been solved for many modern units.

Straight-tube shell-and-tube designs: This type of unit is a common choice for handling heavy fouling fluid/liquids or scaling applications (Figure 3). The straight tubes allow for the removal of the head assemblies and mechanical cleaning. This feature is especially important if the tube-side fluid/liquid is prone to heavy fouling or scaling. In addition to having the capability for multiple tube-side passes, the equipment can be constructed for a single tube-side pass of the fluid/liquid through the unit. This means that 100% counter-current flow can be achieved between the tube-side and shell-side fluids. The fixed tube-sheet construction, however, does limit the ability to handle large temperature differences between the fluids.

Figure 1. Shell-and-tube heat exchangers transfer heat by distributing the heating or cooling medium through the shell and heating or cooling the liquid through the tube, or in rare cases vice-versa.

Figure 2. U-tube heat-exchanger designs allow for large temperature differences between the tube-side and shell-side fluids with the U-tubes expanding or contracting independently of the shell assembly.

Because the tube bundle and the shell assembly are not independent in this type of heat exchanger, any differential thermal expansion or contraction between the two will result in stresses being transferred to the joint of the tube and tube-sheet. The produced thermal loads/stresses can be sufficient to cause a break in the mechanical bond and, consequently, a failure. While the expansion joint or similar provisions can be incorporated into the shell to absorb the stresses, this is an expensive alternative and not desired.

The expansion joints can be subject to fatigue of its own based on the thermal cyclic rate and operational parameters.

These have been special provisions with many requirements for maintenance and operation. They should only be used in special applications. As a rule of thumb, differences between the average fluid temperatures greater than about 35°C should be checked for excessive stresses. Even though the difference between average operating temperatures may not indicate a differential thermal movement problem, the heating up and cooling down from extreme operating/environmental temperatures may cause excess stresses at the tube-sheet interface. The bundle assembly is non-removable in most cases. There is no possibility for bundle removal in fixed tube-sheet equipment.

FIXED TUBE-SHEET HEAT EXCHANGERS

This is the most commonly used heat exchanger in ordinary and conventional services. It typically has the lowest capital cost per square meter of heat-transfer surface area. Fixed tube-sheet heat exchangers consist of a series of straight tubes sealed between flat, perforated metallic tube-sheets. The straight tubes usually are mechanically rolled into a header at each end of the shell. The headers are welded/integral to the shell and act as both a tube-sheet and mounting flange for each of the tube-side heads. As a result of its welded construction, the fixed tube-sheet heat exchanger can accommodate high pressures, say over 70 Bar(g). There is no gasket or packing joint inside the shell, eliminating potential leak points. This equipment type is suitable for higher-pressure or risky services. However, because the tube bundle is not removable, the shell side of the heat exchanger (outside of tubes) requires chemical cleaning. The inside surfaces of the individual tubes can be cleaned mechanically after the channel covers have been removed. The fixed tube-sheet heat exchanger is limited to applications where the shell-side fluid is non-fouling. Fouling fluid/liquid should be routed through the tubes.

FLOATING TUBE-SHEET AND FLOATING-HEAD HEAT EXCHANGERS

A floating tube-sheet type is a removable bundle with a stationary tube sheet at one end of the unit and a floating (pull-through) tube sheet at the opposite end. The floating tube sheet is independent of the shell and fits inside the shell and head assembly diameters. To contain the shell-side and tube-side fluids at the floating tube-sheet end, a gasket or packing is usually used.

The floating-head heat exchanger provides all the advantages of a straight-tube unit without the disadvantages of the fixed tube-sheet type. This equipment type is relatively expensive and rarely used in ordinary applications. The ability of the tube sheet to move or float within the shell and head means that the equipment can handle large temperature differences without creating excessive stresses.

HAIRPIN HEAT EXCHANGERS

A variation of the single-pass shell-and-tube heat exchanger is the hairpin-type heat exchanger (Figure 4). This type is single-pass shell-and-tube equipment that has been folded in half, giving it a hairpin appearance. What distinguishes it from the traditional shell-and-tube exchangers are the end closures, which allow for thermal movements without expansion joints and the removal of tubes. This type is often used in special services. Examples are when there are solids in the stream, high-pressure services for tubes or high flow-rate ratios exist between tube and shell fluids.

PLATE-TYPE HEAT EXCHANGERS

These units have emerged as an alternative to shell-and-tube heat exchangers for many applications (Figure 5). They can help optimize thermal performance by enabling a number of close-temperature approaches and cross applications that previously were not economical or practical with shell-and-tube heat exchangers. They are compact, lightweight, efficient and easy to maintain.

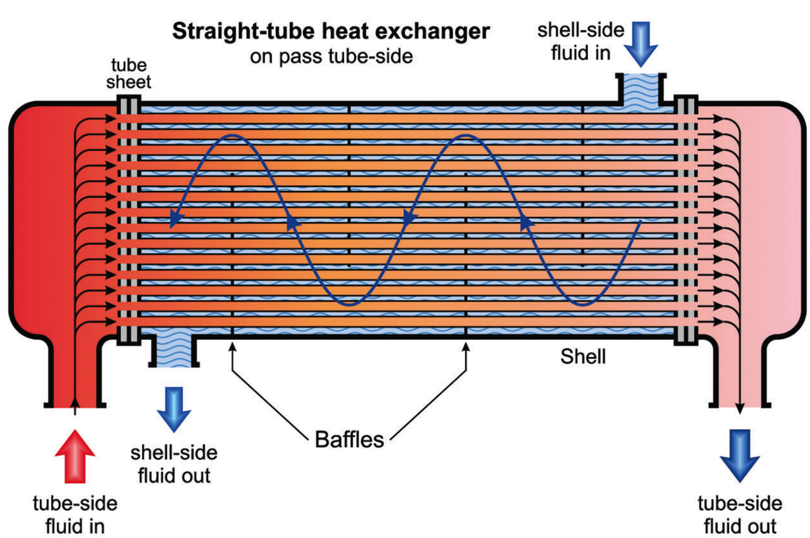


Figure 3. Straight-tube heat exchangers are commonly used for handling heavy fouling fluid/liquids or scaling applications. The straight tubes allow for the removal of the head assemblies and mechanical cleaning.

Figure 4. The hairpin heat exchanger includes end closures, which allow for thermal movements without expansion joints and the removal of tubes.

Figure 5. Plate-type heat exchangers help optimize thermal performance by enabling a number of close-temperature approaches and cross applications that previously were not economical or practical with shell-and-tube heat exchangers.

In its most basic form, a plate-type heat exchanger consists of corrugated plates compressed in a frame. They are available in many different models, types, configurations and constructions, including prime surface type and plate-and-frame designs, as examples. They come with either gasketed or welded construction.

PLATE-AND-FRAME HEAT EXCHANGERS

Fabricated from a series of channel plates that are pressed together to form a plate pack, these units come with holes at the corners of the plates to form a continuous passage or manifold. This subassembly distributes the heat-transfer media from the inlet of the heat exchanger into the plate pack for each of the fluids. The media then flow into the narrow channels formed by the plates. The gasket arrangement on each plate distributes the hot and cold media into alternating flow channels throughout the plate pack. Hot and cold media flow usually counter-current to each other.

The most common type of plate-and-frame heat exchangers are gasketed plate units.

Heat exchangers of this type include a series of channel plates that are mounted on a frame and clamped together. Each plate is made from pressable materials, such as stainless steel, and is formed with a series of corrugations. The most common pattern of corrugation is the herringbone or chevron pressed into each plate to produce highly turbulent fluid flows. The high degree of turbulence results in high heat transfer coefficients and keeps fouling to a minimum. In addition, the corrugations add rigidity to each channel plate. This allows the use of thinner plate material and improves heat transfer. Also included with each plate is an elastomer gasket. This gasket is used for sealing purposes and to distribute the fluids properly in the plate heat exchanger. Spaces between adjacent plates form flow channels for the hot and cold fluids.

Some of the benefits of a plate-and-frame heat exchanger include 100% counter-current flow, high turbulence and thin plate material, making it is a highly efficient device that typically yields heat transfer rates three to five times greater than conventional shell-and-tube heat exchangers. The design also is more compact than other heat exchangers.

However, high maintenance costs and operational difficulties have been reported for certain applications, requiring more frequent replacement of gaskets. In this case, chemical processing plants may opt for units that don't need gaskets, such as printed circuit heat exchangers.

By carefully considering the appropriate heat exchanger design for their operating environment, chemical processing plants can minimize costs and boost efficiencies throughout their operations. ●

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By Jeff DeWitt, Applications Engineer, Swagelok

Lower Maintenance Costs Through Modern Gas Panel Management

Modernizing gas distribution components in your system can help you move gas more efficiently and effectively

GAS PRESSURE control panels typically include a complex array of tubes and pipes that are often arranged in unintuitive ways. This presents a problem for maintenance technicians who often struggle to access the components for repair. They end up having to disassemble multiple threaded connections and put them back together – a costly, time-consuming task that can lead to extended downtime. Also, technicians may encounter unlabeled valves or regulators, which can make ordering replacement parts challenging.

Reliability is essential in these systems because the gases are necessary for plants and laboratories to perform their basic functions. That's why it's important to fix any system deficiencies and make maintenance activities easier to perform. This may involve reconfiguring flow paths in your existing gas panels and using bendable tubing to reduce potential leak points and enable easier access to components. It may also include technicians tagging each significant component so they can quickly order a replacement when problems arise. Alternatively, a facility may choose to swap out its older systems with more modern gas pressure control panels, which typically require less maintenance than their predecessors. By adding such panels to systems, the cost of maintenance may be reduced significantly and directly affect a facility's bottom line (Figure 1).

SIMPLIFYING MAINTENANCE THROUGH OPTIMIZED DESIGN

In the past, gas panel designs have often located service-needy components in hard-to-reach enclosures or placed them behind pipes and tubes that must be taken apart to reach them. In such instances, maintenance technicians may struggle to understand how the gas panels work, which can interfere with their ability to provide appropriate maintenance. It can also increase the amount of time technicians must spend on panel maintenance that could be devoted to other areas in the plant.

Additionally, gas supplies must be curtailed to the location where service is being done, which leads to unplanned – and often unnecessary – downtime. Stopping production and testing to perform maintenance on gas panels is costly and can hurt facilities' profitability.

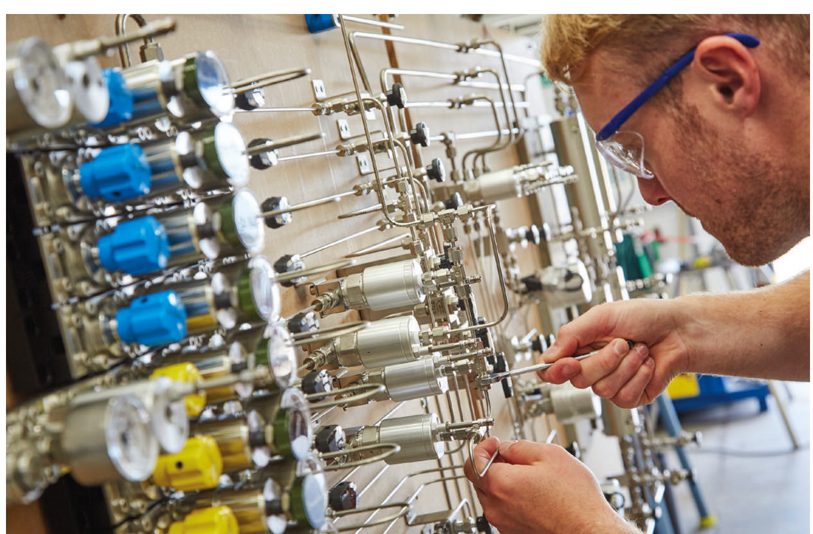

Figure 1. Newer gas pressure control panels are often designed in ways that are more intuitive for maintenance technicians, decreasing the time, labor, and costs associated with keeping them in working order compared to legacy systems. *Images © 2023 Swagelok Company*

Figure 2. Adding modern gas pressure control panels to existing gas distribution systems allows maintenance technicians to more easily access components that need to be repaired or replaced.

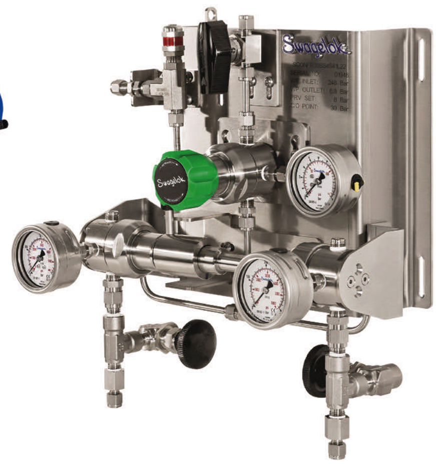

Figure 3. Newer gas panels are frequently designed in modules, allowing technicians to repair and replace parts of the panel without taking the entire system offline.

In contrast, modern gas panels are designed with maintenance in mind (Figure 2). Frequently serviced components like regulators and pressure valves are easily visible to technicians and appropriately labeled so no guesswork is involved. Modern gas panels are built modularly, which means technicians can work on specific components of the panel without taking it out of service (Figure 3).

While a simple plug-and-play replacement with a new gas panel may be the most efficient fix for a hard-to-service legacy panel, facilities also have the option to reconfigure their existing panels to make maintenance easier. As an example, technicians may reroute tubing or use flexible hoses to enable easier access to other components. Such actions may be a more cost-effective approach when various panel components are still in good working condition with a long service life anticipated ahead. For example, if you've recently replaced a regulator in an older panel, you may prefer to make other adjustments to make the panel easier to operate, rather than take that regulator out of service just to replace it with a different one housed in a preassembled gas panel.

REDUCING LEAKS THROUGH PROPER TUBE FITTINGS

Traditional threaded connections can be difficult to maintain and reassemble, which is why most facilities use tube fittings instead. They are sturdier and more effective at reducing small, imperceptible leaks that could cost facilities money and safety if not stopped promptly.

For example, a common gas like nitrogen that is used to perform many functions in laboratories, refineries and other facilities may not pose an immediate threat to employees. Over time, however, the leak could prove to be costly. Now multiply one leak by the number of tubes that carry the gas around the facility, and you will understand how expensive it is to pay for gas that escapes the system through poor tubing connections. Gases that cost more money than nitrogen illustrate how critical it is to find and correct such leaks.

Searching for small leaks across an entire system cannot always be a priority at a facility because chemical or processing plants are complicated ecosystems with many competing priorities. Some priorities may supplant leaks on any given day. To prevent as many leaks as possible, facility operators should purchase high-quality tube fittings to provide reliable, leak-tight performance over the life of the system.

CHOOSING THE RIGHT COMPONENTS IS VITAL

If your gas panels and distribution systems are constructed of high-quality individual components, maintenance-related labor costs may be reduced – and your system could run at peak performance.

Regulators are a prime example of a component that can have an outsized effect on how well your system functions. Tradition says these components should be replaced every five years with a well-designed system. Most maintenance technicians would not question this conventional wisdom because changing regulators every five years feels like the right amount of time necessary to prevent performance issues. Not all regulators are created equal, however. For the best results, consider using regulators that have been subjected to millions of testing cycles and have the potential to last as long as the gas distribution system will be operating. Using such high-quality parts could functionally eliminate the associated downtime and labor inherent in component replacement, as you may be able to simply swap out the entire gas panel with a new one and be back online in no time. That means fewer interruptions, less downtime, and an understanding that your gas distribution system will operate at peak performance and safety for years to come.

JEFF DEWITT is an applications engineer for Swagelok. He can be reached at jeff.dewitt@swagelok.com.

Master the Art of Early Ordering

Balance factors to reduce time from concept to execution

Early purchasing is usually done when time is critical.

EARLY PURCHASING is done when time is critical. Experienced engineers are required to balance factors and make quick decisions to reduce time from concept to execution.

When it comes to project management, change creates both challenges and opportunities. Market opportunities come and go, political changes drive regulatory changes and technology creates new opportunities. All projects require some commitment of capital and future operating costs. Reducing the time between having a concept and getting a project into the field and making money reduces the uncertainty of future changes making a project unprofitable.

Recent increases in interest rates have also increased capital sensitivity. The shorter a period between capital commitment and earnings return reduces financing charges.

Both these factors continue to maintain pressure on the long-term drive to reduce project execution times. Regretfully, equipment delivery times have not improved over the last several years. If anything, complex, major equipment has longer lead times than ever. One area this is especially true for is major machinery such as compressors.

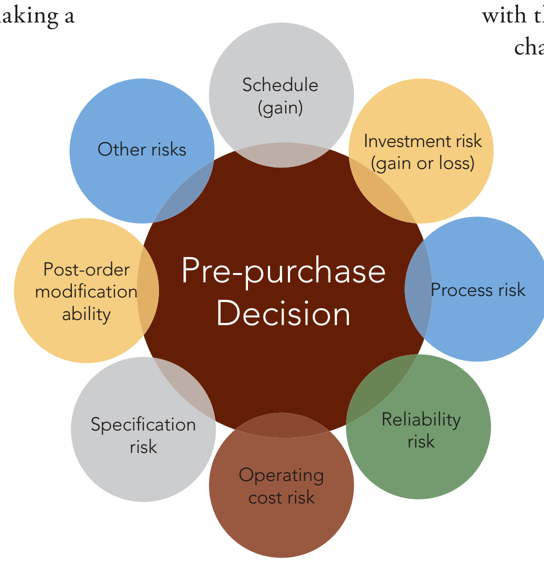

Figure 1. When deciding to order early, evaluate all aspects of pre-purchasing to get a better sense of the costs and risks involved.

EARLY ORDER RISKS

Of course, one response is to pre-order long-lead equipment early. Early ordering has the benefit of reducing project execution time, but it does have some potential costs. How the costs balance is critical in deciding if to early order. The benefit-balance for early ordering changes with the situation. Figure 1 illustrates the balance behind the decision for a recent case of an early order of three screw compressors. The specific points included one with a clear benefit, one with an unclear cost-benefit balance and six areas that had possible costs. All had to have some evaluation to understand if early-ordering was attractive.

The clear benefit area of early ordering was many months of schedule savings. In fact, after the early order the compressors were no longer on the critical path for project execution.

The unclear area was in investment risk. Ordering now commits capital earlier. This may bring finance charges and make capital unavailable for other investments. Additionally, the project may be canceled after the order. This risk can be reduced by careful negotiation of explicit cancelation charges with the supplier. Prices can also change. Ordering now may mean that future price drops if the equipment market softens cannot be captured. However, ordering now can lock in supply and avoid future price increases. Overall, investment risk for the compressor order was judged to be a minor factor and could be in either direction. It had no significant affect on the early-order decision in this case.

The other five explicit but inter-related areas analyzed were post-order modification ability, specification risk, process risk, reliability risk and operating cost risk. Finally, other miscellaneous factors were lumped together under other risk.

Post-order modification risk included potential costs of having to modify the order if some critical change had to be made. This risk of modifications can be reduced by increasing the flexibility of the purchased compressor. But increased flexibility nearly always incurs both capital and operating costs. The overall balance for this case was that some flexibility would be added up to about 5% increase in compressor capital cost plus 1-2% increase in operating cost. This was judged as being clearly worth the expense given the amount of schedule gain.

Process risk was the ability of the compressors to meet required process conditions even if the final feed composition was changed. Since screw compressors are positive displacement machines, molecular weight changes to the feed had only a minor impact. The largest risk was that a higher molecular weight would lead to increased power demand and exceed the motor capacity. As a result, extra motor power was added. The cost of this change was included in the flexibility cost analysis mentioned previously.

Specification risk applied to the decision to not require the compressor API (American Petroleum Institute) standards. An off-the shelf, vendor-standard compressor was purchased instead. This decision reduced cost and made delivery faster. The potential cost was reduced reliability. However, with three parallel machines in service, the plant would still be able to run. Increased maintenance costs and some loss of future capacity might result, but the increased production from a sooner startup more than compensated for this decision.

Other risks combined multiple factors, but none were significant enough to influence the decision either for or against pre-purchasing.

FINAL THOUGHTS

Early purchasing is usually done when time is critical. The final decision to pre-purchase was overwhelmingly justified by many months of reduced delivery time and a much sooner unit startup. As discussed, short-cut evaluations that mix qualitative and quantitative criteria are often used. Experienced engineers with a breadth of experience are required to balance the factors and make the quick decision needed. ●

ANDREW SLOLEY,
Troubleshooting Columnist

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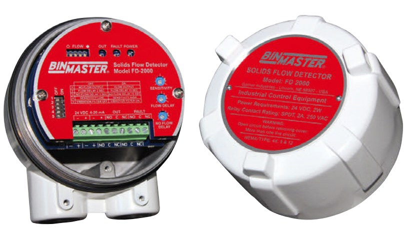

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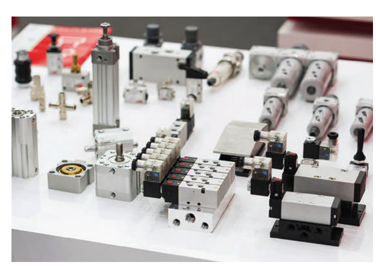

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U.S. Chemical Weapons Stockpile Nears End

The multiyear project to destroy chemical agents will conclude by Sept. 30

Once operations are complete, the pilot plants will be decontaminated and dismantled.

AFTER EIGHT years and more than 780,000 projectiles, the U.S. Army Pueblo Chemical Depot has destroyed the final munition in its chemical weapons stockpile.

Since starting operations in March 2015, the Colorado-based depot has processed more than 2,613 tons of chemical weapons in its chemical agent-destruction pilot plant (PCAPP). These include 155-mm and 105-mm projectiles and 4.2-in. mortar rounds containing a mustard agent.

The projectiles and a portion of the mortar rounds were destroyed in the main plant under the supervision of trained operators using automated technology beginning in September 2016.

The mustard agent was neutralized; its byproduct, a hydrolysate, was broken down into salt, water and organics using a biotreatment process.

Projectiles deemed unsuitable for automated processing, plus the remaining mortar rounds, were destroyed in static detonation chambers (SDCs).

Earlier, 951 problematic projectiles were demolished using an explosive destruction system.

Engineers from Bechtel Defense and Space in Reston, Virginia, led the effort. The United States is now nearing its commitment to destroy all chemical weapons by Sept. 30.

The Blue Grass Army Depot, based in Richmond, Kentucky, is destroying the remainder of the original 30,000-ton stockpile. Also led by Bechtel, operations are expected to finish shortly.

As of June 2023, the Blue Grass chemical agent-destruction pilot plant (BGCAPP) had destroyed more than 496 tons of the depot's remaining 523 tons of munitions.

These include the GB and VX chemical weapon delivery systems. After draining the agent, the warheads were placed in containers and stored in igloos at the depot. They will be destroyed in an SDC unit later. Rocket motors will be shipped to Anniston, Alabama, where they will be destroyed in an SDC facility.

Once operations are complete at the Kentucky site, both the PCAPP and BGCAPP will be decontaminated and dismantled.

Meanwhile, in May, the Organization for the Prohibition of Chemical Weapons (OPCW), based in the Hague, the Netherlands, inaugurated its new €34-million (US$37-million) Centre for Chemistry and Technology (CCT).

The plan is to consolidate some of the organization's existing laboratories onto one site and add new monitoring and training programs.

The new center's warehouse contains analytical equipment ready to be dispatched around the world.

The OPCW investigates alleged chemical weapons attacks and sends inspectors to chemical facilities in member countries, often at short notice, to search for evidence of the production of banned chemicals.

"The centre will allow the OPCW to enhance the [lab] verification regime through maintaining and developing our knowledge, skills and expertise related to chemical weapons," said OPCW director-general Fernando Arias at its opening.

The new facilities are part of a network of 25 OPCW-designated labs. The remit of the CCT includes putting these labs through a periodic certification process to renew participation in the network. The CCT also trains chemists from labs that want to match its standards and join the list.

To provide knowledge to as many nations as possible, the OPCW is working on certifying labs in African countries for the first time: current trainees include scientists from Algeria, Morocco, Kenya, Nigeria and South Africa.

Although most countries (except Egypt, Israel, North Korea and South Sudan) have officially renounced the use of chemical weapons under the Chemical Weapons Convention (CWC) international treaty, such chemicals continue to be used illegally.

The OPCW believes it has played a central part in response to crises. For example, its investigators found that nerve gas and chlorine were used in the Syrian civil war. In 2018, an OPCW team investigated the attempted assassination of a Russian dissident in the U.K. that involved a nerve agent called Novichok.

Former Russian military officer Sergei Skripal, his daughter Yulia and police officer Nick Bailey survived after being hospitalized in critical condition following the attack.

However, there was no response to a *Chemical Processing* query about exactly what the OPCW's new monitoring and training programs will involve, what type of analytical and other equipment is contained in the crates at the CCT, or if the organization itself is involved in work to develop new detection and disposal methods for chemical weapons.

SEÁN OTTEWELL, Editor at Large

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