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IMPROVE TREATMENT OF SEAWATER FOR COOLING

AUGUST 2020

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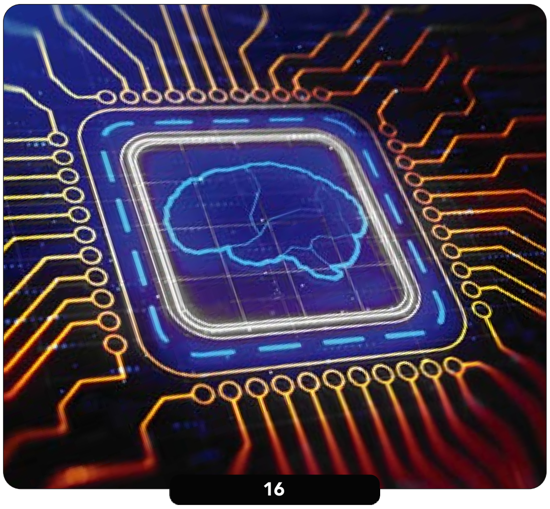
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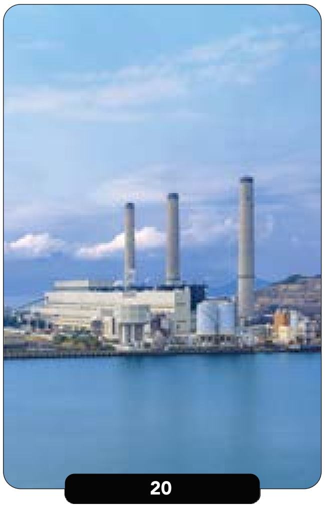
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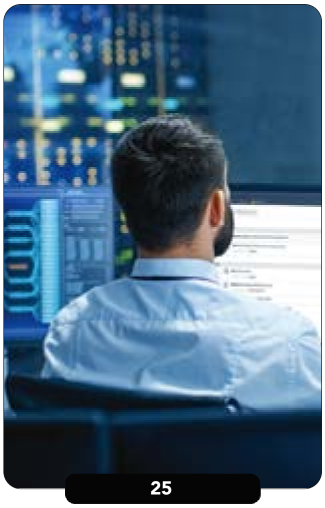
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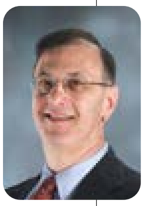
Keep Cool about Cooling Water

Enhance your knowledge about this essential utility



Many engineers lack a good backgrounding.

THE HEIGHT of the summer always provides a telling test to plants about the health of their cooling water systems. Unfortunately, lots of sites likely will struggle to maintain acceptable performance. Too often, cooling water systems don't get adequate attention. One contributing factor is that chemical engineers rarely learn much about such systems beyond how to calculate heat transfer between the water and the heat transfer fluid or process stream.

We at *Chemical Processing* have recognized this deficiency for some time and have striven to provide useful information about the selection, operation and care of cooling water systems.

For instance, most engineers probably find the choice of cooling tower fill somewhat mysterious because they lack background on fill types and their most appropriate application. So, fairly recently we ran a cover story "Understand the Importance of Correct Cooling Tower Fill," http://bit.ly/2R5svzI, that describes the different varieties of fill and underscores the key role that the fouling tendencies of the water plays in selection.

Many plants on coasts rely on seawater for cooling. So, this issue's article "Improve Treatment of Seawater for Cooling," p. 20, offers guidance on how to minimize makeup and optimize seawater treatment programs. It discusses best practices such as precise control of chemical treatment dosage and digital monitoring of heat exchanger performance. An earlier article, "Consider Open-Rack Seawater Heat Exchangers," https://bit.ly/2OlyooP, explores design and mechanical issues of such units.

Plants that use fresh water for cooling face water treatment challenges, too — as covered in several recent articles: "Improve Your Cooling Tower Treatment," http://bit.ly/2Z3k0Et, looks at environmental friendly options that may offer better corrosion and fouling protection; "Plants Benefit from Better Cooling Tower Treatment," https://bit.ly/3frCw2p, highlights the results at two plants that adopted new chemistry; "Conquer Cooling Water Treatment Challenges," http://bit.ly/2Pq7oDt, discusses how advances in technology can help forestall corrosion, scaling and fouling; and "Don't Foul Up Your Water Treatment Program," http://bit.ly/2IQvp6Y, warns that requests for proposals often contain inadequate details.

Ambient conditions impact the performance of cooling water systems. Their design accounts to some extent for this. In addition, many plants turn off cooling tower fans and cooling water pumps during the winter. However, capitalizing on the cold weather may provide a greater opportunity to save energy as "'Tis the Season to Save Energy," https://bit.ly/32hG9E9, illustrates.

We've also covered a variety of maintenance issues: "Is Your Cooling Tower a Dust Filter," http://bit.ly/2ON2ymt, delves into issues that accumulation of dust from the air can cause; "Enter a Cooling Tower with Caution," http://bit.ly/2EbSLTb, provides tips for safely carrying out an inspection; and "Keep Your Cool in Hot Weather," http://bit.ly/2yuRbW8, stresses the need to address any issues with tower fill before summer arrives.

In addition, check out the article "Water Conservation Efforts Pay Off," http://bit.ly/2M4nnot, which details the success of one company's multifaced worldwide initiative.

The summer is not the time to find that your cooling system gets you into hot water. ●

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Webinars Round Out New Normal

You can tap expertise on myriad topics via virtual events

Webinars are the perfect platform for SMEs to deliver their messages.

"NOBODY TOLD me there'd be days like these. Strange days, indeed." John Lennon didn't have a global pandemic in mind when he wrote those words but they ring true with what's been happening this year. The new normal has caused workplaces to adapt.

According to our annual salary survey "Salary and Satisfaction Survive the Pandemic" (https://bit.ly/39iASOq), about two-thirds of survey respondents are doing their jobs differently. For example, 40% said they are currently working remotely full time; 25% split their days between on-site and remote work.

Since the pandemic, attendance at our live webinars has increased — presumably because people have more time to fit these free, hour-long events into their schedules. And with most trade shows and in-person events cancelled for the rest of the year, webinars are the perfect platform for subject-matter experts (SMEs) to deliver their messages.

We have plenty of topics and experts on hand to help you achieve success. Here is what is on deck for the remainder of the year. You can learn more and register for one or more of these at https://bit.ly/2OJDuuY. If you can't make the live session, once registered, you can view the webinar later on demand.

Non-Invasive Ultrasonic Meters Take on a New Challenge *Sept. 1.*

This presentation will highlight general uses but will mainly focus on new applications in the chemical industry. These include mass flow and concentration metering (replacing Coriolis), and contamination detection, steam measurement using transit time (temperature limited), and steam measurement using cross correlation (no practical temperature limit). SME: Frank Flow, regional sales manager, Flexim Americas Corporation.

Process Safety: Lessons from Other Industries *Oct. 1.*

Poor culture can result in incidents. Sometimes changes occur after incidents. In this webinar, we will explore cases in different sectors, including theme parks and the finance industry, to see what learnings parallel with process safety. SME: Trish Kerin, director, IChemE Safety Centre, Institution of Chemical Engineers.

Pick the Proper Heat Exchanger to Optimize Process Performance *Oct. 13*

The correct choice and use of heat exchangers can support reliable operations and reduce equipment failure and downtime. If properly designed, installed and maintained, a heat exchanger can be the most trouble-free piece of equipment in the system. To assist with choosing the right type of heat exchanger, we will review the different types, including shell and tube, plate and air cooled, and their advantages and disadvantages. SME: Mike Kissel, global product manager, Standard Xchange, a Xylem Brand.

Powder & Solids Series: Testing for Effective Control of Particulate Air Pollution *Oct. 21.*

What tests should you perform on bulk solid material when designing an air filtration system? This webinar will describe the needed material tests and how the results affect sizing, and performance and selection of baghouses, cartridge filter units, and cyclones. The Kansas State University - Bulk Solids Innovation Center will issue a certificate of completion for 1 professional development hour. SME: Todd Smith, business and strategy manager, Kansas State University, Bulk Solids Innovation Center.

Combustible Dust Roundtable *Nov. 5.*

Industry leaders in hazard identification, evaluation and control of combustible dust hazards will join us for an exclusive roundtable discussion. Our panelists will answer tough questions to increase awareness of the hazards and the available safeguards of fires and explosions within combustible solids processing and handling industries. SME: Guy Colonna, senior director, NFPA (National Fire Protection Association).

Leveraging OHS for Process Safety *Dec. 3.*

Organizations usually have more occupational health and safety (OHS) personnel than process safety personnel. How can we take advantage of the great work done in OHS to improve process safety? Leveraging the systems, tools and people enables the potential to enhance process safety more quickly than trying to create new systems. This webinar will explore areas where similarities exist and how they can be used. SME: Trish Kerin, director, IChemE Safety Centre, Institution of Chemical Engineers

In addition to all these upcoming events, you can access our on-demand webinar library. It covers topics including preventing human error, how to avoid common mistakes in vacuum system upgrades, real-time machinery diagnostics and creating a process-safety culture. Access all of these and register for the upcoming webinars at https://bit.ly/2OJDuuY. ●

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Properly Hand Off a Project

Take some steps to enhance its prospects for success

ENGINEERING PROJECTS usually migrate from the original designers to others. In my 40-year career, I've seen success and failure in projects I've handed off. The outcome usually depended upon whether the person taking on the project properly understood and adhered to the original design.

In all the successes, the original designer — me — was available for course correction if an issue arose. We then made changes that remained true to the original design.

In contrast, the failures invariably stemmed from straying too far from the original design — while not seeking or ignoring my advice. This is important. If a project engineer, in striving to save money, does something stupid, like putting the only shutoff valve for the plant boiler twenty feet in the air without access in the middle of the plant, somebody should be there to head off such a mistake. (I've provided some practical pointers in "Keep Plant Layout from Laying You Low," https://bit.ly/31Qf8aR, and "Prevent Post-Project Pitfalls," https://bit.ly/3iGtale.)

This underscores why early involvement in projects by production is so crucial. However, production engineers are experts in their product, not the process that makes it. Thus, it's equally essential to involve the original designer to explain the importance of design choices. For instance, in one project, to save money, globe valves were replaced with cheap ball valves, which didn't permit adequate control.

As for the boiler shutoff valve, I was the one who had to close and open this valve while crawling on two hot 4-in. pipes without a safety line. "Hey, I don't get hazard pay," the welder grinned.

Big capital projects consist of a bunch of small ones. Unfortunately, staff meetings are far removed from the smell of burnt welding rod and rarely delve adequately into details. Anyone familiar with refineries knows that the engineers who did the preliminary design usually aren't the same ones who build and commission the process. That might explain why one project placed a new flare stack so close to an employee parking lot that paint started peeling off cars! Maybe a short phone call could have prevented this?

Another way to heighten attention to detail is a concept called early contractor involvement, which gets such firms involved at the design concept or schematic phase (see: "Involve Contractors Early," https://bit.ly/3fdgwrS).

There's another issue with missing the subtleties of a design: no one budgets or plans — nor can they — for the additional burden to commissioning. We ask commissioning engineers to work 24/7. Now, we're expecting them to fix problems created late in the design process. Something's got to break. I remember a quote once that $1 spent in early design is worth $100 during commissioning; this probably is an underestimate.

A large part of the problem with keeping true to the original design is that engineers often are lousy communicators. I really wish colleges would require a tough technical communication class: reading, writing, presenting, listening, interpersonal skills and leadership. I've tortured several newly minted engineers, drilling into them the importance of writing and presenting. In the U.S. Air Force, all officers take a course using a book called "The Tongue and Quill" — you can't very well lead if you don't hone your communication skills. A few of my victims actually thanked me.

Pay attention to how you leave a project to posterity.

Pay attention to how you leave a project to posterity. Start with engineering reports on every facet of the design. Include: annotated site plans, equipment general arrangements, and elevations (in pdf or jpg format or both); marked-up photos (jpg) and photo sets for more details; "final design" construction piping and instrumentation diagrams (which should get updated to "as-built" versions), instrument specifications and even layout drawings. If you don't know computer-aided design (CAD), learn it! You can store photos in text documents, spreadsheets and even on CAD drawings. Do everything you can to ease access to data. Review your work with operations and maintenance staff. If they don't have time to review the text, prepare bullet points for a hallway ambush. File everything and, if the company allows, take a copy with you — so, if necessary, you can review a project with them over the phone. If you've signed a confidentiality agreement, remember it remains in force after you leave.

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Higher-Selectivity Gas Separation Beckons

Approach combining big data with machine learning predicts the best-performing polymers

A NOVEL computational method enables rapid design and development of an advanced filtration system for reducing greenhouse gas emissions, say its developers. The team, comprised of scientists from Columbia University, New York City, and the University of South Carolina (USC), Columbia, South Carolina, combined big data and machine learning (ML) to identify gas-filtering polymer membranes with markedly better selectivity for carbon dioxide. The approach has broader applicability, they believe

"Our work points to a new way of materials design and we expect it to revolutionize the field," enthuses Sanat Kumar, professor of chemical engineering at Columbia.

Kumar and his collaborators created a ML algorithm to investigate what structure would make the best membrane to separate CO_2 from other gases. The algorithm correlates the chemical structure of the 1,000 currently tested polymers with their gas transport properties. The team then applied the algorithm to more than 10,000 known polymers to predict which would produce the best material in this context (Figure 1).

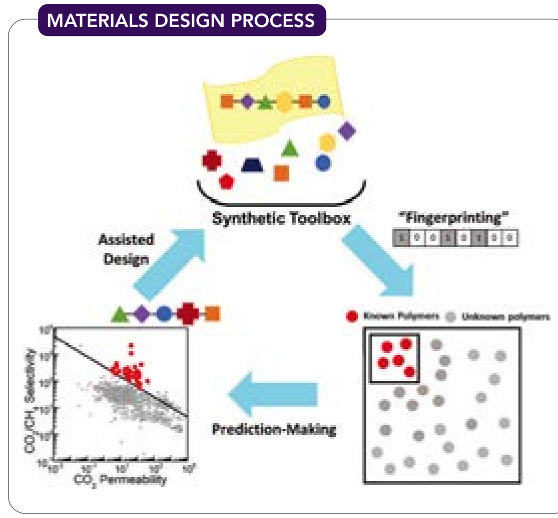

Figure 1. Starting with knowledge of the structure of the polymer building blocks, the team developed a machine learning algorithm that finds the best material for a given application. *Source: Columbia University.*

The resulting 100 polymers had never been tested for gas transport but were predicted to surpass current membrane performance limits for CO_2/CH_4 separations. *Science Advances* contains more detail.

Next, to test the algorithm's accuracy, Brian Benicewicz's group at USC, synthesized two of the most promising polymer membranes and found they exceeded the upper bound for CO_2/CH_4 separation performance, exhibiting selectivities around 7 and 5.5 times better.

"This means if you contact a membrane with CO_2/CH_4, and let us say the selectivity is 10, …CO_2 will go through in 10 times the volume as CH_4. So, if you started with a 50/50 mixture then your outlet composition would be 90/10 CO_2/CH_4. Let us say our selectivity is 5 times — namely, it is 50. In that case, the outlet would be 98/2 CO_2/CH_4, which means you do a better job of getting the CO_2 out of the feed stream in that you lose less CH_4," elaborates Kumar.

The researchers say the method is easily extendable to other membrane materials. Thus, their next step is to generalize their approach to other material properties. "That is simply an exercise of inputting more data. Going beyond that is a question of inverse design. Namely, if you want a polymer (material) with a desired property, can we tell them which polymer to try? For the moment this is simply the opposite of what we currently do now — that is, if you give me the structure of the material, I can give you properties. In inverse design, you give me properties and I will find you some target materials that satisfy these goals," says Kumar.

The methodology has significant potential for commercial use. "If we better purify streams, say, coming out of gas-fired power plants or of fracked gases, then this technology has implications in power plants, fracking of gases, CO_2 sequestration, etc.," believes Kumar.

The team also intends to explore membranes for water purification or other applications, but has not yet started this work.

"ML is a very powerful tool for design. It allows you to find new materials for a purpose, but at the current stage it does not help with understanding. Namely, it can find you better materials for a particular application. However, it will not tell you why this material is better," adds Kumar.

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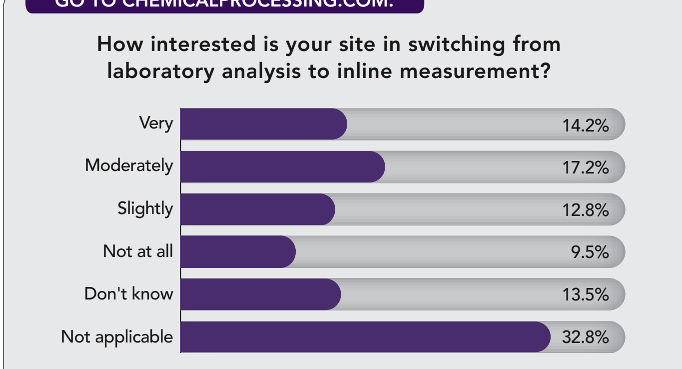


Far more respondents indicated moderate or greater interest than slight or no interest.

Recycling Bolsters Bioplastic Economics

POLYLACTIC ACID (PLA), a bioplastic made from starch and other polysaccharides found in sustainable raw materials, is enjoying growing demand. It boasts similar properties to polystyrene and polyethylene terephthalate, and is replacing those polymers in disposable cups, packaging materials and toys. However, producing PLA is relatively costly. Now, though, a process developed by researchers at the University of Birmingham, Birmingham, U.K., and the University of Bath, Bath, U.K., promises to improve PLA economics.

Their process — for the catalyzed methanolysis of end-of-life PLA products using an ethylenediamine Zn (II) complex — yields methyl lactate, a low toxicity, biodegradable solvent that can be used in products as diverse as cosmetics and pharmaceuticals. The new chemical recycling process would allow production of new PLA or other valuable chemicals from the methyl lactate — resulting in a circular economy.

The researchers tested three different PLA samples: a cup, a toy and a 3D-printed material (Figure 2), at three temperatures: 70°C, 90°C and 110°C. With all three samples, they could obtain high selectivities and yields (>94%) of the green solvent despite the different additives, such as colorants, in the items.

The next step in the development is scaling up from the 300-ml laboratory-based work to pilot trials, says lead researcher Joe Wood, a professor in the school of chemical engineering at the University of Birmingham.

"A goal of scale up would be to create a mobile processing unit that could be transported on a van and deal with a couple of tonnes per day of waste, collected at sites such as recycling centers. Ultimately, a bioplastics refinery would deal with mixed wastes to produce multiple products on a large scale," he adds.

The catalyst also will get further attention. While the team is happy with both its selectivity and yield, the catalyst does contain zinc. "Although this is less toxic than other metals, one goal would be to use a metal-free organocatalyst instead," explains Wood.

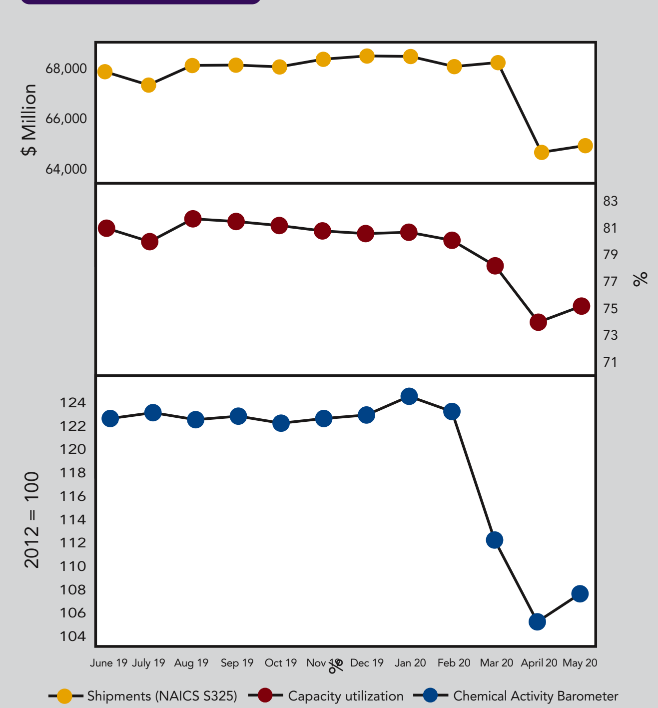
In addition, while the catalyst didn't seem too sensitive to the presence of unknown additives and uncontrolled particle size with the three items that were recycled, the researchers need to carry out further characterizations of such factors to determine their detailed effect on the catalyst, he notes.

PLA RECYCLING

Figure 2. New catalyzed methanolysis process can turn 3D printer waste into methyl lactate. *Source: University of Birmingham School of Chemical Engineering.*

Since publication of an article in a recent issue of *Industrial & Engineering Chemistry Research*, the work has attracted interest from several companies and discussions about future efforts are ongoing, concludes Wood.

ECONOMIC SNAPSHOT



All three metrics increased. *Source: American Chemistry Council.*

Speak the Language of Energy Efficiency

A simple equation can help determine the maximum efficiency of an ideal heat engine

We never see "ideality" in industrial applications.

MATHEMATICS IS an incredibly efficient language. With just a single, short sentence, it can say what takes several volumes in English. One such "sentence" is the equation for Carnot efficiency (η):

$$\eta = 1\text{-}T_c/T_h$$

where T_c and T_h represent sprecific cold and hot temperatures. With just five letters (admittedly, two of them are subscripts, and one is Greek), one number, and two mathematical symbols, this equation unlocks one of the greatest secrets of thermodynamics. The equation is a quantitative expression of the second law of thermodynamics; I hinted at it in a recent column (see, May 2020 issue, "Double Up on Cogeneration," https://bit.ly/3fcqABC). But what does it mean, and how does it apply to energy-efficient design and energy management?

The Carnot cycle, first proposed by French military engineer Said Carnot in 1824, was the first successful theoretical model of an "ideal" heat engine. Our equation expresses the maximum efficiency of this ideal heat engine. For every unit of heat flow that enters the heat engine, η is the maximum number of units of mechanical power that can be produced.

A heat engine is any device that converts heat to mechanical power. The ones we encounter most often are internal combustion engines, steam turbines and gas turbines. In a recent column ("Take a Closer Look at Cascaded Efficiency," March 2020, https://bit.ly/2R0yYd5), I compared the "cascade efficiencies" of electric- and gasoline-engine cars. Heat engines dominate both cascades. Steam turbines and gas turbines produce the electric power to charge electric cars, and internal combustion engines power gasoline-fueled vehicles. Because the same limiting efficiency equation applies to all heat engines, there isn't as big a difference as might be expected between the overall efficiencies of these different types of cars. The situation changes somewhat when alternative methods are used to generate the electricity — but that is a different subject.

The beauty of the equation is its remarkable simplicity. η depends on just two things — T_h, which is the inlet (hot) temperature and T_c, which is the exhaust (cold) temperature. Both are expressed as absolute temperatures, in either the Kelvin or Rankine scale, and assumed constant. The equation applies equally to heat engines that use a gas, liquid or mixed working fluid. It is also striking that pressure does not appear explicitly in the equation — although, as we shall see, pressure does vary along with temperature in practical heat engines.

The equation assumes all of the conditions are "ideal" — no friction, no heat loss, no fluctuations in conditions. We never see "ideality" in industrial applications. Rather, η represents the theoretical maximum efficiency; it defines an upper limit. Real efficiencies are always lower. Much of the research and development work in energy efficiency focuses on minimizing non-idealities in equipment designs, thus bringing design efficiencies closer to η. The resulting improvements include, for example, reducing frictional pressure drops in gas and steam turbines.

The equation also tells us that the Carnot efficiency increases as the ratio T_c/T_h decreases, which means high inlet temperatures and low exhaust temperatures are desirable. This fact has driven a multi-year trend in gas turbine designs towards higher inlet temperatures, which increase T_h, and also towards larger pressure ratios, which lead to lower exhaust temperatures, T_c. Similar considerations also apply in the design of chemical plants that use steam turbines. For example, there is a focus on minimizing heat losses from steam piping by better insulation, and decreasing pressure drop — such as, by reducing the number of bends, fittings and valves. This ensures the highest possible temperature T_h (subject to design limits) entering the steam turbines, and greatest pressure differential across the steam turbine, which maximizes power generation and lowers the exhaust temperature T_c. Where condensing steam turbines are used, a strong incentive exists to optimize the design of the condenser and the vacuum system to ensure the lowest possible exhaust pressure, which leads to a low exhaust temperature, T_c. Turning to operation and maintenance, fixing leaks in vacuum systems, together with cleaning fouled condensers, can sometimes improve steam turbine efficiencies by 5% or more.

All of this flows from a simple equation with just five letters, one number, and two mathematical symbols — and we have only scratched the surface. ●

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EPA Axes Temporary Enforcement Lull

On Aug. 31, policy designed to ease compliance requirements during the pandemic will end

THE U.S. Environmental Protection Agency (EPA) issued in March a temporary enforcement policy relaxing certain compliance obligations because of the COVID-19 pandemic. On June 29, the agency announced an "addendum on termination" that aims to end the policy on August 31, 2020. This column discusses the termination memorandum.

BACKGROUND

On March 26, the EPA announced its temporary policy regarding enforcement of environmental legal obligations during the pandemic. The EPA states that its temporary enforcement discretion policy applies to civil violations during the outbreak. The policy addresses categories of noncompliance differently. For example, according to the EPA, it "does not expect to seek penalties for noncompliance with routine monitoring and reporting obligations that are the result of the COVID-19 pandemic but does expect operators of public water systems to continue to ensure the safety of our drinking water supplies." To be eligible for enforcement discretion, facilities must document decisions made to prevent or mitigate noncompliance and demonstrate how the pandemic caused the noncompliance.

The policy does not apply to imports. The agency, according to the policy, is "especially concerned about pesticide products entering the United States, or produced, manufactured, distributed in the United States, that claim to address COVID-19 impacts." The EPA "expects to focus on ensuring compliance with requirements applicable to these products to ensure protection of public health."

TERMINATION ADDENDUM

According to the addendum, "EPA will not base any exercise of enforcement discretion on this temporary policy for any noncompliance that occurs after August 31, 2020." The date "reflects the appropriate balancing of the relevant factors; it recognizes that the circumstances surrounding the temporary policy are changing, but also ensures that there is adequate time to adjust to the changing circumstances." The memorandum urges entities to make every effort to comply with their environmental compliance obligations; the temporary enforcement policy "applies only to situations where compliance is not reasonably practicable as a result of COVID-19. These situations should become fewer and fewer." The addendum provides that the EPA may terminate the temporary enforcement policy on a state or national basis, in whole or in part, at any earlier time. If the EPA does terminate the policy before August 31, 2020, it will provide notification at least seven days prior.

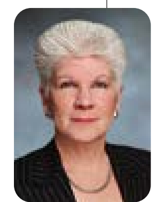
The memorandum notes as states and businesses re-open, a period of adjustment is expected as regulated entities plan how to comply with environmental legal obligations and with public health guidance from the Centers for Disease Control and Prevention and other agencies regarding actions intended to stem the transmission and spread of COVID-19. The memorandum states, "it is now appropriate to expressly include a provision in the temporary policy that covers termination of the temporary policy, and to make such changes to the policy as are needed to reflect the impact of the changing circumstances on facility operations, worker shortages, and other constraints caused by the public health emergency."

DISCUSSION

The EPA's "termination memorandum" was expected. The policy was widely misinterpreted as an end-run around enforcement and EPA detractors used it as a basis to criticize the agency. Whether the agency is anxious to end the policy as a result of the criticism or believes the policy has outlived its utility is unclear.

The new concern is the "termination" may be premature and thus possibly overly optimistic. As COVID-19 cases are surging in a growing number of states, some might argue the need for the relief offered under the enforcement discretion memorandum is every bit as crucial now as when it was issued. It is unclear what likely is expected to be different by the end of August. Should the amount of cases not materially change, presumably the EPA would revisit the end date and reactivate the policy. We can only hope there will be no need to do so.

The EPA has updated its frequently asked questions about the temporary enforcement policy (https://bit.ly/2BlLi3e) to include helpful questions that readers may find useful. ●



The new concern is whether the "termination" is premature and overly optimistic.

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Clamp-On Flow Meters Ideal For Troubleshooting, Diagnostics, Leak Detection

FRANK FLOW
Chemical Industry Manager, FLEXIM Americas Corp.

I would consider using a non-invasive, clamp-on flow meter before anything invasive.

FLOW MEASUREMENT is a critical aspect of chemical processing. The effectiveness of operations depends upon accurate flow measurement data, as does maintaining compliance with regulations. Clamp-on ultrasonic flow meters can handle all types of corrosive liquids as well as gases, and are insensitive to changes in temperature, viscosity, density and pressure.

To learn more about clamp-on ultrasonic flow meters, Chemical Processing queried Frank Flow, chemical industry manager at FLEXIM Americas Corp. FLEXIM is an Edgewood, New York-based provider of non-invasive, ultrasonic flow meters.

Q. *What are the advantages of ultrasonic technology for flow meters?*

A. There are a lot. I would start by stating transit time ultrasonic technology's biggest advantage is the range or scalability of the measurement. While extremely accurate and sensitive even in low-flow scenarios, they are still able to measure high velocities. The technology is capable of catching low-velocity flows likes leaks or unseated check valves, but can also measure very high velocities you might only see on gas measurements. This massive "turn-down ratio" is unique to ultrasonic flow measurement and makes it exceedingly versatile.

Ultrasound gives you more information about the process than just flow velocity. You've also got the potential for an analytical measurement by measuring the sound speed of the medium along with diagnostics that provide health of the measurement or can provide a clue about other things going on inside your process.

When ultrasound is employed externally via non-invasive clamp-on meters, you have all the advantages above plus intendance of pressure and temperature variation and aggressive media. Plus, you don't have to cut the pipe, providing safety, cost, and speed of installation advantages.

Regarding safety, FLEXIM is the only supplier of clamp-on ultrasonic systems for liquids and gases with SIL certification worldwide.

Q. *What are the limitations of this technology?*

A. The sound wave; it's a mechanical wave. Something that absorbs or interferes with the wave is where you have limitations. Typically, where you'll find something like this could be in two-phase flow. Both liquids in a gas or a certain amount of gas entrainment in liquid can absorb that signal.

In measuring velocity, you need a good representative profile; and profile disturbances will influence the accuracy of these systems -- you have to take that into account.

Ultrasound is not a silver bullet technology but it can be applied to nearly any flow-measurement need that's out there.

Q. *Is it beneficial to use multiple clamp-on meters?*

A. That depends on the nature of the application. A single channel or a single set of transducers often work in a reflect path. So, you've got two beams in there providing cross-axial flow averaging. But if you've got poor inflow conditions or a larger pipe or something more critical, then you can add a second set of sensors to the measurement to get better averaging of the profile.

With more critical applications like check meters on gas transmission lines or applications with high value fluids, you could deploy up to four sets of sensors. Now you have eight beams through there. All still centerline to centerline with our technology, but you've now got a better representative profile of what's going through there.

Q. *When should you consider a clamp-on ultrasonic flowmeter for permanent installation?*

A. If you can measure externally and provide a better range, a higher degree of accuracy, highly repeatable value, robust measurement, and can easily calibrate, then I would consider using a non-invasive measurement before I would consider anything else.

Clamp-on meters can make measurements better than prevailing or past technology with a higher degree of repeatability and with a higher degree of predictive diagnostics that allow you to address potential issues before the measurement stops.

The technology is different from what most people have used in the past. You have to understand where it works and where it doesn't. But where it does work, it makes a lot of sense. The obvious case is on larger lines. Larger lines with other technology cost more as the size goes up. Whereas, a clamp-on meter's price increase basically stops at a certain point. You get to a dual-channel flow meter and the price is capped there. It doesn't matter if it's on an 8-inch line or a 96-inch line, it's the same price.

Other obvious applications include aggressive media that destroy or foul invasive technology. A good spot for clamp-on flow meters are regulated meters that require calibration and traceability because the transducers are easily removed and reinstalled vs. other technology that requires a system shutdown and/or calibration lab to certify the device.

Q. *How do you determine the best location?*

A. You have to consider inflow conditions and even outflow conditions. Is it coming off of an elbow or a T or out of a valve or some funky piping arrangement? These are concerns that need to be addressed.

A new and innovative FLEXIM feature is a programable disturbance correction in the meter. You program the metering point distance from an elbow, and the meter corrects the profile based on laboratory studies. Considerations still need to be made for the type of disturbance, but this feature allows users to achieve better measurement certainty when profile induced error would have otherwise corrupted the calculated volume.

For chemical processes, repeatability is king. Not necessarily accuracy, but it's being able to repeatably report the same value while seeing the same flow rate. And in those cases, we might elect to move the meter toward the source of the disturbance because you get a repeatable value, which ultimately helps control the process.

Q. *Are there any issues with outside influences?*

A. No, because most of the gear can be designed for environmental influence. We have resistance temperature detectors (RTDs) in each one of our sensors to account for differences in temperature. Let's say you have a system out on a pipe and it's a sunny day. One transducer is in the sun and the other one's in the shadow. There's a significant temperature difference between those two transducers. And, since you're using a soundwave the temperature influences the speed of sound in the transducer block. This impacts the refraction of the wave as it travels from the transducer to the pipe and through the media. This slight change in the angle of the soundwave will be registered as flow if not corrected. If you don't know the temperature, the meter has to assume the shift is flow related and starts to drift. FLEXIM is the only one that actually corrects for temperature effects in each transducer. This is the ASME MFC 5M standard for clamp-on meters as they are technically a refractive system as the wave form is passing through solid pipe into the fluid at non-right angle.

CLAMP-ON ULTRASONIC FLOW METER

The FLUXUS F721 features a state-of-the-art hardware design and its powerful digital signal processing surpasses any other non-intrusive ultrasonic flowmeter in terms of accuracy, reliability and versatility.

Q. *What about maintenance?*

A. There is little to no maintenance. We recommend calibration every five years for a meter where a traceability procedure is required. Transducers can be removed and calibrated back at the factory lab, or validated in the field by another certified device. As far as the device lifetime, there should be no reason these things can't last 50 years. As long as they're not abused or destroyed by something, it should be longer than that.

Q. *What troubleshooting or other temporary duties does the clamp-flow meter suit?*

A. If you think about it, only a clamp-on ultrasonic meter can be a portable device. And we have such a portable solution as well, which is nice when you just need to do a flow survey for pumps or some upsets going on in your process. It helps you get a better understanding of what might actually be going on in the process. From that standpoint, the portable device can be a great asset for temporary use, flow surveys, or the validation of other meters.

At FLEXIM, our aim is to offer you the most suitable and highest quality measuring system for your measuring task and to be a reliable partner at all times, providing you with the best possible support and service. ●

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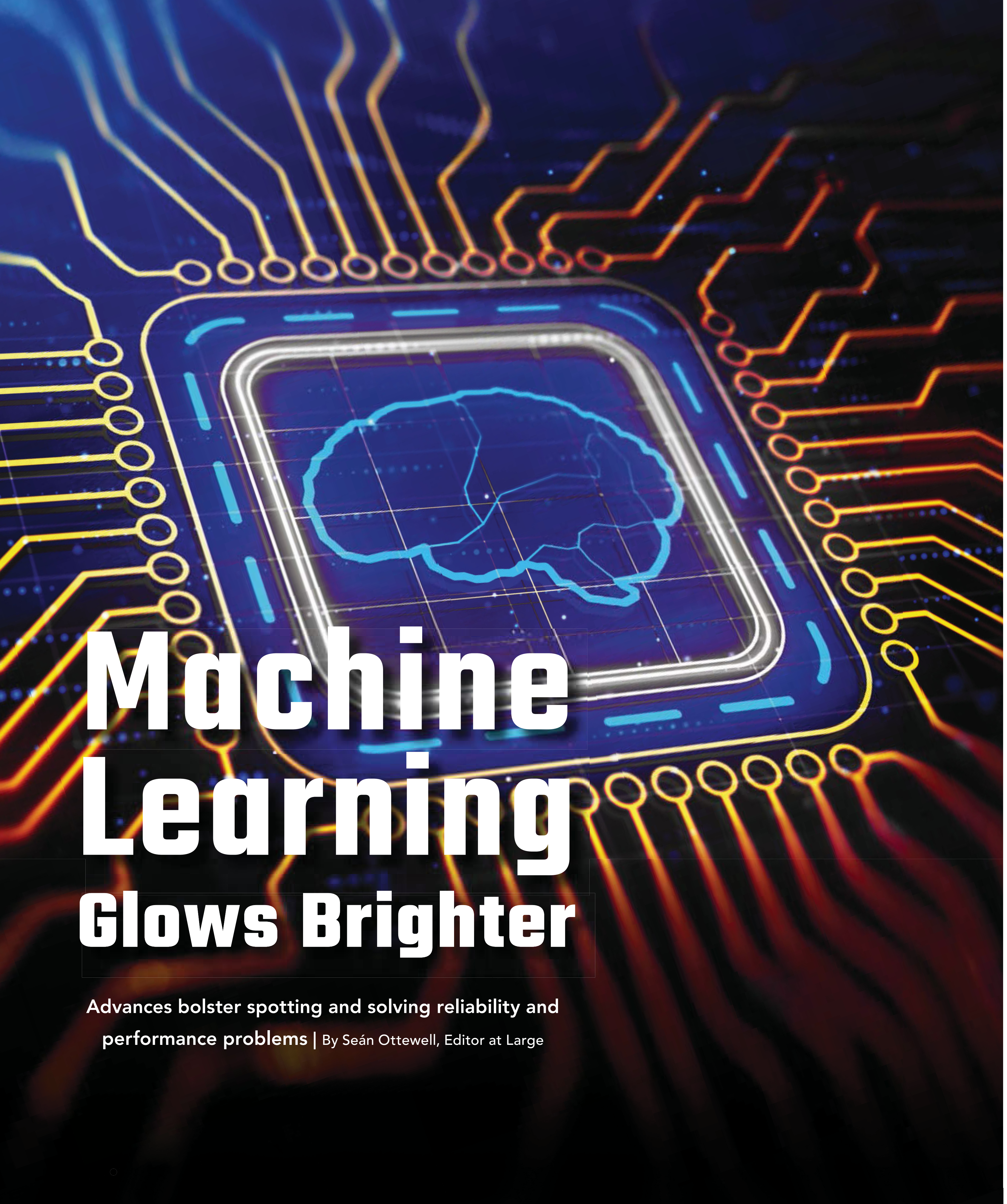

Machine Learning Glows Brighter

Advances bolster spotting and solving reliability and performance problems | By Seán Ottewell, Editor at Large

MACHINE LEARNING, the backbone and main enabler of artificial intelligence (AI) systems, is giving the chemical industry ever greater insights into its operations and maintenance — as the experiences of Nouryon, AVEVA and AspenTech show.

As part of its strategy to pioneer new technologies, Nouryon Industrial Chemicals, Amersfoot, the Netherlands, has signed a framework agreement with Semiotic Labs, Leiden, the Netherlands, to use that firm's SAM4 self-learning technology to help predict when to maintain and replace pumps and other rotating equipment. SAM4 relies on voltage and current waveform analysis.

AkzoNobel Specialty Chemicals, the predecessor to Nouryon, started working with Semiotic Labs in 2018 after Semiotic was a winner in that year's Imagine Chemistry Challenge ("Imagine Chemistry Challenge Awards Support to Startups," http://bit.ly/2P2Qnms), a contest the chemical maker ran specifically for startups involved in areas of interest to it.

The new deal follows a successful 6–7-mo. pilot implementation of the technology at Nouryon's chlorine plant at Ibbenbüren, Germany; that pilot focused on 20 pieces of rotating equipment. Nouryon now is rolling out SAM4 at its seven other chemical sites in northwestern Europe. The company expects to monitor 30% of the rotating equipment at these plants by the end of next year. A further rollout may take place depending on the results.

"We selected Semiotic Labs technology for a number of reasons: first, the sensor isn't placed on the rotating equipment itself but in an electrical cabinet and can be accessed remotely [Figure 1]; second, it's easy to install; and, thirdly, I had a good experience with the company previously, when they showed what they could do for the rail infrastructure reliability in the Netherlands. The bottom line is that we need to have knowledge about our assets," says Marco Waas, director R&D and technology for Nouryon Industrial Chemicals.

During the Ibbenbüren pilot, SAM4 identified three potentially very important issues.

One involved the motor driving a huge conveyor belt transporting salt. Once the initial problem was corrected, SAM4 pinpointed yet another problem: salt deposits falling off the conveyor were increasing friction in the pump, too. "So not only the pump, but also the conveying process itself was an issue," Waas explains.

The company also found it had installed an inappropriate pump in one location. The unit was oversized, consuming more energy and likely suffering a shorter operating life than a correctly sized pump.

In the third case, SAM4 revealed that a pump was operating at a point near to where cavitation could occur. "We are monitoring this very closely and deciding which type of pump is best to replace it with," adds Waas.

One benefit Waas didn't anticipate beforehand is a roughly 15% reduction in pump energy use; the company currently is working to better understand the reasons for this.

"Of course, the more data you have, the better the predictive ability of the sensors to identify important fingerprints in the data. So, we are pooling our data with two other companies who are using the technology on their rotating equipment: Vopak [Rotterdam] and Schiphol Airport [Amsterdam]. The three of us share data to improve our ability to detect potential problems," he notes.

Tank storage company Vopak trialled the technology on business-critical pumps at its sites in Vlaardingen, the Netherlands, and Singapore last year. It now has signed an agreement with Semiotic Labs to scale up SAM4 deployment to additional terminals while expanding its use at the original pilot sites.

Nouryon Industrial Chemicals also is testing two other predictive maintenance technologies: small inert pipeline sensors known as Pipers (a 2019 Imagine Chemistry winner — see: "Imagine Chemistry: Two Startups Win Novel Contest," http://bit.ly/2rPCwp2) from Ingu Solutions, Calgary, Alberta, Canada, that freely float down a line and collect valuable data about pipeline integrity; and a climbing robot from Invert Robotics, Eindhoven, the Netherlands, which was a 2018 winner.

"We have tested Pipers in a 24-km salt pipeline in Denmark to measure all kinds of parameters, including temperature, pressure and the condition of pipewalls. They are very useful because most of

EASY INSTALLATION

Figure 1. Sensor mounts in electrical cabinet rather than on rotating equipment. *Source: Nouryon Industrial Chemicals.*

our pipes are underground, so knowing exactly where a problem is developing makes maintenance much easier," stresses Waas.

Because the 8-kg robot climbs, it can handle duties such as inspecting storage tanks. "Before, you would have to scaffold throughout a tank and use maintenance staff in situations that can be very hazardous. Now, we only need to scaffold to any areas that the robot identifies as having problems, for example cracks," says Waas. The use of machine learning technology coupled with more data from the new diagnostic tools will make it easier and faster to identify and deal with potential problems, he adds.

SIGNIFICANT SAVINGS

A patented predictive algorithm at the heart of the machine learning technology of AVEVA, Cambridge, U.K., plays an integral part of a larger AI strategy aimed at anomaly detection, predictive forecasts, prescriptive guidance and more.

"The company's predictive analytics system has detected many hundreds of millions of dollars in avoided costs across its global customer base — including several individual 'catches' that have been in the tens of millions of dollars each," notes James H. Chappell, global head of AI and advanced analytics, Houston.

A case in point is a Covestro plant that in July 2018 suffered major corrosion damage due to hydrogen chloride formation caused by water leaking from the water side of a steam generator to the process side. This resulted in significant damage to critical equipment and led to a 20-day outage.

AVEVA's predictive analytics team carried out a study on a year of historical data using the company's Prism software. This found spikes occuring ten days prior to the event.

"AVEVA's analysis, which took less than two hours, showed that the predictive model would have caught the issue one full month prior to the actual incident. This was a catastrophic failure of the motor and the integrally geared compressor was a highly valued asset to the overall process," he says.

Covestro has fully implemented Prism at the plant and has purchased licenses for seven more facilities.

Another example is from an industrial gas manufacturer that, prior to a scheduled maintenance outage at a plant, identified a vibration sensor anomaly. Technicians found a cracked impeller in a turbocompressor. This early catch prevented reactive maintenance and unplanned downtime, saving over $500,000.

"Compressors are an excellent candidate for machine learning to provide early detection of issues, and customers have leveraged our technology on hundreds of these types of equipment," stresses Chappell.

The company now can generate high-dynamic-range predictive models that can provide a wider range of detection, have increased sensitivity for earlier detection, and can work with grassroots plants or units coming out of major maintenance where data are scarce. They should help users optimize operations and get key guidance for cost-versus-risk decisions.

Over time, Chappell foresees machine learning evolving to handle larger datasets both faster and with fewer false positives. AVEVA already has developed a capability for "grey box" modeling, i.e., combining first principles simulation and AI.

"There are many situations in the chemical industry where first principles algorithms aren't accurate enough to properly model certain assets and processes, or it becomes too time consuming — and costly — to adequately tune the algorithms," he explains.

AI technology such as advanced neural networks can simulate those assets or processes better through data-driven learning. AI determines output values for integrating into the overall simulation model. "This provides significant cost saves and reduced deployment time. For the chemical industry in particular, this is especially valuable," notes Chappell.

The ultimate goal is to have machines make recommendations and humans do the final interpretation based on the information available. To this end, AVEVA currently is infusing AI into software across all areas of its business.

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INTEGRATED VIEW

Figure 2. Looking at equipment reliability and overall process performance separately blunts benefits achievable. *Source: AspenTech.*

BROADER FOCUS

"What's changing is that the technology is now much more accessible and engineers find it much easier to apply. You do still see little pockets where they see the technology and decide to try it only in one or two very specific situations. However, one-off solutions are not enough. You have to look at plants, whole facilities, other sites, etc. You need this technology across the business," emphasizes Paige Marie Morse, chemical industry director, AspenTech, Bedford, Mass.

In any project, AspenTech typically looks first at two specific issues: equipment reliability, so it can get some warning before any failures occur to avoid safety/health/environmental impacts; and overall process performance. Hence, many of the company's tools, including automated machine-learning condition-monitoring Mtell and multivariate analysis tool ProMV focus on these two areas.

"However, you must remember that these two issues are interwoven and that you can't look at them in isolation [Figure 2]," Morse cautions.

The key is to analyze historical data from when a plant was operating well and then look for deviations when it isn't.

Different sectors of the industry pose disparate challenges, too. For example, batch processors often use the same assets to manufacture a variety of products — some perhaps in high demand and others less so. Most profitable operation depends on maximizing output of high demand products. "We can use simulation here to help these companies get creative with their assets," she says.

Another imperative is achieving process consistency, either between runs or across multiple lines.

As an example, she cites a batch chemicals manufacturer with three identical process lines running next to each other. The first one always manufactured the same product while the slate of the other two varied. In ten years of operation, the company noticed that, for a few days every year, at a random time, one of the lines not dedicated to the specific product would go off-specification. Analyzing the data with ProMV showed this only happened when one of the other lines made a particular product. The analysis determined the link between the lines that generated quality issues, which then was resolved.

"Digital technology that uses machine learning provides insight on operating anomalies that can create problems with equipment. Mtell uses machine learning to analyze production and equipment data, and learn from previous performance to predict a future breakdown and suggest an alternative solution," Morse adds.

In another case, this time for commodity chemicals, a European petrochemicals producer used Mtell to develop a data-driven approach to maintenance planning. The new plan enabled the company to eliminate two days of shutdown per year on each piece of equipment, saving $1.8 million/y in downtime costs.

Another issue — running assets safely at less-than-optimum throughput — is one that AspenTech increasingly faces: "This is hugely important in the case of separation towers, for example, where the trays are designed to work best at 90% capacity. If you dial back to 80%, there's no way they will be as efficient because you get leakage through the trays," she notes.

"At the same time, sensor technology is getting deeper and cheaper. So, there's even more data now but our algorithms are getting more efficient at detecting which of this data is garbage. You have to clean up the data so that you are left with the real data sets. We are getting much better at this by working closely with customers to define outlying data and so building AspenTech experience with chemical and refining processes," Morse stresses.

The company also is improving its AI capabilities with the 2019 strategic acquisitions of Sabisu, Redcar, U.K., and Mnubo, Montreal. Sabisu's flexible enterprise visualization and workflow technology has been rolled into Aspen Enterprise Insights. Mnubo can assemble and deploy AI-driven Industrial Internet of Things applications quickly at enterprise scale and will help AspenTech's vision for the next generation of asset optimization technologies that combine deep process expertise with AI and machine learning.

Improve Treatment of Seawater for Cooling

New strategies overcome common problems and save money

By Robin Wright, SUEZ Water Technologies & Solutions

MANY CHEMICAL plants across the globe use seawater as a cooling medium. Depending on specific plant cooling requirements, these systems can demand several thousand gallons of fresh seawater makeup per minute. The high volumes of makeup water used represent a significant expense on two fronts: the energy to pump the water and the chemicals to treat it. So, optimizing both seawater demand and chemical treatment strategy is critical.

However, plants that rely on seawater for cooling have struggled to do this. For years, conventional seawater cooling programs have used outdated chemistry guidelines that were adapted from freshwater cooling systems or oilfield brines. These adaptations can be imprecise and have led to an unending battle against a range of negative outcomes: high chemical costs, reduced heat transfer efficiency, unscheduled plant shutdowns, lost production, steep maintenance expenses for electrochlorinator units, and excessive water pumping.

Fortunately, new approaches that use digital monitoring and computerized saturation models to optimize cooling programs have emerged. For instance, SUEZ Water Technologies & Solutions' new OptiSea chemical treatment program combined with its proprietary MonitAll digital monitoring device have enabled several advances on this front.

Here, we'll look at common problems that arise from the use of faulty models in plants relying on seawater for cooling, and how new digital strategies are overcoming these difficulties.

MINIMIZING SEAWATER MAKEUP

Seawater cooling systems at chemical plants typically use a cooling tower to provide some level of water reuse. As a secondary benefit, they are designed to minimize thermal discharge that could damage coral reefs.

Devising an operating strategy for seawater cooling systems isn't a simple task. Seawater chemistry varies significantly across the globe. This means different systems may require disparate types or dosages of treatment chemicals, and the maximum amount of water reuse will differ from plant to plant. A treatment strategy also must consider other plant-specific operating conditions, including operating temperatures, water flow velocities and environmental discharge limitations.

The calculation of makeup demand is an essential baseline inquiry that underpins many other decisions. The demand depends upon the amount of water reuse, which is measured by a dimensionless number called "cycles of concentration," *C*.

$$C = \text{makeup flowrate/blowdown flowrate} \quad (1)$$

It also can be expressed in terms of the salt concentration of the makeup and recirculating water (blowdown) streams. For practical purposes, conductivity measurements often are used:

$$C = \text{blowdown conductivity/makeup conductivity} \quad (2)$$

To safely minimize makeup water demand and pumping costs, you must know the upper operating limit of *C* to avoid scale formation in heat exchangers. Then, you must operate the cooling tower system accordingly to ensure you are maintaining the tower water chemistry in a safe range.

If the plant is operating at constant heat load, as *C* increases, the flow rates of both makeup and blowdown decrease. Therefore, operating at higher *C* means reuse of more water. However, as seen in Equation 2, operating at higher *C* also increases the salt content of the water. If *C* is raised too high, some dissolved salts (primarily calcium salts) can precipitate out of solution to form scale on heat transfer surfaces throughout the plant, reducing heat transfer efficiency. For these reasons, it's desirable to design the chemical treatment program and operating conditions such that *C* is as high as possible without risking scale buildup in the heat exchangers.

In the past, due to treatment chemical limitations, seawater cooling treatment programs only could operate at a *C* between about 1.2 and 1.7. Recent advances now allow some systems to operate at a *C* of 3.1. This reduces makeup water demand by nearly 50% and cuts pumping costs proportionally as well.

PROPERLY MODELING SATURATION

Once operating parameters for the cooling tower are established, attention can turn to chemical treatment programs. Until recently, such programs for seawater cooling systems relied heavily on the use of saturation "indices" to predict scaling tendencies for calcium carbonate ($CaCO_3$) and calcium sulfate ($CaSO_4$), the two most common deposits found in seawater-cooled heat exchangers. These models attempted to predict chemical treatment rates and safe operating concentration ratios for seawater cooling systems using open recirculating cooling towers.

Unfortunately, traditional equilibrium models don't work effectively in seawater cooling systems due to the high ionic strength of these waters. Using an inaccurate model to develop a treatment strategy leads to predicted chemical treatment or cooling tower blowdown rates that are either too high or too low. This could result in high water usage, excessive treatment cost or a loss of heat transfer efficiency in the plant.

Calcium carbonate is by far the most common scale encountered in seawater cooling systems. To define safe operating conditions, some water treatment consultants still employ commonly used saturation indices such as the Langelier Saturation Index (LSI) or the Stiff-Davis Stability Index (SDSI) to predict calcium carbonate solubility. However, these indices aren't designed for seawater and don't consider the complex interaction of ions. The LSI was developed for fresh potable water systems and the SDSI was designed to predict calcium carbonate scaling potential in oilfield brines. They don't perform well in seawater and, so, neither should serve as a basis for designing a chemical treatment strategy for seawater cooling systems.

That has led some consultants to either develop their own equilibrium modeling tools or use commercially available software to predict calcium carbonate solubility. These models rely on an activity coefficient, a factor used to account for deviations from ideal behavior in mixtures of chemical substances. For aqueous solutions, several available equations predict activity coefficients as a function of ionic strength.

Unfortunately, published activity coefficient curves were developed for ionic strength solutions typically <0.1

LIMITED OPERATING WINDOW

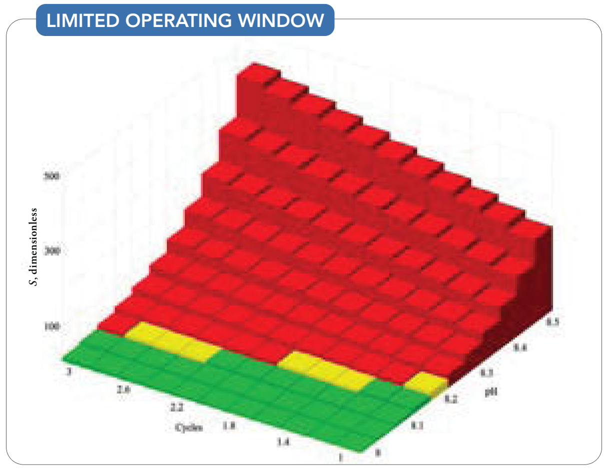

Figure 1. Calcium carbonate solubility curve at 120°F points out risk of precipitation when pH is 8.2 or greater even at low cycles of concentration.

TREATMENT'S IMPACT

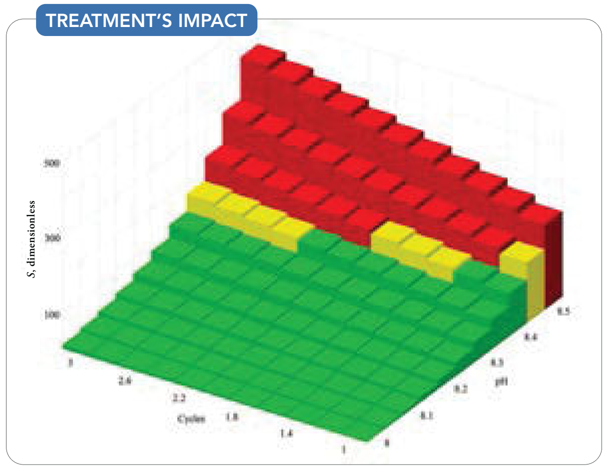

Figure 2. A proprietary treatment for 120°F seawater dramatically expands safe operating conditions to allow operation at higher cycles of concentration and pH.

and, at most, <0.5 (molal). Cycled-up seawater has an ionic strength >1. These activity coefficient curves don't work well for seawater and can provide misleading results if used to design a treatment program for a seawater cooling system. Also, these models don't accurately predict the pH and alkalinity relationship in seawater or "cycled" concentrated seawater. Knowing this relationship is crucial to performing accurate calcium carbonate solubility calculations.

To overcome the problems with published equilibrium models, a proprietary software package was developed. This software incorporates accurate activity coefficient and pH calculations. It also accounts for the effect that anti-scalants and treatment chemicals exert on calcium carbonate formation and utilizes empirical data to support the model.

Figures 1 and 2 illustrate the output of the proprietary saturation modeling software. Figure 1 shows the solubility of calcium carbonate at 120°F in Caribbean seawater with no chemical treatment applied. The data indicate that without treatment, calcium carbonate will form. The red bars point out that calcium carbonate will be a problem even without cycling if the pH is over about 8.1. Because natural seawater has a pH of roughly 8.1–8.4, using untreated seawater in cooling systems wouldn't be advised.

Figure 2 shows that a proprietary anti-scalant product allows safe operation of this system at a *C* of up to 3 if the pH remains below 8.4.

These graphs not only visually represent the safe operating window for these particular chemical treatment programs — but also shed light on the remarkable room for improvement at many seawater cooling facilities.

ADOPTING BEST PRACTICES

The primary function of chemical treatments used in seawater cooling systems is to inhibit mineral scale formation on heat transfer surfaces. Some treatment programs also incorporate chemicals designed to disperse suspended solids, which minimizes potential for heat exchangers to become fouled with inorganic debris (i.e., mud, sand and silt). Mineral scales and foulants provide an insulating layer on heat exchanger surfaces and reduce the heat transfer efficiency. The goal of the chemical treatment program is to maintain clean heat exchangers, free of scale and foulants, so that the process is more energy efficient. Unlike in freshwater cooling systems, corrosion typically isn't a problem in seawater cooling systems because these systems employ corrosion-resistant metallurgies and often utilize lined transfer piping in the water distribution circuits. For these reasons, seawater cooling systems usually don't require corrosion inhibitors.

In the past, seawater cooling treatment programs primarily focused on scale-control treatment chemicals, often using phosphorous-based anti-scalants. These phosphorous-based treatments can effectively control scale but they are coming under increased environmental scrutiny due to their potential to cause algal blooms and damage coral reefs. While governmental restrictions on phosphorous discharge aren't yet in place globally, end users should seriously consider the public relations issues that could result from an unsightly algal bloom created by unnecessary discharge of phosphorous.

Phosphorous-based anti-scalants have had a long history of success in seawater cooling applications. For this reason, they remain in use at many plants. However, new products that aren't based on phosphorous chemistry allow chemical plants to operate at a higher *C* than possible with phosphorous-based treatment chemicals. Doing so can provide substantial water savings and avoid the potential for algal blooms in plant outfall.

Many available treatment formulations include a fluorescent dye that enables the user to check the product concentration in the cooling water. Fluorometers designed to detect these dyes are available commercially and test procedures are easy to perform. However, the inclusion of dye components adds significant cost to the program and provides questionable value. You never can recover 100% of the dye in seawater samples; the recovery rate typically

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varies from 69% to 80%. This means that actual treatment dosages could be as much as 31% higher than necessary. Without the dye and without the ability to analyze the product concentration in the cooling water, you would never really know if you dosed enough chemical to avoid a failure. Given that some systems use several hundred thousand dollars in treatment chemicals annually, a 31% overfeed represents a substantial unnecessary expense. Moreover, the potential costs associated with a failure could be substantially higher, up to 10 times or more. Neither of these situations, to overfeed or underfeed, are acceptable.

Instead of feeding the chemical and testing for an ingredient, plants should adopt "smart" chemical feed pumps — now available at a nominal cost — to ensure the system always gets the correct amount of treatment chemical. These pumps continuously monitor actual chemical application rates and can automatically adjust rates based on system flowrates. Real-time data from these pumps can go to a distributed control system or cloud-based data management system to provide early warning alarms in the event of an immediate pump failure or, the more challenging to detect, slow failure over time. Pump repairs, of course, then must occur expeditiously, so chemical treatment can resume as quickly as possible.

Retrofitting existing chemical feed systems with smart pump technology is easy; it simply involves choosing a pump manufacturer, pump size (maximum flowrate and desired turndown capability), selecting the correct materials of construction based on the chemical product to be added to the cooling system, and ultimately replacing existing pumps with the new pumps. Making effective use of the technology and its added benefits may require installing an upgraded chemical feed controller and a connection to a cloud-based data management system, such as SUEZ's InSight, to gain visibility to critical information reported by the new smart pump technologies. Water treatment companies typically offer these systems (pumps, controllers, data management, etc.) as a complete package to ensure successful implementation of the technology.

MONITORING PERFORMANCE

Cooling water heat exchangers at chemical plants rarely are outfitted with enough flow and temperature instrumentation to enable real-time monitoring of heat transfer performance. To make up for this deficiency, some plants perform periodic temperature and flow checks or utilize process simulation software to model heat exchanger performance and cleanliness. However, these periodic checks don't always identify problems in time to avoid significant losses in heat transfer and efficiency.

Advances in digital monitoring can help optimize the chemical treatment strategy. A digital probe can deliver data to the cloud on a constant basis and can alert personnel by sending text messages or emails if operations fall outside established parameters. While multiple heat exchanger simulators exist, the only technologies that provide enough information for a chemical operation are those that give a real-time analysis of cleanliness factor. Typically, these digital systems monitor heat transfer across a known surface and provide a real-time calculation of a cleanliness factor for the probe, reported in a cloud-based data management system. Real-time or near-real-time data offer early warning and enable proactive adjustments to the system or chemical treatment program to prevent costly deposition in heat exchangers.

MOVING FORWARD

Until now, chemical treatment strategies for seawater cooling systems suffered from several deficiencies. While obviously there's no "one size fits all" treatment approach for seawater cooling systems, a comprehensive, cost-effective and technically sound treatment strategy should:

1. Use the most cost-effective and environmentally acceptable chemical treatment.
2. Precisely control the chemical dosage.
3. Minimize the amount of seawater usage with respect to chemistry and environmental discharge limitations.
4. Measure cooling system heat-transfer performance to confirm results and provide an early warning if problems occur.

Faulty assumptions lead to imperfect treatment strategies. By using sound saturation models that function accurately over a wide range of seawater cooling applications, plant operators can get accurate, optimized programs that are custom-tailored to their specific plant operating conditions. ●

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COVID-19 Reshapes Production Team Collaboration

Lack of face-to-face communication necessitates changes | By Andreas Eschbach, eschbach

IN RESPONSE to the global pandemic, it's vital for chemical manufacturers to maintain production for the good of the economy and society at large while keeping their employees safe from infection. Increased workload caused by greater demands or reduced staffing (or both) means that people have less time to communicate. Employees may be carrying out extraordinary tasks or covering assignments for incapacitated colleagues, making communication that much more important. However, because COVID-19 has brought the need for social distancing to the plant, face-to-face communications have become impossible or difficult at best.

Handling this emergency demands a balanced approach that takes into account hazardous operations, environmental impacts, health and safety aspects, product quality, and long-term consequences on business continuity and profitability.

Despite the pressure to keep production going, a chemical maker must assess how plant operations must change to address the crisis. The company always has the option to shut down the plant if the costs of operating don't meet the benefits (to worker safety, for example). Prudently maintaining operations requires defining how operating procedures must change and, for instance, balancing the risks of COVID-19 exposure with the process safety of the overall operation.

SHIFT COMMUNICATIONS' KEY ROLE

Running a 24×7 chemical operation requires the close collaboration of people with different skills and responsibilities, all focused on a single outcome. At the end of each shift, a different set of hands takes over. Continuity is key to ensuring safety and efficiency; this relies on seamless communication between shift teams. Because the handover between shifts is one of the most critical activities undertaken at chemical processing sites, most plants mandate that shift handovers always should involve face-to-face interactions between individuals working in the same role. This gives incoming personnel about to start their shift the best opportunity to understand what is happening and,

hence, what they must do to keep the plant running safely and efficiently. However, COVID-19 is disrupting this established and time-tested procedure — reducing or even eliminating the opportunity to meet face-to-face.

Staffing shortages can mean that some roles go unfilled on every shift. So, handing over to a particular individual may not be possible. Moreover, in a crisis, there probably are more unplanned activities to monitor, adding to the quantity and complexity of the information that must be communicated. What's more, shift workers are likely to be fatigued and stressed, raising the potential that critical issues get ignored and fall through the cracks. So, the usual handover practice no longer suffices. Instead of just doing a rushed summary immediately before the handover takes place, staff must log observations, tasks and conditions during and throughout every shift. This provides the incoming shift with an accurate and structured protocol describing the true condition of the operation for which they now are taking responsibility.

Good practice requires a plant to:

1. Maintain an up-to-date and accurate chronological log.
2. Allocate time at the end of each shift to allow the outgoing supervisor to prepare for the handover. This is to ensure the documentation from the outgoing shift completely and accurately describes the current condition of the plant.
3. Avoid shift-to-shift contamination between the incoming and outgoing teams by conducting a remote handover via video conference.

ACHIEVING A GREAT SHIFT HANDOVER

Conducting good shift handovers when face-to-face contact isn't possible may pose some difficult challenges. Electronic logs and handover reports can assist greatly because people can talk through the information on the phone or via webcam. This can go a long way to overcoming the shortfalls of non-verbal communication. Sharing computer screen displays, particularly those from control systems, and using photos and other images are other useful ways to allow interaction and prompt discussion.

Don't expect people to be naturally good at a shift handover, especially one performed remotely. They must be skilled at communication and share common goals. To support this communication, base each element of the shift protocol on a well-structured information design. This structure contains: the status of safety-critical systems and production performance as well as executed activities, ongoing work and priorities, among other things. Good procedures emphasizing how to communicate effectively backed with appropriate training can be essential. Platforms supporting shift handovers and other structured communication technologies can make a big difference in supporting shift-to-shift collaboration.

BRINGING IN THE BROADER TEAM

Shift team members aren't the only staff on the front line. Operations management, engineering, quality and the like play essential roles in keeping production on track as well as ensuring safe operation. It's vital, even in normal times, that these disparate departments work as one team. To do this, they must collaborate using a common knowledge platform. Increasingly though, due to the pandemic, people performing some or all of these roles are working remotely from home, making this knowledge sharing all the more difficult. (In a recent *CP* online poll on the impact of COVID-19, more than 40% of respondents indicated that they were only working remotely; see: https://bit.ly/2O8qcbb).

To illustrate the problem, first think of a plant operation as an orchestration of processes and tasks, some operating over several days or even weeks, each involving multiple roles and responsibilities. An engineer may need to inform the responsible control room operator or shift supervisor of a temperature change required for a reactor prior to a grade change, for example. Unfortunately, this may not involve simply communicating with a specific individual but instead with whichever person is performing that role at the moment, thus making email communication impossible. (Or, perhaps, the individual operator who received an email has called in sick and a colleague is filling in.) Engineering may need to communicate a condition to a role, such as a board operator, or even to an entire production team.

Now, consider the situation when the engineer responsible for a production process is working remotely. Here, the front-line "essential" workers on shift in the plant become the engineer's eyes and ears. They must send this information at the right time and in the right context for the engineer to make correct and timely decisions. This transparency is essential for maintaining production performance, quality and safety.

During normal times, managers and technical staff can meet with front-line workers and each other whenever they like via formal meetings or informal sessions. Popping into the control room or process areas is a useful way for managers not only

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to talk to front-line workers but also to see for themselves what really is happening. They can access the data they need easily; if they can't find what they want, they can go and look for it.

The current crisis now is forcing teams to make decisions on the fly with greater urgency. Thus, immediate and transparent access to information and data becomes essential. Having a single source of truth for all parties reduces risk and promotes the efficacy of these decisions. In addition, fewer people generally are available on site to take action due to more staff working remotely. Having seamless access to a production knowledge base helps all involved to cover more areas.

ADAPT ADROITLY

The new normal is here to stay, and manufacturers across the board are taking action to minimize the impact on their operations. A recent survey by the National Association of Manufacturers, "Economic and Operational Impacts of COVID-19 to Manufacturers," https://bit.ly/3iGQM9r, indicated that about 80% of manufacturers foresee a financial impact. An analysis by PwC, "COVID-19: What it means for industrial manufacturing," https://pwc.to/3eiuAze, noted that more than 50% expect the pandemic to affect their operations.

To respond, leading manufacturers are dramatically changing how they work within their production plants. To manage this change, they have learned that effective communications provides a vital layer of protection in their operations. This is especially important in chemical making, which often involves operations that can be hazardous to employees and the environment.

Ultimately, what we've learned through this COVID-19 pandemic is that life is unpredictable. Just as most of us as individuals were ill-prepared for this crisis, chemical manufacturers were equally challenged to quickly and efficiently adapt their processes and streamline their decision-making and communications while protecting their workforce and keeping plants running smoothly. ●

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Should You Use a

Wired or Wireless Instrument?

Follow a decision tree to select the optimum option

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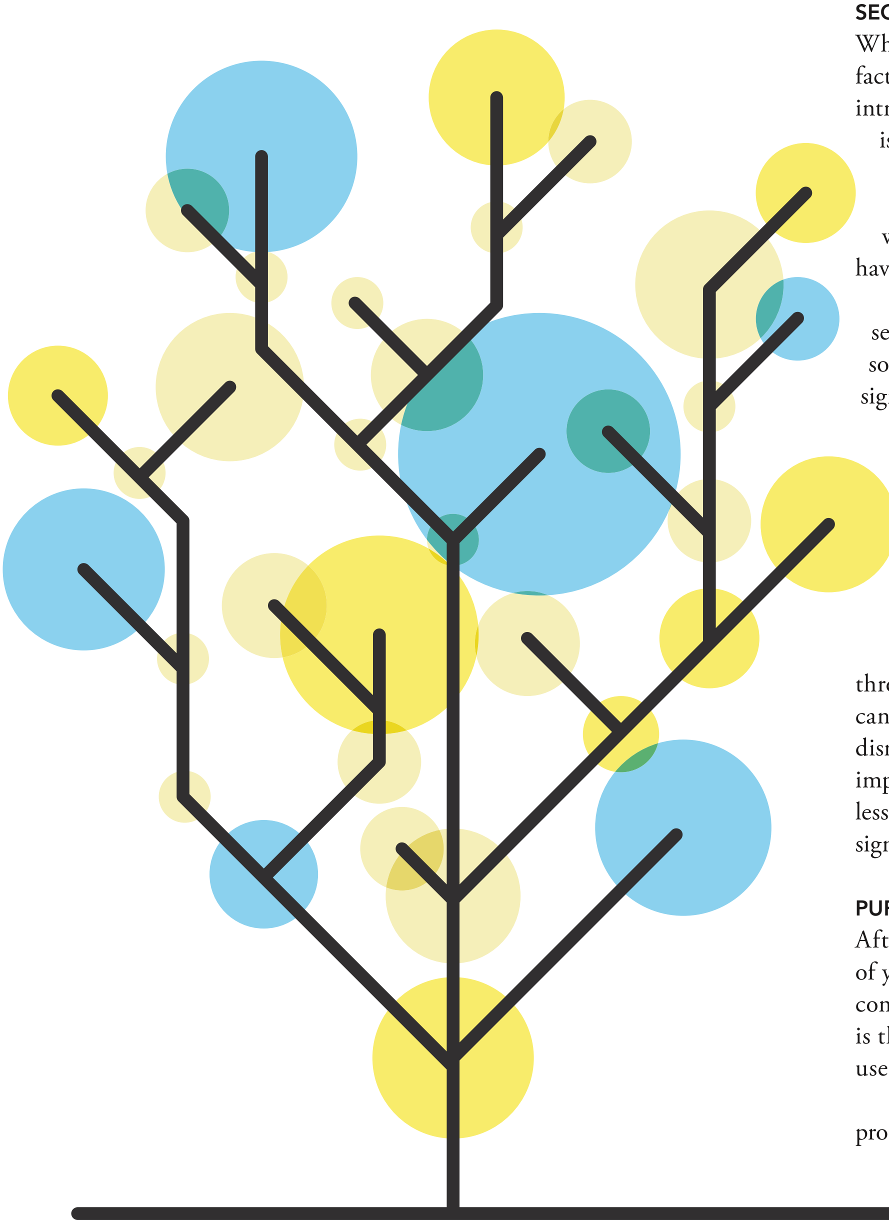

WITH ALL the information available for wired and wireless instruments, how do you choose which one to use? It's a difficult decision because both methods of communication pose tradeoffs. To find the most suitable option for a particular application, you should consider a variety of factors; these include: security, purpose, economics, location and distance.

To help you make an informed decision, we've provided a decision tree (Figure 1) that can simplify the selection process and ensure you don't overlook key considerations. Let's look at the various key elements on that decision tree.

SECURITY

When starting down the decision tree, the first factor you face is device security. To truly prevent intrusion regardless of whether the instrument is wired or wireless, designers must look at the system level as opposed to each individual device. In many cases, the system includes both wired and wireless instruments, which each have vulnerabilities needing protection.

Most wireless devices now have built-in security; however, with a wireless system, someone with an antenna could penetrate the signals and intercept data or disrupt the network by overloading it with large amounts of dubious messages intended to cause other communication devices to compete for bandwidth. On the other hand, connecting a wired system to the outside world, as is now common, opens the network to a whole host of potential entry points.

Incursion into company networks, whether through an attack on a wired or wireless system, can be costly in terms of capital, manpower and disruption of operations. While security is an important factor for any system, using a wireless instrument instead of a wired one offers no significant advantage.

PURPOSE

After security, you must think about the intent of your system — specifically, whether it's for control or monitoring. The system purpose often is the primary factor in determining whether to use a wired or wireless instrument.

Let's first explore the case of a system used for process control. When selecting an instrument for a process control system, you must consider three important factors: reliability, latency and bandwidth.

• *Reliability.* This is the most significant characteristic for a control application. If the signal going from a device to a controller isn't reliable, the process may not operate correctly; in the most severe cases, this could result in loss of life or property. Reliability applies to both wired and wireless devices. With a wired instrument, false or no readings could occur if the wires aren't properly terminated. For a wireless instrument, the controller could get incorrect information if the channel doesn't provide ways to correct for errors in the communications; the bad data could lead the controller to make inappropriate decisions.

In the end, a wired instrument is more reliable than a wireless one due to the nature of its design and how it communicates with the system.

• *Latency.* In general, a wireless instrument will have higher latency than a wired device. However, the latency of data communications can depend on many factors, e.g., processor speed of the computing environment, available memory, communication rates, the distance the communication travels, data packet size and protocol utilized. That said, in some cases, these factors may not affect latency in any way.

A test of Modbus TCP versus Secure Modbus that took place at an experimental power plant provides a case in point. Secure Modbus imposes additional requirements to confirm access and, so, seemingly would have greater latency than Modbus TCP. However, even with the larger packet sizes for Secure Modbus, this test showed there's no noticeable difference in latency.

Ultimately, latency's impact largely depends on the application. For monitoring systems, a wireless latency of 50 ms may be acceptable. On the other hand, control systems always must respond quickly when an event occurs, making a wired instrument the better choice.

• *Bandwidth.* Here, we're referring to system bandwidth as opposed to signal bandwidth, although both are important. System bandwidth is a function of the channel the data pass through. In a wired system, the wiring — be it copper or fiber optic cable — is the channel; for a wireless system, free space is the channel. Most conditions that impact free space typically have a negligible impact on a wired channel.

Some factors can influence bandwidth on a wired channel, with fiber optic less susceptible than copper. Copper wiring has issues with temperature, skin effects and long distances, all of which add impedance to the signal, reducing the overall signal-to-noise ratio.

Temperature, humidity, atmospheric pressure and other naturally occurring physical properties influence bandwidth of the free space channel. Noise from these sources injected into the channel eliminates, or possibly attenuates, the signal strength — affecting the frequency, speed of data transfer and the magnitude of the signal. To counteract these issues, a wireless system typically uses methods such as spectrum spreading and error coding within the communications protocol. Modern wireless systems also incorporate design techniques that provide the communication protocols ways to help eliminate issues such as multi-path errors, i.e., where the same signal gets picked up from a reflection off an object in a different path to the antenna.

In contrast, these physical properties have no impact on a fiber optic cable. So, its bandwidth is significantly higher and more reliable.

Thus, for process control, a wired instrument (preferably communicating via fiber optic rather than copper) usually is the better option because it minimizes the potential risk of process failures.

However, if process failures are more of an irritation than a major concern, then you should factor economic considerations into your decision.

In contrast, for process monitoring, while reliability, latency and bandwidth still are necessary, their influence normally pales compared to the economic factors of choosing a wired or wireless instrument.

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ECONOMICS

Financial factors fall into two general categories: device economics and installation economics. More often than not, installation economics primarily will drive your decision between wired or wireless. However, you also should evaluate device economics, including power costs. So, let's start there.

• *Device economics.* Many people make the mistake of only considering the cost of the instrument itself. A wireless instrument, due to the additional circuitry associated with the wireless interface, generally is more expensive than a wired one. While instrument cost does play a role, you must not overlook the power costs.

• *Power costs.* You first should check whether power is available at the location planned for the instrument. If power isn't available, a wireless instrument has the advantage because it typically operates in a true wireless fashion using a battery for power, eliminating the need to run conduit with power wires to the device. However, if power wires are already at the location, you can choose either a wired or wireless instrument.

Next, you should consider how often the data need updating. With a wireless system, the power budget is very important because battery life depends on update rates,

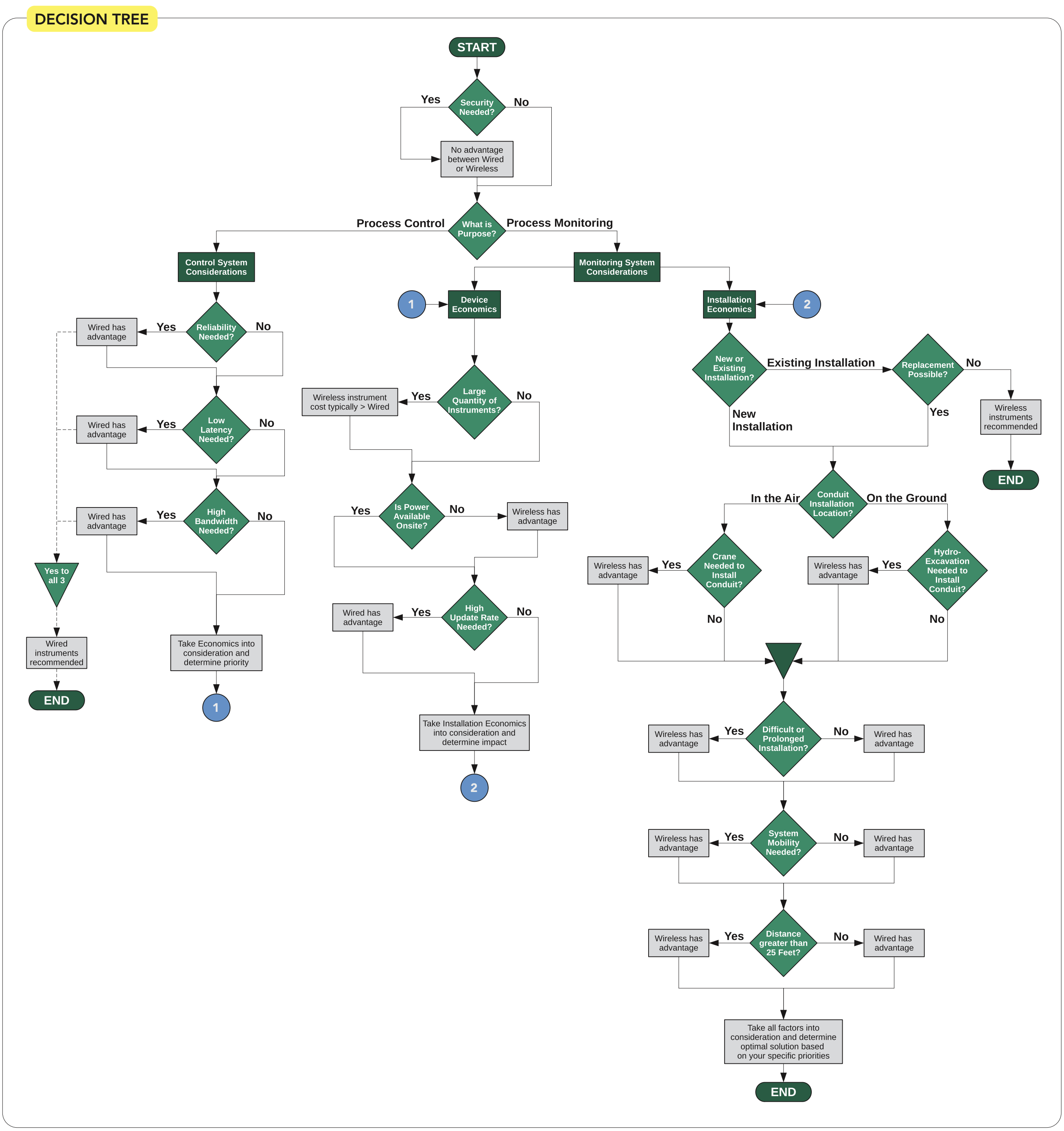

Figure 1. A variety of factors influence the selection of the most appropriate type of instrument.

battery capacity and system power level requirements. To help extend the battery life, you can outfit many wireless instruments with a rechargeable battery and an attached solar-panel charging system. (Such a combination can work great in optimal conditions but may not suit all locations.) Even with a solar panel and charger, you still must pay attention to update rate because a fast update rate drastically can reduce battery life. If you can't use a rechargeable battery, you must replace the battery when it runs out. If your system has a high update rate, the cost of replacement batteries can become substantial — even more so if the system has many battery-powered devices. Under these conditions, a wired instrument has the advantage.

As previously stated, device economics and power costs probably won't determine if you should choose a wired or wireless instrument but you still should keep them in mind during your deliberations.

• *Installation costs*. These normally are the most influential economic factors. A lot depends on whether you're replacing an existing wired system or dealing with a new installation. A wired instrument can become very expensive because the installation cost and time required rapidly increase with the length of conduit duct banks and cable needed.

Let's start by considering an existing installation. First, you must determine if you can replace the system.

A wired system for a hazardous location where conduit duct banks already are installed poses significant replacement challenges. The conduit seals used in hazardous locations are practically impossible to break, making swapping out the existing wiring impractical. Instead, you would need to run new conduit and couple it with larger conduit in a non-classified area.

Likewise, replacing the wired system for a critical application or continuous process may raise daunting difficulties. Lost production costs or other reasons may require the process and system to stay operational. Although adding new wires to in-place conduits may be possible, pulling new wire risks creating potential failures to the existing system. These failures might occur immediately or intermittently over a longer span of time, which can make diagnosis and troubleshooting hard.

If your existing system can't be replaced, you must place most importance on mitigating risk to the running processes.

Under these circumstances, the better choice is a wireless instrument because its installation will have little to no impact on the system currently in place. Once finished, you can transition the process to using the new wireless system and, if possible, then remove the existing wired system.

Conversely, if you can shut down the process to replace the system, you essentially are looking at a new installation. So, next, we'll compare the actual cost of installation, which primarily depends on the location and distance.

LOCATION

Will installation occur in the air or on the ground? The answer to this question will inform if equipment will need to be rented.

If conduit must go up many feet in the air (e.g., on top of a storage tank), installation may require the use of either a crane or man-lift. Likewise, ground installation frequently mandates removal of material from the ground to enable deploying conduit. Digging for new conduit can be tedious, time consuming and costly, so many companies resort to hydro-excavation to remove material for laying new conduit. If you must rent equipment to install conduit, a wireless instrument has the economic advantage.

Next, you must consider if installing conduit will be difficult or require a prolonged period. For instance, deploying conduit in a confined space can be both tedious and take a single technician a long time. In such a situation, a wireless instrument's ease of installation strongly may favor its choice. Indeed, while quantifying the value of installation ease can be difficult, that factor can be a big reason to select a wireless instrument.

Also, consider if the system must move location frequently. A wireless instrument, because it allows equipment to move freely without being tethered to a single spot, clearly has an advantage in mobility.

DISTANCE

The final factor you must consider is how far the instrument is from the controller. To illuminate the economic impact of distance, let's look at some real-life examples.

Separate studies of a wired versus wireless system were conducted on a feed mill and an ethanol plant (Dittbenner, "Wired vs. Wireless System Comparison," https://bit.ly/2Z4IErA). The parameters for the first study included a distance of approximately 1,000 ft from end devices to the controller location as well as a 120-ft run to the top of the conveyor. This resulted in a need for more than 1,100 ft of conduit and the potential expense of a crane or man-lift for installation. The costs were estimated at over $100,000 for the wired system and $55,000 for the wireless system. For the second study, the overall distance was around 3,000 ft; the wired system cost was estimated at $270,000 versus $65,000 for the wireless system. In both studies, the runs were quite long, which not only increases the cost of cable and conduit but significantly boosts installation labor.

If the distance is less than 25 ft, a wireless instrument probably won't make sense from an economic standpoint. On the other hand, a distance exceeding 25 ft favors a wireless device because it likely will cost substantially less than a wired one.

OTHER WIRELESS COSTS

While not shown on the decision tree, if a wireless instrument seems the best choice, you should keep in mind some other costs.

Although a wireless system installation can be as simple as pointing the end device's antenna at the controller's antenna, not all wireless installations are problem-free and without additional cost considerations. Situations with very-long-distance communication (greater than half a mile) may require a path study to ensure the antennas won't suffer interference from the surroundings. Path studies look at many factors to validate the communication channel will have enough signal present for reliable communications. These path studies examine foliage, radio topology, terrain, frequency and antenna gain to help determine the proper antenna placement and height.

Additional costs for a wireless system may include protective devices such as radio-frequency-specific surge suppression or structures — which can be very costly to design and build — to support antenna heights needed to achieve a reliable communications channel.

MAKE THE RIGHT CHOICE

Depending on your application, the decision tree may not provide a definitive answer as to which technology you should use. However, you are now aware of the many, and sometimes overlooked, factors that come into play and whether a wired or wireless instrument has the advantage.

You might decide to prioritize ease of installation over the most-cost-effective choice, or you may choose to go wired because reliability is your primary objective. Ultimately, every situation is unique, and the optimum option always will depend on which factors are the highest priorities to you. ●

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AMMONIA MAKER SOLVES SUPERHEATED STEAM FLOW-MEASUREMENT ISSUES

Replacing existing system with novel meter design improves performance and eliminates costly maintenance | By Michael Machuca, Emerson

A MAJOR manufacturer of agricultural chemicals located in Louisiana uses superheated steam with methane to create ammonia in a reforming process. About 300,000 lb/h of superheated steam at 750°F and 545 psig goes to the reformer. Efficient plant operation depends on maintaining the correct steam-to-methane ratio in this process. Insufficient steam increases unreacted methane and reduces hydrogen output. It also raises the carbon deposition rate on the reformer tubes, necessitating more frequent cleaning. Any excursions from the proper value of steam flow demand correction in a timely fashion. Otherwise, there's a high risk of reformer tube cracking that can cause a safety issue requiring the reformer to shut down. Applying excess steam to the reformer also has negative consequences — wasting energy, reducing ammonia production and decreasing the thermal efficiency of the plant.

Because this measurement is so critical, the plant used devices with a specific safety integrity level (SIL). It relied on four SIL-2-rated differential pressure (DP) transmitters with an orifice plate on the superheated steam measurement. One transmitter served to control the ratio of steam feed to the reformer. The other three transmitters comprised the safety system and operated in a two-out-of-three (2oo3) voting configuration. Detection of low steam flow cuts off gas to the reformer, shutting it down to prevent any reformer tube damage.

One of the byproducts of the operation was the formation of carbamate salts. These salts would drop out of solution in the liquid-filled impulse lines and often plug the high side of the differential pressure leg. Even after application of heat tracing, the plugging persisted. The plant had to devote an excessive level of maintenance to the measurement point. Transmitters would become damaged, requiring repair or replacement. Moreover, technicians had to blow down the impulse lines to keep them clear, increasing the safety risk to these personnel. Overall, the maintenance program markedly boosted operating costs and technician overtime.

Failure of this loop can lead to millions of dollars in production losses from a reformer tube failure, which can take over 30 days of downtime to repair. In one instance, the transmitters failed to read below the trip point, causing major reformer tube damage during a process upset.

A TELLING COMPARISON

Due to the high maintenance, risk for damage and safety concerns, the plant sought a more-reliable solution that would still meet its SIL-rating requirements. It considered several different flow technologies but none had the desired capabilities.

Ultimately, the plant decided to conduct a two-month pilot test and installed an Emerson Rosemount 10-in. quad vortex flowmeter upstream of the DP orifice system. This uniquely designed vortex flowmeter has four independent transmitters with four corresponding independent sensors mounted to two independent shedder bars — all contained in one meter body. With this configuration, the plant could achieve the SIL rating required. Just like with the DP orifice-based system, one vortex transmitter handled control while the other three transmitters operated in a 2oo3 voting configuration for the safety system. In addition, the plant chose the quad vortex meter because its body design has no moving parts and, more importantly, no ports or crevices that can clog with carbamate salts.

As part of the pilot test, the plant monitored both the quad vortex flowmeter and DP flowmeter system for several months. The quad vortex meter proved far superior in reliability and accuracy in this application. So, the plant switched automatic and trip control over to the quad vortex.

The quad vortex flowmeter, which has been installed since November 2017, has required no maintenance, completely avoiding the maintenance cost associated with the DP flowmeter system's plugged impulse lines. Eliminating impulse line cleaning has kept instrument technicians out of harm's way, thus reducing safety risks. No unscheduled shutdowns due to superheated steam flow-measurement issues have taken place.

Testifying to its happiness with the quad vortex meter's performance and immunity to carbamate salt buildup, the plant purchased a second meter and removed the original quad vortex meter in May 2019 for inspection and a calibration check. The original meter was returned to the factory where it went through the calibration facility. The meter passed all calibration checks and was still within specification after the pilot test. ●

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Are Jitters Justified?

Explosion during last startup raises a variety of concerns

TAKE A MULTIFACETED APPROACH

You should consider three aspects: possible proximate causes of the explosion; OSHA PSM (29 CFR 1910.119) accident investigation; and constrained resources and diplomacy.

First, as far as possible causes, the release of acrid orange-yellow gas indicates that nitric acid decomposed. This can occur either thermally or because of incompatible chemicals. Thermal decomposition generates water vapor, NO_2, and O_2 and by itself won't account for the explosion. Nitric acid is an oxidizer and is incompatible with a number of other compounds, including organic chemicals, flammable hydrocarbons, H_2S, ammonia and SO_2. Get a list of incompatible chemicals from the vendor. Oxygen generated by nitric acid decomposition in conjunction with organics (say, impurities) possibly could have created a "flammable range;" this could have led to an explosion. You must look thoroughly into all steps and liquids involved during the startup. Were any changes made in feed or equipment prior to the startup that could explain the explosion?

Next, let's strategize about the accident investigation. Corporate engineering terming the damage "minor" ignores personnel safety considerations. Without a good understanding of potential causes for the explosion, starting up the plant would be imprudent. Explain to them that OSHA PSM (29 CFR 1910.119 (m)) mandates a prompt and thorough accident investigation and remedial action.

The accident investigation process broadly should focus on finding proximate (immediate) and ultimate causes of the incident. Proximate causes could include, for example, changes in process, operations or personnel (poor training). Ultimate causes, on the other hand, could reflect structural or management issues such as inadequate commitment to safety, insufficient training, poor records, lack of employee participation, etc.

For the accident investigation, you can draw upon a vast number of resources, including experienced outside consultants. At the end of the investigation, you should feel sufficiently confident that you have identified the most probable proximate cause(s) and have taken corrective steps. In addition, to ensure long-term safety, you must address ultimate cause(s).

The loss of experienced workers and lack of safety appreciation at corporate level create a difficult situation. You must maintain your focus on safety and the environment but must do this in the context of corporate's financial focus. Consider:

- Short-term, emphasize the need and regulatory mandate for accident investigation. Quantify the profits the company will lose because of non-compliance and potential for another accident.
- In the mid-term, think about expanding your procedure to include relevant sections on safety precautions in startup, normal operation and shutdown. Add appropriate alarms and interlocks to minimize unsafe events. Also, bear in mind that head-pressure-based instruments are very sensitive to liquid density and will show incorrect level during startup or operations if liquid density changes; provide density correction.
- In the long run, address structural issues such as management

THIS MONTH'S PUZZLER

We've run our nitric acid purification process (figure online at https://bit.ly/2ZLcMZj) for about ten years. Recently, we shut it down for minor repairs. Less than an hour into the subsequent startup, an explosion occurred. The building was filled with acrid orange-yellow gas. This prompted a unit evacuation. We barely had time to complete the emergency shutdown procedures before the general evacuation. Fortunately, nobody was hurt.

Here's the simplified startup sequence we use: confirm all product and raw material valves are closed except vent valves — only V-100 has a car-sealed open; open waste valve (timer); unlock pump P-100 (choosing either A or B); set P-100 to 0.9 gal/min until the level gauges (LG-103) indicate column C-101 has achieved normal (45%) level; shut down P-100; unlock TC-104 after confirming that isolation valves on H-101 are open; initiate condenser flow (H-101); unlock FC-102 and set steam flow to 360 lb/hr; vent noncondensables from the steam trap using the gate valve upstream; monitor TI-101— when it reaches 265°F, set LC-101 to automatic; restart P-100; raise the high level alarm to 85% and set the low level alarm to 30%; manually adjust the cooling so temperature indicator TI-103 stays below 100°F and TI-104 remains at less than 130°F.

We've run this process unchanged for many years. Unfortunately, we've lost about 40% of our senior engineers and operators after an investment company purchased the plant.

What do you think went wrong? What can we expect as far as a U.S. Occupational Safety and Health Administration (OSHA) investigation? What can be done to improve the safety of this system? Corporate engineering wants us to start up in three weeks because damage was minor.

commitment (or lack thereof), training, safety systems, etc. Given corporate's focus on finance, you must help them recognize "safety risks" and the need for resources to ensure a safe plant. Try to quantify benefits or potential losses.

Instilling safety culture would be a slow process but long-term rewards would be immense.

GC Shah, Senior Advisor, Safety and Environmental, Wood, Houston

PLAN A GRACEFUL EXIT

Every major accident in the past twenty years ended with corporate blaming the field engineers and middle managers for its own neglect. Expect to wind up a scapegoat but conduct a good investigation; it will look good on your resumé.

The late Trevor Kletz, the renowned safety guru, cited three good reasons for avoiding a fast startup after an accident: 1) you don't know how to prevent a reoccurrence; 2) equipment might be damaged; and 3) you've done nothing to reassure operators and the public that everything is okay.

The biggest problem with your plant is lack of experience. Instructions can't be taught because they don't match reality. Often, nobody includes operating instructions in the as-built exercise. Procedures become less written and more rote. Corporations don't pay adequate attention to updating instructions, drawings, files, etc., so these fall into disrepair. The best solution is to bring in a few retired operators and engineers as consultants. One change you will want to push is to automate the process as much as practical.

Now, let's use a microscope. The accident occurred before the process was running in a stable mode. Could something

Process Puzzler continues on p. 38

OCTOBER'S PUZZLER

We manufacture formaldehyde using DuPont's Formox process in a 30-yr-old system. Methanol is oxidized over a molybdenum-iron oxide catalyst at 600°F in a fixed-bed reactor: $CH_3 + ½O_2 \rightarrow CH_2O + H_2O$. We replaced the catalyst several months ago — we had stretched the service life of the old catalyst to 18 months from the usual year because of the pandemic.

We recently suffered a tube failure in the cooling water (boiler feedwater) surrounding the reactor. The downtime finally allowed us to inspect the reactor. We'd wondered for three months why methanol conversion dropped from 88% with fresh catalyst to a paltry 79%; the methanol registered downstream had crept up slowly. (We had ignored this because the old catalyst gave 83% conversion.) In addition, we saw more paraformaldehyde fouling of downstream equipment as we raised the reactor temperature to 690°F from 620°F. We also increased the oxygen content to the reactor by 25% to push the reaction. The effect was negligible in improving conversion. However, we noticed an increase in trace formaldehyde in the absorber downstream.

We run our boilers at 400 psig. The recovered steam produced by the reactor feeds into the main feedwater tank. Some engineers at corporate call it "dirty steam" and worry the boilers are being fouled. One suggestion was to sample the feedwater tank and discuss additional chemical treatments to prevent a plantwide problem with steam.

What do you think caused the cooling water leak? Is there really a problem with the boiler feedwater? Did our attempt to raise conversion lead to any lasting damage? Is there a way to identify this problem before it prompts major problems?

FORMALDEHYDE PROCESS

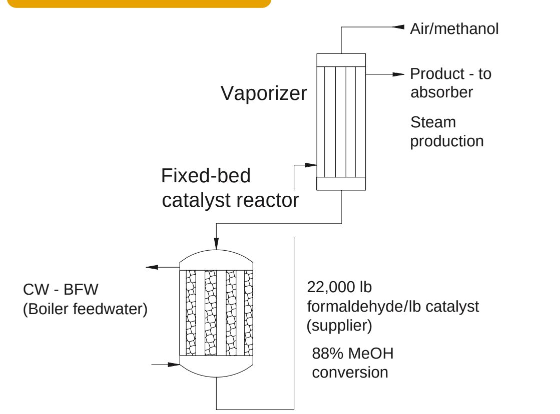

Figure 1. Failure of cooling water tube raises concerns about broader problems.

Send us your comments, suggestions or solutions for this question by September 11, 2020. We'll include as many of them as possible in the October 2020 issue and all on ChemicalProcessing.com. Send visuals — a sketch is fine. E-mail us at ProcessPuzzler@putman.net or mail to Process Puzzler, *Chemical Processing,* 1501 E. Woodfield Rd., Suite 400N, Schaumburg, IL 60173. Fax: (630) 467-1120. Please include your name, title, location and company affiliation in the response.

And, of course, if you have a process problem you'd like to pose to our readers, send it along and we'll be pleased to consider it for publication.

Pre-empt Liquid Pooling in Vapor Lines

Keep pipe slope below a critical angle to avoid possible corrosion

LOW FLOW rates prompted by the pandemic can cause a variety of problems. Last month, we looked at the risk of sedimentation from liquid streams and the potential for under-deposit corrosion ("Keep Under-Deposit Corrosion Under Control," https://bit.ly/2ZtVq2V). Liquid pooling caused by low flow of vapor also can make corrosion worse. Knowledge gained by the pipeline industry can help us identify possible corrosion problems related to such low flow.

First, understand that vapor flows may include small amounts of liquid. For example, while a line coming from a hot separator drum, contactor or distillation tower initially only will contain dew-point vapor, minor heat losses can cause small amounts of liquid to form. If the system is mixed oil-water, the liquid could be oil, water or both.

A small amount of water inside the pipe often is worse than a lot because it can selectively absorb ionic species from the gas. This may concentrate impurities. In contrast, extra water may dilute the mixture and lower the impurity concentration. Similar problems can happen with organic liquids. Organics may selectively absorb additives or impurities from the gas.

Many vapor-phase corrosion control additives can selectively absorb. This can prompt multiple problems. First, it robs the vapor phase of corrosion inhibitor, altering additive performance. Second, too high a concentration of inhibitor in the liquid can create deposits or other difficulties — potentially causing corrosion instead of preventing it.

Sloping lines can prevent drip accumulation and aging of liquid (see: "Grasp Line Layout," https://bit.ly/2AXkbuX). Unfortunately, sloped lines can make piping layouts significantly more complex and expensive. Drain points are one response to this.

However, liquid can accumulate in other areas such as low points caused by damage, foundation shifting, pipe support restraints, thermal expansion or complicated pipe layouts. Pipeline corrosion work has identified liquid accumulations in sagging low points as the culprit behind many problems.

High vapor velocities keep liquid moving along and prevent accumulations. But what vapor velocity is high enough?

Basic analysis in multiphase flows with free surfaces often uses a form of the Froude number (F) — based on the ratio of the flow inertia to gravitational forces — to examine slip between the phases:

$$F = (\rho_L - \rho_G)/\rho_G \times (g_c \times d_{id})/V_G^2 \times \sin(\theta) \qquad (1)$$

where ρ is density, g_c is the gravitational constant, d_{id} is the inside diameter of the pipe, V_G is gas velocity and θ is the critical angle. At slopes steeper than this angle, a liquid pool forms on the bottom of the pipe. At slopes lower than this angle, momentum imparted by the vapor keeps the liquid moving.

A modified form of this equation proposed by the National Association of Corrosion Engineers for 4-in. to 48-in. pipe diameters defines the critical angle as:

$$\theta = \arcsin\left[0.675 \times \rho_G/(\rho_L - \rho_G) \times V_G^2/(g_c \times d_{id})\right]^{1.091} \qquad (2)$$

You can use any consistent set of units, so long as they cancel each other out; the arcsin is dimensionless.

One example of the use of this equation was for investigating corrosion problems in a vapor line from an amine regenerator. The regenerator overhead acid-gas was mostly hydrogen sulfide with some ammonia and saturated with water. The question was how low a velocity the line could handle without accumulating liquid in some small pockets caused by improperly installed pipe supports.

For ease of monitoring, results were graphed as pressure drop versus the angle in the line that could be tolerated before forming a stagnant liquid spot. Because the vapor and liquid densities were relatively constant, pressure drop correlates very well with the critical angle, as shown in Figure 1.

One interesting observation from this ties directly to standard design practices for plants. For this service,

A small amount of water inside the pipe often is worse than a lot.

AMINE REGENERATOR INSIGHTS

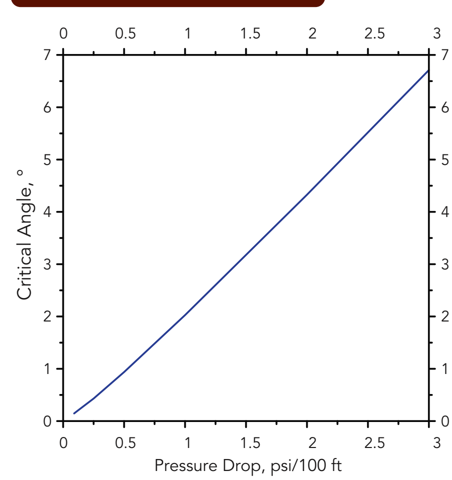

Figure 1. Line defines the maximum conditions tolerable to avoid liquid accumulation.

designers often use pressure drops of around 1 psi per 100 equivalent ft of pipe for selecting line sizes. For a 20-ft span between piping supports, this gives a 4.25-in. deflection before liquid pools form (if the line is evenly bent). In comparison, dropping to 35% of the flow rate incurs a pressure drop of 0.125 psi/100 ft. — giving a 0.44-in. smooth deflection before liquid pooling is likely. For this plant and this line, flow rates below 35% did create the possibility of liquid pooling.

Analysis of expected flow rates identified locations needing extra care for monitoring and draining liquid low points.

The lower rates at which many plants now are operating may result in liquid pooling in lines and, depending upon system chemistry, the possibility of corrosion problems. While not perfect, using an analysis developed by the pipeline industry can help identify areas where pooling can occur. ●

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PROCESS PUZZLER (CONTINUED)

left over from the shutdown have contributed? Could it be the startup procedures differ from those for normal operation? Did something unique in this shutdown affect the procedures in a way unforeseen by a safety review? This could be as simple as somebody forgetting to close a vent valve.

I don't see a lot of redundancy in your controls. Temperature control is crucial in the bottom of this type of tower; the type of measurement and its location could result in stable control or a potential blind spot. In addition, a steam system often can pose issues from the header steam traps to the boiler return: built-up condensate means poor heat transfer and wound-up steam control valves. One safety recommendation would be to add more instruments and perhaps switch from K-thermocouples, typical for older systems, to RTDs.

A key problem is the single level instrument in the bottom of the flash column. If it reads false-high, and steam was added to the column, a flash boil-up could occur that would pop the rupture disc, as happened. So, I recommend a non-contact level sensor and a redundant measurement.

Here's another recommendation that will prevent an evacuation: relief to the scrubber. That will eliminate the emission problem. That's probably on OSHA's checklist — so if you bring it up first, you're being cooperative.

Next, look at the maintenance. Was everything working on the day of the accident? Was anything recently repaired, replaced or bypassed? Cast a wide net. What was the condition of streams into and out of the column? Include the equipment upstream and downstream and, especially, check the utilities.

Let's move on to the procedure. The basic procedure looks sound, provided the cooling fluid on the condenser is correct and the condenser isn't fouled. Turning steam on a column without a condenser would cause the rupture disc to blow within a few minutes but only if the reboiler steam loop was out of control or the condenser was undersized or reboiler oversized. Walk down the procedure with operators on all shifts who experienced the accident. Look for deviations from the written procedure. Then, repeat this exercise, separately, with a retired operator. Again, look for deviations.

So, in summary, look for anything that would increase the heat load inside the column. In the end, you will want to recommend automation, new more-accurate operating procedures, some real-time checks on operator performance, and retraining. You may not be there to see these improvements but it looks good if you do a professional job of lighting the way.

Dirk Willard, consultant
Wooster, Ohio

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The redesigned ASV, BSV, and CSV rotary screw vacuum packages offer capacities from 141 to 554 acfm at 99% vacuum. Featuring a new cabinet and air flow design, these 10–40-hp units provide quiet operation in a compact footprint. The models have wide-opening cabinet doors for easy access to maintenance points. The full enclosure, TEFC motor and gasketed doors with soundproofing reportedly make them ideal for use in high-dust environments. The new cooling air flow design features a dedicated cabinet fan and topside discharge for better oil cooling. It can be easily ducted to remove or recover waste heat while further reducing noise.

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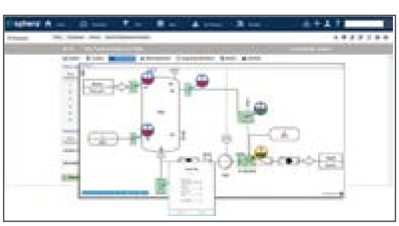

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The interactive piping and instrumentation diagram (P&ID) software helps companies better plan and manage the execution of isolation activities so work can be done safely on a part or section of the plant. Available on SpheraCloud, a SaaS-based and mobile platform, the software allows users to upload their PDF schematics and mark up the electronic document with actions, rules and isolation points. These data are then automatically carried into the integrated isolation planning process. Engineering, maintenance and operations can collaborate on isolation planning and provide operational feedback to engineering. The software also systematically captures the management-of-change process, thus eliminating rework by automating plans.

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Flow Chemistry Gains New Focus

Major chemical maker and academic researchers team up to address skills gap

"It's a learning curve for everybody."

A PARTNERSHIP between BASF, Ludwigshafen, Germany, and Imperial College London (ICL) will involve a number of flow chemistry projects at the university's Center for Doctoral Training (CDT) in next-generation synthesis and reaction technology.

"This research is a real opportunity to complement world-scale production with a more flexible alternative," says Christian Holtze, senior research engineer at BASF with a background in microfluidics. "While we already use continuous processes routinely to manufacture chemicals at large — typically kilotonne-scale, a key challenge is to implement flow chemistry at smaller kilogramme scales, specifically for R&D and the manufacture of low-volume, high-value chemicals, including speciality chemicals, which to date are predominantly made in batch processing, for example in stirred tank reactors," he adds.

Holtze recognized microfluidics had greater value to BASF in reaction chemistry than formulation chemistry, and thus looked at how to boost the use of flow chemistry in its operations. His role now is matching BASF's needs, mainly in agrochemicals, with ICL's flow chemistry expertise.

BASF in fall 2020 will fully fund 10 PhD students, a local support structure at ICL for at least four years, and two other PhD students at Cambridge University, Cambridge, U.K. The company could make funds available for more projects in the future.

The work will be conducted at the Molecular Sciences Research Hub (MSRH), ICL's new home for chemistry at its White City campus in West London. MSRH research facilities include advanced flow chemistry, automation and data science technologies.

"Chemistry students are traditionally taught to use round-bottom flasks for reactions. One of our priorities is to promote better awareness of other reaction technologies, particularly flow chemistry, as part of their essential training of our CDT program, and hopefully we can extend this further to undergraduate teaching," notes Mimi Hii, professor of catalysis at ICL. "While continuous flow processes are routinely taught in chemical engineering courses, the basic concept is hardly mentioned in chemistry courses at any university. There is also a need to better understand the control and automation technology involved with flow chemistry," she notes.

This knowledge will be further developed at MSRH's Center for Rapid Online Analysis of Reactions (ROAR).

"This is a suite of highly automated reactors — including continuous flow equipment — and instrumentation that generate a large quantity of high-quality data," says Hii, who is also director of ROAR.

The idea here is that CDT students will pick up skills, such as machine learning and Python programming, and so begin to better understand the language and tools used by other disciplines involved in flow chemistry work. "It's a learning curve for everybody, but with the CDT we can address the skills gap between academics and industry," believes Hii.

BASF also has grown a corporate flow chemistry research community at Ludwigshafen. It draws on 20 experts within the company dedicated to tackling the challenges involved in moving from lab- to commercial-scale flow chemistry production.

"The overall size of this program is owing to the challenge of implementing flow chemistry in industry: it must be considered in a holistic way, by providing a seamless workflow from early-stage lab experiments all the way to pilot scale and production concepts. Now is the right time to do this as more equipment related to flow chemistry is becoming commercially available. Also, first examples of best practice are coming from the pharmaceutical industry, while machine learning capabilities and computational power today are beyond anything that was available even a few years ago," says Holtze.

"Business-wise, it's about finding the best partners to collaborate with. That way you can develop the technology faster and it becomes easier to commercialize," explains Darren Budd, commercial director (U.K. and Ireland), BASF. "We do a lot of scouring the globe for such technologies. Now we've got a solid base through the CDT and students will get some really good ideas about how we can use flow chemistry technology inline in our production processes. We're all excited with where CDT work can go," he adds.

For example, he believes the pandemic presents an opportunity here, with flow chemistry technologies helping produce products nearer to markets, thus avoiding some of the supply chain problems the virus caused. Flow chemistry may be game-changing, too, when hazardous chemicals needed in some processes are expensive and potentially dangerous to ship. ●

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