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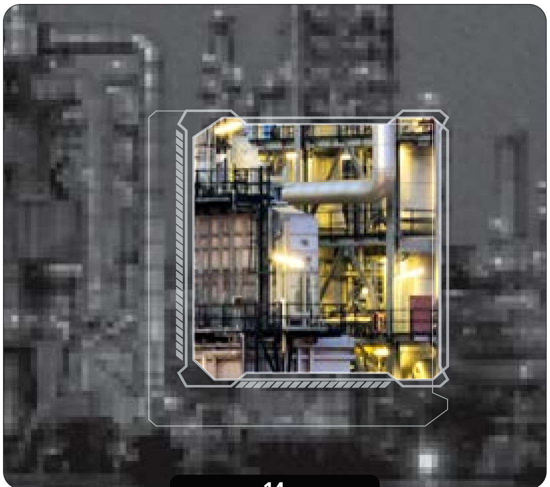
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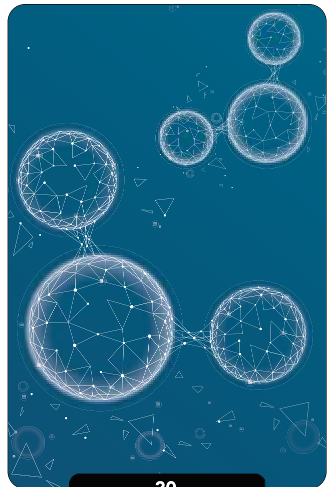
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Leverage Cost-Saving PdM Tools for Wastewater Pumping Systems

Justin Lesley and Matt McMahan, Motion Industries

Dwindling maintenance workforce is a problem plaguing many industries these days, and especially in the municipal wastewater industry. With ever-changing budget cuts and experienced maintenance staff aging out, today's municipal maintenance personnel need to adapt to a modern approach, to ensure their equipment's health with more efficient maintenance and reliability practices.

Many treatment plants are still using the same pumps and transfer systems that were designed many years or even decades ago, supplying a population that at the time was much lower in census counts compared to today. This often means they are pushing antiquated equipment to the max to keep up with demand. As many communities across the country may have plans to upgrade these supply and treatment plants, existing operations are asked to maintain current equipment to the best of their abilities – while they wait on construction and implementation of new facilities with appropriately sized pumping systems.

Motion Industries has helped tackle many of these issues with state-of-the-art predictive maintenance solutions that allow wastewater departments to maintain plants that once required three times the workers. Predictive maintenance (PdM) solutions work by measuring and analyzing data that is collected from sensors installed on pumps and other components within a pumping system. The key data points to track and communicate are discharge pressure, flow rate (GPM), bearing temperature, vibration, motor speed (RPM), motor load (AMPS), and leak detection. As data is collected and analyzed, technicians can configure thresholds within the solution software to indicate a steady state or normal operating condition. As parameters change or exceed a normal operating threshold, alarms are triggered. Most modern PdM solutions can push those alarm notifications out to stakeholders (like technicians and engineers) in order for maintenance to be scheduled. Notifications can come in the form of emails or text messages, in addition to displays within a web-based dashboard (user interface) and/or smart phone app.

Many of today's condition monitoring solutions are in the "flag-waving" stage of their evolution. They simply identify when key performance indicators (KPIs) change and notify users that something is different. While flag waving is certainly useful, the ultimate goal of advanced PdM solutions is to prescribe the problem that caused equipment to exceed its normal operating threshold, as well as a suggested, appropriate action to rectify it. Additionally, advanced software may include severity indicators and an associated timeline showing how much time operators have to address problems before a catastrophic failure occurs. This level of functionality is called "prescriptive maintenance," because the diagnostic part of the normal process is automated within the software.

Modern predictive maintenance solutions give reliability professionals the machine health data they need to properly plan and prioritize their efforts. Instead of waiting until components fail in the field or perform inefficient, time-based maintenance on assets that don't actually need attention, reliability teams can maintain equipment based on its true condition. Wastewater facilities are leveraging PdM tools to extend the life of equipment and maintain them with a smaller reliability work force. Contact Motion Industries for help to get started.

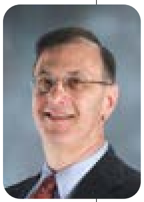
Justin Lesley, Industry 4.0 Innovation Manager at Motion Industries, directs IIoT strategy and partnerships related to the MRO industry. His career centers on operational efficiency supported by his Lean Manufacturing and Six Sigma certifications combined with his engineering credentials. Lesley guides manufacturers along their digital transformation journey by helping them utilize connected predictive maintenance solutions.

Matt McMahan has worked in the process pumps industry for 18 years. As a Motion Industries Account Rep Specialist focusing on process pumps, he is responsible for training his branches, troubleshooting for valued customers, sizing pumps for applications, product marketing, supplier interaction, and business development. McMahan is also a Corporate Trainer and teaches the Mi Process Pumps Class for participants across the country.

For more information, visit **MotionIndustries.com/chemicalprocessing** or discover P²MRO, Mi's latest Industry 4.0 technology designed to improve your plant's uptime and efficiency (**https://tinyurl.com/y6d9v7x6**).

ChemE Wins Genius Grant

Professor gets award for making chemicals from renewable resources



The 21 winners in 2020 span a broad range of fields.

THE JOHN D. and Catherine T. MacArthur Foundation (www.macfound.org), Chicago, annually awards fellowships — often referred to as "genius grants" — that provide each winner with $625,000, no strings attached.

Besides bestowing a sizable and unrestricted grant, the program also is unusual in the breadth of fields considered and its use of a constantly changing, widely diverse pool of nominators.

The foundation selects fellows using three criteria: 1) exceptional creativity; 2) the promise for important future advances based on a track record of significant accomplishments; and 3) the potential for the fellowship to facilitate subsequent creative work.

Its website gives details of all awards since the fellowships began in 1981. The winners come from an incredibly diverse variety of fields and backgrounds.

In early October, the foundation announced its 2020 roster of fellows. (See: www.macfound.org/programs/fellows/.) The 21 winners span a broad range of fields, including anthropology, biology, physics, playwriting, poetry, property law and sociology — and, for the first time, chemical engineering. A couple of previous winners have doctorates in chemical engineering but don't work as chemical engineers: Melody Schwartz (2012 winner), a bioengineer, and Linda Griffith (2006), a biotechnologist.

The chemical engineer honored is Paul Dauenhauer, a professor in the Chemical Engineering & Materials Science Department of the University of Minnesota, Minneapolis. The MacArthur Foundation cited him for "developing new technologies for converting renewable, organic materials into chemicals used in products such as plastics, rubber and detergents."

Dauenhauer has devised methods for using substances such as wood and crop waste to produce *p*-xylene and isoprene that boast quality and production costs comparable to fossil-fuel-based versions. He also has developed a new class of surfactants from sugar and fatty acids that suits myriad cleaning-product formulations and offers better biodegradability than petrochemical-derived alternatives as well as novel and desirable properties.

Prof. Dauenhauer told me:

"... It is wonderful to see external recognition that creativity plays a key role in inventing and designing new technology, particularly chemical processes that address issues of sustainability. Chemical engineering is a core research area in using materials and energy sustainably without long-term impacts on the environment including the oceans, the air and land. Our focus has been on making both renewable materials such as plastics, rubbers and detergents but also carbon-free fuels that can be manufactured from wind and solar power. These new processes and associated materials can allow a continuing benefit and high quality of life but limit or negate the negative impacts on the world around us. The MacArthur Fellowship is a validation that these areas of research are critical to society, and we aim to use this support to pursue some of the most high risk and high reward intellectual endeavors."

As he notes, the award testifies to the increasing importance now placed on sustainability in chemicals manufacturing. An article from our September issue "The Future is Circular," https://bit.ly/33XQMwr, delves into the status of the chemical industry's transition from a "take-make-waste" mindset to one focused on renewable feedstocks and energy and re-use of end-of-life material. ●

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Should You Go Batch or Continuous?

The choice isn't always clear for particulate solids

Six key factors can influence the decision.

THE MOST common question I get when developing a new process that involves solids is: "Should it be batch or continuous?" The standard answer always is: "It depends." And, sometimes, the right answer is "neither" — because you may be better off to use batch on front-end operations followed by a continuous process; solids are not simple one-phase systems.

Of course, economics ultimately determine the choice. How long do you expect this product to last in the marketplace? How much capital are you willing to risk? Product development generally takes place in batch operations. So for scale-up, because of the many factors that come to play with solids processing, I usually suggest first going to a 10× batch operation before considering an expansion to continuous. Then, when evaluating what type of operation to use for large-scale production, look at the following factors:

• *Market*. We often think that a high production rate calls for a continuous process. Large-scale continuous production certainly boasts economic advantages. However, a continuous operation may limit your flexibility in altering the product to respond to market demands. So, you always should consider the "what ifs." For instance, if you anticipate the eventual need to change particle size, doing so can be difficult in a continuous process, especially if the new size results in a lower production rate. To avoid this unpleasant surprise, challenge your marketing people to investigate how long the market will last and what competitive products may crop up in the near future that may reduce the product's lifetime.

• *Existing equipment*. Ask about what assets you already own that will work on this product and whether a plant could integrate the product into its current operations. This can be a Catch-22 with most crystallizers or dryers originally designed for a specific product. You must resolve issues concerning suspension of the solids on the new product, heat transfer and encrustation. My experience with using existing equipment hasn't been good. The operators seldom are alerted to the differences between the new product and what they have been making for years. While not a safety issue, processing may involve subtle changes in flowability or temperature sensitivity.

• *Complexity*. Batch operations may be good when many steps are involved and the same type of equipment could handle multiple steps — for example, a repeated sequence of crystallization, followed by a filtration, then a reaction and another crystallization. While common in pharmaceutical operations, those steps can raise questions of contamination or the extra cost of cleaning the equipment.

• *Potential for change to the model*. Batch operations allow for alterations that may occur in the process. The model developed from research could have missed some heat-transfer issues or mixing problems that didn't show up on a small scale. If you have these concerns, I suggest further batch scale-ups before looking at a continuous process.

• *Expansion potential*. If you have to boost production, adding another solids processing device is a quick but expensive solution for batch systems. In contrast, upping the output in a continuous process may be as simple as adding a new pump or increasing the temperature. Work with the research or development team to assess how to expand operations in the most cost-effective manner.

• *Regulations*. Often, compliance with government regulations, such as those of the U.S. Food and Drug Administration or Environmental Protection Agency, favors batch operations. They may allow you to limit losses from a bad batch or give you an opportunity to recoup your costs by selling that batch to a secondary market. On the other hand, documenting compliance is easier and less costly with continuous operations. Also, the evolution of online instrumentation into a reliable part of chemical operations favors a continuous process.

One additional item to consider when choosing between batch and continuous is that we are working with particulate solids. My company participated in a study of the outcomes of projects for the production of chemicals. While a few projects involving gases and liquids failed to meet on-time delivery or expected project cost, projects involving solids generally failed to achieve expectations. Two never started up. With solids, plan on extra time and costs, especially if it is a continuous process. So, unfortunately, the answer to the original question still is "It depends." ●

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Do Pressure Relief Right

Consider nine pointers to develop a suitable design

Always adhere to the 3% pressure drop rule.

A REFINER hired me to review project drawings from one of the country's largest engineering firms. I was aghast that one drawing showed two pressure relief valves (PRVs) in series. The only defense I heard was that the refiner had signed off on it.

A year later, I worked with a vendor of a twin-seal block valve investigating a mysterious failure of its valve in a refinery tank farm; we found that two PRVs in series accounted for that failure.

Pressure relief work is fairly intricate. Generally, companies set up "survey" teams that create their own, often flawed, design principles. I've worked on a few of these teams, so let me share some of what I've learned.

First, let's look at the 3% pressure drop rule stated in API-520 "Sizing, Selection, and Installation of Pressure-Relieving Devices, Part II — Installation." You should follow that rule. There may be wiggle room, as this video, https://bit.ly/3jANF2L, reveals, but even its presenter warns you shouldn't deviate unless you've got a good lawyer.

Another reason for keeping to the 3% rule is the pan-handle model for pressure drop calculation: a drop above 15% requires using an assumption of either isothermal or adiabatic conditions, neither of which can be modeled easily for two-phase flow. Besides, once you see drops that high, the Mach number rises and gas flow gets unstable (much worse with two phases). As a rule of thumb, a Mach number above 0.7 is extremely noisy.

Second, every pressure vessel should get a relief device. You may be able to ensure a vessel is connected to another without the risk of isolation but you can't guarantee a pressure event will affect the two vessels in the same way. Fires are unpredictable, so don't try to handicap a fire. Too often, I've seen designs with a single relief device protecting several vessels as a group. API and ASME require individual protection.

Third, no such thing as a winning relief scenario may exist. You can't protect a reboiler from a fire by securing it from a stuck-open steam valve with a flow orifice. You must weigh each scenario on its own merits and decide if your solution protects against each credible scenario.

Fourth, let's consider insulation credit for the fire scenario. API-2000 "Venting Atmospheric and Low-Pressure Storage Tanks" discusses the heat absorbed by a pool fire in detail and covers the use of an F-factor, an allowance for insulation. API provides a calculation procedure for reducing F and, thereby, Q (the BTU/h absorbed by the vessel wall). Generally, engineering firms resist using an F below 0.3 (1 in. of insulation) because they justifiably are wary that the insulation will get proper maintenance.

There's a general understanding about what qualifies as in-place insulation that can resist a fire. The only acceptable jacket is stainless steel; the straps holding the insulation in place must be stainless steel or another metal with a suitably high melting point. Also, the insulation must not burn or decompose at the temperature limit expected in a pool fire. Per API-521, 5.15.1.2.2, this is 1,300°F or the practical limit of the vessel wall (heads generally fail last) at the corresponding vessel design pressure.

Fifth, every vessel with a liquid has a fire scenario — even a tank filled with water. I recommend tank designers use a fire case for ease of sizing the relief nozzle, then raising the nozzle to the next full size.

Volatile, flammable liquids always pose the question of which latent heat to use to calculate the relief flow rate. The accepted practice is the liquid after the third flash; however, I suggest looking for the maximum flow rate because that will open the relief device.

Sixth, thermal expansion should include all the pipe around a valve (you may need more than one valve) and heating from other sources.

Seventh, the relieving temperature in a fire case depends on the vapor pressure of the liquid composition. This must exceed the normal operating temperature.

Eighth, the 25-ft rule in fire sizing only applies for isolated vessels. If a vessel is inside and a pool fire could occur on any floor around the vessel, the fire area must include that part of the vessel wall.

Lastly, forget about fire-sizing for a gas-filled vessel: https://bit.ly/34oOMMR. Vessel rupture occurs before the PRV opens. ●

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Broader Use of Atmospheric Nitrogen Looms

Combining two reactions enables bonding with organic compounds

ATTEMPTS TO combine atmospheric nitrogen and benzene to create ammonia usually fail because benzene degrades before a chemical reaction can take place. Now, researchers at Yale University, New Haven, Conn., say they have found a way to combine the two to produce aniline, which is a precursor to materials used to make an assortment of synthetic products.

Researchers have long focused on “nitrogen fixation,” a process to create ammonia from atmospheric nitrogen. Yale chemistry professor Patrick Holland and his colleagues believe this nitrogen could play a wider role — if researchers can find ways to make other compounds with atmospheric nitrogen.

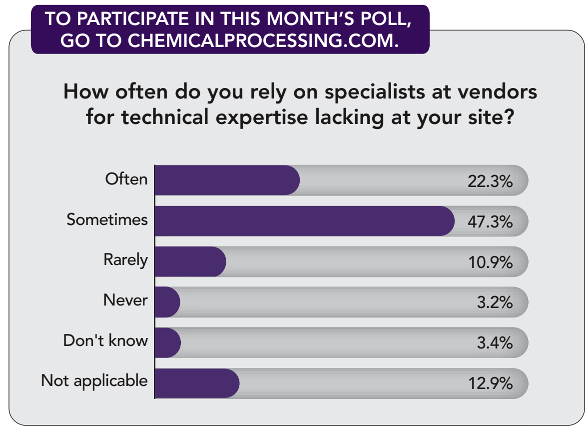
“In the long run, we hope to learn how to use the abundant nitrogen in the air as a resource for synthesizing the products needed by society,” notes Holland.

Holland and his colleagues used an iron compound to break down one of the chemical bonds in benzene, and treated the nitrogen with a silicon compound that allowed it to combine with benzene (Figure 1). A recent article in *Nature* contains more details.

The researchers believe the ability of these iron complexes to generate a hydrocarbyl group on the iron through C–H activation, and then transfer it to an activated N_2 provides a new strategy for coupling hydrocarbons to N atoms from atmospheric N_2.

“There are many known reactions that break C-H bonds for cross-coupling, and many known reactions for reducing N_2, even though both are difficult and give a limited number of products. By combining these two powerful reactions, we have a way to put nitrogen atoms from the atmosphere into organic compounds, which is new. And, this was only possible because of the new C–N bond forming step,” Holland elaborates.

“Fundamentally, we’re showing a new way of thinking about how to encourage nitrogen to form new bonds that may be adaptable to making other products,” he adds.



More than two-thirds of respondents said their sites called upon vendor specialists at least sometimes.

The team next would like to improve the energy efficiency of the process and find an electrochemical reduction route rather than use sodium metal. “We would also like to avoid the ‘temperature cycling’ method described in the paper to enable continuous formation of product. Accomplishing these goals will require more detailed understanding of the key steps of C-H bond cleavage, N_2 binding, and H atom loss within the mechanism. We have a three-year grant from the Department of Energy that aims to resolve these issues,” says Holland.

Scaling-up the process for industrial use does pose challenges. “First, the turnover number is very small. Second, it uses sodium metal as a reductant. Third, it requires cycling the temperature between room temperature and -100°C for the current implementation. Obviously, we hope to improve in the future, as noted above,” Holland explains.

“This is a fundamentally new reaction, which will require more research before development into an efficient industrial process is possible. However, it is an exciting idea for the future, to convert arenes into anilines without dependence on nitric acid or high temperatures,” he concludes.

OVERALL REACTION

Figure 1. Researchers devised a new method for potential future catalytic systems that couple nitrogen atoms with abundant hydrocarbons. *Source: Patrick Holland, Yale University.*

Industry Eyes Bio-Based Nylon Precursor

A SUSTAINABLE process to manufacture adipic acid, a key precursor to nylon, is attracting significant industrial interest, note its developers at the University of Edinburgh, Scotland.

Production of adipic acid now relies on fossil fuels and generates the potent greenhouse gas nitrous oxide. However, the Edinburgh team has taken a biosynthetic route by altering the genetic code of *E.coli* bacteria and then growing them in the lignin-derived feedstock guaiacol. After 24 hours at 37°C and atmospheric pressure, the one-pot process transforms the guaiacol into adipic acid. This requires no additional additives or reagents and generates no byproducts.

"It's been great to receive so much interest from industry already, although I can't mention which companies right now," says Stephen Wallace, principle investigator of the study and senior lecturer in biotechnology at Edinburgh's school of biological sciences.

Noting that the annual worldwide production of adipic acid is around 2.6 million tons and worth $6.3 billion, he adds: "The bio-based production of adipic acid from sustainable feedstocks is such a vital solution to limiting the damaging environmental effects of the current adipic acid process that we are really motivated to work as closely as we can with industry as soon as we can to evaluate the translation of this research."

Wallace and his team now are striving to improve the process in several ways, including raising adipic acid yield to over 90% from 60% and developing better ways to isolate it from the engineered cells.

"This was only demonstrated on a small scale at this point, around 0.7 g/L, but scale-up is certainly something we're working on currently," he explains.

Other improvements could come from a better understanding of the action of the chaperone proteins the team used to help fold the enzymes that catalyze the adipic acid reaction within the bacteria.

Wallace believes such knowledge could improve enzyme solubility and, therefore, reaction yield and productivity (Figure 2).

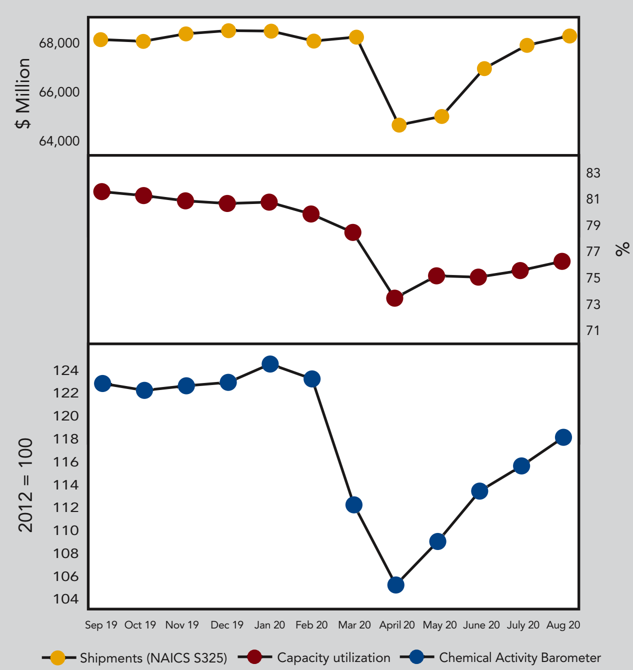
Similarly, the team also is working to understand better — and hopefully optimize — the "unusual, dramatic and quite unexpected" role that different combinations of chaperones and the M9 media used in the study have on adipic acid yield.

"I think being able to precisely control these in a bioreactor will only lead to positive increases in the yield when we scale-up. We are looking into the use of stirred-tank reactors now — and this is also something we're looking to collaborate on with industry," Wallace concludes.

FURTHER RESEARCH

Figure 2. Improving enzyme solubility should lead to increased adipic acid yield. *Source: Mirren White, University of Edinburgh.*

ECONOMIC SNAPSHOT



Again this month, all three metrics rose. *Source: American Chemistry Council.*

Learn from Your Electric Bills, Part 2

Simple calculations can determine the correct power factor that reduce electric bills

Installing a capacitor bank will increase the power factor.

TEXAS A&M University's Industrial Assessment Center (IAC) recently assessed a manufacturing plant and discovered savings of $127,000/y in correcting power factor (PF) on the site's electric service. Do you understand how PF affects your electric bills? If you don't, don't feel bad — probably 99% of plant managers I ask that question answer back with a blank stare! A low PF dramatically increases your billed demand.

Total apparent power in electric circuits is the sum of the "real power" and "reactive power," as total power = real power + reactive power. Real power is able to do work, measured in kW. The reactive power is consumed in energizing a magnetic field, denoted as kVAR. Electric motors are the main users of reactive power, because of the magnetic field generated in their windings. The PF is the ratio of the real power (P_r) to the apparent power (P_a), or PF = P_r/P_a.

Real power and reactive power are 90° out of phase, so they have both magnitude and direction — i.e., they are vector quantities. Their vector sum is the total apparent power, denoted as kVA. We illustrate this as the PF triangle shown in Figure 1.

The beauty of using the PF triangle is that the standard trigonometric relations (sine, cosine, etc.) enable you to solve the elements of the triangle given the minimal information of any right triangle. The PF is equal to the cosine of the phase angle.

As discussed in my previous column (see, "Learn from Your Electric Bills, Part 1," https://bit.ly/2SxKmgQ), most electric companies bill industrial customers both for energy used (kWh), and for demand (rate of energy used, kW). PF can affect the billed demand, although the energy delivery companies in Texas have several different ways of handling this. Some bill on total apparent power (kVA), so any increase in PF reduces the bill. Others specify a minimum PF (PF_{min}) in their rate tariffs. If the actual power factor (PF_{actual}) exceeds the minimum, billed demand will equal actual demand — i.e., the real power (kW). If PF is less, the formula used to set the billed demand is

Billed demand = actual demand × ($PF_{min} \div PF_{actual}$)

With a PF_{min} of 0.95 and a PF_{actual} of 0.75, this calculation gives a ratio of 1.267. This means your billed demand is 26.7% more than your actual demand.

Installing a capacitor bank will increase the PF. The capacitors function exactly opposite to the reactive power vector, reducing the total reactive power and the phase angle, and shortening the apparent power vector as seen in Figure 1.

Using the geometry of the PF triangle, we can readily calculate the impact of a capacitor bank, and the resulting demand savings in an electric bill. This is how the IAC determined the savings for the plant mentioned in the first paragraph. Appendix 1 (see, https://bit.ly/375gZep) contains a detailed calculation of a similar example.

Now, find 12 months of your electric bills and discover the savings for PF correction at your site!

POWER FACTOR TRIANGLE

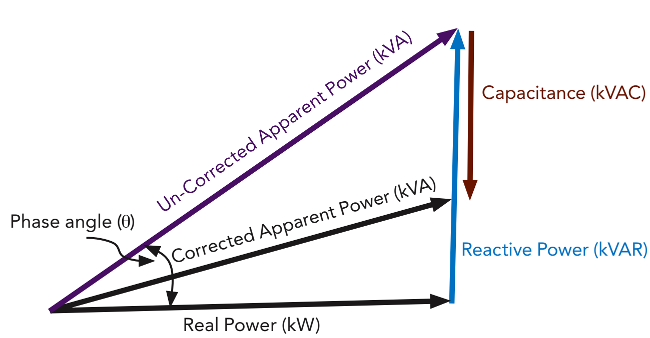


Figure 1. Simple trigonometry can be used to determine power factor.

JIM EGGEBRECHT, PE, Guest Contributor
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Editor's note: This article was written by a colleague of our regular columnist, Alan Rossiter. Jim Eggebrecht, PE has worked at the Industrial Assessment Center (IAC) at Texas A&M University in College Station, Texas for over 27 years as the assistant director. The IAC is a national program of the U. S. Department of Energy's Advanced Manufacturing Office. Eggebrecht has completed over 450 energy assessments for a range of manufacturing facilities. He is also the executive director of the Industrial Energy Technology Conference, hosted by the Texas A&M Engineering Experiment Station, the Texas State Energy Conservation Office, and the Louisiana Department of Natural Resources.

Pandemic Spurs Enforcement Revisions

Memorandum directs federal agencies to consider principles of fairness

For entities subject to enforcement scrutiny, these are wonderful precepts to live by!

THE WHITE House Office of Management and Budget's Office of Information and Regulatory Affairs (OIRA) issued memorandum M-20-31 on August 31, 2020, on the implementation of Section 6 of Executive Order (EO) 13924, "Executive Order on Regulatory Relief to Support Economic Recovery." This article explains the guidance, why it may prove useful to know about its content, and how to leverage the guidance successfully in future enforcement actions and adjudications.

Section 6 of the EO directs the "heads of all agencies" to "consider the principles of fairness in administrative enforcement and adjudication" enumerated in the EO and to "revise their procedures and practices in light of them, consistent with applicable law and as they deem appropriate in the context of particular statutory and regulatory programs and the policy considerations identified in section 1 of this order." The memorandum requests that agencies coordinate with OIRA staff to issue any needed final rules by November 26, 2020 (absent a waiver granted by the administrator), with a request for public comment that agencies may consider in any future revisions.

To assist in implementing Section 6, the memorandum suggests certain "best practices" as the agencies review their existing procedures and prepare any needed revisions. These include, among others, the government should bear the burden of proving an alleged violation of law; administrative enforcement should be prompt and fair; administrative adjudicators should operate independently of enforcement staff on matters within their areas of adjudication; all rules of evidence and procedure should be public, clear and effective; penalties should be proportionate, transparent and imposed in adherence to consistent standards and only as authorized by law; administrative enforcement should be free of improper government coercion; liability should be imposed only for violations of statutes or duly issued regulations, after notice and an opportunity to respond; and administrative enforcement should be free of unfair surprise. For entities subject to enforcement scrutiny, these are wonderful precepts to live by!

The guidance is best understood with reference to EO 13924, which directs federal agencies to undertake certain steps in response to the economic implications of COVID-19. As noted above, Section 6 of the EO identified ten areas agencies were to consider, but set forth little direction on how best to do so. The guidance fills in the blanks. While the guidance relates to the impacts of COVID-19, the plain language makes clear the "best practices," and signals a clear invitation to rely on enforcement discretion well beyond COVID-19-related enforcement situations.

Agencies have until November 26 to issue final rules incorporating Section 6 principles. Whether in fact any will is unclear. The election will have passed and depending upon the results, the guidance will either continue to resonate with federal officials, or not.

However, unless and until the guidance is withdrawn, entities subject to enforcement may want to at least leverage its language to achieve a more favorable enforcement outcome. Consider, for example, the best practice to ensure all penalties are "proportionate" and "transparent." Often the calculation of penalties is difficult to understand, not transparent and done inconsistently despite the existence of penalty policies. Similarly, the best practice to ensure administrative adjudications are "prompt" is game changing — or could be. Administrative enforcement actions, particularly under laws like the Toxic Substances Control Act that rely heavily on science, can proceed with glacial speed. Regional EPA offices often must rely upon EPA headquarters staff for scientific support and direction, thus prolonging cases and delaying resolution. The guidance is a convenient reference document to cite when pushing for a faster pace. Finally, the guidance stresses the need to avoid unfair surprise by preceding enforcement action with a warning. This, too, is a useful precept to advance if an enforcement action is seemingly sudden and its initiation without warning.

As noted, if the administration changes because of November's vote, this guidance may not survive long-term. Assuming it does, the best practices espoused are defense words to live by. Entities that find themselves in actions brought by the government may wish to read the guidance and hold the government's feet to the proverbial fire. The best practices are solid principles to point to in leveraging a favorable result in cases that are a surprise, where penalties seem disproportionate, and where resolution is delayed.

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

FIND MISSED OPPORTUNITIES IN PROCESS CONTROL

Process insights can spur improvements in control

By Gregory K. McMillan, Emerson

THE BEST process control in terms of ability to improve operational efficiency and capacity requires an understanding of the process relationships and the effect of operating conditions set by the automation system. Thus, process engineers clearly should play an important role in process control — but usually don't. This lack of involvement leads to lots of missed opportunities to enhance a plant's process control system.

So, here we'll look at some common opportunities, explaining why they are overlooked and how to take advantage of them.

PONDER FIRST-PRINCIPLE PROCESS RELATIONSHIPS

These relationships can define process cause and effects that can lead to improved controller tuning and performance by the selection of better tuning rules and process variables for scheduling of tuning settings. They also affect the choice of control valve trim and the feedforward design. An online appendix, https://bit.ly/31zATe1, describes many of these relationships and their implications.

DISTURBANCE LOCATION

This is the most fundamental missed opportunity with widespread implications. It stems from a failure to realize that most disturbances aren't on the process output but, rather, on the many inputs to the process, which we term load disturbances. For instance, if you think about the temperature and composition control of any volume, the changes in process streams entering the volume are the disturbances. Likewise, for level and gas pressure control, the disturbances are changes in flows going into and out of the volume. The material and energy balances that determine the value of the process variables being controlled result from inputs; pointing this up, the dynamic model is the integration of the derivatives for these balances. Even control valve problems and pressure changes show up as changes in flows into or out of the process. For surge and pH control, there are momentums and charge balances but material and energy balances still are at play. All this is obvious to a process engineer. Theoreticians and practitioners without a chemical engineering background may view disturbances as being on the process output, making the response for disturbance rejection similar to what is needed for a setpoint response.

Studies in a chemical engineering department over 40 years ago determined that proportional-integral-derivative (PID) control was near optimal for load disturbances [1]. However, control theoreticians developed internal model control (IMC) and touted it as better than PID control. IMC tuning and an emphasis on closed-loop time constant for setpoint response focused on a gradual response to minimize overshoot of the controller output of the final resting value (FRV) for a new setpoint.

For self-regulating processes where the process time constant is much larger than the deadtime, the approach to setpoint is too slow and never will reach setpoint for integrating and runaway processes without FRV overshoot. A fix is to use integrating process tuning rules that emphasize load disturbance rejection with an arrest time instead of relying on the closed-loop time constant as the key parameter for getting the tuning settings. Self-regulating processes with a ratio of process time constant to deadtime greater than four then are classified as near-integrating processes and integrating process tuning rules used. A setpoint lead/lag or a PID structure that puts a 0–1 factor on the effect of setpoint changes on the proportional and derivative mode response provides the desired setpoint response.

PROCESS RESPONSES

Process engineers can better understand the what, why and where of different process responses. The open-loop response (response with controller in manual) indicates the type of process. The open-loop response for a self-regulating process will settle out at a new steady state for a given load disturbance. This response is seen in the derivative for the material or energy balance where there's a term with the process variable that has the opposite sign of the term for the effect of process inputs, resulting in negative feedback in the process. For a near-integrating process, the time to steady state is too long and the response with FRV overshoot needed for load disturbance rejection is similar to that for an integrating process. Composition and temperature control of vessels and columns have a near-integrating response. The open-loop response for an integrating process is a ramp with no steady state in the operating limits. There's no opposite sign term with the process variable in the derivative and, consequently, no negative feedback in the process. The classic example is level but gas pressure, batch composition and temperature control also have an integrating response. The open-loop response for a runaway process will accelerate toward a limit, triggering the safety instrumented system or blowing a relief device. The term with the process variable has the same sign as the one for process inputs in the derivative, causing positive feedback in the runaway process. Common examples are temperature control of highly exothermic reactors and parallel heat exchangers as well as flow pressure characteristics of steam jets and axial or centrifugal compressors to the left of the surge point. The need for more-aggressive proportional action to provide negative feedback correction increases as you go from near-integrating to integrating to runaway processes.

Many people don't realize that too low a controller gain, not just one too high, can cause large oscillations of processes lacking negative feedback, resulting in a window of allowable controller gains. This window closes for excessive deadtime or a secondary time constant. The oscillations generally are much larger and slower for too low a PID gain, too. Most of control theory concentrates on too high a controller gain that causes an unstable process whereas the more frequent case is too low a controller gain. Another chemical engineering department reported over 40 years ago on the dire consequences for a runaway process [2]. While process design should minimize the chances of a runaway, most notably by sufficient cooling capability for exothermic reactors, the increase in heat release is so great for some polymerization reactors that providing fast-enough cooling isn't possible. For safety reasons, a controller isn't placed in manual long enough to see the acceleration, so the positive feedback process time constant is estimated from the derivative for the energy balance.

An appendix available online discusses how you can use material and energy balances to determine the types of process responses and identify process time constants and process gains. (See sidebar.)

TITRATION CURVES

The titration curve from a laboratory often has an abscissa that simply is the volume of reagent added to the sample. You must divide that abscissa by the sample volume and correct for any difference in reagent strength. Often a lab will use a lower reagent concentration than the plant, which is a clue to why pH control is so difficult. You must convert the plant curve abscissa to the ratio of reagent flow to process flow, which — for identical volumetric flow units for reagent and process flows — then is the same ratio as the laboratory curve. The slope of the titration curve is part of the process gain term used for PID tuning and loop analysis. We'll cover the opportunity to get this term and others to correctly describe the open-loop response in the next (terminology revelations) section.

Most computer-generated titration curves using even the most sophisticated software are way off in slope. For strong acids and bases, the theoretical curves have a slope that changes by a factor of ten for every pH unit deviation from neutrality. This theoretical calculation is attractive because it's so easy; some articles in the literature suggest linearization by converting the controlled variable from pH to hydrogen ion concentration by a simple theoretical equation. However, in almost all plant applications, seemingly negligible concentrations of dissolved carbon dioxide from exposure to air and weak acids, bases and conjugate salts make the lab curve slope four orders of magnitude less than the theoretical curve in the neutral region. A charge balance that includes all these components by fast interval halving is the solution,

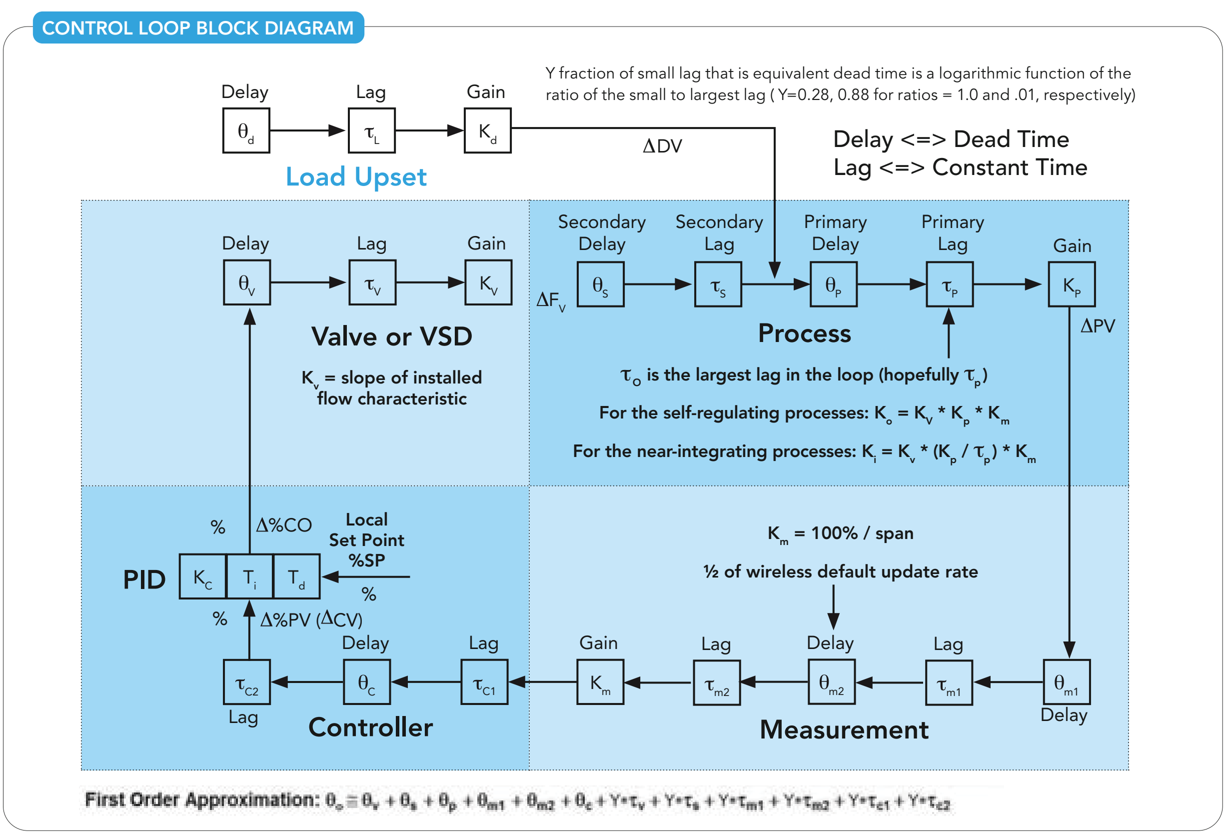

Figure 1. Every part of the control loop affects its dynamics.

as detailed in "Improve pH Control," https://bit.ly/3m8XndR. You may need to adjust carbonic acid concentration for the model curve to match the lab curve slope in the 4–8 pH region, which often is the sector requiring the most-exact slope because the setpoint frequently is near 7 pH.

TERMINOLOGY REVELATIONS

The literature and most software use the terms process gain, process deadtime and process time constant although all the other parts of the control loop affect the terms; Figure 1 shows a block diagram for a PID loop that indicates the impacts. By using more encompassing terms, we can focus on how each part of the control loop influences dynamics — the process part, in particular, often is neglected and not thoroughly analyzed. Better terms are open-loop gain, open-loop time constant and total-loop deadtime.

Consider a self-regulating loop manipulating a valve or variable speed drive (VSD) with flow and process variable engineering units (eu). The open-loop gain (K_o) is the product of valve or VSD gain (K_v), process gain (K_p) and measurement gain (K_m). K_v is the slope of the installed flow characteristic of the valve or VSD in flow eu per % PID output. K_p is the change in the process variable (PV) in PV eu per flow eu. For temperature and composition control, the process gain first is analyzed as the slope of a plot of temperature or composition versus the ratio of manipulated flow to feed flow as seen in a titration curve. You must multiply the slope, i.e., the change in PV eu per change in ratio, by a hidden factor that is the inverse of the feed flow; process gain then is PV eu per manipulated flow eu. The subsequent multiplication by K_m, which, in most cases, is simply 100% divided by measurement span, gives a dimensionless open-loop gain (% PID PV per % PID output) for self-regulating processes. Despite what many academics may think, nearly all industrial PID algorithms work in % signals, not eu.

The open-loop time constant is the largest one in the loop. For composition and temperature control of back-mixed liquid volumes and heat transfer manipulation, the largest time constant is in the process. For flow and plug-flow volumes without heat transfer, the largest time constant is in the automation system — usually the result of a slow sensor (e.g., electrode or thermowell), high transmitter damping or signal filter setting or a slow valve response.

The total deadtime is the summation of all deadtime sources as you traverse the loop. Except for columns, conveyor systems, reagent injection and large plug-flow liquid volumes, the source of most of the total deadtime usually is the automation system.

HIDDEN FACTOR

This factor, which is the inverse of feed flow, is obvious from the derivative for the energy balance. Process engineers can appreciate the consequences in that the open-loop gain dramatically increases at low production rates. That, combined with a larger deadtime from higher transportation delays for lower flow in plug-flow

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volumes, often steeper slope in the plot of temperature versus the ratio, greater valve stiction near the closed position, and more noise in flow signals cause oscillations unless addressed by process, equipment and automation system design.

For example, jacket temperature controllers should manipulate a makeup coolant flow with a recycle and pressure control of cooling water return flow to keep jacket flow constant. A precise throttling valve must regulate the coolant; this should consist of a globe valve with low-friction packing, a sensitive diaphragm actuator and a high gain sensitive positioner.

DEADTIME SOURCES

The minimum peak error and minimum integrated error for a load disturbance is proportional to the deadtime and deadtime squared, respectively, for aggressive PID tuning (e.g., high PID gain and low reset time). The total deadtime is the summation of pure delays plus a fraction of time constants smaller than the largest time constant. As the ratio of the small time constant to largest one approaches one, the fraction approaches 0.88. For equal time constants in series, the deadtime is a fraction of the sum with the fraction approaching 0.88 as the number of time constants approach 100. The deadtime from wireless and digital devices is half the update or execution rate or scan time. The deadtime from at-line analyzers is the sample transportation delay plus half the cycle time plus analysis time.

RATIO CONTROL

The literature touts feedforward control, typically ignoring flow ratio control, which actually is more widely useful. Provided you have good flow meters, keeping a manipulated flow in the right ratio to a feed flow is a great step forward; temperature and composition are plotted against a manipulated to feed flow ratio and the process flow diagram shows the flows for normal operation. You correct that ratio by adjusting a bias for back-mixed volumes and the actual ratio for plug-flow volumes. Many unit operations, most notably distillation columns, are started up on ratio control until the composition or temperature measurement represents desired operating conditions. The ratio uses mass flows in honor of the mass balance. For gas pressure control, flow measurements are too slow, necessitating flow feedforward using linear installed flow characteristics achieved by linear trim and a large valve-to-system pressure drop ratio or by signal characterization.

CORIOLIS METERS

When mass flow measurement is required, opting for pressure and temperature compensation of velocity and volumetric flow meters may not suffice. Process engineers realize that these measurements depend upon a known and constant composition.

Coriolis flow meters are the only true mass flow meters independent of composition. They don't drift to any extent or require periodic calibration; are least affected by upstream and downstream piping configuration; provide an exceptionally accurate density measurement that can be used for an inferential composition measurement for two components with significant density differences; and boast an order-of-magnitude better accuracy and rangeability than all other flow measurements when you take into account the signal-to-noise ratio and all the installation, operating condition and long-term effects. For liquid reactors, the choice is obvious to achieve the right stoichiometry but a closer look at most other applications would reveal the long-term benefits of Coriolis meters for process performance.

VARIABILITY TRANSFER

Process control doesn't make variability disappear but transfers the variability from a key process variable such as temperature, composition or pressure to the manipulated flow. Some applications require tight level control — e.g., reactor residence control by manipulation of discharge flow or material balance control of distillate receivers for internal reflux control by manipulation of reflux flow. For volumes where level can vary, the transfer of variability is minimized just to keep the level within an operating range that doesn't activate alarms. This strategy is called maximization of absorption of variability and most notably is used for surge tanks. Tight or loose level control is achieved by tuning rules that don't violate the low gain limit for integrating processes by keeping the product of the controller gain and reset time greater than twice the inverse of the integrating process gain for level loops. The tuning rule gets more sophisticated for the less-common loops that have a large deadtime.

EXTERNAL-RESET

Controller gains aren't as large as they should be, often because the operator doesn't like sudden changes in manipulated flow. Simply turning on external-reset and using a feedback of the actual manipulated variable, as first documented by Shinskey, will prevent a PID changing faster than a manipulated variable can respond. This enables the use of setpoint rate limits on any manipulated flow.

External-reset feedback has many other benefits, including the stopping of oscillations from a slow secondary loop, slow control valve or VSD, deadband, resolution and sensitivity limits, and unnecessary crossings of split range points. It can handle fast opening and slow closing surge valves and deal with slow wireless update rate and analyzer cycle times for self-regulating processes without retuning. It also can facilitate a fast recovery for abnormal operation and a gradual optimization by valve position control [3] [4] [5].

SEIZE THE OPPORTUNITIES

Using their process knowledge, process engineers can steer automation systems away from many wrong terms suggested by the literature and can discover many missed opportunities. A digital twin that has process and automation system dynamics can provide the knowledge discovery needed. By developing online process metrics, engineers can show the benefits in case studies in the digital twin and, most importantly, the actual process. They can find the consequences of abnormal operation and mistakes as well as viable solutions. Metrics can reveal the value of improvements and consequences of missing or misguided automation. Learning from mistakes and making the most out of opportunities by a synergy of process and automation knowledge and the digital twin as the proving ground are the keys to a future of innovation [6] [7] [8]. ●

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Modeling Buoys Water Systems

Insights on water chemistry can provide significant benefits

By Seán Ottewell, Editor at Large

WATER AND its associated electrolytes influence a vast number of chemical reactions and processes, including oxidation and reduction, neutralization, pH control, flue-gas treatment, waste stream clean-up, mineral scaling and corrosion. These, in turn, affect the design of equipment and processes as well as lifecycle optimization — and, therefore, productivity and profitability.

So, properly accounting for water chemistry and its evolution is crucial.

"However, while water-chemistry-based process modeling optimizes the performance of assets and processes, it's very hard to do right," cautions A. J. Gerbino, vice president, application consulting and client success for OLI Systems, Parsippany, N.J. "It's not something that should be considered just as a side application."

Doing it right means having comprehensive capabilities for electrolyte modeling and simulation — so the company's software products cover electrolyte chemistry analysis, aqueous corrosion modeling, process flowsheet calculations and process modeling integrations.

GETTING THE HOLE PICTURE

Figure 1. Alloy corrosion is one of many issues that modeling is tackling. *Source: OLI Systems.*

"What's different about our approach is that we use electrolyte thermodynamics to understand the core mechanisms that are at work in, for example, redox reactions, ion exchange processes and surface complexation. It is essential that we model all of these," he adds.

Gerbino cites the growing use of reverse osmosis (RO) membranes in water treatment as a classic example of why this approach is important.

In one project, the operating company had multiple species of dissolved boron present in its wastewater.

"Standard RO modeling packages treat these species — and different species of many other contaminants — as the same. They aren't. We have developed RO object calculations that use the properties of the different cations, anions and neutrals in the water to predict their permeability across membranes," he explains.

Once the composition of the permeates and concentrates was calculated accurately, OLI Systems' software tools estimated the scaling hazards they pose and advised the operating company on how to optimize the use of scale inhibitors.

"Note that we don't solve the problem; what we do is provide a better understanding of the water being used and how much precipitate there could be — so dosing can be much more accurate," says Gerbino.

This same knowledge also is key to optimizing emerging membrane technologies, for example, nanofiltration, osmotically assisted RO, ion-selective membranes and membrane distillation.

It can provide insights on issues as diverse as amines and their associated hydrochlorides, mercaptan chemistry, alloy corrosion and working out the optimum salinity in cooling water applications (Figure 1). A common use is to identify causes of mineral scaling, e.g., with acid gas scrubbing; there, the risk of such scaling rises if the concentration of the metal carbonate gets too high. Condensation in the overheads of hydrofluoric (HF) acid alkylation units, used by refineries to boost octane levels and reduce knocking, can cause corrosion problems, too.

The June 21, 2019, blaze at the Philadelphia Energy Solutions refinery, which released more than 5,000 lb of HF acid into the atmosphere, underscores the risk. The U.S. Chemical Safety and Hazard Investigation Board subsequently found that the likely culprit for the initiating event, a faulty pipe elbow, was just 0.012-in. thick (https://bit.ly/3ddj34Y). The company has since gone out of business.

(Editor's note: HF alkylation also poses significant challenges for sealing of flanged connections; for details on how one refinery has achieved unprecedented sealing performance, see: "Refinery Tames Tough Sealing Service," https://bit.ly/2SEnxs8.)

"The bottom line is that modeling should be used wherever water is being used in a process," stresses Gerbino.

The company now is focused on unlocking the benefits of advances in software automation, the Industrial Internet of Things, analytics, cloud platforms, artificial intelligence and predictive maintenance.

At the heart of this effort is its electrolyte chemistry digital-twin framework that carries out data reconciliation and analysis of plant-level chemistry models using operations data. This will deliver improved accuracy in three areas: prediction of plant electrolyte chemistry behavior; sensitivity analysis and planning for asset/process design; and soft sensors to non-invasively predict many key parameters including pH and composition.

Early 2021 should see the launch of a new series of products, including OLI Cloud Apps, OLI App Builder Platform, OLI Cloud application programming interfaces (APIs) and OLI Optimizer Tool, that take advantage of the development.

"Our Cloud APIs will give users rapid access to the information they need in a way that is much simpler for them to scale and integrate with other process simulation and optimization tools which a plant is using," claims Vineeth Ram, the company's chief revenue officer.

EVOLVING CONSTRAINTS

The challenge for many water-treatment systems is that their original design constraints don't remain fixed over their lifecycle, notes Jason Nichols, advanced analytics leader, Suez – Water Technologies & Solutions, Niskayuna, N.Y.

Operating an existing design with new constraints while maintaining safety margins requires an operational knowledge of the water chemistry and how that chemistry evolves over time, he stresses.

"If the evolution of water chemistry is considered at design time, rather than designing to static maximum load/minimum quality requirements, operators could better manage changes in constraints during the lifecycle of a system. It often isn't. However, you do need to know a heck of a lot about the water chemistry involved when designing, or reimagining the design, for water treatment systems to be optimal over their entire lifecycle," he explains.

Usually economic pressures are the short-term drivers for Suez customers needing to reduce operating costs, most commonly by producing more or cleaner water with the same size equipment, or by cutting energy or maintenance costs.

Heat exchangers exemplify this, Nichols notes. Typically only investigated during planned maintenance outages, they are coming more under the spotlight as companies look to use renewable fuels and decrease greenhouse gas emissions.

"People want to see what is happening in terms of underlying trends within heat exchangers which affect, for example, fuel and anti-scalant consumption. Even if heat transfer efficiency is improved just by an extra 0.25%, it's worth a lot of money over time. So we use models that can be executed in real time from plant data to find ways of improving their availability and reliability," he says.

Corrosion chemistry is another hot topic for Suez, reflecting operating companies' concerns about expensive retrofits as well as harder access to capital. So, the firm has developed a number of proprietary models for various water chemistries to help equipment last longer. "Understanding how corrosion is actually evolving in a system in real time is key for condition-based maintenance plans to make that happen," Nichols notes.

Driving all this modeling work is an effort to understand the true variance of process data (Figure 2).

Nichols points out that many chemical processes typically run at steady state — so even with large amounts of data, the signal often doesn't show much variance. However, when external pressures, such as economics, weather leading to shutdowns or differing water qualities, disrupt steady-state assumptions, process monitoring and analytics can't account for much of the variability. Hence, data-driven approaches are necessary, he says.

"The solution is to not try to infer that which you already know. In my experience, the amount of data needed to statistically infer a process model is far less than what's needed to calibrate one."

As an example, he cites an ultrafiltration (UF) fouling model the company is working on. It has studied the reasons for underlying changes in system performance and generated equations to describe the non-fouling-related variations in the system.

"So, we can model a wastewater UF system and account for process variances as the process goes up and down in production. This is simply real-time process normalization but it allows us to then use data-driven models to infer the long-term fouling and short-term external factors that aren't accounted for. We take the same approach with heat exchangers, falling-film evaporators, compressors, UF/RO systems, etc.," he explains.

The next step for Suez is getting process models to correctly simulate dynamic controls. However, uncharacterized hysteresis in system responses and long time constants for degradation in its models make predicting where a system is going into the future challenging.

"This is also tough to get using a data-driven solution. Most plant owners won't let us drive their plant to the edge of the performance envelope just to collect some data for our models! Being able to model non-steady-state process dynamics means we can do simulations and drive the simulated plants into known fault zones and create algorithms to spot these situations in the field," Nichols concludes.

TAKING A DIFFERENT TACK

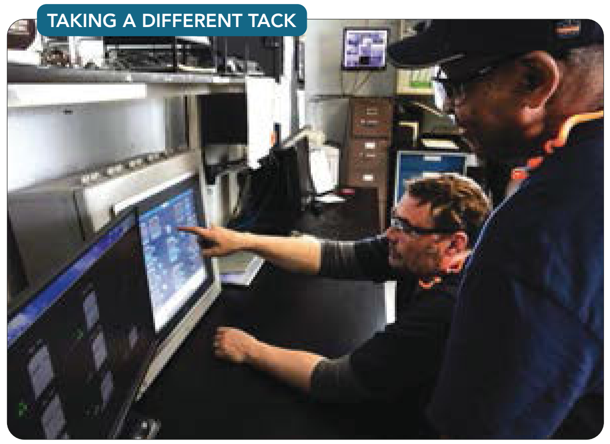

Figure 2. Understanding the true variance of process data requires a data-driven approach. *Source: Suez – Water Technologies & Solutions.*

ASSSESSING SCENARIOS

The value of modeling lies in the ability to run a lot of 'what if?' scenarios without the need for laboratory or pilot testing, says Matt Gerhardt, vice president of industrial water at Brown and Caldwell, Walnut Creek, Calif.

"It's both faster and less expensive. So, for example, we can demonstrate if an existing water-treatment system is adequate or whether it needs to be expanded/upgraded — and the implications of such decisions on overall plant performance, optimization, opex, capex, etc.," he points out.

Operating companies typically call upon the firm to carry out modeling for material compatibility, permit compliance, evaluation of wastewater treatment chemicals when a plant is expanding or a new product is being brought online, and assessment of alternative treatment chemicals.

Brown and Caldwell models physical and chemical treatment processes with OLI Systems Flowsheet and Studio, and biological treatment processes with BioWin from EnviroSim, Hamilton, Ontario.

One recent project involves a specialty organic chemicals manufacturer that produces a waste requiring anaerobic treatment. The waste also contains a lot of nitrogen. "We used BioWin to model and create a series of anaerobic and anoxic treatment tanks linked in series without inter-stage sludge removal," notes Gerhardt. Subsequent pilot tests with the new process convinced the chemical maker to build a full-scale $100-million facility.

Another involves a starch manufacturing plant in the U.S. that modifies starch with phosphorus to use as a thickener in food processing. "However, the company's wastewater contains an enormous amount of phosphorus — a sizable fraction of the state's total phosphorus discharge," he explains. Following requests by the local regulator to reduce this, Brown and Caldwell modeled the process and now is doing pilot tests to recover the phosphorus using calcium and then turn it into fertilizer for resale.

Another project posed an interesting situation: the treatment plant was deemed to have too much total ammonia — the product of un-ionized ammonia (NH_3) plus ionized ammonia (NH_4^+) — in its wastewater. Here, modeling the wastewater flow from the outfall pipe provided an understanding of how pH and total ammonia concentration change with distance from the outfall.

"We showed that the concentration of un-ionized ammonia and pH dropped within a very short distance, due to both dilution and conversion to ammonium ion. It turned out that this was happening in such a small volume that the existing effluent discharge wasn't an issue: it was an argument accepted by the local regulator."

New processes demand new wastewater-treatment strategies, stresses Gerhardt, citing as an example the situation faced by a company developing a COVID-19 vaccine.

"I can't say much about this except that it was a brand-new process with new compounds for which treatability and toxicity data were not available. We developed a plan for evaluating treatment in parallel with the vaccine development and other testing to prevent wastewater treatment from becoming the rate-limiting step. I'd say what was unique about this was that a lot of things that ordinarily would have been done sequentially were happening in parallel to meet schedule."

A couple of modeling issues still pose challenges for his engineers, Gerhardt admits. One relates to the adsorption strategy the company uses to remove arsenic and selenium from water and wastewater. A common treatment system involves adding an iron salt, adjusting pH to precipitate iron oxyhydroxide, and then adsorbing the arsenic or selenium onto the iron oxyhydroxide surface. "I do not know of a good way to model this, because the amount adsorbed per unit mass of iron is not fixed and is not easily predicted."

Also, he would like to be able to simulate chemical and biological treatment technologies at the same time because they increasingly are being used together. "At the moment, [we] have to export data from one into the other. I think that's because they are really two very different fields of expertise," he notes. ●

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Avoid Costly Failures of Shell-and-Tube Heat Exchangers

Understand the most common causes and how to prevent them

By John Boyer and Jim Klimek, Xylem

MANY PROCESSES use heat exchangers to adjust or maintain the temperature of streams and unit operations. An efficient heat-transfer system plays a key role in cost-effective manufacturing — while a heat exchanger failure can lead to costly downtime.

Plants often rely on shell-and-tube heat exchangers. Properly selected, installed and maintained, these units can operate reliably and efficiently for long periods. Failures, when they occur, commonly stem from three causes:

1. Chemically induced corrosion resulting from a chemical interaction with circulating fluids;
2. Mechanical damage due to, e.g., metal erosion, steam or water hammer, or thermal expansion; and
3. Scale, mud or algae fouling that creates an insulating effect and, ultimately, corrosion.

You can avoid each of these types of failure.

Here, we'll review the operational problems that can develop in a shell-and-tube heat exchanger and describe corrective actions you can take to prevent them.

GENERAL CORROSION

Figure 1. This usually involves a relatively uniform attack over a surface, often without evidence of its occurrence.

CHEMICALLY INDUCED CORROSION

These failures result from the complex chemical interaction between the materials of the heat exchanger and the fluids circulated through it and numerous other system controls. Common types of chemically induced corrosion failures include:

- general corrosion;
- pitting corrosion;
- stress corrosion;
- dezincification;
- galvanic corrosion;
- crevice corrosion; and
- condensate grooving.

General corrosion. A relatively uniform attack over the tube, tube sheet, inlet bonnet/channel or shell characterizes this type of corrosion (Figure 1). You may see no evidence that corrosion is occurring.

Fairly stable aggressive conditions generate this type of attack. Low (< 7) pH combined with either carbon dioxide or oxygen can produce this attack on copper. A blue or bluish-green color can appear on the tubes as a result of a carbon dioxide attack on the surface of a copper tube. Various chemicals such as acid also create this type of metal loss.

The solution: Choose a material with adequate corrosion resistance for the environment and use proper treatment chemicals to maximize heat exchanger life. It's important to keep in mind the various factors working in combination. Most material/chemical compatibility charts don't account for this, so you many need to consult a metallurgist.

Pitting corrosion. Localized pitting frequently occurs in both ferrous and nonferrous metals. It results from the electrochemical potential set up by differences in oxygen concentration within and outside of the pit; this often is referred to as a concentration cell. The oxygen-starved pit acts as an anode while the unprotected metal surface serves as a cathode. You only may see a small number of pits — however, any one can cause a heat exchanger failure.

Pitting corrosion is most likely to occur during shutdown periods when there is no flow and the environment is most suitable for the buildup of concentration cells. Scratches, dirt or scale deposits, surface defects, fractures in protective scale layers, breaks in metal surface films and grain boundary conditions can further enhance the susceptibility to pitting corrosion.

The solution: Select suitable materials of construction. In addition, properly clean and prepare the heat exchanger for shutdown periods. Failure to do so can result in pitting corrosion beginning within a matter of days; it eventually will lead to failure of the surface and cross contamination of the two fluids.

Stress corrosion. This form of corrosion attacks the grain boundaries in stressed areas. Heat exchanger tubes usually have both avoidable and unavoidable residual stresses. These stresses result from drawing or forming the tube during manufacture, forming U-bends or expanding the tubes into tube sheets. Failures from this corrosion take the form of fine cracks that follow lines of stress and material grain boundaries.

Chloride ions can cause stress corrosion on stainless steel tubes while ammonia can prompt stress corrosion cracking on copper or copper alloy tubes.

The solution: Keep tube wall temperatures below 115°F (calculated with maximum, not average, fluid temperatures) to prevent stress corrosion cracking problems with a chloride ion concentration up to 50 ppm. Where you expect low concentrations of ammonia, use copper-nickel alloys because they have good resistance to stress corrosion cracking.

Dezincification. This creates a porous surface due to chemical removal of zinc from the alloy. Dezincification occurs in copper-zinc alloys (containing less than 85% copper) when they come in contact with either stagnant solutions or water with a high oxygen and carbon dioxide content. The effect tends to accelerate as temperature increases or pH decreases below 7.

The solution: Use a brass with lower zinc content or one containing tin or arsenic to inhibit the chemical action. You also can forestall the problem by controlling the environment, i.e., avoiding contact with stagnant solutions or water with a high oxygen/carbon dioxide content.

Galvanic corrosion. This occurs when dissimilar metals are joined in the presence of an electrolyte such as acidic water. It usually produces a higher rate of reaction on the less noble metal, causing it to corrode quickly.

The solution: First, check the galvanic chart (Figure 2), which shows the relative potential of materials to support this type of corrosion; metals grouped together have lower tendencies to produce galvanic corrosion. Avoid coupling two metals from substantially different groups in an electrolyte, otherwise substantial corrosion of the less noble metal will result. Typically, a voltage difference greater than 0.2 V suggests a galvanic risk; the further apart the metals are, the greater the risk of corrosion. Consider not only the different materials for the heat exchanger components but also for piping and fittings connected to the heat exchanger.

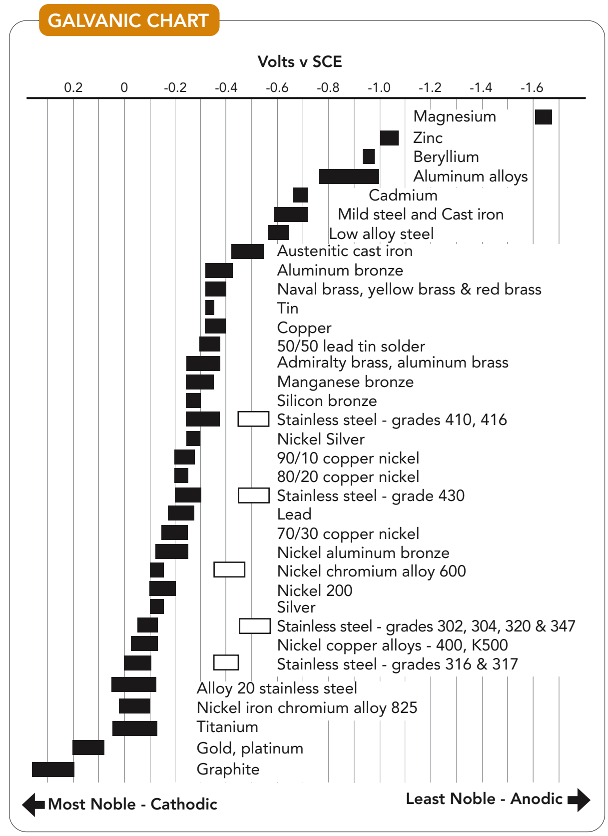

Figure 2. Choosing metals relatively close to each other will decrease the propensity for galvanic corrosion.

Crevice corrosion. Such corrosion originates in and around hidden and secluded areas, such as between baffles and tubes, or under loose scale or dirt. It requires oxygen to begin. A localized cell develops, with the resulting corrosion appearing as a metal loss with local pits. This often gives the impression that erosion is taking place. Relatively stagnant conditions must exist for crevice corrosion to occur.

The solution: You often can control the attack by ensuring that velocities suffice to prevent stagnation or the accumulation of solids. Also, bear in mind that process fluids believed to be oxygen free may not be; achieving oxygen-free process fluids is difficult.

Condensate grooving. This occurs on the outside of steam-to-water heat exchanger tubes, particularly in the U-bend area. It shows up as an irregular groove or channel cut in the tube as the condensate, in the form of rivulets, drains from the tubing (Figure 3). A corrosion cell usually develops in the wetted area because of the electrical potential difference between the dry and wet areas. The condensate, which must be aggressive for grooving to take place, wears away the protective oxide film as it drains from the tubing.

The solution: You usually can reduce condensate grooving by controlling condensate pH and dissolved gases, and through cleaning the outside surface of the tube bundle to remove oils that prevent uniform wetting.

MECHANICAL FAILURES

These can take many different forms including, but not limited to:

- metal erosion;
- steam or water hammer; and
- thermal expansion and cycling.

Metal erosion. Excessive fluid velocity on either the shell or tube side of the heat exchanger can cause damaging erosion of metal from the tubing. This can accelerate any corrosion already present because erosion potentially can remove the tube material's protective film, exposing fresh metal to further attack.

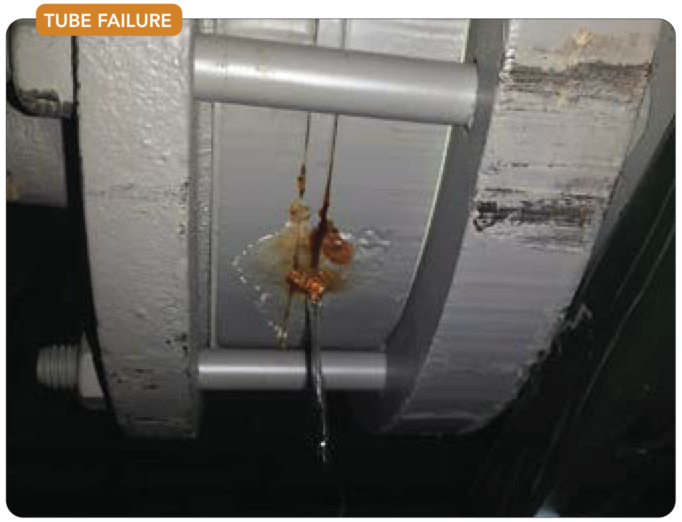

Figure 3. Condensate draining from tubes in steam-to-water heat exchangers can cut a channel in metal.

The areas most prone to erosion are the U-bend of U-type heat exchangers and the tube entrances. Tube entrance areas can experience material loss when excessively high velocity fluid from a nozzle splits into much smaller streams as it enters the heat exchanger. Excessive velocity occurring at the entrance area of tubes typically produces a horseshoe-shaped erosion pattern.

The solution: Keep flow to the maximum recommended velocity in the tubes and entrance nozzle. This value depends on many variables including tube material, the fluid handled and temperature. Materials such as carbon steel, copper-nickel and stainless steel withstand higher tube velocities than copper. Typical tube velocity limits are: copper — 8 ft/s; carbon steel — 9 ft/s; 90/10 copper-nickel — 11 ft/s; and stainless steel — 11 ft/s.

Erosion problems on the outside of tubes can occur with impingement of wet high-velocity gases such as steam. You can control wet gas impingement by oversizing inlet nozzles or placing impingement baffles in the inlet nozzle.

You can determine typical shell-side nozzle velocity limits to prevent impingement erosion on the outside of tubes via an equation involving density, ρ, and shell nozzle velocity, V2:

$\rho \times V2 = 1,500$

where density is in lb-m/ft^3 and velocity is in ft/s.

Steam or water hammer. Pressure surges or shock waves caused by the sudden and rapid acceleration or deceleration of a liquid can create steam or water hammer. The resulting pressure surges can reach levels up to 20,000 psi, which is high enough to rupture or collapse the tubing in a heat exchanger.

In a water/steam heating application, damaging pressure surges can lead to an interruption to the flow of cooling water. The stagnant cooling water is heated beyond its boiling point to generate steam; the resumption of the flow causes a sudden condensing of the steam that produces a damaging pressure surge or water hammer.

The solution: Always start cooling water flow before applying heat to the exchanger. Also, use modulating control valves rather than fast-acting shut-off valves, which open or close suddenly and cause water hammer. If you handle condensable fluids in either the shell or tubes, vacuum breaker vents can help prevent steam hammer damage resulting from condensate accumulation.

The installation of properly sized steam traps with return lines can help forestall steam hammer by stopping condensation from accumulating in the shell. Also, ensure the lines are pitched to a condensate receiver or condensate return pump.

Thermal expansion and cycling. Accumulated stresses associated with repeated thermal cycling or expansion can result in tube failure. Exchangers with U-tube-type construction best handle thermal expansion and cycling because the bundle can expand and contract within the shell. With a straight-tube fixed-tube-sheet design, the tubing can't expand or contract.

The problem becomes much worse as the temperature difference across the length of the tube increases. The temperature difference causes tube flexing, which produces a stress that acts additively until it exceeds the tensile strength of the material, which then cracks. The crack usually runs radially around the tube and often results in a total break. In other cases, the crack occurs halfway through the tube and runs longitudinally along it. Failures due to thermal expansion of fluids most commonly afflict steam-heated exchangers.

The solution: Put relief valves in the heated fluid system to avoid this kind of failure. Also, it's advisable to provide some means to absorb fluid expansion. For example, installing a tank in the heated fluid system prevents periodic discharge of relief valves, which results in a loss of system fluid and places an undue burden on the valve. Position these devices between the heat exchanger and any shut-off or control valves.

SCALE, MUD AND ALGAE FOULING

Various marine organisms or deposits can leave a film or coating on the surfaces of heat transfer tubes. The film

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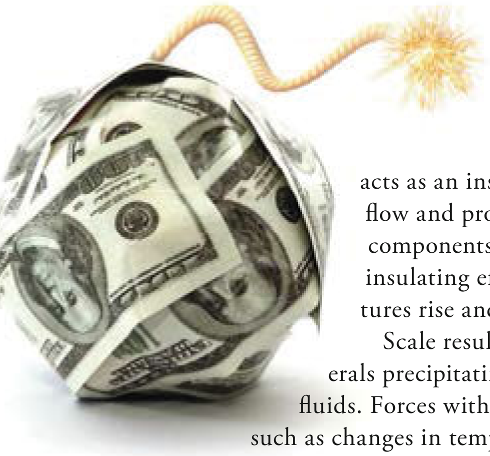

acts as an insulator, restricting heat flow and protecting the corrosive components. As a result of this insulating effect, tube wall temperatures rise and corrosion increases.

Scale results from dissolved minerals precipitating out of heat transfer fluids. Forces within the heat exchanger, such as changes in temperature or chemical reactions, alter the solubility of these minerals. For example, calcium bicarbonate, a common constituent of many waters, releases carbon dioxide when heated. This reduces the material to calcium carbonate, which is a relatively insoluble compound that precipitates and coats heat transfer surfaces.

The solution: Experience shows that increasing the fluid velocity reduces the rate of precipitation. Of course, you must match fluid velocity to the tube material's ability to withstand the erosive effects of velocity.

Suspended solids usually are found in the form of sand, iron, silt or other visible particles in one or both of the heat transfer fluids. If velocities aren't high enough to keep them in suspension, particles settle out, causing the same kinds of problems associated with scale from dissolved solids. In addition, many suspended solids are very abrasive to tubing and other heat exchanger parts. When handling abrasive suspended solids in a heat exchanger, you must keep fluid velocity low enough to prevent erosion.

Algae and other marine organisms are a serious problem if they get in the heat exchanger. In many cases, the environment in the heat exchanger spurs their rapid proliferation, which restricts flow and impedes heat transfer.

The solution: Chemical algaecides such as chlorine can effectively control algae and other marine organisms; always check to ensure any chemical treatment is compatible with the materials of construction. High fluid velocities also discourage their attachment and expansion. ●

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Figure 1. Sturdy chutes already are in place as belt conveyor is being constructed.

Don’t Fall Short with Transfer Chutes

Understand key points about these bulk-material-handling units | By Amin Almasi, mechanical consultant

TRANSFER CHUTES guide and control bulk materials moving from one piece of equipment or place to another, for instance, from one conveyor to the next. These chutes find wide use in many configurations and arrangements.

While chutes are important components in material handling systems, they usually don’t get adequate attention. As a result, they often create bottlenecks in the systems and require extensive maintenance and repair. It is far cheaper to carefully engineer and manufacture a chute than to deal with the consequences of a poorly designed or fabricated one. So, here we will discuss practical pointers on engineering, operation reliability and maintenance of chutes.

DESIGN ISSUES

Ensuring smooth flow of bulk materials without any accumulation or plugging anywhere depends on the proper size and slope of chutes. Different guidelines exist for the cross-section, sizing, slopes and dimensions of chutes. Minimum cross-sectional area of chutes often is specified as 5–8 times the area of cross load of the preceding conveyor (or upstream equipment). Avoid any ratio below 4.5.

Undersized chutes have resulted in blockages and other problems. In practice, chutes should be able to store some volume of material in case of emergency, for instance, malfunction, a temporary stop of the next conveyor or equipment or a surge in upstream conveyor/equipment.

Avoid direct impact of bulk material on the next conveyor belt or piece of equipment. While a very steep angle is not desirable, the slope should suffice to ensure good flow of the bulk material. The optimum angle of inclined surfaces of chutes depend on the specific service and bulk material. However, as a rough guideline applicable to many materials, using a surface inclined at 65° or even 70° of valley angle will properly guide bulk materials. Valley angles below 55° are risky. In addition, the chute design should have a minimum amount of throat constriction and have sufficient support.

Unfortunately, many traditional designs for chutes don’t meet these cross-section and valley angle guidelines, undermining prospects for smooth and trouble-free flow of bulk materials. Indeed, such chutes often provide poor performance.

The bottoms of chutes are frustums of cones or truncated pyramids to aid the discharge of materials. Good chute design requires more than having the correct cross-sectional area and slope.

When bulk material discharges to a chute and impacts the chute surface, its velocity decreases. The larger the impact

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angle, the bigger the change in velocity. Sliding friction with the chute surface can decrease the material stream velocity even further. If the friction between the bulk solid and the chute walls and wear liners becomes too great, bulk material flow may halt on the chute surface, creating a plugging condition; this not only can cause operational problems but also can present a set of new dangers such as risk of fire or explosion. In addition, flow issues such as "arching," "ratholing," etc., can occur. Poor chute performance also can lead to material spillage, considerable dust generation and many other operational problems.

Moreover, when flow abruptly resumes again such as when arches and ratholes collapse, sudden dynamic forces act on the chute or surrounding equipment. These forces can cause structural damage. Also, the development of eccentric flow channels within a chute, particularly due to multiple or offset outlets, can result in non-uniform loading along the outer walls of the chute that may cause wrinkling or buckling of the chute.

The internal surface of a chute must contend with constant abrasion from the flow of material and can suffer wear and damage. Sometimes, such degradation is very fast and can be catastrophic. So, providing replaceable liners made of suitable abrasion-resistant material nearly always is necessary to cope with the impact and erosion. The selection of lining material depends on the service and application. Alloy steel is widely used but ceramic, rubber and other types of linings are available.

ENSURING ADEQUACY

The engineering, manufacturing and operation of a chute depends on knowing the properties of the bulk material in relation to the flow surfaces. Serious flow problems can result from not having accurate data or not testing the actual bulk material transported and the actual lining considered for the chute. Data from the testing of the specific bulk material and the particular construction materials, such as alloy steel or ceramic liners, are critical. These data will help predict the flow of the material through the chutes and, thus, enable coming up with a design to reduce wear on components and eliminate the escape of fugitive material like spillage and airborne dust.

Chutes should be strong and rigid to resist massive forces and potential erosion and corrosion (Figure 1). For commonly used applications, chutes usually are constructed from steel plates of 8-, 10-, 12- or 16-mm thickness or more. Specifically, small and medium chutes (bunkers, hoppers, etc.) generally use 8-, 10- or 12-mm plates. Large chutes (or silos) might need thicker plates, sometimes even 16- or 20-mm ones, depending on load calculations and modelling.

Ease of maintenance is a key consideration. Chutes often are constructed in flanged sections connected with bolting. The number and sizes of bolts are important. As an indication, common chutes use M16 or M20 bolts. Sections requiring removal for maintenance most often are fitted with lifting eyes or lugs located in convenient positions. Frames, flanges, supporting structures or head integral with plate fabricated items should be made from thick plates or properly selected profiles; such flanges typically are fabricated from 16- or 20-mm (or even thicker) plates.

A chute usually comes with a large hinged inspection door — generally at least 600 mm × 600 mm — to enable the clean-out of blockages and to ease inspection and maintenance; necessary maintenance tools may mandate even larger dimensions. The inspection door should be dust tight as well as easily opened and closed without the use of tools.

Gates find wide use in material handling systems to control flow of material in transfer points and different chute systems. They may be placed on the bottom or side of bins, tanks, hoppers or similar equipment to feed materials onto conveyors or other material-handling equipment. However, gates also have other applications — for instance, a flop gate can enable feeding from a single source to two locations. Gates come in many different types and models; they can be manually operated or powered by electric motors or pneumatic actuators. All too often, gates suffer operational problems because of lack of adequate attention to their design, engineering and operation.

Using a proper simulation method to observe and verify the flow of bulk materials in chutes is extremely important. Many simulation and modelling methods, such as discrete element modelling, suit this purpose. These can provide an excellent way to understand material stream flow behavior in a given configuration and enable ensuring optimum material stream trajectory. To reduce wear, you should minimize free fall heights and changes in the direction of material flow. This not only decreases impact forces but also attrition, dusting and fluidization of fine materials. You also can limit dusting by keeping the material in contact with the surface, concentrating the material stream, centering the stream and ensuring it stays in the direction of flow, and maintaining as constant a velocity as possible through the equipment.

It also is necessary for the entire cross-sectional area of the outlet to be active. Any system or equipment used in the outlets should be capable of continuously withdrawing bulk material from the entire outlet. A restricted outlet (e.g., due to a partially open slide gate) will result in funnel flow with a smaller active flow channel regardless of the outlet configuration.

BELT CONVEYOR CONSIDERATIONS

When feeding a bulk material containing a mixture of fine and lumpy material to a belt conveyor, you can arrange the chute to first deposit the fines on the belt. This bed of fine material then acts as an impact absorbing layer for the more-severe lumpy material.

Off-center or improper loading of the belt is a major problem that poor chutes can create. A chute should place bulk materials in the center of the belt. The direction of the material down the chute should match the direction of the belt travel. The speed of the discharged materials should equal as closely as possible the belt speed. The speed of the bulk material as it leaves the chute depends on the velocity of the material entering the chute, the chute angle, the fall, the material density and the flowability of the material. To increase the speed of material, use a steep chute angle — but angles above 75° result in a rapid decrease in the forward speed. Conversely, reducing the chute angle raises the material speed in the direction of belt travel — but angles less than 55° cause slow flow of the material through the chute.

Each service and application has an optimum chute angle; this optimum angle usually is between 60° and 75°. Heavier materials, because they flow more quickly through the chute, can get by with a relatively smaller chute angle, while light materials require a steeper angle. Lumpy materials tend to tumble and bounce in steep chutes, impeding the material flow. Therefore, while increasing the chute angle is desirable for light materials, for lumpy ones you should limit the chute angle to not more than 70° to prevent this tendency.

In many instances, the material may enter the chute at a very high velocity. A relatively low chute angle would limit, and possibly could retard, the material speed. However, opting for such a chute angle isn't recommended practice unless the exit speed is close to that of the belt. An alternative means of limiting high lump velocities is to hang baffle bars or similar devices in the path of the lumps. ●

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Photo courtesy of Lanxess

Specialty Chemicals Maker Does More with Data

Specific steps foster the success of global roll-out of advanced analytics | By Edwin van Dijk, TrendMiner

CHEMICAL MANUFACTURERS have been capturing data from operations for many years. Many of those companies have used the sensor-generated data to improve operational performance through various analytical means. Recent years have seen a lot of developments due to the rise of data science and "lighthouse" projects to prove data analytics can bring organizations to new levels of efficiency, safety and agility.

Developments in "big data" analytics, machine learning and application ease-of-use have spurred increasing interest — and led to two major groups trying to analyze operational performance issues:

- engineers on-site focusing on daily troubleshooting and continuous improvement projects typically using spreadsheets and trend charts, etc.; and
- a central team that includes data scientists handling more-advanced data science modeling.

These groups fundamentally differ in their approach. On-site engineers, who have been trained in the concepts of separation technology, and mass and heat transfer, use their technical knowledge and hands-on experience to address emerging production issues. In contrast, data scientists focus on modeling and interpreting the data generated by the plant.

BRIDGING THE GAP

Now, though, new so-called self-service industrial analytics tools enable the engineers to handle analyses that previously required a data scientist. The tools eliminate the need to develop a data model and, so, allow the engineers to work directly with and in their trend data using pattern recognition technology (Figure 1) in combination with data science techniques and machine learning technology in the back end.

Analytics-empowered engineers themselves can tackle many operational issues such as:

- *Solving previously unsolved questions.* By using search, filtering, automated pattern recognition and recommendations from the analytics platform, they can find potential root causes of performance drops.
- *Testing and verifying the validity of a hypothesis.* Often people in operations have a theory about what's causing certain operational behavior. Using data analytics to assess the soundness of this supposition can eliminate the need for discussions that can consume a lot of time.
- *Finding new ways to improve performance.* Insights obtained from data can illuminate previously unappreciated opportunities to enhance operations.
- *Using actionable dashboards to monitor operational performance in real time.* Time-series data can

underpin the creation of best-performance operating windows or fingerprints of good behavior. Such dashboards can serve to monitor ongoing operations and alert key stakeholders to take appropriate, proposed action.

- *Gaining additional awareness into operational performance.* Use of contextual information from third-party business applications, together with other contextual information from other systems, can provide a full operational context to the engineers.

Engineers now can work on more and more difficult use cases. At the same time, the greater efficiency of data scientists' tools enables them to work on less complex use cases. This gives an overlapping area, where the two groups understand each other better and can start collaborating.

A CORPORATE EXAMPLE

Lanxess, Cologne, Germany, is a specialty chemicals company active in 33 countries. It focuses on developing, manufacturing and marketing chemical intermediates, additives, specialty chemicals and plastics. To thrive in this very competitive sector, Lanxess realized it needed to give its production specialists the tools to continuously improve operational performance of their plants.

Lanxess chose to implement self-service industrial analytics software to bring transparency to its production processes and democratize data for all its operations-related employees. The tool now is installed at 75% of Lanxess' plants worldwide, including all major sites in Europe and North America, with further roll-out continuing. The results have catapulted the company ahead of the competition.

Savings in individual cases have topped six figures, and such wins are multiplying across the group. However, even more importantly, everyone from plant managers to production-line employees now have real-time access to actionable, live production and operational data. That means predictive maintenance and automatic yield calculations, fluid optimization of chemical runs for purity and energy efficiency, and golden-batch detection and analysis.

Jörg Hellwig, chief digital officer of Lanxess, considers digitalization central to the company's future success. The company established a dedicated service unit in 2017 to push digital business models, introduce new technologies along the entire value chain, and work on the use of big data and the embedding of digital skills among its employees. Hellwig notes that data have empowered production specialists to significantly increase capacity utilization, which cut costs and improved energy efficiency. Moreover, those tools now enable personnel to continuously optimize operational performance across its production plants.

ADDRESSING ROLL-OUT CHALLENGES

Making analytics-driven decision-making possible at scale in a global organization requires the data to be available, accessible and digestible for the users. Having provided an application to the engineers is no guarantee they will use the new tool. Engineers typically need to see the added value for themselves to become enthusiastic. Lanxess facilitated that transformation by overcoming the following challenges:

1. *Proving initial value.* When users see the value a new tool can bring, the interest will rise among others to see how they can apply the tool to their own daily operational challenges. Champions were assigned to help these people start using the analytics capabilities themselves.
2. *Making self-service analytics available on a global scale.* The tool itself was made available to all users. With a modern web-based application, this was easy enough. However, the availability of the data of all the production facilities in a harmonized configuration and nomenclature was crucial for knowledge exchange and speeding up the learning curve.
3. *Changing behavior/perception of production data on the plant level.* Some users are more receptive to change than others. Therefore, common change-management tactics were applied to help change the behavior of the users.

A POWERFUL TOOL

Figure 1. Pattern recognition analyzes performance, finds the root cause of an issue, and enables real-time monitoring of production.

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4. *Taking common decisions on a global level.* Although democratizing analytics means everybody can use the software, some decisions still must be made centrally, requiring upper management support for the central team.

The digitalization business unit of Lanxess realized a successful roll-out demanded several key steps.

The first was the creation of a central project with a dedicated roll-out team within the business unit. This roll-out team consisted of operations technology specialists with engineering and production data analytics expertise and with some information technology background.

Second was adding project management personnel to the team responsible for digitalization projects within Lanxess, to complement its engineering and production data analytics expertise. These experts helped the local plants and users become successful with the new tool by setting up the roll-out structure and determining the roles and responsibilities of the team. At each site, the roll-out team started with a kickoff meeting to set the goals and expectations, select the key stakeholder for the plant, and plan on-site training.

To inspire the users to change their behavior, Lanxess took a third step: the creation of individual success plans in cooperation with the business units the people were working for, with clear roles and resource commitments. The people could fall back on a global process and asset analytics community to exchange ideas and best practices. The individual success plans were determined in line with the yearly reward per working group. The person or team with the best solved use cases was entitled to present those achievements at the global management meeting.

The last step was the creation of a digital working group for production that acts as a steering committee, with stakeholders from business-unit production management. Members include the plant manager, a plant engineer and foreman or, optionally, a shift foreman and at least one operator (ideally, one per shift or more). The steering committee gets a bimonthly status report on progress and holds a biweekly operational meeting with the local working group focusing on best practices and best use cases to leverage at other sites, too.

A RESOUNDING SUCCESS

Lanxess today has converted over 75% of its production facilities to use industrial analytics and enable its operational experts to make analytics-driven decisions that can increase its capacity and lower costs at the same time. The company has significantly raised its capacity utilization in selected plants, optimized resource efficiency and reduced maintenance costs with the help of industrial analytics. In some cases, this has resulted in savings amounting to hundreds of thousands of euros. Further benefits should accrue through the structural business unit enablement and support by the central and local champions. ●

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Conquer Compressed Air Challenges

Carefully consider what's contributing to capacity issues

CHECK CURRENT CONSTRAINTS

The puzzler presents a number of plausible scenarios that merit consideration. However, some additional quantitative information will be helpful. Consider the following before adding a new compressor to boost air capacity:

1. In addition to Fermenter No. 3, some 8–10 intermittent new periodic high or periodic low users were added. In the absence of quantitative information, it's hard to compare the consumption with the compressor capacity. You can do a number of tests that involve keeping selected new users on to see if the compressor can keep up with the demand. Of course, you must check with Operations to ensure such tests don't disrupt its fermentation and packaging requirements. These tests may show whether the compressor is adequate for the new configuration.
2. Check compressor operation — seemingly minor items such as "unloaders," if not set properly, could cause the compressor to deliver inadequate pressure; or an inlet air filter, if partially clogged, adversely could affect compressor capacity. Similarly, air inlet/outlet valves or packing leaks merit checks. Trace discharge piping to the fermenters to make sure all valves, including block valves, are completely open while other valves on equipment not in service are closed.
3. Perform an air leak survey. Plug in all leaks.
4. Explore ways in which you can stagger fermenter air addition with the other big users such as packaging. This will minimize peak demand.
5. If the problem of "bad batches" is from the new fermenter only, then check the piping and sparger layout for potential flow restriction to that fermenter.
6. Check the air dryer to determine if change of air-dryer charge is required. Of course, you must make sure charge regenerations are carried out properly and in time.
7. Confirm the new instrument air system provides dry air at the required pressure to the valves on the "acid egg" container. Check actuators on these valves. Inspect internals of these valves and replace if necessary.

GC Shah, senior advisor
Wood, Houston

BUILD SLOWLY

Obviously, you're up against politics: you need to convince corporate and your managers to let you explore bottlenecks in the compressed air. Start small. When Governor Clinton of New York built the Erie Canal, he did the opposite of what others tried: he started with the easy part of the canal so he could learn as he went.

The best way to convince people is to identify some high air demands from the packaging equipment lines and create loops to allow the pressure to balance, thereby reducing downtime on the lines. That will be a big money-maker.

The truth is that water interacting with the acid really is causing the corrosion in the eggs. So, tackle the dryer next. A cheap fix is a series of water/oil traps in the system — if you can chill the traps, even better. This

THIS MONTH'S PUZZLER

We shoot sulfuric acid into our yeast fermenters as a nutrient. When we bought the facility three years ago, it had two fermenters. Since then, we've added another fermenter as well as expanded our packaging lines and other parts of the plant (see figure online at https://bit.ly/37mfatP). We now are seeing delays in the injection time that are affecting our yields. We must inject the right amount of acid during a precise ¼-hr window to maximize yield and product quality.

I think the culprit is compressed air, which we ignored in the expansion. I generated a diagram of the users of the compressed air system.

The technology expert at corporate instead blames corrosion in the valves in the top of the acid egg. "I've seen it a dozen times," he declares. He also says the actuator may be fouled. The air for the valves used to come from the compressor but a new instrument air system was installed to eliminate oil that was fouling control valves.

I talked to the boiler-house operators who manage the compressor. They note the compressor tripped several times in the last three months and the dryer is having trouble keeping the air wet bulb down to -20°F — in fact, they say it sometimes runs at 32°F. This brought a "See, I told you" from the corporate engineer, who claims the water in the air was causing corrosion in the acid egg valves. The operators also mention a drop reported in pressure whenever the new packaging line is running. The foreman there tells me that half the lines frequently are down. The fermentation operator says blowing down the egg line after shots leaves acid in the lines.

Do you think corporate is right? Is there anything we can do about the problems with the compressor?

should win some support at corporate. If space or available money won't allow a larger dryer, consider a smaller dryer where it counts, like for air to the acid eggs. You even may want to think about breaking up the air system and connecting the separated section to another compressor system.

Acid in the lines, as reported by the operators, is common. It doesn't matter what the pipe material is: acid will eat it. Change the procedure to include flushing with water briefly and then blowing with air; do this a couple of times, perhaps. You could recover the acid and use it.

Dirk Willard, consultant
Wooster, Ohio

JANUARY'S PUZZLER

We meter corrosion inhibitor (an aqueous mixture of sodium benzoate and sodium nitrite) into tanker trucks containing our product, ethylene glycol radiator fluid. Previously, we metered the inhibitor into lines to the product tanks. Corporate and our customers can't seem to decide if they want to continue the current approach or revert to the original system. Complicating this further, corporate is grappling with whether to increase the injection rate by 25%. Now, it's October in Indiana and winter is coming. "What are we going to do when winter comes?," an operator complained. Money is tight, I told him.

We use 275-gal totes of inhibitor, and go through 8 or even 12 on some days. Storage space limitations restrict us to only six totes near unloading; the others are stored way across the plant, taking a fork truck about 30 minutes to deliver.

Safety already is upset by the lack of containment around the totes. Because the whole system is "temporary," we're using a ½-in. air-diaphragm pump and a ¾-in. garden hose strung 75 ft from the totes outside the dike wall to the loading arm 18 ft above ground level.

Sales is thrilled because the chemical in the totes includes new additives the customer wants. Production is concerned about the additional inventory filling its warehouse and yard — and also displeased with the slow filling rate that adds 20 minutes to the operation and requires an operator on standby because the measurement is by tote level. I'm not happy that we're wasting ingredients due to all the leaks. I'm not sure how quality control feels about this.

How can we prepare for winter at this late date? Should containment of a water solution worry us?

Send us your comments, suggestions or solutions for this question by December 11, 2020. We'll include as many of them as possible in the January 2021 issue and all on ChemicalProcessing.com. Send visuals — a sketch is fine. E-mail us at ProcessPuzzler@putman.net or mail to Process Puzzler, *Chemical Processing*, 1501 E. Woodfield Rd., Suite 400N, Schaumburg, IL 60173. Fax: (630) 467-1120. Please include your name, title, location and company affiliation in the response.

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

Choose the Correct Cooling Medium

Consider a variety of factors when deciding between air and water

You must consider both summer and winter operating conditions.

HEAT REJECTION generally involves either air or water cooling. When adding a new exchanger, the practicality and economics of the choice vary with service requirements, climate conditions and site-specific factors. The cost of equipment certainly plays an important role. However, economics also significantly depend upon site factors, including differences between wet-bulb and dry-bulb temperatures, local climate (temperatures), availability of water, whether the exchanger will be stand-alone or added to a current system, and existing plant practices.

Air coolers are self-contained units. An air cooler requires electrical supply for the fans but little else for installation. Water coolers include two major components, an exchanger that cools the process and a cooling tower that rejects the heat, as well as a water distribution system linking them.

The two components required in using cooling water can make even a straightforward economic comparison of air cooling versus water cooling difficult. However, as a rule of thumb, if the necessary process temperature is 50°F (28°C) higher than the dry-bulb temperature, the economics generally will favor air cooling. If the needed process temperature is closer than 50°F to the dry-bulb temperature, then water cooling likely becomes a strong contender.

You must consider both summer and winter operating conditions to understand the capital tradeoffs for air versus water cooling. Air cooling effectiveness changes with dry-bulb temperatures while water cooling effectiveness changes with wet-bulb temperatures.

For air cooling, summer operation is most difficult. The dry-bulb temperature is high, which gives low temperature differences in the cooler, increasing needed surface area. The lower possible air-temperature rise also boosts total air required. Winter operation tends to be easier; the air temperature is lower, temperature differences increase, and necessary air decreases. This points up the value of including some method to vary air supply. Otherwise, the denser winter air will lead to greater power consumption then.

For water cooling, summer most limits the process exchanger. Wet-bulb temperatures are high, reducing temperature differences and increasing water demand. In the winter, cooling water temperatures drop, temperature differences rise and water demand falls. The process cooling exchanger has more duty capability in the winter.

However, roughly one percent of the water passing through the cooling tower evaporates for every 9°F (5°C) drop in water temperature. As air temperatures drop, the amount of water vaporized to go from the dry-bulb to the wet-bulb temperatures decreases. So, colder weather requires more air in the cooling tower to remove the same amount of duty. Operation of some cooling towers is more limited in the winter than the summer; this can be an unpleasant surprise.

You should include two other factors when evaluating air versus water cooling: variability within a day, and maximum and minimum temperatures.

In most areas, the dry-bulb temperature varies much more through the day than the wet-bulb temperature. This means air cooler performance tends to change more than water cooler performance during the day. Additionally, rain can dramatically alter air cooler performance. Rain storms rapidly convert air coolers into wet-surface coolers, substantially boosting their cooling capability. In contrast, upsetting a water cooler system requires a prodigious amount of astonishingly cold rain.

Essentially no upper limit exists to air cooler operating temperatures, so long as you ensure personnel safety and use correct mechanical arrangements. Indeed, air coolers have handled process inlet temperatures over 1,000°F (538°C). However, processes can suffer low temperature problems with air coolers; very cold air can solidify many process streams.

In contrast, you should not operate cooling water exchangers with excessive process temperatures. High film temperatures on the water can rapidly foul heat exchangers. You should keep bulk return water temperatures in water coolers below 125°F (52°C). Many plants that expanded without upgrading their utility systems now exhibit higher average return temperatures — often reaching 130–135°F (54–57°C) — particularly in summer operation. These plants tend to have high rates of carbonate fouling.

On the low temperature side, cooling water systems moderate temperature extremes. Outside of locations like Alaska, few cooling water systems have problems with below-freezing temperatures — as long as they are running with some process heat input.

The selection between air and water cooling requires balancing many competing performance and cost tradeoffs. Neither method suits all applications.

ANDREW SLOLEY, Contributing Editor
ASloley@putman.net

Explosion Isolation Valve Eases Installation

The Q-Flap NX inlet explosion isolation valve is designed to prevent explosion propagation through ductwork. The improved design features magnets that hold the flap open and reduces the pressure drop across the valve, meaning that the suction from the dust collector only moves the product. This saves energy because fans require less horsepower, and the dramatic reduction in pressure drop improves product flow. The design also allows for up to two elbows in ductwork prior to valve installation which eases retrofit. An optional auto cleaning feature decreases downtime and speeds up cleaning.

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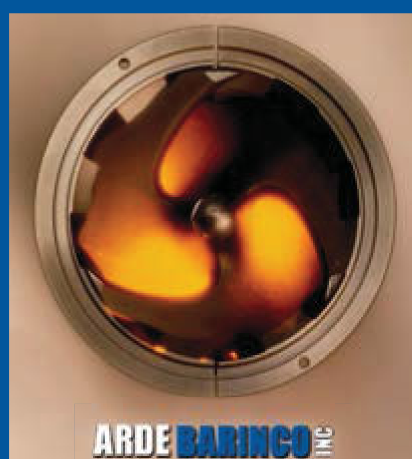

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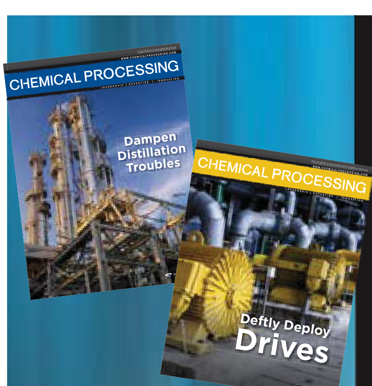

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Sustainable SAPs Beckon

Products aim to rival or exceed performance of petroleum-based absorbents

The market for SAPs extends beyond disposable diapers.

MOSTLY USED to prevent diapers from leaking by soaking up urine, superabsorbent polymers (SAPs) are proving to be one of the most successful chemicals ever developed. Research and analysis company Statista, New York City, predicts their market value to reach $70.4 billion by 2024.

However, SAPs' manufacture is largely fossil-fuel based. So, the hunt is on for sustainable raw materials.

One option is to use wheat gluten (WG) proteins, a coproduct from wheat starch and ethanol processing composed of proteins that make it a promising material for absorbency applications.

In a recent issue of *Advanced Sustainable Systems*, researchers from the KTH Royal Institute of Technology, Stockholm, Sweden; the SLU Swedish University of Agricultural Sciences, Uppsala, Sweden; and Kyoto University, Kyoto, Japan, describe the synthesis of superabsorbent particles from nontoxic WG protein: a natural molecular cross-linker named genipin (a hydrogenated glycoside extracted from the fruit of gardenia jasminoides), together with a dianhydride (ethylenediaminetetraacetic or EDTAD), generate a material with a network structure capable of swelling up to 4,000% in water and 600% in saline solution.

This represents a tenfold increase compared to the already highly absorbing gluten reference material. The carboxylation (using EDTAD) and the cross-linking of the protein result in a hydrogel with liquid retention capacity as high as 80% of the absorbed water remaining in the WG network on extensive centrifugation, which is higher than that of commercial fossil-based SAPs.

While the market for SAPs extends beyond disposable diapers, Antonio Capezza, a researcher at both the KTH and SLU, notes that they are the most demanding in terms of urine absorption properties: "By aiming to match or exceed the absorbency performance of petroleum-based superabsorbents used in many disposable diapers, we can meet the standards for most other applications that require them."

These include personal care and medical products, flood water mitigation and rainwater retention for agriculture, among others, he adds.

Swedish innovation agency, Vinnova; grain and bioenergy specialist, Lantmännen; and hygiene and health products and services supplier, Essity funded the project. The next step is to scale up production of the material so the researchers' industrial partners can test it in different applications.

Meanwhile, Ecovia Renewables, Ann Arbor, Mich., a University of Michigan-based start-up, is developing a range of superabsorbent biopolymers that could enable widespread use of compostable diapers. This, the company says, would greatly reduce the 3.5-million tons of disposable diaper waste currently entering U.S. landfills each year.

Ecovia's fermentation-based bioprocess uses renewable feedstocks such as glucose and glycerol and a companion chemistry platform based on gamma polyglutamic acid to produce a family of what it describes as high-performing, multi-functional biopolymers for use in R&D activities.

Key among these is its range of AzuraGel superabsorbent biopolymers. These 100% bio-based, non-toxic and biodegradable materials absorb up to 300 times their weight in water and show improved absorption under load over starch-based biopolymers. They are being developed to minimize cost of production and maximize feedstock flexibility.

Ecovia believes its biopolymers could serve in other important absorption situations, including: packaging; soil moisture retention; seed germination and plant growth; as tackifiers for revegetation and erosion control; and in vegetable gum formulations.

Eyeing the same market are Archer Daniels Midland Company (ADM), Chicago, and LG Chem, Seoul, South Korea, who are working together to create biobased acrylic acid — a key chemical in the manufacture of SAPs.

Despite the growing demand for products developed from renewable materials, acrylic acid currently is produced almost exclusively from petrochemicals. LG Chem is one of the world's leading manufacturers of acrylic acid; the two firms are working to develop economically viable production of 100% bio-based acrylic acid using ingredients from ADM's corn processing.

To support production, LG Chem is considering building a bio-SAP plant in North America, and exploring additional bioplastic business opportunities.

"ADM currently produces about 30 different products from a kernel of corn, and we're eager to explore the possibilities provided through bio-based acrylic acid," says Chris Cuddy, president, carbohydrate solutions for ADM. ●

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