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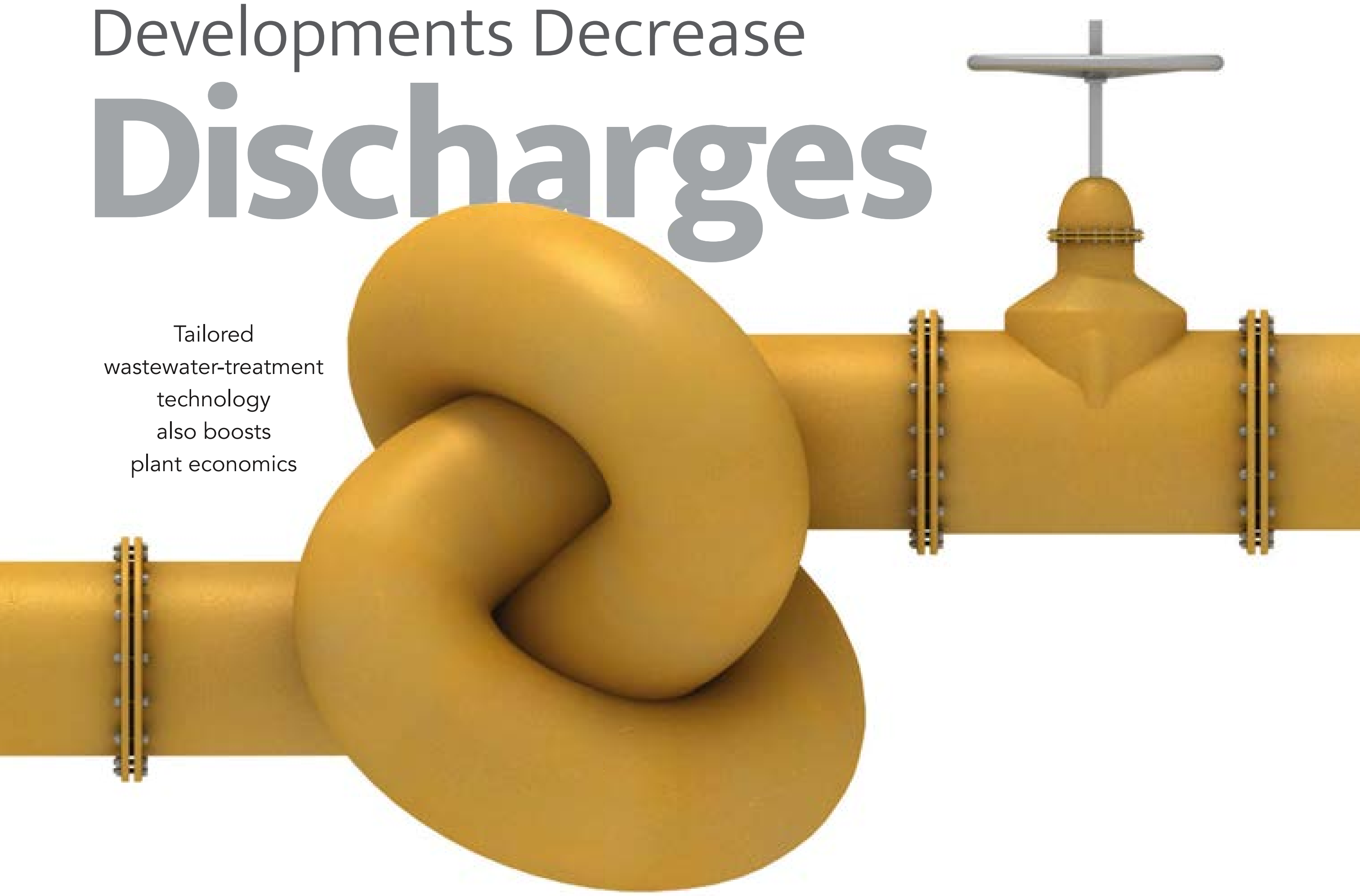

Tailored wastewater-treatment technology also boosts plant economics

MARCH 2022

Reduce Your Supply Chain Vulnerability

Use Your Head With Headers

Consider Agitation Agglomeration For Dust Control

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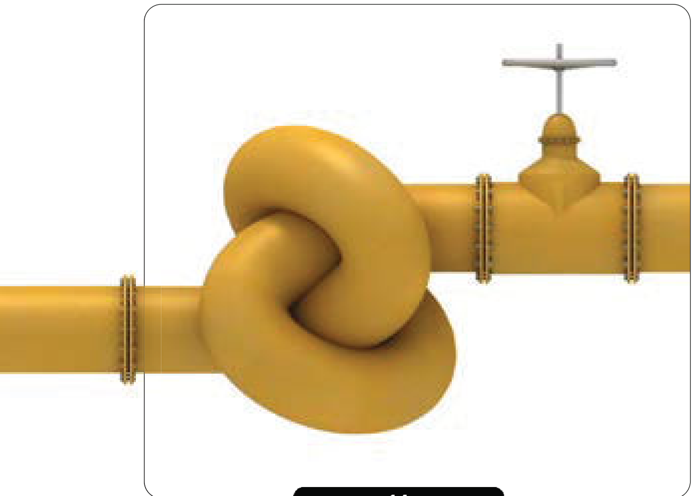

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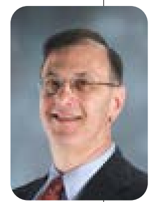
Chemical Processing (ISSN 0009-2630) is published monthly by Putman Media Inc.,1501 E. Woodfield Road, Suite 400N, Schaumburg, IL 60173. Phone (630) 467-1300. Fax (630) 467-1120. Periodicals postage paid at Schaumburg, IL, and additional mailing offices. Postmaster: Please send change of address to Putman Media, PO Box 1888, Cedar Rapids IA 52406-1888; 1-800-553-8878 ext. 5020. SUBSCRIPTIONS: Qualified reader subscriptions are accepted from operating management in the chemical processing industries at no charge. To apply for a free subscription, email putman@stamats.com. To nonqualified subscribers in the United States, subscriptions are $68 per year. Single copies are $15. Canadian and other international annual subscriptions are accepted at $200 Airmail. Single copies are $16. Canada Post International Publications Mail Product Sales Agreement No. 40028661. Canadian Mail Distributor information: Frontier/BWI, PO Box 1051, Fort Erie, Ontario, Canada, L2A 5N8. REPRINTS: Reprints are available on a custom basis. For price quotation, contact Foster Reprints, (866) 879-9144, www.fostereprints.com. Putman Media Inc. also publishes Control, Control Design, Food Processing, The Journal, Pharma Manufacturing™, Plant Services and Smart Industry. Chemical Processing assumes no responsibility for validity of claims in items reported.

Dust Never Sleeps

Allocate adequate attention to address safety, health and other hazards



YES DUST, not only rust, remains a persistent problem. (No, Neil Young and Crazy Horse didn't issue such a sequel to their 1979 "Rust Never Sleeps" album.) Indeed, dust continues to pose an ongoing issue almost everywhere. It's unsightly but also so much more than that in many situations.

On a personal level, I'm continually grappling with dust accumulating on my many manual typewriters. These machines have loads of small gears, levers and other parts that act as dust magnets. The build-up isn't just an aesthetic issue but can make the typewriters sluggish to operate or even compromise how well they type. The glass doors on the display cabinets I have do help keep out a lot of dust but certainly don't provide hermetic sealing. I must dust the machines — more frequently than I now do, chides my wife. I have run through a lot of cotton swabs and pipe cleaners removing dust. Cleaning the typewriters is a chore, but I do get some satisfaction in restoring the machines to more-pristine condition.

In industry, dealing with dust may not give many engineers as much satisfaction. Regardless, most manufacturing plants must contend with dust. Loading, unloading and handling of solids as well as various processing steps can create dust. Appropriate sealing and other containment measures can prevent escape of particles, while using vacuum and other techniques can collect errant particles. Nevertheless, many sites still suffer significant issues with dust. Build-up on surfaces or high ambient levels in the work environment, at best, might indicate inadequate housekeeping or, at worse, major operational failings. This dust can lead to product impurities as well as create health and safety issues. Thus, plants usually must strive for effective dust control.

Reflecting the importance of properly dealing with dust, *CP* devotes considerable attention to the topic. For instance, this issue's article "Consider Agitation Agglomeration for Dust Control," p. 24, covers an often-overlooked option when handling bulk solids that can offer a variety of benefits. In addition, a number of other recent articles provide important insights related to both safety and environmental issues. These include: "Address Explosion Risks Via Dust Hazards Analysis," https://bit.ly/3s42tMU; "Take Key Steps Against Combustible Dust Hazards," http://bit.ly/2ANOvFJ; "Tackle Combustible Dust Risks," http://bit.ly/2YQedH1; "Deftly Deal with Dust," http://bit.ly/2wsVHna; and "Is Your Cooling Tower a Dust Filter," http://bit.ly/2ON2ymt.

CP also has published a number of eHandbooks (free downloadable multi-article pdfs) such as "Diminish Dust Dangers," https://bit.ly/3GGco0F; "Deftly Deal with Dangerous Dusts," https://bit.ly/3L8Zc7H; and "Deter Danger from Dust," https://bit.ly/3upmZKP.

In addition, we are continuing our series of free online "Combustible Dust Roundtables" in which experts cover best practices and answer audience questions. This year's first roundtable will take place on May 11th. For more details and to register, go to: https://bit.ly/3471JP1. The second roundtable is slated for November 2nd; see: https://bit.ly/3Hxot9m. Earlier roundtables are available on demand; check out: https://bit.ly/CP_Webinars.

So, don't let your knowledge get dusty! Take advantage of these valuable resources.

Our free online "Combustible Dust Roundtables" continue this year.

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Crystallization is Easy

This unit operation can add much more flexibility to a process design

It's hard to seed a continuous crystallizer.

A BOSS of mine regularly reminded me that making chemicals is fun. He would say this immediately after presenting me with a new production-line problem to solve. Yes, I enjoyed the challenge; eventually all was fine, if not fun. Difficulties with crystallization particularly come to mind. Crystallization seems a simple operation. You just cool the solution and out drops your product. We should be so lucky! Making a crystalline product must be one of the most complicated operations next to brain surgery. First, the crystals don't like being out of their mother solvent unless given no alternative. Second, nucleation is a random event. Slight changes in their environment (temperature, impurities, etc.) will prompt fine crystals to return to the safety of the solvent. Third, often there are different crystal forms (habit, polymorph, etc.) that change or interfere with the final product's characteristics. Fourth, particles can interact with surfaces to stick or agglomerate. They even can generate fine particles through secondary nucleation, making filtration a nightmare.

So, how do you prevent these bad things from happening? It all starts with the right data. Make obtaining the solubility curve your first step — and always remember there's more to a solubility curve than just solubility. My March 2018 column "Get a Solubility Curve," http://bit.ly/2JR2P5M, outlines the eight steps you should take to ensure the curve correctly represents your process. This is especially important when modifying an existing process because ingredients may have changed slightly over the years.

You should start by reviewing the solubility curve with a chemist and looking for the meta-stable-zone width. This will tell you the precision of process control necessary to prevent spontaneous nucleation. Process control includes not only temperature but also mother liquor strength and agitation. Those two factors often are overlooked. A high solute concentration at the beginning of a batch can allow an unstable polymorph to crystallize and grow. The problem may not show up in the crystallizer but, instead, downstream in separation, drying or material handling. You even may produce an amorphic compound rather than a crystal.

The type of crystallizer chosen for a compound can profoundly impact product quality and ease of manufacturing. Almost all products start out in a batch operation but going to large-scale production often requires a continuous process.

We like batch operations because the equipment can serve for many different products or steps in the production cycle. There's more flexibility in generating supersaturation and nucleation, as well as a wide variety of particle size distributions. It's hard to seed a continuous crystallizer. However, batch flexibility comes with a few problems, not to mention cost. The most common challenges include more-precise temperature control, prevention of segregation (poor agitation), scaling of heat-transfer surfaces, and secondary nucleation. On the plus side, batch crystallization successfully can handle difficult separations such as polymorphs and chiral chemicals through seeding or precise temperature control. You can control scaling of heat-transfer surfaces or fouling of the evaporation chamber by staying inside the meta-stable zone or providing low-solute-concentration wet/dry interfaces.

Continuous crystallizers seldom are designed for flexibility. Instead, they generally are tailored to produce one product shape, color and size so the downstream equipment can expect a consistent material once the process stabilizes. While you have a broad range of equipment choices, once a unit is installed there's little room for change. Forced circulation devices have a low velocity region that separates the larger particles from the finer material. Growth occurs in the suspension, and nucleation usually happens by evaporation of the solute. Cooling can be used but often is a waste of energy.

Generally, forced circulation yields a wide particle-size distribution; Ostwald ripening can narrow this. Several types of crystallizers, e.g., draft-tube units, can give a narrower size distribution through fines destruction loops and elutriation channels. In addition, a host of solution crystallizers, such as the scrapped crystallizer, can produce a slurry or paste. It all depends on what you want as your final product. Solution crystallizers allow you to tailor the particle size for more-cost-efficient downstream processing such as solid/liquid separation. ●

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Appreciate the Help You Receive

Many people will have a hand in your successful project

Most sales engineers will help an inexperienced engineer, to a point.

I COULD see right away what Frank couldn't. He had been collecting samples and overseeing testing of boneyard coils from our O_2 heater for several years to identify the cause of a problem afflicting the coils. From my previous experience as a research engineer, I could tell it was a well-organized study. I had done aging and mechanical-properties studies, and, so, clearly spotted creep failure.

I wrote a report describing the math behind this type of failure and, eventually, an expert explored our coil failure further. I used his results to accurately predict and prevent a failure. Later, another engineer, Bill, expanded on my work, which finally convinced corporate to allow us to make some changes to ameliorate this problem.

The solution stemmed from team effort. It resulted from handing down data from one engineer to another until there was indisputable evidence that management could not ignore.

In another situation, I discovered a broken pump whose failure would have ruined the company. I am grateful to the old Navy boilermaker who had watched the pump degrade for years and collected the supporting data I used to convince management of the epic impending disaster.

CHECK OUT PAST FIELD NOTES

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

My point is that I, like most engineers, have benefited from the work of others. They sometimes contributed in ways that were direct but usually in ways indirect and often invisible to me.

Just think about it. You benefit from well-laid-out piping-and-instrumentation diagrams, site plans, instrument drawings, etc.; without these, you have nothing to go by. Often engineers avoid offering solutions because of the exhausting effort anticipated to collect the data necessary to write an engineering report.

Ask any engineer sizing a pump how much easier isometric drawing would make the task. I've been at job sites where I relied on Google maps to construct a plan view that I could feed into a hydraulic model; after that, you must do an elevation survey and a complete walkdown with photographs.

If you rely on laboratory work for product quality or material balances, you owe a big thanks to the chemists who provide those vital data. Sadly, most laboratories can't provide viscosity and density data, so I generally get those data myself. (An earlier column, "Get Into the Thick of Things," https://bit.ly/3o2Rpyv, recommended using Zahn cups for viscosity data, while another, "Plug Gaps in Aqueous Solution Data," https://bit.ly/3KWb8tE, covered how to find viscosity, density and other physical properties of such solutions.)

Consider the help you get from technical staff at constructors and vendors. Many operating companies have decimated their project groups and now tend to hire the cheapest (least experienced) engineers. So, project work often is in the hands of greenhorns who don't know pipe from wire conduit.

Most sales engineers will help an inexperienced engineer, to a point, but sales engineering staffs have thinned over the years. By showing technical acumen, a salesperson can impress you and build goodwill. There are limits, though. For instance, pump sales engineers won't do isometrics and sizing calculations for you but will give you advice based on past projects. Always remember they're out to make a sale. The size and frequency of your company's purchases play into how much they're willing to help; don't count on extensive efforts if your company likely won't give them business for several years.

Constructors also consider the prospect of future projects from your firm. They want your work next year but, if there's a downturn in your business and the capital budgets for maintenance and projects shrink, they may not be so helpful. Expect the most help from constructors that are familiar with your facilities, have done faithful work for many years, and are confident about getting future business from your company.

Recently, I did a walkdown for bidders on a rework job; this involved relocating pipe and conduit prior to installation of a knockout drum. The electrician, a contractor who had worked for us for many years, pointed out some conduit issues he knew might pose a problem. This was very helpful and I really appreciated his contribution. You always should show gratitude to those who make your job just a little bit easier. ●

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ML Speeds Nanomaterial Discoveries

Novel machine learning technology helps to find catalysts for green energy and waste reduction

NANOPARTICLES HAVE broad applications as alternative materials to shrinking natural resources. However, nanochemistry's vast compositional and structural tunability limits researchers' ability to efficiently identify new materials to expand their use.

To speed up materials discovery and guide the synthesis of novel nanomaterials, researchers at Northwestern University, Evanston, Ill., and the Toyota Research Institute (TRI), Los Altos, Calif., turned to applied machine learning (ML). An algorithm combs a defined dataset, called a "megalibrary," to accurately predict new structures and catalysts critical to green energy and waste reduction processes.

ML applications well suit tackling the complexity of defining and mining the massive "materials genome," but the difficulty in creating datasets to train algorithms hinders their use. Combining a megalibrary with ML may finally eradicate that problem, says Chad Mirkin, a nanotechnology expert and professor at the university's McCormick School of Engineering.

"This AI-driven approach will impact most industries that would benefit from the discovery of new materials with enhanced properties and functions, and it is already playing a critical role in many sectors. For example, the megalibrary platform is an efficient and powerful way to sift through the materials genome and find the best catalysts for a variety of chemical reactions," notes Mirkin.

Megalibraries can house millions of nanostructures, each with a slightly distinct shape, structure and composition. Current libraries consist of over 220 million particles in a 2-cm^2 chip. Building smaller subsets of nanoparticles in the form of megalibraries will bring researchers closer to completing a full map of a materials genome, the team believes.

In a study highlighted in an article in the journal *Science Advances*, the team compiled previously generated megalibrary structural data consisting of nanoparticles with complex compositions, structures, sizes and morphologies. They used these data to train the model and asked it to predict compositions that would result in a certain structural feature. With little knowledge of chemistry or physics, using only the training data, the model accurately predicted complicated structures that have never existed on earth.

"We asked the model to tell us what mixtures of up to seven elements would make something that hasn't been made before," explains Mirkin. "The machine predicted 19 possibilities and, after testing each experimentally, we found 18 of the predictions were correct."

The team is developing a number of screening technologies that enable extracting more and different types of information about a megalibrary at an even faster pace. "These approaches enable the high-throughput characterization of the catalytic, structural, and optical properties of the millions of nanoparticles in the array at the single-particle level," he says.

Targeted properties also will become more complex. Mirkin elaborates: "We aim to identify and understand how a nanomaterial's structure affects its functionality. This requires collecting crystallographic information and functional metrics that can be used to develop our predictions, and disentangling such relationships in particles of ever increasing structural and compositional complexity is no easy task. But, the ability to target not only specific structural motifs, but also particular functional parameters directly for specific applications, represents a significant advance."

"We have funded development relationships with pharmaceutical companies, chemical companies, companies in the clean energy and oil and gas sectors, and government research laboratories that are interested in using the approach to explore routes to a wide range of materials that are aligned with their interests," reveals Mirkin.

In addition, a startup company called Stoicheia, spun out of Northwestern last year, is commercializing the megalibrary technology. "Stoicheia is utilizing this technology to discover new materials independently and in collaboration with industrial partners. It is generating massive, high-quality structure-function datasets that will be the basis of an AI-driven materials discovery factory that will operate at an unprecedented rate," concludes Mirkin.

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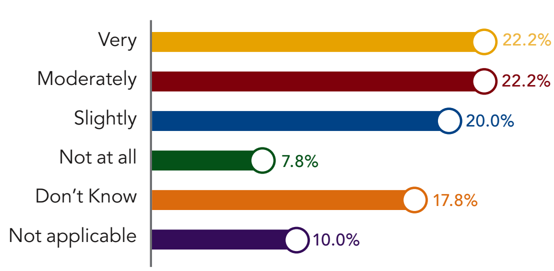
How well prepared is your site for a natural disaster?



Less than one-quarter of respondents called their sites very prepared.

Alloying Amps Up Catalyst Activity

RESEARCHERS IN Japan have developed a highly active and durable metal-phosphide nanoparticle (NP) catalyst for the deoxygenation of sulfoxides. Their development already has drawn interest from the pharmaceutical industry, where deoxygenation of sulfoxides is an important reaction step in the production of bioactive sulfides used in many anti-inflammatory and anti-ulcer drugs.

"In particular, we are being consulted about whether catalytic reactions of complex compounds containing sulfur, such as pharmaceutical intermediates, can proceed well with metal phosphide catalysts," explains research team member Takato Mitsudome, associate professor in the Department of Materials Engineering Science, Graduate School of Engineering Science, Osaka University, Osaka, Japan.

The team found that alloying platinum, palladium, rhodium and ruthenium with phosphorus significantly improved the catalytic activity of precious metal NPs for the deoxygenation of sulfoxides when using hydrogen. Notably, it increased the activity of ruthenium NPs ten-fold over previously reported catalysts, and also enabled them to withstand levels of sulfur that completely deactivated non-alloyed counterparts (Figure 1). Details on the research appears in a recent article in *JACS Au*.

Alloying involves integrating phosphorus into the metal framework of the catalyst; in reaction terms, this promotes both a ligand effect and an ensemble effect. The first is an electron transfer from the ruthenium to the phosphorus that, in turn, facilitates the heterolytic dissociation of hydrogen to produce active hydrogen species for the deoxygenation of sulfoxides. The second is a set of surface effects that suppress any strong coordination with sulfide products. Analyses revealed this dual role accounts for the enhanced catalytic activity and durability of ruthenium NPs.

Previous research by the same group found that non-precious cobalt phosphide or nickel phosphide catalysts are extremely active in industrially important selective liquid-phase molecular transformations such as transformation of biomass-derived molecules; hydrogenation of nitriles, carbonyls, nitroarenes and sulfoxides; reductive amination of carbonyls; and alkylation of oxindoles.

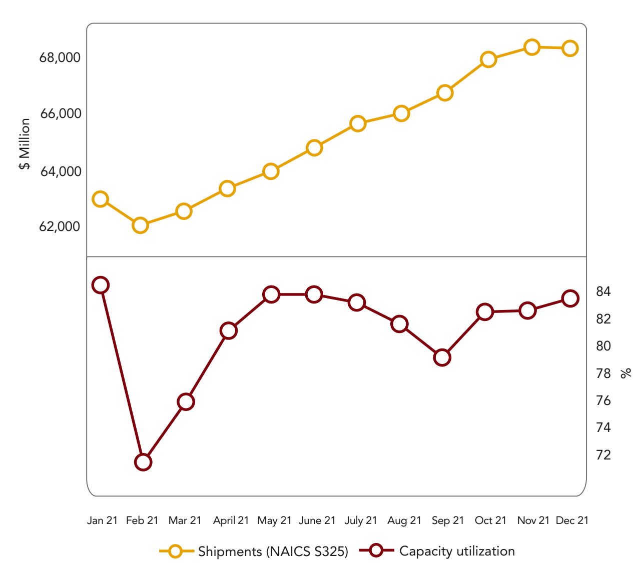
These earlier findings prompted the Osaka team to investigate its alloying process on the far-less-well-studied precious metal NPs.

"We expect that our metal phosphide catalyst will make a significant contribution to a lot of chemical processes which suffer from catalyst deactivation caused by sulfur. But beyond this, we believe phosphorus alloying can be a powerful method for designing highly active and durable metal nanoparticle catalysts for a variety of organic syntheses," adds Mitsudome.

MUCH GREATER ACTIVITY

Figure 1. Ruthenium alloyed with phosphorus provided a ten-fold increase in catalytic activity compared to unalloyed material. *Source: Osaka University.*

ECONOMIC SNAPSHOT



Shipments dipped but capacity utilization rose. *Source: American Chemistry Council.*

Squeeze Out the Heat

Heat recovery isn't always a simple endeavor

Combining several exchangers in series enables a closer temperature approach.

THE HEAT exchanger system can have a huge impact on the overall energy efficiency of an industrial process (see, "Take the Heat Off Pinch Analysis," from July 2019, https://bit.ly/3ES2A3I and "Design in a Pinch," November 2021, https://bit.ly/3FQoi8i). Most heat exchangers handle one "hot stream" at a relatively high temperature and one "cold stream" at a lower temperature; the temperature of the hot stream falls, while that of the cold stream rises. Simple, right? Not always.

Shell-and-tube heat exchangers (STHEs), the main workhorses in the process industries, consist of shells (pressure vessels) with bundles of tubes inside. Relatively cheap and robust, STHEs can be fabricated from a variety of materials and are typically easy to clean and maintain. They also can be designed for a wide range of sizes, operating temperatures and pressures.

An STHE has two flow paths — the "tube side" (i.e., inside the tubes), and the "shell side" (i.e., inside the shell, but outside the tubes). Depending on various factors, such as flow rates, viscosities, and propensity to fouling, we can choose to route the cold stream through the shell side and the hot stream through the tube side, or vice versa. (For more on which fluid should go on which side, see: "Pick the Right Side," https://bit.ly/35leiET.) Below we assume the hot stream is on shell side.

Heat transfer is most efficient with countercurrent flow, and a uniform temperature difference between the hot and cold streams. In most STHEs, the shell-side flow path has just one pass — in at one end, and out at the other. (Most shells contain baffles perpendicular to the tubes, so the shell-side path also includes a cross-flow component.) However, the tube-side flow path is usually multi-pass — from one end of the STHE to the other and back again, often several times. The tube-side flow therefore alternates between countercurrent and co-current relative to the shell-side flow. This can lead to "temperature cross," where the outlet temperature of the hot stream is lower than the outlet temperature of the cold stream. When this happens, the tube-side fluid heats up when flowing in the countercurrent direction, but cools down in part of the co-current pass (see Figure 1). This limits the achievable temperature approach; adding heat transfer area does little to increase heat recovery.

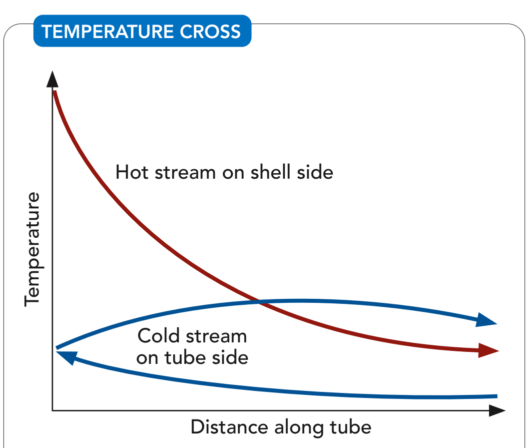


Figure 1. Tube-side fluid heats up when flowing in the countercurrent direction, but cools down in part of the co-current pass.

We can achieve a closer temperature approach by combining several STHEs in series. The temperatures of both the hot and cold streams now change only a relatively small amount within each STHE, thus avoiding temperature cross. However, adding STHEs is more expensive than simply increasing the heat transfer area in a single STHE. The extra cost can be significant, especially where close temperature approaches are needed, either because of process constraints or to maximize heat recovery.

Other options are sometimes possible. For example, "F-shell" STHEs have two shell-side passes. If there are also two tube-side passes, this yields pure countercurrent flow. Plate heat exchangers and spiral heat exchangers, and some other types, also offer countercurrent flow; in certain cases, they are a cost-effective option for achieving close temperature approaches. ●

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Additional information:

Alan Rossiter & Beth Jones, "Energy Management and Efficiency for the Process Industries," AIChE/John Wiley & Sons, Inc., Hoboken, New Jersey, 2015, Chapter 10, Enhanced Heat Transfer and Energy Efficiency, by Thomas Lestina.

PFAS: One Size Does Not Fit All

Regulating per- and polyfluoroalkyl chemicals within one category remains challenging

Each PFAS has a unique chemical identity and toxicological profile.

PER- AND polyfluoroalkyl substances (PFAS) are getting a lot of attention in the United States and globally. Their varied chemical properties make categorizing "PFAS" into a single category chemically and scientifically questionable. Increasingly, the ability to make distinctions among this large chemical category is challenging, yet failure to do so could be unwise. This article provides information on PFAS, and offers a few suggestions to keep in mind when making business decisions.

The U.S. government claims some 4,000 PFAS exist, and are used to make fluoropolymer coatings and products that resist corrosion, grease, water, stains and heat. They are found in consumer and industrial applications, including non-stick coating in cookware, stain-resistant clothing, furniture, food packaging, adhesives, electrical insulation wire, tank linings and firefighting foams. The carbon-fluorine bond is the chemical backbone of PFAS and one of the shortest and strongest bonds known to exist. The bond makes PFAS highly resistant to breakdown, hence, their nickname "forever chemicals." Human exposure to PFAS occurs through consuming PFAS-contaminated water and food and/or by using products that contain PFAS.

In 1999, the U.S. Centers for Disease Control and Prevention measured at least 12 PFAS in human blood serum, indicating exposure to these chemicals in the U.S. population. It is believed PFAS contamination in humans and in the environment pervades the globe. While the measurable presence of a substance in serum alone doesn't tell us whether it causes an adverse effect, it is clear people don't want PFAS to contaminate their bodily fluids, consumer products, or groundwater.

A high-profile lawsuit about 20 years ago ignited the controversy. Plaintiffs, landowners, sued a chemical manufacturer of two PFAS — perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). They alleged injuries from contaminated drinking water from a PFOA manufacturing site in West Virginia. The court later certified the plaintiffs as a class; the parties settled in 2004. The settlement included an agreement to create a scientific panel to evaluate potential links between exposure to PFOA and PFOS and adverse human health effects. In 2011, the panel determined a probable link between PFAS exposure and certain diseases — including kidney and testicular cancer, and thyroid disease — and other adverse health effects. Litigation targets now include manufacturers that use or used PFAS in their products.

The Biden Administration is committed to addressing PFAS. Its "PFAS Strategic Roadmap: EPA's Commitments to Action 2021–2024," issued last October, outlines dozens of regulatory initiatives to address PFAS contamination. Congress has enacted several measures included in defense appropriation actions that resulted in regulatory actions implemented by the U.S. Environmental Protection Agency (EPA). Notably, the agency proposed last year a Toxic Substances Control Act reporting rule that requires "each person who has manufactured" a PFAS since January 2011, in any quantity, without exemptions, to report certain information to the EPA. Similar initiatives are emerging in the European Union, the United Kingdom, and elsewhere globally, but less aggressively.

Advocates, armed by science, routinely note PFAS are diverse and there's no one-size-fits-all approach to regulation. Each PFAS has a unique chemical identity and toxicological profile. Structural differences in carbon chain length, degree of fluorination, and chemical functional group influence the substance's mobility, fate, degradation in the environment, and toxicity in biological systems. While some grouping is scientifically supportable, PFAS are not mutually interchangeable. A commitment to science is essential to ensure recognition of PFAS with positive societal applications like life-saving medical devices or low-emission vehicles.

Suggestions to assist the PFAS decision-making process include:

- Make a chemist part of the business team. It is vital to include a chemist, preferably one familiar with this class of chemistry.
- Be careful in due diligence. Because the universe of PFAS is large and chemical-specific information lacking, not much information on a particular PFAS may exist. This is tricky in due diligence matters. A checklist approach ("Are PFAS part of the raw materials?" and similar broad questions/statements) is devoid of meaning in any scientific sense.
- Understand the applications. Knowing how PFAS are used and their end-of-life options is critical.

PFAS are not a one-size-fits-all issue. It will take a strong commitment to science to optimize their value while blunting the proliferation of substances that may pose unreasonable risk.

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Data Lassos Supply-Chain Challenges

Gain an edge via predictability and customer/supplier relations

RANDY SMITH
Co-founder and CEO,
Vicinity Software

"We've got some real challenges ahead of us, but they're very manageable with a system where you can get to your data to be able to make decisions."

SUPPLY-CHAIN ISSUES, global competition and the need to deliver high-quality products are challenges facing many chemicals manufacturers today. To meet these challenges, you must keep track of inventory, improve operations, make better products and drive smart, sustainable growth. It's a tall order but the right tools will help. To learn about industry-specific solutions, Chemical Processing sat down with Randy Smith, co-founder and CEO of Vicinity Software. The Marietta, Georgia-based company's VicinityChem is a comprehensive process-manufacturing ERP software system designed for chemical manufacturers.

Q: In today's climate, what do chemical processing facilities need to do to keep up with inventory changes?

A: In terms of supply-chain issues, we're really having all kinds of new challenges and struggles. It is becoming more important to know what you've actually got on hand, what you've already ordered from various suppliers and what their timelines are of delivering that product to the facility in a timely basis.

Knowing what you've got available and then predicting into the future what your usage is going to be so that you can communicate that with your suppliers is key. You need to be able to reveal real-time inventory quantity on hand. When you record a transaction, you are updating the system in real-time. You are able to use calculations in the system, material-requirements planning to help you identify what you're going to need and when you're going to need it, and also when you're going to see shortages in the future.

There are so many unknowns; if you can control the things you can control and do that without spending a lot of time and effort to do so, that will put you ahead of those in line for the same chemicals, the same ingredients you're needing. I think that's an important key to making it through the next few years as the supply chain starts to settle back in.

Q: How important is it for facilities to know how changes in inventory costs will affect production?

A: Not only are we having supply-chain issues, price changes are very volatile right now, too. We're seeing it at gas pumps, grocery stores, in supply chains for chemicals. Manufacturers really have three ways to address this. One is to increase their prices to the customers. Two, they can absorb the price increase; or three, they can find substitutes for those ingredients, if that's even possible. Factor in transportation costs that are increasing as well — just getting the product from point A to point B is becoming more important. So, basically, with this increased volatility of price, we need to be able to calculate the costs of production more accurately and out into the future. In other words, knowing if my cost is a dollar today, it's probably going be $1.10 in the future pretty quickly. And being able to get ahead of that cost change is a real challenge for many chemical manufacturers. What they need is a system that allows them to look at the current inventory price as well as projected prices without having to do any work and be able to deal with price volatility.

Q: What are the benefits of an accurate chemical usage forecast?

A: Who is your ideal customer? They are typically people who are predictable. They are easy to work with even if you have slippages in your production schedule, they're able to adjust with that. So, being able to predict what your raw-material usage is going to be and communicate that to your supplier makes you a better customer for your supplier. And when you're a better customer for your supplier, you're going to start getting breaks. Whether that be price breaks or availability of inventory, or when you do need something expedited, they'll go out of their way to solve that problem for you, because you've already paid that forward by making your supplier's life a lot easier. You're stabilizing their production schedule. You become a more predictive type character. You become a good customer.

And to be able to do that, you need a system that can look at those quantities on hand, look at the material requirements planning, to identify where your shortages are going to be so that you can communicate that with your supplier on a timely basis.

A: Why is it important to review vendor performance on a regular basis?

A: Everything changes over time. The same company that you bought from five years ago may not be the same today or into the future. They've got their own supply issues, they may have management issues, changes in management. They may have gone through an acquisition where they're now part of a larger group or a conglomerate. So, over time companies can change. Those changes can have an impact on things like quality, price, delivery times, and even customer service. The challenge associated with that change is you need to have some type of systematic strategy to look at vendor performance, something objective. Whether that be meeting lead times, or price increases, or potentially adjusting to a change in the production schedule for you, coming up with some type of reasonable method to identify how they're performing against what you need.

And remember that not all suppliers are the same and they supply different products and those products may have more effect on your ability to produce than other products. Looking at the suppliers related to each other—putting them in categories of how critical to your business success is really important. And when you do start seeing changes in real-time and communicate with that supplier, "Hey, we're seeing X, Y, and Z, is there a reason here for this? Is there something we can do to help with that? Is that something you're going to be able to address?"

With VicinityChem, matched with Microsoft Dynamics, you're able to monitor those vendor relationships and how they're supplying to you. This information becomes really helpful for the procurement folks to have that conversation. It can be a difficult conversation, but if you come with actual metrics, you come with things that you are tracking and say, "This is what we're seeing, how can we work together to make this change?" It will go so much better with your supplier.

Q: What about the importance of data analytics?

A: VicinityChem has been around for about 20 years and I've been in formula and batch manufacturing for probably closer to 30. And it's really been interesting that previously, we were really struggling to get data. It was very dependent upon somebody in an IT environment or somebody keeping big stacks of papers or keying that into Excel, etc. I think the opposite is true now. We have way more data than we ever knew what to do with. And it's readily available. The key question is what are you going to do with that and how are you going to make sense of it?

We can get data out of a control system, a piece of equipment or the web. But what do we do to be able to make that meaningful? You need to keep that data in its original source. There's no reason to push that out to Excel and create a whole other stockpile of data, but rather leave it in the system. Or, maybe there's analytical data out in the web that you can just extract over time and you can see that data in real-time.

For example, housing starts, if that's relevant to your industry, you'll be able to see that and over time, those numbers are going to change. Don't bring it into your system, but rather leave it out there and analyze it, extract that data if you will, use it with various tools. And when you do that, you start decoupling yourself from IT departments that have to import or export data, or get it from one source to the next source. With today's technology, you're able to actually reach in and see that data and use it and correlate it with your existing data. You can take this information and put it up on a webpage so that your salesperson is able to see that data. That data now becomes meaningful to the company and to the individual. And I'm not having to wait for an IT department to go and put it in a dashboard or in a graph that is helpful to me. I am able to do that.

Q: Do you have anything to add?

A: I think it's important for people to realize that the tools are out there and they're not as scary as people might think. You don't have to invest a huge amount of time or effort to be able to look at data. We've got some real challenges ahead of us, but they're very manageable, especially with a system where you can get to your data—whether that be pricing data, inventory or compliance data. You're able to get to that data to be able to make decisions that are even more important than they were last year. As we come out of the pandemic, as the supply chain starts to hopefully clean itself up in the months and years to come, things will get a bit easier for us. And once on the other side of it, we will be stronger and more versatile and more agile as we move forward.

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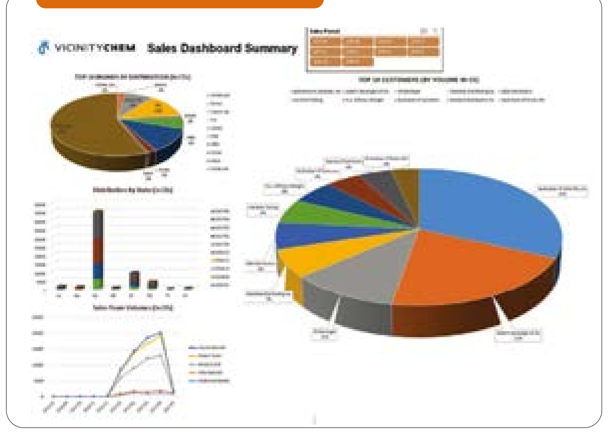

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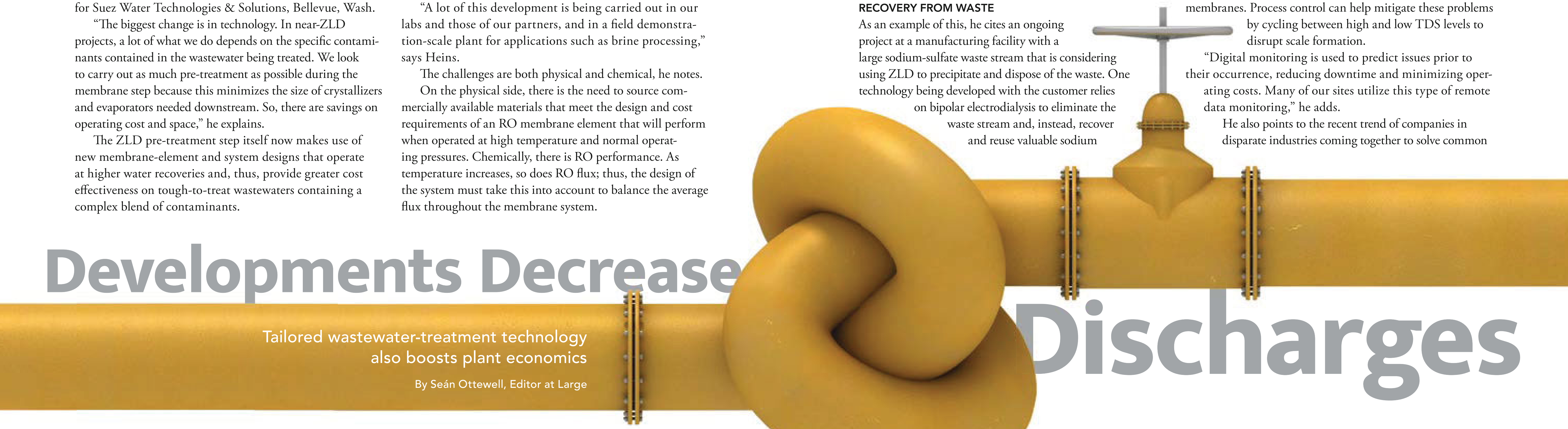

Tailored wastewater-treatment technology also boosts plant economics

By Seán Ottewell, Editor at Large

DEMAND FOR zero liquid discharge (ZLD) and near-ZLD projects is evolving as chemical companies look for more-tailored technologies that not only meet regulatory requirements but also generate greater economic benefits, reports Bill Heins, global leader, new market development for Suez Water Technologies & Solutions, Bellevue, Wash.

"The biggest change is in technology. In near-ZLD projects, a lot of what we do depends on the specific contaminants contained in the wastewater being treated. We look to carry out as much pre-treatment as possible during the membrane step because this minimizes the size of crystallizers and evaporators needed downstream. So, there are savings on operating cost and space," he explains.

The ZLD pre-treatment step itself now makes use of new membrane-element and system designs that operate at higher water recoveries and, thus, provide greater cost effectiveness on tough-to-treat wastewaters containing a complex blend of contaminants.

In certain circumstances, where somewhat lower permeate quality is acceptable, for example, the membranes themselves can be designed to be "looser."

"The trade-off here is between higher flux and higher rejection. In these circumstances, we can optimize the process with, for example, low energy membranes where a higher total dissolved solids (TDS) permeate is acceptable. In other cases, higher recovery is the objective, and we can achieve recovery from 75–95%," Heins adds.

Using a looser RO membrane permits passage of monovalent salts such as silica and sodium chloride. Such a membrane gives high recoveries without needing a concentration step and, thus, avoids issues related to high osmotic pressure or precipitation due to high concentration.

However, when concentrating salt at high recoveries — a common requirement — osmotic pressure often is the limiting factor. Here, ultra-high-pressure membranes allow operation at higher pressures, in turn, enabling much higher salt concentration while still producing a reverse osmosis (RO) permeate.

High temperature RO remains an important area of interest for Suez, which is working with both universities and customers to develop innovative designs. These include, for example, new membrane elements that can operate at higher temperatures, different module designs, and alternative materials of construction, including glues, that can withstand higher temperatures.

"A lot of this development is being carried out in our labs and those of our partners, and in a field demonstration-scale plant for applications such as brine processing," says Heins.

The challenges are both physical and chemical, he notes.

On the physical side, there is the need to source commercially available materials that meet the design and cost requirements of an RO membrane element that will perform when operated at high temperature and normal operating pressures. Chemically, there is RO performance. As temperature increases, so does RO flux; thus, the design of the system must take this into account to balance the average flux throughout the membrane system.

In certain circumstances, membrane processes can concentrate organic contaminants of concern to minimize the volume of the waste stream (Figure 1). This concentrated waste then can undergo further treatment to destroy these contaminants or to capture them — using ion exchange (IX), activated carbon adsorption or similar processes — for subsequent disposal, or be disposed of directly if allowed by regulation. "In some circumstances, the contaminants can be recovered and reused in the process," Heins explains

EASING TREATMENT

Figure 1 Membrane systems such as PROflex can concentrate organic contaminants in a waste stream. *Source: Suez Water Technologies & Solutions.*

RECOVERY FROM WASTE

As an example of this, he cites an ongoing project at a manufacturing facility with a large sodium-sulfate waste stream that is considering using ZLD to precipitate and dispose of the waste. One technology being developed with the customer relies on bipolar electrodialysis to eliminate the waste stream and, instead, recover and reuse valuable sodium hydroxide and sulfuric acid. This would yield an economic benefit to the customer, decrease overall carbon footprint, and greatly reduce the need to purchase and transport chemicals to the site.

"These types of solutions, where we can eliminate waste, recover a useful product, improve economics, and reduce carbon footprints are the holistic solutions we are developing much more today," he stresses.

Integrating pre- or post-treatment steps may make sense, counsels Heins. Depending on the chemistry involved in the ZLD process, possible upstream technologies include IE, nanofiltration (NF) and RO while, downstream, IE or RO and electrodeionization (EDI) may boost polishing. "This is especially important if we are trying to minimize the size of ZLD systems while at the same time maintaining process operability. It's really bringing optimization to customers based on their project-specific needs. One example here is using clarification/softening and RO preconcentration upstream of a ZLD system and then RO/EDI for permeate and distillate polishing for use as boiler feedwater."

Don't underestimate the importance of process control, for example in scale management, Heins cautions. Here, the challenge is to avoid irreversible scaling or the fouling of membranes. Process control can help mitigate these problems by cycling between high and low TDS levels to disrupt scale formation.

"Digital monitoring is used to predict issues prior to their occurrence, reducing downtime and minimizing operating costs. Many of our sites utilize this type of remote data monitoring," he adds.

He also points to the recent trend of companies in disparate industries coming together to solve common problems, citing various green hydrogen projects around the world. "There are lots of synergies," Heins concludes.

PURSUING ENVIRONMENTAL GOALS

At Chemours, Wilmington, Del., 2030 Corporate Responsibility Commitment (CRC) goals commit the company to reducing air and water process emissions of fluorinated organic chemicals (FOCs) by 99% or more.

"Reduced discharge approaches are one avenue we're pursuing to meet this CRC goal and improve our water management practices," notes Steven Grise, an engineering fellow with Chemours.

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The company's Fayetteville manufacturing site in North Carolina (Figure 2) is at the forefront of FOC emission-reduction efforts, most recently with the implementation of a new pilot treatment plant.

Grise outlines the overall challenge: "Products at our Fayetteville site are produced in batches or campaigns which presents treatment challenges for the aqueous effluent as there are changes in its composition. In addition to the normal process challenges, we must also consider equipment cleaning for the production changeover, plus point sources such as pump seal flushes. To add further complication, multiple sources of compounds come from various parts of the process and numerous collection points such as sumps, scrubbers, and trenches."

For the pilot system, the first step was separating non-contact water from the contaminated process water.

Figure 2. North Carolina plant is at forefront of company's efforts to reduce emissions of fluorinated organic chemicals. *Source: Chemours.*

"Segmenting these water flows was worth the effort — and investment — as it resulted in lower volumes of effluent that required treatment," states Grise.

Next, the company segregated and redirected streams to create distinct water and air streams for mitigation. Removal of gas-phase emissions left a complex mixture of aqueous FOCs and contaminants from multiple sources.

Chemours determined that an additional segregation step was necessary to separate high TDS/high total organic carbon (TOC) flows from streams with more-moderate FOCs concentrations and lower TDS levels.

"Significant effort was required to redirect the streams to two separate sets of tanks, resulting in water solutions of different compositions. The composition of one tank was amenable to RO technology for treatment with a series of bag and cartridge filtration units for suspended solids removal," Grise explains.

The RO treatment train uses spiral-wound membrane elements designed for high pressure and high salt rejection. High pressure allows the first pass to concentrate both FOCs and other associated salts and material in the plant water. The high salt rejection results in a small-enough membrane effective pore size to reject a very high percentage of FOCs.

The second-pass RO membrane provides additional polishing of FOCs. The concentrate from the second-pass RO treatment is recycled to the feed water for the first-pass RO system. The final step is to polish the second-pass permeate with granular activated carbon (GAC) and a mixed-bed deionization resin.

"Efficiency testing of the pilot treatment system showed that FOCs are removed with an RO efficiency of greater than 99%. Water recovery varies because the inflow TDS varies but generally runs in the 65–75% range," reports Grise.

"An important characteristic of the RO/GAC/IE effluent is that the produced water is of near-demineralized quality. While this quality water is not acceptable for some ISBL [inside battery limits] applications, it is recyclable as a clean water source for many areas on the Fayetteville works site. This is an ideal result for the sustainable operation of an industrial manufacturer," Grise emphasizes.

The 2030 CRC goal to reduce process emissions of FOCs and associated work to continually improve water management practices mainly will drive Chemours' adoption of minimal liquid discharge (MLD) and ZLD approaches, he says.

"When looking at the industry's adoption, there are major challenges in the drive to ZLD. One real-world challenge relates to a scenario whether 100% of the water used in a process can be recycled. In certain plant designs, rainwater intrusion may be inevitable and tip the balance of what can be reused to a point where some limited amount of liquid discharge will be necessary. A second challenge relates to managing the remaining solid residue after ZLD is achieved, as companies will be challenged to find ways to recycle or utilize those solids within their processes," Grise cautions.

Like Heins, he is looking to the synergies created by green hydrogen and fuel cells via water electrolysis.

Last August, as part of its commitment to enabling the transition to a global hydrogen economy, Chemours

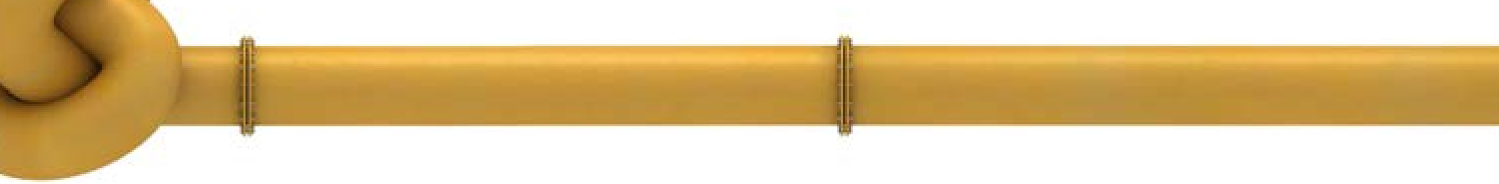

Figure 3. Unit will play a key role in Norwegian ammonia producer's decarbonization efforts. *Source: ITM Power.*

joined the leading European fuel cell and hydrogen technology association, Hydrogen Europe, Geneva, Switzerland.

THE PROMISE OF PEMS

"This opens doors for Chemours to collaborate and contribute to solutions that positively impact the global community and drive the movement to establish hydrogen as a preferred solution in clean energy," explains Grise, adding that membership will give the company the opportunity to apply its Nafion proton exchange membranes (PEMs) to a broader base of applications.

An announcement at the end of January by Linde Engineering, Pullach, Germany, further highlights the growing significance of PEMs. The company will construct and deliver a 24-MW green hydrogen plant for fertilizer manufacturer Yara, Oslo, Norway. PEMs will be at the heart of the electrolyzer in that plant, destined for Yara's site in Porsgrunn, Norway.

Using power from renewable sources, the electrolyzer will have a capacity of around 10,000 kg/d of hydrogen. Its output will partially replace the grey hydrogen currently used at Yara's Porsgrunn ammonia plant. This, in turn, will remove 41,000 t/y of carbon dioxide emissions from that plant.

The electrolyzer itself (Figure 3), which comes from ITM Power, Sheffield, U.K., will produce enough hydrogen to create 20,500 t/y of ammonia. This then will be converted to between 60,000 and 80,000 t/y of green fertilizer. It will mark Yara's first step toward decarbonization of its ammonia production.

The company's first green ammonia products are expected to hit the market by mid-2023. ●

REDUCE YOUR SUPPLY CHAIN VULNERABILITY

Focusing on four fundamentals for increasing customer centricity can play an important role

By Matthew Reymann, SAP

PRODUCT SCARCITY, delivery delays and lengthy lead times are frustrating customers — and providing a powerful reminder to chemical makers and other manufacturers that they need to redouble their efforts to build a more-customer-centric supply chain. Indeed, many companies now realize they should put customers at the center of supply decision-making.

Supply chain planners on the whole apparently grasp the critical importance of customer focus. A recent report from Oxford Economics, Oxford, U.K., based on a survey of 200 supply chain planning executives noted "increasing customer satisfaction" was most frequently cited as the top organizational goal. Yet despite those good intentions, supply disruptions continue to plague industries from chemicals to automobiles to lumber. In a notice to customers about potential product delays as a result of raw material shortages from severe weather, Roger Lee, North American president of Ellsworth Adhesives, Wilmington, Mass., called the supply crunch in the chemicals industry "an unprecedented situation, unlike any supply chain challenge" the company has seen in its 40+ years, and blaming potential delays on "causes beyond our reasonable control."

However, when it comes to building a customer-centric supply chain, there is much that chemical companies — and suppliers in many other industries for that matter — *could* and probably *should* control. Our extensive experience working with chemical businesses around the globe to build more robust and responsive supply chains indicates that real customer centricity depends on succeeding in four areas: greater visibility, integrated and intelligent insights, a strong business network, and a focus on sustainability. So, let's now look at each of these.

GREATER VISIBILITY

The more visibility that suppliers have into the needs of their customers, and the needs of their customers' customers, the better equipped they'll be to understand and align with their customers' business interests and strategic priorities. Today, however, that level of visibility appears elusive. In the Oxford Economics survey of supply chain executives, just 27% said they have full visibility into customer behavior.

Leveraging digital capabilities to connect suppliers more effectively with their customers (and customers' customers) would go a long way toward addressing that visibility gap, particularly within sales and operating (S&OP) processes. Today we see many chemical companies doubling down on demand planning capabilities and advanced forecasting that enable them to leverage science, statistics and machine learning to better understand how the market is shifting. For example, forecasts can consider external variables to better incorporate market conditions into a consensus demand plan. In addition, algorithms can consider growing or declining markets, new product introductions and intermittent demand. System capabilities can automatically define demand patterns, identify outliers and even select the appropriate algorithm to achieve highest accuracy. Furthermore, segmentation capabilities help operationalize a customer strategy with the right priorities to meet business objectives.

As we are seeing in the chemical market today, companies that are investing to strengthen and integrate their S&OP processes, and bolstering their demand planning competencies with machine-learning-powered tools and other advanced supply chain capabilities are better equipped with improved visibility to stay a step ahead of disruption, meet their customers' expectations and provide strong, accurate signals to the operational side of the business.

This visibility must prevail across the enterprise. As companies translate customer demand to procurement, manufacturing, asset and logistics requirements, they must be able to understand the complete pulse of the business and have a good vantage point of the interconnectedness of

end-to-end processes. Furthermore, chemical companies must execute with flawless quality, 100% regulatory compliance and world-class safety. Some chemical makers, therefore, are adopting “control tower” capabilities to truly understand the health of the supply chain. Digital capabilities are key to advancing these efforts, even extending visibility beyond the walls of the business to further link ecosystem partners across the value chain.

However, that level of intelligence appears to be lacking today. In the Oxford Economics analysis, just 38% of supply chain planners said they have full visibility into their company’s end-to-end design-to-delivery process. Those planners “find themselves at the head of a long, complex chain of processes which must work in concert, so they need to have a 360° view of the organization to effectively map the itinerary.”

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INTEGRATED AND INTELLIGENT INSIGHTS

Ensuring the right products get where they need to be in a timely fashion, even in the face of unprecedented disruption, takes fully integrated end-to-end planning. End-to-end planning requires vast business capabilities and processes to align across multiple business planning applications and technologies (for example, aligning next-work planning and execution processes). The real potential game-changer here is the ability to integrate these processes and data to foster customer-focused decision-making at every level of the supply chain. To succeed, chemical makers must continue to push the status quo and embed intelligence in these end-to-end processes; this will redefine supply chain planning, enabling supply chain professionals to understand exactly how operational activity will impact the business and the customer. Companies that can make these connections and put this kind of intelligence to work will give themselves a big advantage.

The reality is that this 360° view can elude supply chain planners with disparate systems and broken business processes. Data may be relatively available, but without business context or the ability to integrate those data across business processes, value is lost. For example, integrating a financial plan into the S&OP cycle, collaborating with suppliers, resolving exceptions and analyzing real-time overall equipment effectiveness bring together data to drive business outcomes. Integration of end-to-end business processes bridges the gap between this 360° view and supply chain execution, a fundamental element of digital capabilities, because visibility without action is just visibility. It must be accompanied by crisp execution.

In practice, that means aligning people, processes and technology in the context of integrated business planning and supply chain execution. Chemical manufacturers must be able to bring data into a holistic customer-focused operational strategy that can scale up to the enterprise level and down to the plant floor. Strong scenario and exception planning capabilities give companies a huge edge in a volatile business environment, enabling them to make customer-focused decisions, with the ability to predict, plan, sense and act with a high level of responsiveness, even amid unprecedented supply chain conditions.

Here again, end-to-end business processes leveraging integrated business planning technology and a digital core can play an instrumental role in producing the kind of intelligence that enables a firm to elevate customer-centricity via improved supply chain execution. For example, as companies assess demand long-term, they also must refine the short-term operational forecast. Machine learning enables demand-sensing capabilities to adjust to short-term changes, creating new levels of agility — and keeping suppliers attuned to market changes. From an execution standpoint, this positions chemical manufacturers to have inventory in the right place at the right time, avoiding unnecessary costs and churn to fulfill orders on time. An operational control tower sitting over these end-to-end business processes — i.e., an integrated digital platform — enables seamless navigation among applications and source systems (production planning, transportation management, etc.) as well. Essentially, this control tower allows companies to connect the dots strategically and operationally, and to thoroughly understand what is currently happening, and what is likely to happen, across the enterprise, and to do so through the lens of the customers’ business priorities.

What’s also exciting is the adoption of data science in a very functional business setting. Supply chain experts have continued to bring new skills and competencies to the table in recent years; now these skills include the advanced application and use of data to strengthen supply chain initiatives. With the chemicals market facing ongoing commoditization, the need for enhanced optimization and modeling will become critically important. Optimization certainly is not a new topic but the ability to orchestrate and scale models on a common platform integrated with a holistic end-to-end plan will open new sources of value. Data intelligence is a natural extension or even a fundamental element of end-to-end planning, helping chemical companies solve the most-complex industry supply chain challenges — and for customers to benefit as a result.

A STRONG BUSINESS NETWORK

"Today's reality is that nobody does business alone," my colleague, supply chain expert Martin Barkman, wrote in a recent article in *Forbes* (https://bit.ly/3o9hOKY).

That reality was laid bare by the pandemic, the blocking of the Suez Canal by a grounded container ship, and other disruptions. The supply chains that fared best were those built as business networks — ecosystems with multiple layers of suppliers, customers and their customers' customers, along with logistics providers and other relevant parties, all connected digitally in real time, working off common data sets, sharing analytics-based insights, and, as a result, making better-informed decisions collaboratively, as market conditions dictate, without the latency in communications that have plagued so many supply chains. As Barkman writes of the network construct, "You can onboard new partners, share plans, make modifications, align the needed resources, and trigger production runs. This is the definition of agility."

Establishing common digital channels to share information further addresses the visibility gap. One thing we've learned from the recent rash of supply chain disruptions is the fortunes of the various segments of a supply chain are intertwined; their ability to securely share information is not just mutually beneficial but essential to ensuring supply chain integrity. The ability to share data and projections about near- and longer-term demand for specific products, including newly developed ones, along with upstream information about raw materials availability and logistics, provides a lot more certainty and a lot less guesswork for customers.

As alliances such as the new Catena-X initiative are demonstrating, business networks enable industries to embed in one another's value chains, a development that can improve the customer-centricity of the supply chain. The aim of the Catena-X Automotive Network (https://catena-x.net/en/) is an open ecosystem; vehicle manufacturers and suppliers, such as BASF and Henkel, are working to create a uniform standard for information and data-sharing throughout the entire automotive value chain. The emergence of business networks like this reflects the new realities of the chemical business, where companies recognize their best chance of elevating their value in the eyes of customers is to compete as part of a broader ecosystem, rather than head-to-head against other individual companies.

A FOCUS ON SUSTAINABILITY

The growing global emphasis on sustainability, net-zero emissions and decarbonization creates new opportunities to better align with your customers, diversify revenue streams and, in the process, make progress toward your own sustainability goals. For example, suppliers can identify feedstock constraints or more effectively model byproduct supply to identify opportunities to repurpose material and drive circularity. By better understanding how their products are experienced by customers, chemical manufacturers can gain insights that can be incorporated into research and development, manufacturing and asset planning processes to begin designing sustainability into the supply chain, perhaps even accelerating demand.

Additionally, this collaborative, network approach opens doors for co-innovation of customized products and even new business models like outcome-based billing based on product yield or efficiency. As part of a connected network of external stakeholders, a company can respond rapidly to market needs and establish a common platform for collaboration. Ultimately, based on operational and experience data and intelligent insights from the connected, collaborative ecosystem, they can respond to customer demand for innovative offerings such as proprietary, co-developed product formulations designed specifically to support a higher, sustainability-focused purpose.

The spirit of sustainability-focused co-innovation — and of customer-centricity — is evident in Green Token (www.green-token.io), a cross-industry partnership that is developing Industry 4.0 tools and processes. It aims to give various segments of the polymer supply chain a common platform on which to manage sustainability and circular-economy-type business initiatives around the pressing problem of plastics waste. Among the partnership's highest priorities is helping consumer product goods companies reduce their plastics' footprint. As producers of monomers as well as polymers, chemical makers are key players in the success of this renewable value chain. Eastman Chemicals, Kingsport, Tenn., for one, has embarked on this journey to provide visibility to sustainable products in the value chain, helping to accelerate innovation and sustainability in the industry (see: https://bit.ly/3IQIxnE).

Meanwhile, the extended business network construct also can provide the platform for a chemical company to advance its climate action strategies, helping it understand and manage its impact on people and the environment. SAP's Climate 21 (https://bit.ly/346oKBN) is such an initiative. It aims to help businesses understand, manage and report their greenhouse gas emissions; this will enable companies to quantify and articulate their carbon emissions reductions not only for compliance purposes but also, potentially, as means to differentiate themselves from the competition in an area, carbon footprint, that is increasingly important to shareholders, investors, customers and the public at large.

Traditional key performance indicators and processes are evolving not only because of increased demand for sustainable products but also due to a strategic commitment from the industry to lead with purpose. Again, supply chain teams should have the vantage point to steer companies with a holistic view of the enterprise. With sustainability initiatives like these, along with customers' elevated expectations fundamentally changing the way chemical companies operate, supply chain organizations have a central role in ensuring this strategic shift is well-executed and the business outcomes it yields are positive for the customer and the company alike. ●

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CONSIDER AGITATION AGGLOMERATION FOR DUST CONTROL

This often-overlooked option can offer many benefits | By Chris Kozicki and Carrie Carlson, FEECO International

CHEMICAL PROCESSORS frequently work with bulk solids in the form of dust and fines. Such solids can pose significant challenges, presenting a wide range of issues for the facility, the process, and the product.

Chemical makers have various options for managing dust — from making equipment dust-tight to keeping dust down with a spray system. One frequently overlooked way to avoid the problems associated with dust is to use agitation agglomeration; this physical treatment of fines not only eliminates dust but also offers a number of other advantages as well.

Here, we'll cover the basics behind this approach to dust control, the many benefits it can offer, how it works, and when it's a realistic option.

WHEN DUST CONTROL IS IMPORTANT

The issues associated with dust are nearly endless. Moreover, they don't occur only at a single point in the lifecycle of a material; in most cases, dust is a problem at every step.

In addition to creating a housekeeping issue, dust can present safety hazards and often results in material loss, which directly impacts the bottom line. Even in cases where producers simply are looking to deposit their dust into a landfill, the material can become windblown, resulting in a liability.

Ultimately, the issues associated with dust relate to:

- reduced process efficiency;
- increased process upsets;
- poor plant housekeeping;
- material loss;
- improper feeding and dosing;
- decreased equipment life;
- storage problems; and
- safety hazards.

Therefore, the best approach to dealing with dust is to prevent it right from the start. Depending on the specific type of process, chemical makers may have the option to integrate an agitation agglomeration step at the start of their production line to prevent dust from causing issues in downstream equipment. Or they can use the technique as a finishing treatment to improve shipping, handling and storage, as well as, in some cases, to provide their customers with a better product.

AGITATION AGGLOMERATION

Agglomeration is the process of particle size enlargement. While often only considered as a means to produce specific forms of material from fines (e.g., a pillow or cylindrical pellet), the technique also is a powerful tool for managing dust because enlarged particles are less prone to becoming airborne.

Agitation agglomeration is a non-pressure technique, i.e., it uses means other than pressure to encourage the gathering and joining of fines into larger, consolidated particles. This type of agglomeration also often is referred to as wet granulation or tumble-growth agglomeration, for its employment of a tumbling action to encourage pellet formation.

The technique uses moisture and agitation to bring particles together into a seed pellet or nucleus. The capillary forces created by surface moisture on the nucleus continue to gather more fines in a layering effect similar to that of rolling a snowball. Moisture and fines are continuously added, while the material is constantly rolled from the tumbling action, causing it to collect more and more layers.

The approach can produce everything from a homogeneous mixture of liquid and solid feed components (often in the form of "fluff") to refined pellets. The process can take place in various types of equipment, as we'll cover later.

Agitation agglomeration also boasts a unique advantage over pressure agglomeration because it yields more-spherical pellets. Unlike the jagged granules and cylinders made via pressure agglomeration whose friable edges rub together and break away to produce fines and dust (a phenomenon known as attrition), the agglomerates from agitation agglomeration do not have sharp, friable edges. These granules subsequently experience significantly less attrition once agglomerates are formed, mitigating dust issues during handling, transfer and shipping procedures.

BENEFITS FOR DUST SUPPRESSION

Many other approaches to dust control are reactive, treating dust that already has formed. In contrast, agglomeration prevents dust formation, largely eliminating the potential for dust and any of its associated issues.

This means processors can cut down on labor and maintenance associated with housekeeping and clogged equipment, and enjoy a generally improved production environment. It also means less material loss and fewer liabilities.

Further, because agglomeration effectively changes the physical form of the material, it generally provides many other benefits:

- better flowability;
- improved shipping, handling, and storage;
- significantly reduced potential for caking;
- more accurate metering/dosing;
- cleaner production environment;
- less waste and product loss;
- control over physical characteristics;
- elimination of segregation;
- enhanced performance of downstream equipment; and
- greater reuse potential.

Of course, depending on the particular material and equipment configuration, not all these benefits may result.

Figure 1. Conditioning, which can produce such agglomerates, often provides a quick and straightforward option for de-dusting.

Figure 2. A pin mixer, because of its intense spinning action, yields small, dense pellets.

AVAILABLE TECHNIQUES

Chemical producers can carry out agitation agglomeration via conditioning, micro-pelletizing and pelletizing, with some overlap between techniques. Let's now look at each.

Conditioning. This generally is considered as blending a liquid component, binder or water with a solid feed to de-dust the material or roughly agglomerate it.

Conditioning often serves to de-dust fine materials such as ash, either for a beneficial reuse application or deposit into landfill. Sometimes, producers can consolidate waste management by using a liquid byproduct or waste as the liquid component for de-dusting. In such cases, blending the solid and liquid material can create a stabilized mixture for disposal.

Conditioning typically occurs in a pugmill (paddle) mixer but pin mixers and granulation drums are alternative options.

The conditioning approach is best for settings in which specific granule properties are not important. The objective may be to roughly agglomerate (Figure 1), homogeneously mix, de-dust, or even increase the material's bulk density. This option is a favored approach for processors looking for a quick and straightforward way to de-dust their material.

Micro-pelletizing. This is a more-refined version of conditioning in which the goal is not only to de-dust the material but also to produce small, uniform agglomerates, often with a higher density.

Micro-pelletizing is chosen when it's necessary to achieve certain granule properties, such as particle size distribution and bulk density, from ultra-fine materials. This technique is standard practice in the carbon black industry and also widely used in processing coal dust and clay fines.

Micro-pelletizing typically takes place in a pin mixer. Such a unit can produce small, dense pellets (Figure 2) thanks to its intense spinning action. A disc pelletizer (pan granulator) also may carry out micro-pelletizing, but the resulting pellets are larger and not as dense. In addition, homogeneous mixing does not occur with a disc pelletizer, unlike with the pin mixer.

Pelletizing. This option — not to be confused with pelleting or extrusion, which is a type of pressure agglomeration — is chosen for producing larger refined pellets (Figure 3).

Figure 3. Fine material (left) is turned into larger, refined pellets (right) by this technique.

Typically, it utilizes a disc pelletizer, as this offers a high level of size control, or a granulation drum.

Pelletizing often serves as a means of dust control in metallurgical applications such as when smelting metallic ores.

Common practice is to precede the disc with a pin mixer to form seed pellets or homogeneously mix the solid and liquid feed components, leaving the pelletizer the sole job of enlarging the pellets. Similarly, a mixer may precede a granulation drum.

The best option for a particular application is highly subjective; it depends on a number of factors, most notably the characteristics of the feedstock, desired capacity, and product goals. For example, a disc pelletizer usually is chosen when a high level of on-size product is the top priority, while a granulation drum often is selected when high throughput is essential, even though it doesn't offer as much size control during operation. Similarly, a pin mixer is better at densifying material than a pugmill mixer. However, the intense spinning action isn't appropriate for all materials.

Sometimes, a combination of equipment may make the most sense.

Always keep in mind that all types of equipment can be engineered with customizations such as hoods, seals and dust pick-off points to minimize the amount of dust that occurs during the actual agglomeration process.

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INAPPROPRIATE APPLICATIONS

Agitation agglomeration can lend chemical processors a lifeline in managing their dust and fines. However, it's not a blanket solution applicable to all materials. Some settings don't suit the approach, either because it's not practical, not economic or, in some cases, not even physically possible. So, let's look at the key limitations.

When material is hydrophobic. Agitation agglomeration uses surface moisture to create capillary action, which then brings and holds particles together. However, with hydrophobic materials, particles can't join together because they actually are repelled by each other, preventing agglomerate formation, or even the conditioning (de-dusting) of the material in some cases.

Many organic materials, such as fats, are hydrophobic and, therefore, do not respond favorably to agitation agglomeration.

If the material needs drying. As mentioned, agitation agglomeration relies in part on the addition of moisture; depending on the process, moisture may require removal after agglomeration. If a drying step is necessary, the process may become economically unfeasible in some applications, particularly those involving low-value materials, due to the added energy and capital costs associated with a drying step.

When liquid addition is not feasible. In some cases, adding a binding agent or water may not be an option,

for example, where water would cause a chemical change or create a strong exothermic reaction. This can pose an issue with materials that contain a high percentage of calcium oxide.

Some materials may require a binding agent other than water to de-dust sufficiently; in certain settings, adding such an agent might be unacceptable because it could change the composition of the material.

When working with a narrow moisture range. Every material has its own unique range of moisture at which it will agglomerate or de-dust. In some cases, this window can be very narrow. Often, in these situations, a fine line exists between the different saturation states (pendular, funicular and capillary). This can result in the process vacillating easily between de-dusted material and "mud" and, subsequently, suffering frequent process upsets.

DEFINING THE PROCESS

Assessing whether agitation agglomeration for dust control makes sense must start with determining whether or not agglomeration is physically possible for the particular material. Then, it's necessary to establish the process and feedstock parameters required to produce the desired result while also evaluating the economic feasibility of the intended process.

Is agglomeration feasible? Because not all materials respond readily to agglomeration, determining whether or not agglomeration is even an option may require some testing. A processor with suitable on-site research-and-development capabilities may conduct testing internally. (Bench-top mixers can provide some indication on whether agglomeration is possible but, typically, more-in-depth testing must follow.) Or an external testing facility such as the FEECO Innovation Center can do the evaluation.

Testing begins with evaluating the material's initial response to agitation agglomeration, typically by running it through a batch mixer with water (or the intended liquid additive) as a binding agent.

Depending on the results and process goals, subsequent trials may involve use of a different mixer or other binding agents to achieve better results. Modification of feedstock conditions also may take place to try to achieve adequate agglomeration.

Developing the process. Once it's established that agglomeration can sufficiently de-dust the material, testing can move on to establishing the process parameters necessary to produce the desired characteristics in the material, e.g., reaching a target bulk density, increasing particle size, achieving a homogeneous mixture, etc.

Depending on the equipment being tested, process variables evaluated during testing might include:

- mixer speed/revolutions-per-minute;
- pin/paddle arrangement;
- retention time;
- liquid and solid feed rates;
- feed location;
- spray port placement;
- disc speed and angle;
- potential wear points and problem areas;
- materials of construction; and
- appropriate binder/liquid additive.

Determining economic feasibility. Because every application is unique, each requires evaluating a number of factors:

- capital cost of equipment;
- operating expense;
- cost and availability of binding agent (if applicable);
- value of end product, or value saved in waste-management costs;
- available spatial footprint for system integration;
- facility modifications required to integrate system; and
- potential in upgraded value of product.

A CASE STUDY

Carbon black is an important component in the production of many chemical products and industrial materials. However, its ultra-fine particle size makes handling,

Figure 4. Manufacturers of the material long have relied on agitation agglomeration to increase particle size and improve handling and safety.

transporting, and using the material both a challenge and a potential liability (due to inhalation and combustion risks).

To circumvent the issues associated with its fine particle size, the carbon black industry long has relied on agitation agglomeration to upgrade the particle size and make handling easier, cleaner and safer. The pin mixer has played a key role in this effort.

Carbon black feeds into one end of the mixer while a spray system mounted in the top of the trough evenly distributes the chosen liquid binder over the rotating bed of material. The liquid addition system and the intense spinning action of the pins inside the cylindrical trough create the ideal environment for densifying and agglomerating the carbon black powder into small micro-pellets (Figure 4).

In one instance, FEECO worked with a consortium of entrepreneurs to engineer a micro-pelletizing system to convert finely divided, tire-derived carbon black into small, dust-free pellets. In addition to the liquid binder spray system and a 22-in. pin mixer, the system incorporated a dryer/cooler, product screening and bulk-bag loading station. FEECO handled equipment design as well as layout of the system in the client's existing facility.

DON'T OVERLOOK THIS OPTION

Dust not only is a nuisance but also a hazard and a drain on profits. Chemical makers face many challenges — managing dust at every step of the production line doesn't have to be one of them.

By employing agitation agglomeration, whether through conditioning, micro-pelletizing or pelletizing, producers can prevent dust from the start. Moreover, the range of additional benefits the technique can offer have the potential to add significant value. ●

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Tumbling Speeds Supplement Blending

New unit significantly reduces mixing and cleaning time

By Stephen J. Knauth, Munson Machinery Co.

SYSTEMIC FORMULAS, an Ogden, Utah-based manufacturer of herbal blends and powdered vitamins, sells directly to homeopaths, naturopaths, nutritional consultants, and other healthcare professionals. "Our products are complicated, with multiple ingredients and more than 150 different SKUs," says production manager Spencer Hansen. The company offers capsules, powders, liquids and sachet daily-dose packaging.

"We're a niche player in the herbal and vitamin/mineral supplement industry," he notes. "Systemic Formulas is distinct because our products are unique and of the highest quality. It follows that our operators and equipment need to be the best."

EQUIPMENT UPGRADE

As its product line grew, Systemic Formulas streamlined production to meet demand by replacing its paddle mixer with a rotary batch mixer. This switch from agitation to tumbling cut mixing and cleaning time by 80%.

Installation took place in Sept. 2019 — as did disassembly and removal of the old unit. The rotary batch mixer occupies the same room and is gravity fed from the room above, as was the paddle mixer.

The plant operates one shift per day, five-to-seven days per week, depending upon demand. "We create one or two batches in an eight-hour shift, with a

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stringent cleaning protocol required between batches," explains Hansen.

Product recipes contain 15–60 raw materials, including vitamins, minerals, enzymes, RNA/DNA tissue factors, amino acids and botanicals. With so many products, from adrenal health to macular degeneration and weight management supplements, Systemic Formulas' batch production process must provide both flexibility and accuracy.

A hammer mill reduces materials to the desired particle size. They then are transported in 44-gal (194-l) lined food-handling containers to the gravity-fed rotary batch mixer, a 40-ft^3 (1,132-l) model 700-TS-40-SS from Munson Machinery (Figure 1).

Batch sizes vary from as small as 100 lb (45 kg) to as large as 1,147 lb (521 kg); the average batch weighs 880 lb (400 kg) and yields 800,000 ½-g capsules that get packaged into bottles.

BETTER PERFORMANCE

Batch blending takes four-to-six minutes versus 20 minutes for the paddle mixer. "No matter the particle size, it does not under- or over-mix, providing the uniform consistency we need," says Hansen.

The unit's internal mixing flights impart a four-way mixing action that tumbles, folds, cuts and turns the material gently, without the shear of agitated machines. "These delicate ingredients are thoroughly blended without damage," he notes.

To add liquids, an optional pressure pot with an internal atomizer sprays a mist of the particular ingredient required — hemp, wintergreen, grapeseed or other oil — onto a moving bed of material for rapid and uniform distribution.

"The aerating system allows us to add oils without wet spots or clumping," comments Hansen. "Air gaps constantly move the surface area so no snowball-sized clumps occur. The result is a uniform yield that we could not achieve with our paddle mixer."

At the conclusion of a blending cycle, the drum continues to rotate, causing the internal flights to elevate the material toward and through a plug gate valve; this avoids stratification associated with discharging of static batches. "The mixer completely discharges," says Hansen, eliminating material waste and reducing cleaning time.

"Between each batch, we treat the mixer like a big washing machine," Hansen points out. It is prewashed, soaped down and rinsed. This is followed by a second soap cycle with agitation balls and then drying with clean rags or towels. The unit next is rescrubbed, rinsed, sanitized and air dried, after which it is wiped down with alcohol, ready for the next batch.

ROTARY BATCH MIXER

Figure 1. Unit blends ingredients in batches that range from 100 lb to 1,147 lb.

"Cleaning took 2½–3 hours with our old 32-ft^3 (906-l) mixer, which operated like a cement truck with paddles," recalls Hansen. "With the rotary batch mixer, we pared cleaning cycle time down to 30 minutes. The large discharge gate and multiple doors give us easy access for final wipe-down cleaning."

RIGOROUS QUALITY CONTROL

Regulated by the U.S. Food and Drug Administration, Systemic Formulas must trace the lot number of the finished product back to the origin of the raw materials. "Having our own in-house lab gives us control over raw material vendors," stresses Hansen. "Our CEO is a PhD biochemist, so our sourcing agents must find the best vendors of specialty materials. Our purchasers even understand harvest cycles to obtain the purest herbs for our product," he notes.

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Make Problems Evaporate

Successful operation requires addressing a couple of key issues

THIS MONTH'S PUZZLER

Our evaporation train was running perfectly. Then, the internals suffered corrosion and corporate engineering decided to replace the type-304 stainless-steel calandria with one made of type-316L. They also expanded the capacity of the system and installed a radial-flow recompression compressor in the last evaporator of the four-evaporator unit (see figure online at https://bit.ly/3h9FCdS). The compressor recovers steam, which is blended with make-up.

That's when our nightmare began. Solids contaminate steam captured by the compressor. The separator appears to be undersized. After only two years, we are seeing stress corrosion cracking (SCC) in the calandria and even in the shaft and impeller of the compressor.

I'm wondering if we should dig deeper, perhaps look at the steam composition. One engineer suggested treating the steel in the calandria to protect it. Another suspects chlorine SCC but can't find the source; he says we should replace the whole evaporation system with one made of a nickel alloy. An inspection of the compressor seal oil pump reservoir found burnt product, rust and water. A compressor expert corporate hired wants to improve the separation. Any ideas? I'm out of options. Without the recompression compressor, we push our boilers to the limit in running this evaporation train.

FIRST TUNE THE PROCESS

You should consider five points:

1. Stress corrosion cracking (SCC), as the name suggests, is caused by stress, corrosive medium, and metallurgy. It starts with pitting and micro-cracks. Broadly put, if you can control these factors, you can increase the threshold for SCC. Austenitic steels, including 316 (0.08% C) and 316L (0.03% C), are susceptible to SCC. The lower carbon content of 316L relative to 316 offers better protection against carbon precipitation during welding. Although SCC starts with pitting or micro cracks, it is hard to predict or monitor. So:

- Check the operating temperatures, pH, and composition of feed to the crystallizers — especially H_2S and chloride content, because H_2S and chlorides have been identified as two key species causing SCC. Typically, below 140°F, chlorides are less aggressive than at higher temperatures. Upsets in upstream equipment might have increased concentrations of these species beyond their threshold values. The key is to keep concentrations and temperatures below their threshold values.
- Contact the equipment vendor to get help in terms of threshold concentrations of H_2S and CO_2, temperatures and pH to reduce SCC. In addition, check "Materials for Use in H_2S-containing Environments in Oil and Gas Production"(NACE MR0175/ISO 15156 standard).
- Stress annealing to remove residual stresses from welding is not effective for austenitic steels. Alternatives are shot peening near weld areas or grit blasting. Because these operations need careful control to avoid creating stresses at other locations, you should get help from your vendor's corrosion experts and develop detailed procedures for these operations.
- Suitable coatings can help by keeping the corrosive environment isolated from the metal and weld areas. The equipment vendor could offer advice.
- In the long run, review your material selection process. Austenitic steels (304, 304L, 316, 316L) have lower SCC thresholds than those of duplex, ferritic steels such as 430, 444 or stainless steels with higher Ni content (e.g., >25%). Consider alloys such as 439, 444, duplex, super duplex, or high nickel (above 25%). In the selection process, keep in mind the ranges in composition, pressure, temperature, and pH variations of crystallizers/calandrias, as well as welding/fabrication requirements.

2. If the problem of carryover to the compressor is intermittent, it possibly could stem from operational upsets or mechanical breakage of internals. Check data logs or the historian for abrupt changes in flows or levels in the separator and last stages of the crystallizers.

3. Check the demister pad in the separator. To do this online may call for x-ray analysis. Also, check the pressure differential across the separator. Too-low pressure drop could indicate a missing, broken or mis-installed demister pad. Too-high pressure drop causes a higher vapor velocity and carryover.

4. Phase separators are designed using the Souders-Brown equation, which has gas velocity (superficial velocity) as a function of liquid density and the density difference between gas and liquid phases. Check your current operation against empirical charts that show vapor-handling capacity of different-sized separators as a function of pressure. Operating gas flows above the design values obviously means the separator is under-designed. On the other hand, if

operating flows are below the design capacity values, then other problem areas exist.

5. Burnt product and rust (black deposits) in the compressor seal oil probably result from liquid accumulation near the weld areas of the calandrias. Depending on the seal construction, water in the seal fluid could indicate seal failure or water leakage into the fluid system. In addition to SCC, you also may have general corrosion elsewhere in the system, which could be carried over to the separator and compressor.

GC Shah, consultant
Houston

PROTECT AGAINST CHLORINE-SCC

The corrosion problem is system-wide. It started long before the compressor was added but the production increase may have made it worse. You suspect chlorine stress corrosion cracking (Cl-SCC) but don't have the time or money to confirm this.

Look at protection of the bearings and seals from corrosion and contamination — that's a cheap fix. Sure, the compressor still will eventually fail from corrosion but at least not catastrophically.

Now, let's consider the more-expensive solutions.

Spending money on a slightly better austenitic stainless steel (316L) didn't help, which is another clue about Cl-SCC. One option might be nickel cladding. Another could be a material like titanium or a nickel-iron alloy. Titanium generally is less expensive than a comparable nickel alloy. However, it may not have adequate mechanical properties, e.g., for compressor shafts and rotors, but may do fine as a tank wall. The cost of titanium is about 35 times that of stainless steel, so cladding may be the better option; cladding will work for compressor blades but probably not for shafts. The best solution for shafts may be a nickel cladding. Some treatment methods exist to desensitize austenitic steels but they suffer from the same problem as cladding — scratching can undermine them; at least you can make cladding thicker than a couple of molecules.

The solids in the compressor are a big red flag. From the figure, it looks like the separator is a chevron type, which is grossly inadequate for the job you're intending to do. The description says the production rate increased; this means there is less free-board in the evaporators, allowing more carry-over. The solution is two-pronged: First, check the design calculations with the evaporator manufacturer. (Never assume the project engineer did this!) Then, replace the separator with a gas/liquid/solid separation membrane, the multi-million-dollar solution.

While you're doing this, inspect all the evaporators thoroughly for Cl-SCC and take samples for metallurgical analysis. On the side, perhaps you can develop better systems to protect the compressor oil and seals from damage. It's worth noting that oil system failure is the leading cause of compressor fires.

Don't limit your review with the evaporator manufacturer to the last evaporator. Look at the entire evaporator train. Review product changes with quality control. Double check for other changes to the system, feedstock, utilities, controls and even personnel since the implementation of the production increase.

Alternatively, given the costs and complications in preventing damage from Cl-SCC, maybe it might be cheaper to eliminate chlorine from your fresh water source.

Dirk Willard, consultant,
Wooster, Ohio

MAY'S **PUZZLER**

Our plant's old heat exchanger is showing its years. It's a shell-and-tube exchanger with two passes for the tubes and one pass for the shell. A sticky product with a viscosity of 120 cP at 280°F and 80 cP at 150°F goes through the tubes. The density is 0.88 and 0.84, respectively, and the mass heat capacity is 0.82, and 0.9. I estimate a thermal conductivity of about 0.025 BTU/hr-ft-°F at about 100°F. Semi-saturated steam at 150 psig goes through the shell.

In the past three months, operators have noticed burnt product. Looking at the valve performance from trends, the steam valve seems to swing open more quickly and tries to throttle quickly down. Maintenance blames routine fouling. The next outage is due in six months. So, the manager says to run the product a little cooler going into the exchanger. The process engineer warns the pump can't handle that. The production manager complains the steam traps aren't being replaced when they stick open.

I'm not convinced by any of these arguments. The traps are working. While the pressure drop across the tubes is higher than before, we don't have a good flow meter on the product so there's no way to know what normal is.

What do you think is causing the problem? How should I approach my investigation? Is there a way to limp through until the next scheduled outage?

Send us your comments, suggestions or solutions for this question by April 8, 2022. We'll include as many of them as possible in the May 2022 issue and all on ChemicalProcessing.com. Send visuals — a sketch is fine. E-mail us at ProcessPuzzler@putman.net or mail to Process Puzzler, *Chemical Processing*, 1501 E. Woodfield Rd., Suite 400N, Schaumburg, IL 60173. Fax: (630) 467-1120. Please include your name, title, location and company affiliation in the response.

Use Your Head with Headers

Carefully consider the consequences of configuration on flow distribution

Consecutive splitting is a simpler and cheaper alternative.

MANY FLOW systems use manifolds or headers to distribute fluid to multiple paths. Such arrangements often arise with heat exchangers, centrifuges, reactors and other equipment. Usually, the aim is to send the same amount of fluid through each path. Then, after passing through the equipment, the flow recombines.

In some systems, e.g., many of those for fired heaters, keeping flow rates equal is so important that each flow pass has a control valve or other device, such as a critical flow nozzle, to ensure even flow rates. In others, the inherent configuration of the piping and equipment sets the flow allocation.

Figure 1 shows two generic ways for flow splitting and combining using inherent piping and equipment configuration. The bifurcation splitting approach attempts to ensure the same flow rates by having a truly symmetric piping network. This may work if the number of splits is 2^N — but configurations with a different number of splits are not truly symmetrical. Additionally, symmetric splitting tends to be very expensive because it requires a lot of pipe and fittings if a large number of splits is needed.

Consecutive splitting is a simpler and cheaper alternative. For splitting, multiple branches come out of a common line. For combining, multiple branches enter a common line. Figure 1 depicts two major options. In the U-type or reverse flow configuration, the first flow split off is the last flow combined. In the Z-type or parallel flow configuration, the first flow split off is the first flow combined.

Depending upon the situation, the performance of the U-type and Z-type may vary considerably. For convenience, the inlet header often uses a single diameter. With a constant-diameter main header, at each flow split the velocity in the main header drops, per the Bernoulli equation:

$$P + ½\, mV^2 + \rho gH = K$$

where P is pressure, m is mass, V is velocity, ρ is density, g is the gravitational constant, H is height, and K is a constant.

Thus, when velocity drops in the splitting manifold, something else must change. For a simple system, ρ, g and H do not change, so P must. As velocity decreases in the main header, the static pressure increases. In the combining manifold, the opposite occurs. As each flow enters the manifold, the velocity rises and the pressure falls.

When every flow path between the headers is identical, varying pressure drop across the flow paths causes flow rate changes. For the U-type header, the lowest inlet pressure is at the first split. The first split, as the last to join the collection header, also has the lowest outlet pressure. These pressure variations can create flow distribution problems.

The Z-type header also has the lowest pressure at the first split. However, by also joining the combining header first, that split results in higher outlet pressure and a larger flow-rate variation versus a U-type header.

Now, if the pressure drop in each parallel path is very high compared to pressure recovery-loss due to velocity changes, the choice of configuration might not matter. For example, if the pressure drop is 100 psig across a series of heat exchangers in each flow split, having a 5-psig variation due to pressure recovery-loss will impact flow distribution only slightly. Pressure drop is a tremendous way to get even flow rates.

Estimating maldistribution in networks requires considering many more complexities. Among others, pressure recovery downstream of the splits is a significant factor. Also, many headers use gradually reducing diameters on the splitting manifold and gradually increasing diameters on the combining manifold.

In many systems, the choice of a U-type versus a Z-type piping layout can have significant impact. Whenever possible, use the U-type configuration to get more-even flow distribution.

For more on this topic, see my previous columns: "How Important is Piping Symmetry," https://bit.ly/3LvXQEv, and "Avoid Splitting Headaches," https://bit.ly/3gzvGda. ●

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FLOW SPLITTING METHODS

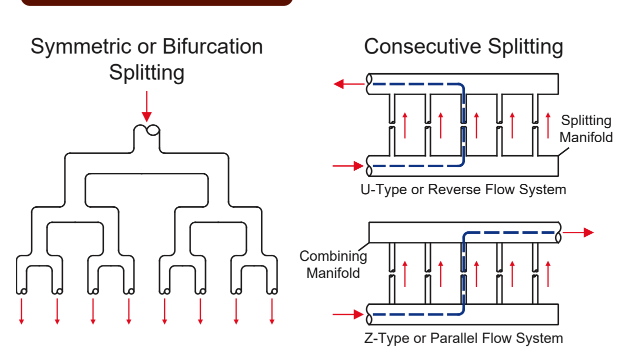
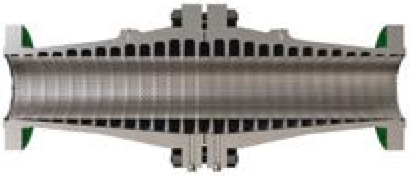


Figure 1. The U-type configuration provides more-even flow distribution.



Silencer Reduces Noise Pollution

The Fisher WhisperTube modal attenuator suits noisy gas or vapor applications in a range of industries. The modal attenuator is a full-bore device offering 15-db sound suppression to reduce noise inside pipes produced by sources upstream, such as control valves or other devices. Installed downstream in place of a pipe spool piece, it generates no additional pressure drop and does not impact process flow. The drop-in device can improve worker safety and regulatory compliance, while reducing the risk of damage to downstream equipment due to high noise levels internal to piping, the company says.

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RTD Assemblies Suit Sanitary Process Environments

Tel-Tru resistance temperature detectors (RTDs) reportedly feature high accuracy, long-term stability, and consistent repeatability. Standard RTD assemblies include a thin-film PT100 platinum RTD sensing element, packaged in a Type-316L stainless-steel probe. The threaded process connections can be paired with a thermowell, while Tri-Clamp fittings also are available. Standard ranges are -60 to 500°F (-50 to 260°C); transmitter models

can be scaled in the field or at the factory to all common requirements. Sanitary probe configurations feature Tri-Clover fittings and surface finishes that comply with 3A Standard 74-07 for hygienic applications. Probes come in .187- and .250-in. diameters with lengths ranging up to 18 in.

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Mixer Speeds Dispersion

The X-Series inline ultra-high-shear mixer is designed for efficient high-throughput emulsification, dispersion and homogenization. Available in both sanitary and industrial configurations, the machine reportedly produces quality dispersions, suspensions and emulsions. The mix head consists of concentric rows of intermeshing teeth; product enters at the middle of the stator and travels outward through the radial channels. Every pass through the rotor/stator exposes the product to tremendous shear due to the combination of very tight tolerances and extremely high tip speeds. It routinely achieves a higher reduction in droplet or agglomerate size compared to traditional colloid mills, says the company.

Charles Ross & Son Company
800-243-7677
www.mixers.com

Valve Controls Steam and Cooling Performance

Copes-Vulcan direct steam conditioning valves (DSCVs) are designed to provide reliable steam control and withstand demanding duty cycles and harsh environments. Combining pressure and temperature reduction in a single unit, the design suits applications where valves typically remain closed for long periods of time to isolate steam flow. They often are deployed as the transition point for piping class and material. The angle-style DSCV offers a high flow capacity to 9,500 Cv. A forged pressure boundary design facilitates compatibility of the DSCV with steam and cooling water pipework. Pressure/temperature ratings up to ANSI Class 4500 are available as standard, with intermediate or split ratings provided as required.

Celeros Flow Technology
832-478-1480
www.celerosft.com

Flow Meters Monitor Air Leaks

The SIL-2-rated FS10i thermal flow meter series offers accurate measurement of air, compressed air and natural gas to improve productivity and quality while also reducing energy and other costs, the company says. Their compact size, plug-in wiring and inline- or insertion-style threaded connection into piping ensure quick and effective installation. The meters are designed for applications that include air compressor efficiency and leak detection, blowers, boiler and burner air, and gas fuel feed lines. The units require no additional pressure, temperature sensors or other components to infer flow measurement. The sealed, no-moving-parts sensor does not foul or clog, and requires no routine maintenance for trouble-free, continuous operation.

Fluid Components International (FCI)
800-854-1993
www.fluidcomponents.com

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Scientists Supposedly Solve Silver Snafu

Researchers address problem of silver leaching from textiles

Silver, a biocide, poses a threat to life in river and sea sediments.

A BRIEF Internet search for "using silver in fabrics" reveals a host of companies manufacturing everything from sportswear to bedding, gloves, medical scrubs and towels.

The common factor among them is the use of compounds containing silver (Ag^+) ions against the predations of microbes, notably those that cause body odor and irritating skin condi-tions.

However, silver has its problems. For example, it can be difficult to apply to soft and porous substrates, such as natural and synthetic textiles, without negatively impacting the textile. Many antimicrobial coatings require complex application strategies and have undesirable qualitative properties that can limit their use. These include high absorbance of visible light and corresponding discoloration, clogging of textile pores, or the incorporation of potentially toxic compounds.

Perhaps the most concerning problem is heavy leaching during use or washing. Silver, a biocide, poses a threat to life in river and sea sediments if it enters the water cycle.

A 2018 report by The Swedish Water & Wastewater Association (Svenskt Vatten), Bromma, Sweden, highlighted the problem. The organization tested silver-containing garments described as anti-odor. Every single one had experienced leaching, ranging from 31–90%, after ten washes — the latter from a pair of sports leggings. The median value was 72%.

This reinforced a previous report by the Swedish Chemicals Agency that found two out of the three silver-containing products it tested had no antibacterial effect after ten washes. In fact, the agency concluded it was almost down to luck if any garment still performed after several washes.

The Svenskt Vatten report also pointed out that research showed silver seemed to reduce the level of sensitivity/resistance of microbes to antibiotics.

Now, researchers at the University of Tokyo believe they have made a breakthrough in tackling silver leaching.

Writing in a recent issue of *Nature Scientific Reports*, the researchers claim to have found the first cost-effective and convenient way to apply a silver-based antimicrobial clear coating to new and existing textiles.

The coating uses the polyphenol tannic acid (TA) found in chocolate, wine and other familiar superstainers to bind silver in such a way that a garment can be washed multiple times without losing its antimicrobial and anti-odor properties.

This Ag^+/TA coating also is completely clear, so it doesn't discolor textiles, and is only 10-nm thick.

Two ways of applying the coating were tested. In the first, of possible interest to commercial fabric manufacturers, textiles are bathed in the Ag^+/TA mixture. The second, which the authors note could suit small-scale settings, involves spraying the garment first with silver nitrate and then with the polyphenol TA binder. An obvious advantage here, they point out, is people can add the coating to existing items of clothing. Both processes take about 20 minutes.

Because of the broad-spectrum antimicrobial protection of the Ag^+/TA coatings observed against viruses, bacteria, and fungi, the authors foresee their "facile, rapid and relatively sustainable" approach will find use in various medical, health and lifestyle applications.

Interestingly, the article's ethics declaration notes one of the authors is an inventor on a patent application with aspects related to this work and is pursuing commercialization of the technology.

While the Tokyo team believe they have solved the leaching issue, others are keen to do away with silver completely.

Parx Materials, Rotterdam, The Netherlands, for example, has launched a pair of anti-odor socks that use zinc as the key ingredient.

The Dutch company focused on zinc because of its well-documented involvement in the human immune system and its ability to fight off bacteria and viruses.

The socks are fabricated with a mix of polypropylene and polyethylene terephthalate yarns, each impregnated with slightly differing versions of the company's patented zinc-containing Sani-concentrate polymer. The metal is integrated in its ionic form, but as an intrinsic part of the polymer it is fixed inside the material with no releasing mechanism or migration.

In tests with three different microorganisms and a selection of different incubation times, it was found that antimicrobial characteristics remain solely on the surface of the material and no zinc leaches out.

To gather some user experience, 500 pairs of socks were tested by interested members of the public. According to the company, some reported the socks contained no foul odor even after using them for 20–30 consecutive days. ●

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