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# Cars Can Drive Circular Chemistry

Report looks at automotive initiatives, challenges and potential

**SOME PHRASES** based on outdated technology still find use today, at least among the older segment of the population. One such phrase that comes to mind is “sounding like a broken record” — which stems from the tendency of a scratch in a phonograph record to cause repetition of a portion of the recording.

Yet, the phrase I keep repeating like a broken a record, “circular chemistry,” is very up-to-date. It’s an approach to manufacturing that’s focused on using renewable feedstocks and re-using end-of-life materials.

This issue’s cover story, “Circular Chemistry Spins Faster,” p. 16, highlights some major moves underway by chemical makers. A recent article, “The Future is Circular,” <https://bit.ly/33XQMwr>, focuses on the essential elements of circular chemistry.

As our latest annual state-of-the-industry forecast “U.S. Chemical Industry Advances Amid Choppy Seas,” <https://bit.ly/3f75vbd>, notes, the automotive industry represents a significant market for chemical products, particularly plastics — more than \$3,000 per light vehicle. So, car makers can play a key role in advancing circular chemistry. A 56-page report released in October by the American Chemistry Council, Washington, D.C., “Transitioning Toward a Circular Economy for Automotive Plastics and Polymer Composites,” downloadable at <https://bit.ly/3eMzoyy>, provides a good overview of the topic.

It includes sections on the need for circular automotive plastics and polymer composites, the progress toward a circular economy, the path forward, and a call to action.

“The transition toward a circular economy for industrial goods will require the automotive industry and its suppliers to rethink the way that vehicles and their materials are designed, constructed, used, and handled at the end of life,” the report states. It notes

that major automakers such as Ford, and Toyota as well as original equipment makers (OEMs) like Goodyear and Michelin have announced goals and initiatives related to circularity. It also cites legislation, particularly in Europe, to foster a circular economy.

While recycling efforts for cars — involving both dismantling and shredding — long have existed, the report cautions that the changing composition of parts and materials in vehicles will require the automotive recycling industry to adapt. Effective partnerships among automotive recyclers, OEMs, materials producers and technology developers would help, it counsels, adding that recyclers also would benefit from information sharing about the state of the art in vehicle and parts design.

The report also highlights efforts by automakers and plastics producers to use renewable feedstocks and repurpose end-of-life materials. It notes that a key element for successful reuse of wastes is effective materials separation and cleaning technologies, and gives a rundown on some promising developments.

Better design also is essential, the report emphasizes, citing, e.g., extended parts longevity and easier disassembly.

Success demands not only development of advanced plastics recycling and recovery technologies, the report stresses, but also deployment of a robust and coordinated recycling infrastructure. It also requires exploring new business models that can support profitable circularity.

Anyone interested in the promise of circular chemistry should find the report compelling reading. ●



More than  
\$3,000 in  
chemicals goes  
into a light  
vehicle.

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# Pandemic Pointers Prove Popular

COVID concerns creep into the most-read content for 2020



This year's content features ways to cope during the pandemic.

**EVERY YEAR** I pull together the most popular content from ChemicalProcessing.com. It offers a barometer of what resonates with our readers. Not surprisingly, this year's content features ways to cope during the current pandemic. Indeed, we ran many news items about plants repurposing to meet sanitizer demands and our columnists counseled how engineers could work more effectively during these unprecedented times.

However, a sense of normalcy remained regarding what is top of mind for visitors to our website: how-to articles and safety concerns.

You can see for yourself, based on 2020 page views at press time, a list of the most popular content by type.

## TOP ARTICLES

1. Choose the Correct Thermosyphon Reboiler. Both horizontal and vertical designs boast benefits for specific situations. <https://bit.ly/36hJtzD>
2. Processing Equipment: Improve Your Critical Drawings. Use best practices to foster consistency in P&IDs and PFDs. <https://bit.ly/32stQEk>
3. Chemical Industry Advances Amid Choppy Seas. Current challenges don't diminish its favorable competitive position. <https://bit.ly/3kfF1X7>

## TOP NEWS

1. Spain Chemical Explosion Kills One, Injures Others. An explosion in a chemical hub in north-eastern Spain caused an emergency response. <https://bit.ly/2GIYX77>
2. Chemical Reaction Triggers Explosions at Pharmaceutical Plant. Series of explosions closed PCI Synthesis in Newburyport, Mass. <https://bit.ly/3pb0moj>
3. Anti-Bacterial Coating May Protect Surfaces from Coronavirus for Up to a Year. Coating protects surfaces no matter how many times it is touched or cleaned. <https://bit.ly/32sqTUo>

## TOP COLUMNISTS

### Chemical Reaction Blog

1. Video: Soap Makes COVID-19 Fall Apart Like House of Cards. <https://bit.ly/3n8868C>
2. Mask Test Uses Fire to Prove Point. <https://bit.ly/3pe97Oz>

### Compliance Advisor

1. Compliance: Russia Creates New Chemical Inventory. <https://bit.ly/3ldV88J>
2. EPA Tells Businesses To Pay Up. <https://bit.ly/3eGPhq3>

### End Point

1. Aging Wind Turbines Pose Recycling Challenges. <https://bit.ly/38lnJ8K>
2. Firms Repurpose To Meet Sanitizer Demands. <https://bit.ly/2JUCLZ3>

### Energy Saver

1. Take A Closer Look At Cascaded Efficiency. <https://bit.ly/35aqnfA>
2. Improve Distillation Control. <https://bit.ly/38pxp1T>

### Field Notes

1. Protect Your Centrifugal Pumps. <https://bit.ly/2IkeryV>
2. Essential Plants Need Effective Engineers. <https://bit.ly/2IjnfVA>

### From The Editor

1. Open Automation Efforts Advance. <https://bit.ly/32ut8Xn>
2. Consider Subtler Covid Consequences. <https://bit.ly/2IgWYr9>

### Making It Work

1. Petrochemical Complex Mega Project Starts Up On Time. <https://bit.ly/3kktHJu>
2. Plant Pioneers Use Of Automation Concept. <https://bit.ly/38q1Kxf>

### Plant InSites

1. Heat Exchangers: Consider A U-Turn. <https://bit.ly/2UbiTmi>
2. Don't Slip Up With Slipstream Filtration. <https://bit.ly/32unEvB>

### Solid Advice

1. Emissions: Rethink Gas Cleaning. <https://bit.ly/36jYBMN>
2. Bolster Your Solids Processing Toolbox. <https://bit.ly/3n5OyIf> ●

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# Write Reports Right

Follow an effective format rather than rigid corporate standards

**FOCUS ON** clarity in an engineering report. While such reports fall into several types — studies (e.g., related to laboratory work or calibration, failures and inspections, or optimization), cost estimates, engineering calculations, and proposals — all benefit from a clear discussion and conclusion. Sometimes this requires flexibility to stray from a company's set format.

All reports should begin with a statement of purpose. A simple phrase such as “determine the variation of viscosity of detergent A” may suffice for lab work while an optimization study or design report may require several paragraphs. Ideally, you should be able to read it out loud in 30 seconds. If you can't, then you'll need a table of contents.

Next is the executive summary. Unless you require a table of contents, you should be able to explain your conclusions in a minute or less. Try this: list what you'd tell the reader, trim this down to no more than five things, and then read the list aloud. You want the executive summary to make sense to a non-technical person; add the numbers but remember the audience. And, importantly, don't present multiple options. Choose one — your company hired you because you could make a decision.

Generally, don't discuss money in the executive summary. Leave that for later in an economics section.

A background section explaining why you've done the study should follow the summary. Paint with broad strokes. Give the history, frame the problem, and familiarize outsiders with the equipment or facility. Site drawings, piping and instrumentation diagrams, etc., are useful. When reporting on a lab result, calibration or other specific hardware-related issues, replace the background section with one on equipment that describes its operation and limits.

An analysis section should come next. It's the heart of the report. Here, explain the scope of the study, describe the alternative options considered and provide a solid foundation for the summary. Be sure to critique your supporting arguments; it's better to be honest than to pretend you have all the answers.

Don't clutter up the section by including myriad details. Refer to them but put the details in an appendix. Strategically place graphic details

such as figures and tables; they can disrupt the flow of the section, making it hard to follow.

Next, if you're evaluating a project, include a section on economics. Here, also, is where you should put the cost of repairs or technical support. This section can get quite intricate because you should explain not only the cost estimate but also the risks to completion and the accuracy of the estimate. Always define the accuracy of cost estimates! Another often forgotten topic to cover is potential economic impacts such as from project delays, construction out of season, etc.

The final section should consist of the recommendations. Think of this as an expanded version of the executive summary. However, not all recommendations make the priority list in the summary. Be sure to check the recommendations against the summary for two reasons: thought continuity and priority. You might find you've missed a recommendation that belongs in the summary.

Now, let's discuss the appendix. It should include anything that supports the recommendations or contradicts them — to explain risk or error. I use a lot of photographs, both for orientation and to validate information like vessel nameplates, equipment models, etc. The appendix also serves as a space where you can expound on ideas summarized in the report. You should exclude items like equipment manuals and other standalone documents. Instead, as appropriate, excerpt sections using screenshot software.

Finally, let's consider how to progress: I start building the appendix first using screen shots of tables and figures generated from a spreadsheet as well as drawings, photos, etc. Always include labels on drawings and the date the photo was taken. Then, write a short executive summary; the final sections to tackle are the ones on analysis and economics.

Work back and forth between recommendations, the executive summary and the analysis to ensure you're supporting the report conclusions and not leaving any unforgiveable gaps.

As always, writing is an iterative process. So, go back several times to check that your arguments can stand up to critics. ●



You should be able to state the report's purpose in 30 seconds.

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# Copper Catalyst Steps Up Yields

Stair-like design helps improve carbon dioxide-to-ethylene conversion efficiency

**NANOSCALE COPPER** wires with specially shaped surfaces can catalyze a chemical reaction to convert carbon dioxide into ethylene, says a research team from the California Institute of Technology (Caltech), Pasadena, Calif., and the UCLA Henry Samueli School of Engineering and Applied Science, Los Angeles.

Using copper to kickstart the CO<sub>2</sub> to ethylene conversion traditionally has posed problems. The initial chemical reaction produces undesirable hydrogen and methane byproduct, and the ethylene conversion efficiency wanes as the system continues to run.

To address these issues, the researchers created a “step” pattern design of the copper nanowires — similar to a set of stairs arranged at atomic scale. This step pattern across the nanowires’ surfaces remains stable under the reaction conditions. An article detailing the system’s durability and selectivity in producing ethylene appears in *Nature Catalysis*.

Computational studies of the reaction show the shaped catalyst favors the production of ethylene over hydrogen or methane. The researchers also report a CO<sub>2</sub>-to-ethylene conversion rate of greater than 70%, much more efficient than previous designs that yielded at least 10% less under the same conditions. Electron microscopy and OH<sup>-</sup> adsorption cyclic voltammetry confirmed the stepped Cu nanowire surface remained stable for 200 hours during the electrochemical CO<sub>2</sub> reduction reaction.

“The idea of using copper to catalyze this reaction has been around for a long time, but the key is to accelerate the rate so it is fast enough for industrial production,” says William A. Goddard III, Caltech professor of chemistry, materials science, and applied physics. “This study shows a solid path towards that mark, with the potential to transform ethylene production into a

greener industry using CO<sub>2</sub> that would otherwise end up in the atmosphere.”

“...It is estimated that ~65% full cell efficiency of ethylene production from CO<sub>2</sub> with 500 mA/cm<sup>2</sup> is required for this process to be cost-competitive,” adds Yu Huang, professor of materials science and engineering at UCLA. “This translates to about 80% efficiency in cathode half-cell reaction. Our demonstrated Faraday Efficiency for C<sub>2</sub>H<sub>4</sub> is close to the target, at ~77% at pH=6.8.”

Huang cites three key challenges to further advance the process: 1) scaling up production of the stepped Cu surface; 2) engineering a full-cell configuration and condition that work for the Cu stepped surface (likely at neutral conditions); and 3) reducing the reaction’s energy consumption or using solar energy to drive the reaction. “To incorporate the material design in a conventional electrolyzer likely takes about five years; using solar energy to drive the CO<sub>2</sub> to fuel transformation likely needs longer time,” she suggests.

The economics of scaling up also poses some issues. “The current approach uses colloidal synthesis which can be readily scaled up, but the process is likely more costly than one would like. Ideally, we should design a cheaper process to achieve the same topography to be more cost effective,” Huang muses.

Metal ion impurities also may pose a problem in this system, so, pure Cu is preferred. “Similar to the existing water electrolyzers, pure water is usually used,” notes Huang.

Using stepped nanowires for other copper-catalyzed reactions holds promise, believe the researchers.

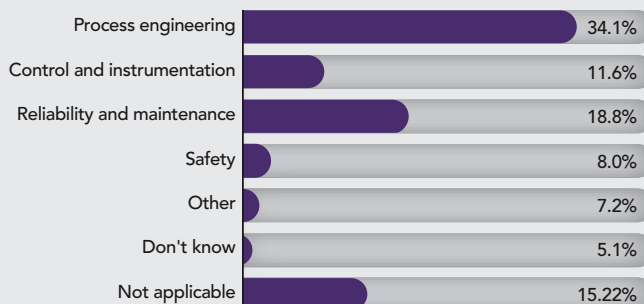
“Although stepped (high-index) facets of heterogeneous catalysts have been recognized to exhibit high catalytic activity, they are generally believed to be unstable. Our studies showed and explained, for the first time, their long-term stability with exceptional performance. This study opens up new possibilities and great potential for the generation and application of unique nanoscale surfaces that are both highly active and highly stable, which will be attractive to the broad community of material scientists and chemical engineering working on catalysis,” believes Huang.

Next, the team will focus on better understanding and designing the optimum microenvironment to facilitate CO<sub>2</sub> reduction to ethylene with high efficiency, in a practical full cell setting. “We hope to achieve the goals in 2–3 years at the lab scale,” says Huang.

“We are interested in collaborating with industries on this project to scale up production of the catalysts and put them to actual use, but we have not been approached yet. One reason may be the demonstrated efficiency is still in the lab and at half-cell level,” Huang concludes. ●

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Which area of technical expertise  
do you consider most lacking at your site?



More respondents cite lack of process engineering expertise.

## Degradable Polymer Rivals PP

A **BIOPOLYMER** produced from industrial leftovers such as waste fats offers properties very similar to those of polypropylene (PP), report researchers in Germany. However, unlike PP, the polymer — polyhydroxybutyrate (PHB) — fully degrades in 6-12 months, they add. Moreover, a new process enables production of PHB on an industrial scale (Figure 1), say its developers at the Fraunhofer Institute for Production Systems and Design Technology (IPK), Berlin.

The researchers used a genetically modified version of the bacterium *Ralstonia eutropha* to metabolize waste residues into PHB. They carried out the process in 1,000-L fermentation tanks kept at 30°C, pH 6.8 and with a dissolved oxygen concentration exceeding 40%.

The team has tested a number of PHB purification steps on the dried cell mass post-fermentation. These include using mealworms, mechanical purification via high pressure homogenization, and purely chemical purification.

“Although various approaches are conceivable and already tested, for production for research purposes we use chemical purification. However, the solvents can be completely recovered and do not burden the ecological balance,” notes Christoph Hein, head of the department of microproduction technology at the IPK.

The only waste materials produced are humus, water and carbon dioxide.

“However, once the plastic has been dissolved from the cell, it is still not ready for industrial use because the hardening process takes far too long,” he adds.

To counter this, the raw material requires mixing with chemical additives downstream in post-production stages. For example, the research team adjusted the plasticizing and processing parameters to trim the recrystallization time to fit the timing of industrial processing. The team also is testing new injection and micro-injection molding processes that they have developed in-house.

The result is the creation of a novel family of materials that satisfy the demands of technical plastics, the researchers claim.

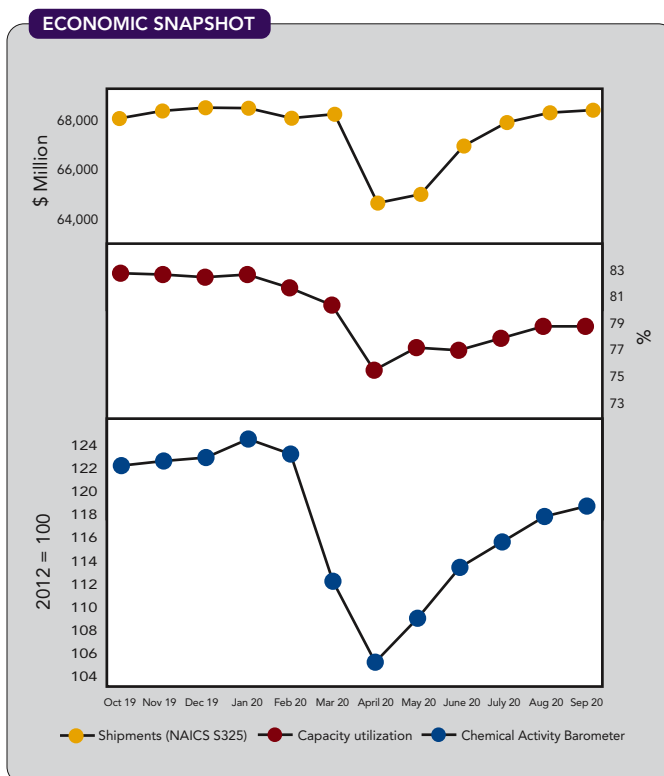
“The new family of materials results from the integration of an HHx chain into the polymer, so that the elastic material properties are significantly improved compared to pure polyhydroxyalkanoates (PHAs) — a group of bioplastics that have a wide range of applications,” explains Hein.

The researchers now are focusing on scaling up



Figure 1. New process allows industrial-scale production of polyhydroxybutyrate. Source: Fraunhofer IPK/Andy King.

fermentation production capacity to the metric ton/month range, further developing additive manufacturing processes, and testing the new materials in primary applications. An industrial consortium involved in the work is carrying out the testing; the identities of the companies involved remain confidential. ●



Shipments and the CAB rose while capacity utilization remained steady. Source: American Chemistry Council.

## Consider ORCs for Waste Heat Recovery

Technological advances and improved economics are spurring use of such equipment



But the times  
are a-changin.'

**OVER THE** past forty years, I have participated in several studies of organic Rankine cycles (ORCs) for recovering low-grade waste heat from chemical and oil refinery processes. ORCs resemble the steam Rankine cycles commonly used for power generation in the process industries — except that, instead of water, the working fluid is a volatile hydrocarbon that better suits operation at low temperatures.

The outcome of our studies has always been the same: “It’s an interesting technology, but the economics don’t work.” The reason is inherent in thermodynamics and, specifically, the Carnot efficiency equation that we discussed in August’s column (“Speak the Language of Energy Efficiency,” <https://bit.ly/2E9YV6N>). If the temperature of the waste heat is low, the maximum efficiency (useful power out/total heat in) also is low. Even if you assign zero cost to the waste heat supplied to the ORC, you still must install a significant amount of equipment (ducting, heat exchangers, expander, electric generator, etc.); as a result, we were never able to achieve an acceptable rate of return.

But the times are a-changin.’ Improved, standardized equipment, manufactured in larger numbers, has cut the unit cost of ORCs. Meanwhile, the economic and societal drivers for waste heat recovery have become much stronger. Loy Sneary, president of Gulf Coast Green Energy, Bay City, Texas, provided the following summaries of three recent ORC projects he facilitated using Reno, Nevada-based ElectraTherm’s ORC technology, the Power+ waste heat-to-power generator.

**Flare reduction.** Here, the ORC was deployed at a Hess Corporation North Dakota oil well pad to demonstrate how waste-heat-to-power technology can reduce flare gas and emissions at the well-head, while producing on-site power. The equipment captures gas, which would otherwise be flared, to fuel a heater that drives the ORC cycle. This provides a practical option for energy recovery in a situation where flaring has previously been considered the only viable solution. In this application, the ORC generates up to 120 kWe of electricity for a single unit and units can be connected in a series. Furthermore, a study by Texas A&M Institute of Renewable Natural Resources, College Station, Texas, verified

the following emissions reductions, compared to the flaring option: CO: 89%; NO<sub>x</sub>: 48%; VOCs: 93%.

**Process fluid heat-to-power.** Plano, Texas-based petroleum extractor Denbury Resources installed an ORC at an oilfield in Mississippi. The ORC recovers heat from produced water supplied at between 190 and 300°F, and makes up to 120 kWe of power. This offsets electric consumption on the site, and also cools the produced water, reducing the temperature by 20–30°F, which can greatly reduce the cost of cooling the liquid. Installation took less than 8 hours, with minimal production disruption.

This approach can be applied anywhere requiring cooling of liquids between 190 and 300°F.

**Radiator replacement.** This application, carried out for the U.S. Department of Defense, was the first fully-integrated stationary engine generator (1.1 MW genset) and waste-heat-to-power generator. It was tested at the Port Hueneme, Calif., naval base and shipped to the Guantanamo Bay, Cuba, for prime power generation. The installation received a successful third-party verification report by Southern Research Institute.

The ORC displaces the radiator’s capital cost and parasitic load, generates additional power, reduces fuel consumption and emissions, and adds resiliency to the genset. Moreover, the ORC system cools the engine even if it is not producing power, so supplemental cooling is not required. Remote monitoring and control enhance ease of operation.

None of these installations are inside a chemical plant or oil refinery, however, obvious similarities exist to the types of processes and equipment we encounter in our facilities — especially in the produced water example. The main message is that the technology has been successfully demonstrated. There is a strong and growing desire across industry to find uses for low-grade waste heat, and ORC technology is definitely an option to consider.

Do you have waste heat streams in your plant that might be good candidates? If so, perhaps it’s time to evaluate the potential for an ORC. Let me know what opportunities you find. ●

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# EPA Announces Carbon Tetrachloride Risks

Final evaluation reveals potential health hazards to workers exposed to the chemical

**THE U.S.** Environmental Protection Agency (EPA) published the final risk evaluation for carbon tetrachloride on November 4, 2020. The EPA found unreasonable risks to workers and occupational non-users (ONU) for 13 of the 15 conditions of CCl<sub>4</sub> use, but no unreasonable risks to the environment. According to the EPA, there are no consumer uses of this chemical. Most agree the findings are not unexpected. This article explains the assessment and the results.

## BACKGROUND

TSCA Section 6 requires the EPA to conduct risk evaluations to determine whether a chemical substance presents an unreasonable risk of injury to health or the environment. For each risk evaluation, the agency must publish a document outlining the scope of the risk evaluation, including the hazards, exposures, conditions of use, and the potentially exposed or susceptible subpopulations. The risk evaluation must not consider costs or other nonrisk factors.

The EPA evaluated workplace exposures and water releases for industrial/commercial uses of CCl<sub>4</sub>. The EPA did not identify any “‘legacy uses’ (i.e., circumstances associated with activities that do not reflect ongoing or prospective manufacturing, processing or distribution) or ‘associated disposal’ (i.e., future disposal from legacy uses) of carbon tetrachloride.” Therefore, the EPA did not add any such uses or disposals to the scope of the risk evaluation following the issuance of the opinion in *Safer Chemicals, Healthy Families v. EPA*. The EPA did not evaluate “‘legacy disposal’ (i.e., disposals that have already occurred) in the risk evaluation “because legacy disposal is not a ‘condition of use’ under Safer Chemicals.”

The EPA made the following final risk evaluation findings, stating, that in making these determinations, it considered the hazards and exposure, magnitude of risk, exposed population, severity of the hazard, uncertainties and other factors.

- There are no consumer uses of this chemical. In the final risk evaluation, the EPA reviewed 15 conditions of use, all of which are associated with industrial and commercial work and primarily involve the manufacturing of other chemicals.

- The EPA assessed CCl<sub>4</sub>'s impact on aquatic and sediment-dwelling species through surface water and sediment exposures, and on terrestrial species. After reviewing these data, the agency found no unreasonable risk to the environment from any conditions of use.

- The EPA found unreasonable risks to workers and ONUs from 13 of the 15 conditions of use of CCl<sub>4</sub>. The agency found unreasonable risks from most commercial uses of CCl<sub>4</sub> to workers in direct contact and workers nearby but not in direct contact with CCl<sub>4</sub> (known as ONUs). Unreasonable risks to workers and ONUs include potential cancer and liver toxicity effects from long-term (chronic) inhalation or dermal (through the skin) exposures. Carbon tetrachloride does not pose an unreasonable risk for two conditions of use: when processed as a reactant in reactive ion etching and in distribution in commerce.

## DISCUSSION

The draft risk evaluation did not find any unreasonable risks for workers. This changed substantially in the final version as the EPA determined that 13 of 15 conditions of use presented unreasonable risks to workers. Relative to the draft document, the EPA found unreasonable risks to ONUs for several additional conditions of use. The bottom line, as noted above, is that 13 of 15 conditions of use presented unreasonable risks to both workers and ONUs and that CCl<sub>4</sub> will, as required by TSCA, be regulated as needed under Section 6. Unlike other risk evaluations, the EPA concluded that CCl<sub>4</sub> does not have “‘legacy’” conditions of use.

The EPA did not evaluate hazards or exposures to the general population in this risk evaluation. The EPA excluded these exposures based on TSCA's function as a “‘gap-filling’” statute. The EPA regulates CCl<sub>4</sub> under the Clean Water Act; Clean Air Act; Federal Insecticide, Fungicide, and Rodenticide Act; Resource Conservation and Recovery Act; and Emergency Planning and Community Right-to-Know Act. As a result, the EPA states it “‘tailored the scope of the risk evaluation’” using authorities in TSCA Sections 6(b) and 9(b)(1). The latter concerns TSCA's relationship to other laws administered by the EPA. The agency has used this argument in other final risk evaluations, and it remains to be seen if this approach prompts legal challenge. ●

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The agency found no unreasonable risk to the environment.

## Not All Check Valves Go With The Flow



**BRIAN STRAIT**  
Business Development and Marketing Manager at Check-All Valve Mfg. Co.

We offer the widest range of spring settings, seat materials and body materials to meet rigorous and specific applications.

**PARDON THE** pun, but check valves are fairly straight forward — they ensure flow in only one direction. In most designs, the upstream fluid force pushes a spring-loaded poppet open, allowing flow. An increase in downstream or back-pressure force drives the poppet back into the seat, stopping reverse flow. But their simplicity shouldn't be taken for granted. *Chemical Processing* spoke with Brian Strait, Business Development and Marketing Manager at Check-All Valve Mfg. Co., and learned that not all check valves are created equally.

**Q: What is the difference between an engineered and a commodity check valve?**

**A:** Well, a commodity check valve is a check valve that would be used in a broad-ranging area of applications and would likely be less expensive and handle less rigorous applications. For many applications that's perfectly acceptable. Whereas an engineered check valve might be built for more stringent application requirements that you'd be addressing.

For example, if you have vertical flow where the flow is downward in a piping system, a commodity check valve — like a swing check valve — wouldn't operate because the checking mechanism would hang open and thereby render it inoperable. With an engineered check valve, you could put the proper internal components in to allow the valve to operate in any flow orientation.

**Q: What are some of the specific applications that can benefit from the engineered check valve?**

**A:** There are several. I like to use a carwash analogy: At an automatic carwash several items from different fluid lines flow through the same nozzle — water, soap, spot-free rinse, things like that. But that media will want to take the path of least resistance like flowing back through the other open fluid lines, rather than through that nozzle. So, to prevent this you need to put check valves in each different fluid line that are geared toward different pressures and flows. The spot-free rinse, for example, comes out real light and misty, whereas water comes out with high pressure, so you're going to have different settings with the different valves to make them work for those particular items.

**Q: What about the specific attributes or features that are available in engineered valves? Is that something that's very case-by-case basis?**

**A:** Somewhat. A lot of engineered products may not offer different variations. However, with our valves, we offer the widest range of spring settings, seat materials and body materials available to meet the most rigorous and specific applications. We only manufacture spring-loaded inline poppet check valves. This is all we do, which allows us to concentrate on providing check valves for practically every service application. We assemble our valves to order and stock a wide variety of components allowing us to ship most of our check valves within one week. We also manufacture custom valves for the most unique application requirements.

People don't realize that the application challenges they encounter could be the result of a misapplied check valve.

**Q: Does somebody call you with the specifications? Do you go out and help them with that? How does that work?**

**A:** We certainly get customers who will have concerns with their existing valve configurations and call us for advice. People don't realize that the application challenges they encounter could be the result of a misapplied check valve. They may have breakdowns periodically and perform regular maintenance and exchange items out, not even realizing that there are check valves out there that can be configured to work in an application.

**Q: Do engineered valves require different maintenance or maintenance intervals than commodity check valve?**

**A:** In my opinion, a properly configured engineered check valve won't require maintenance. It'll last in that application for years, if not

decades of service. Whereas some commodity type of valves may have replacement parts. Swing checks are a real good example. They've got a flapper that swings on a pin and the pin wears out over time because it may not open and close fully. It may bounce around or flutter in the application wearing the pin out, which for some people that's perfectly fine to go replace that periodically. For others, it can be a real issue if their system shuts down because their check valve isn't working.

**Q: Is there anything else to consider with check valves?**

**A:** Well, one I can think of right off the top of my head is water hammer. Most people recognize water hammer as a noise in a piping system. It'll be a bang — literally a bang in the system. You might experience that when you shut off the faucet at home too quickly and it makes a big bang. Well, in process systems, it can be a lot worse. For example, extreme water hammer can move pumps off their moorings. It's basically a hydraulic shock. It's when liquid or media suddenly stops or goes in reverse flow and it creates a hydraulic shock that reverberates down the system. And oftentimes people, unless they've experienced it ahead of time, don't know what's causing that. Oftentimes what causes this is a not having a check valve in the system or a check valve that doesn't close properly to the stop flow or prevent reverse flow before the hydraulic shock begins.

There are many check valves out there that don't. Our check valves close before reverse flow begins, virtually eliminating that issue of water hammer. These inline valves are

#### ENGINEERED VS. COMMODITY CHECK VALVES



Check-All Valves are designed to meet specific requirements for any application.

engineered for silent operation. They close quickly and smoothly to eliminate water hammer and are designed to function equally well in either a vertical or horizontal position, with proper spring selection. Introduced turbulence on the seating surfaces just before the check valve closes ensures positive sealing by removing minute foreign particles suspended in the fluid. The seating surfaces are parallel to each other, thereby eliminating the excessive wear occurring in plug, cone and ball seats.

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

**A:** When it comes to having systems that operate efficiently, you're going to

want different flows that work a certain way. For example, if you're filling orange juice bottles, you want to have the proper flow every time that bottle comes by for consistency. Or if you're having washdown stations where you're spraying chemical on a floor to clean up and get rid of bacteria, you want to have the right amount of chemical applied during every single cycle of cleaning. You don't want to overdo it or underdo it.

So, having a check valve in those situations that can ensure that the proper flows and pressures are available can be really important in a lot of applications.

For more information, visit: <https://www.checkall.com>

# CIRCULAR CHEMISTRY SPINS FASTER



**Developments foster  
use of renewable  
feedstocks and  
end-of-life materials**

By Seán Ottewell,  
Editor at Large

**CIRCULAR CHEMISTRY** — an approach to manufacturing that focuses on leveraging renewable feedstocks and end-of-life materials — continues to advance apace with chemical companies' increasing emphasis on improving their sustainability. Recent developments from the Technical Research Center of Finland (VTT), Enerkem, Avantium, Futerro, ADM and Spiber promise to add to the momentum.

In late September 2020, VTT opened a new platform for process chemistry at its Bioruukki pilot center in Espoo, Finland, bringing its investment there to €35 million (≈\$42 million) since 2014. The new platform (Figure 1) joins three others: thermochemical conversion, biomass processing and textile fiber manufacturing. All aim to scale up new ideas and methods verified in laboratory conditions to industrial scale.

A key area for research at VTT is polysaccharides, especially cellulose and hemi-cellulose from biomass materials such as starch. Tailoring and modifying their chemical structure enable the molecules' use, for example, in barrier or film applications for packaging.

“Over the years, we have developed various ‘tricks’ for dealing with polysaccharides and chemically modify[ing] their properties. For example, we can control cellulose molecular weight via enzymatic treatment



and then modify it with a fatty acid to give a thermoplastic material which can use the normal pelletizing process and equipment,” says VTT vice president Tuulamari Helaja. “Typical production scale is about 100 kg, so enough for customers to test samples,” she adds.

Sugar-based chemistry also is important. In this area, VTT has created platform chemicals including muconic acid, xylonic acid and furandicarboxylic acid (FDCA) — an oxidized furan derivative and valuable building block for a range of polymers.

In the case of FDCA, VTT’s patented technology exploits a novel synthesis route. The proprietary process starts with orange peel or sugar beetroot pulp, extracts pectin and reacts it to aldaric acid. The aldaric acid then is transformed to FDCA in an aromatization step.

The aldaric acid intermediate is much more stable than the 5-(methoxymethyl)furfural and 5-hydroxymethylfurfural intermediates generated in the more common route, notes VTT.

A polycondensation reaction of FDCA with ethylene glycol produces polyethylene furanoate (PEF), which the Finnish group foresees as a potential replacement for the 60-million-mt/y fossil-fuel-based PET used as a packing material. Earlier research has shown PEF to have a 40–55% lower carbon footprint than PET. It also was found to provide a ten times better oxygen barrier, a four times better carbon dioxide barrier, and twice as effective a barrier to water.

“We are offering an attractive route to PEF. At the same time, our biotechnology solution allows the exploitation of biomass waste streams into other useful platform chemicals such as muconic acid and xylonic acid,” comments Holger Pöhler, professor of practice at VTT.

“Biotechnology is one of our core competencies, too, and we are working with fermentation processes at the 10–200-L scale now. Yields are quite low at the moment — 20–40 kg/week — and still at the pilot scale,” he adds.

#### BROADER ROLE

The value of the Bioruukki pilot center goes beyond developing the chemistry. “In the case of the process chemistry pilot platform, its 100–1,000-kg capacity is big enough to give a good insight into the process engineering and the application testing and economics involved with different products,”

says Mika Härkönen, manager, operations support at VTT.

A good example of this in action is a start-up company in Finland that is working with VTT on processes for making cellulose-based textile fibers, he notes. Bioruukki is generating the data needed to take the process to demonstration stage.

This intermediate step between the lab-scale and large-scale manufacturing is the biggest problem with developing such new processes, according to Pöhler. “Before you go to large-scale manufacturing, you need to assess general scalability — such as mass and heat transfer, side products, etc. — to reduce the risk to fail at manufacturing. Companies lack this intermediate infrastructure. We are often asked: ‘Can we run our new process in your 600-L reactor and get 200 kg of product?’ This is happening in very many projects.”

A paradigm shift is occurring in the thinking about the economics of new processes, believes Pöhler. Driven both by the industry and new targets set for carbon neutrality and greenhouse-gas emissions around the world, sustainability is becoming a priority, he stresses.

“The performance of bio-based materials is very similar to that of existing polymers, so there is a momentum to use them now,” Pöhler adds.

However, finding funding is an issue. “Support to larger capex projects needed to keep our pilots competitive falls between two stools — national and EU [European Union]. The cost of an intermediate-size pilot plant is typically €1–10 million (≈\$1.2–12 million), and the challenge is that the EU is not so willing to supply capex for them and the sums are often too



Figure 1. Finish research group has added capabilities for biomass-based piloting and scale up. Source: VTT.

large for national funding bodies of EU member states,” says Härkönen.

When VTT can't get all the equipment needed for a pilot plant, it works actively with the Pilots4U open-access bio-economy pilot network and database that provides access to complementary piloting services.

#### PUSH FOR PEF

Avantium, Amsterdam, the Netherlands, also is eyeing the potential of PEF. Seconding VTT, the Dutch company cites superior performance properties compared to today's widely used petroleum-based packaging materials, adding that PEF is a 100% plant-based, 100% recyclable and degradable plastic.

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Avantium is focusing on commercializing its two lead products, FDCA and plant-based monoethylene glycol (MEG), the two building blocks to make PEF. It aims to take FDCA commercial scale first, with commercialization of plant-based MEG to follow.

The company uses its proprietary Renewable Polymers YXY catalytic conversion technology to produce FDCA — and currently is mulling a 5,000-mt/y plant to manufacture FDCA at Chemie Park Delfzijl, Delfzijl, the Netherlands, that would start production in 2023. The plant will cost about €150 million (≈\$180 million). Front-end engineering design already has started; Avantium hopes to have financing in place by the end of 2020.

For MEG, the company uses its proprietary Ray Technology to convert industrial sugars into MEG via a single-step catalytic process. In early 2020, Avantium commissioned a 10-mt/y pilot plant, also at Delfzijl, to scale up and further optimize the technology and to validate its economics for product applications.

Discussions are ongoing with several potential partners about bringing Ray Technology to full-scale global commercialization.

Meanwhile, the company's Dawn Technology produces industrial sugars and lignin from forestry and agricultural residues. The industrial sugars can serve as

feedstocks in processes making a broad range of chemicals and materials.

A pilot biorefinery (Figure 2) opened at Delfzijl in 2018; since then, trial runs with feedstocks from several partners have optimized the technology further.

In April 2020, the Netherlands Enterprise Agency awarded Avantium €0.5m (≈\$0.6 million) to produce lignin for the development of bio-based asphalt. Large-scale paving of four test roads began in November.

#### RENEWED RELEVANCE

Meanwhile, Enerkem, Montréal, is developing a four-step thermochemical process — involving feedstock preparation, gasification, cleaning and conditioning of syngas, and catalytic synthesis — to convert non-recyclable, non-compostable municipal solid waste (MSW) into methanol, ethanol and other widely used chemicals.

“We think our technology is uniquely useful in the circular economy, one reason being it is feedstock agnostic. We can handle 100% plastic all the way to 100% biomass feedstock if needed and, in fact, that is what the technology was originally created to do during the 1970s fuel crisis. However, as that crisis receded, the demand for biomass-based fuel did, too,” notes Peter J. Nieuwenhuizen, Amersfoort, the Netherlands-based vice president, technology strategy & deployment.

Nearly 50 years later, the situation has come full circle; the company has a new plant in Montréal that handles almost 100% forestry biomass. Its single train produces about 100 kt/y of methanol. “Finance and government support is currently being sought for another in Rotterdam, which will use waste composed of a 55%/45% mix of biomass/plastic and use two trains to manufacture 230 kt/y of methanol,” he adds.

While the calorific value of biomass feedstock is lower, for example, than that of mixed waste, the process itself stays the same.

However, while the trains are linked in parallel to increase production capacity, two really is the optimum number in most cases, he cautions. A two-train setup is capex-efficient but not so big as to run into feedstock supply issues — logistics is a crucial consideration for biomass because supplies must be nearby.

Nieuwenhuizen also points out the economic arguments at play: “Biomass typically costs ≈\$50/t for procurement, whereas MSW attracts a tipping fee of about the same amount. But when we make biofuels from biomass, we get support in EU and U.S. under RED/REDII in the EU and RFS/LCFS in the U.S. legislation.”

#### CHINESE PLANT

In October, Futerro, a subsidiary of Galactic, Brussels, Belgium, started operating an integrated polylactic acid (PLA) production unit at Bengbu, China, in collaboration with its long-term partner there BBKA Biochemical.

PLA is a bioplastic made of lactic acid (LA), which itself is produced by the fermentation of corn sugar or any other form of carbohydrate from biomass.

The new plant has a capacity of 30,000 mt/y and gets LA from an 80,000-mt/y unit that also supplies another Galactic company at Bengbu that uses it as a food ingredient.

Since 2007, Futerro has been developing technology to produce PLA from renewable vegetable resources such as sugar beet, sugar cane, wheat, corn and cellulose. Development work took place at a 1,500-mt/y demonstration unit at Galactic's production site in Escanaffles, Belgium.

The resulting two-step process involves the synthesis of the cyclic dimer of lactic acid — lactide — which then undergoes ring-opening polymerization to produce a PLA with high molecular weights offering attractive mechanical properties.

The work at Escanaffles focused on producing a very high quality PLA with what the company describes as exceptional and controlled optical purity while using low-temperature technologies to avoid degradation or racemization of the products in the production process.

PLA itself has found use for many years in medical applications, such as stitches, because lactic acid has a high level of biocompatibility with humans.



Figure 2. Proprietary technology produces industrial sugars and lignin from forestry and agricultural residues at pilot biorefinery. Source: Avantium.

However, the new Chinese plant opens up a range of novel opportunities — other companies in Bengbu intend to use PLA in food packaging, films, foams, insulation products, textile fibers, 3D filaments, cases for electronics, furniture, carpets, bedding, filters, bottles and cans, and auto parts.

Futerro and BBKA already are planning to increase LA production to 180,000 mt/y and PLA output to 100,000 mt/y.

The Belgian company is offering licenses for the production of LA and PLA and LOOPLA — a new recycling process for converting the polymer back to its constituent monomers.

#### PROTEIN POLYMERS

Also in October, ADM, Chicago, and biotech start-up Spiber, Tsuroka, Japan, announced an agreement to expand the production of Spiber's Brewed Protein polymers for use in apparel and other consumer products.

ADM brings to the pact its expertise in large-scale fermentation technologies, engineering, operations and an extensive agricultural supply chain while Spiber brings its proprietary fermentation process to make protein materials from plant-derived biomass. These materials can be processed into a wide variety of forms, from delicate filament fibers to resins suitable for lightweight composite materials.

The collaboration comes a year after the companies began initial work together to help develop and test Spiber's process at scale. They now will strive to create a pathway to commercial-scale production over the coming years.

The plan is for the polymers to be produced by ADM in the U.S. using plant-based dextrose as a feedstock and then shipped to Spiber downstream facilities for further processing. ●

# Ensure Adequate Fire Protection

Use seven tips to effectively detect combustible gas, smoke and flames

By Aaron Paterson, Det-Tronics

**FIRE RANKS** high on the list of costly risks to chemical plants, according to FM Global, a Johnston, R.I.-based business insurer. The risk of fire often stems from the chemical processes themselves, which frequently involve volatile and flammable materials. To protect workers, chemical plants must have life safety fire systems that detect combustible gases, smoke and flames as early as possible — and communicate detection information in real time to help prevent harm to personnel and property.

While the design and specification of fire and gas (F&G) safety systems require the involvement of experts in the field, some practical knowledge of the subject can help a chemical plant operator better understand the capabilities and necessary ongoing maintenance of its F&G system.

Here are seven tips to help plant personnel ensure their facility has adequate fire protection.

## 1. IDENTIFY FIRE HAZARDS

Before designing and installing a fire protection system, it's important to identify potential fire hazards within the facility by performing a fire hazard analysis (FHA). Chemical plants often conduct FHAs with the help of a consulting fire protection engineer.

An FHA seeks to determine the expected outcome triggered by a specific set of conditions called a fire scenario. FHA fire scenarios take into account building specifications such as room dimensions and contents, construction materials and potential sources of combustion.

Methods used to estimate the potential impact of fire scenarios fall into two categories: risk-based and hazard-based. Both approaches estimate the consequences of possible events. Risk-based methods evaluate the likelihood of different scenarios while hazard-based ones don't.

## 2. LEARN ABOUT STANDARDS AND CERTIFICATIONS

Another important preliminary step is reviewing applicable fire standards such as those from the National Fire Protection Association (NFPA), Quincy, Mass. In particular, chemical plant operators should check "NFPA 70 National Electrical Code" or "NEC (NFPA 70)" and "NFPA 72 National Fire Alarm and Signaling Code." Chapter 17 of NFPA 72 lays out requirements for various types of devices usable to detect indications of fire.

These devices' primary function is to detect a hazard and then signal to alert that an event has occurred. At the same time, it's essential that detectors can maximize false alarm rejection so they don't alarm to non-hazardous events. NFPA 72 defines a nuisance alarm as an "unwanted activation of a signaling system or an alarm initiating device in response to a stimulus or condition that is not the result of a potentially hazardous condition." Nuisance alarms can be costly, causing unnecessary process stoppages that result in significant downtime, so proper device placement is important.

The surest way to know detectors meet safety standards, such as those in NFPA 70 and 72, is to specify equipment with certification documentation. Performance testing and certification verify that a device complies with application standards

and will operate as specified by the manufacturer under a wide range of conditions. A vendor should be able to provide documentation of this independent product evaluation.

## 3. CONSIDER GAS DETECTION FIRST

Because they can alert chemical plant personnel to a gas leak before the gas ignites, combustible gas detectors are considered the first line of defense against destructive fires. NFPA 72 describes a gas detector as "a device that detects the presence of a specified gas concentration." The gas detection system should give an early warning of both the presence and general location of an accumulation of flammable gas or vapor. In addition, advanced systems provide diagnostic functions, historical data logging and digital communications.

Common fixed gas-leak-detection technologies include:  
*Point detectors.* Using electrochemical, catalytic or infrared (IR) technology, these devices provide gas concentration measurements when they come in contact with combustible gases.  
*Line-of-sight (LOS) detectors.* These detect gas along a path between a transmitter and receiver, normally using IR technology.

*Acoustic detectors.* Such devices employ ultrasonic technology to detect gas leaks.

Chemical plants most often opt for catalytic and IR point gas sensors as these offer proven performance and reliability over years of use. IR sensor technology can't detect hydrogen gas, so catalytic sensors are used in areas where explosive levels of hydrogen may occur. Catalytic and IR

detectors typically can be fitted with weather shields or dust caps to protect the sensor and potentially lengthen intervals between maintenance.

Point detector technologies require gas to travel to the sensor; this can necessitate a large number of installation points and a robust placement strategy. Because the detector must come in contact with the gas or vapor cloud, you should locate it adjacent to the equipment being protected. In addition, when determining the proper placement and number of gas detectors required for adequate coverage, you must account for flow considerations from ventilation, fans, wind, convection, etc.

### ACOUSTIC DETECTOR



Figure 1. Device doesn't require contact with gas yet provides fast response to pressurized gas leaks.

To ensure proper operation, you always should install point detectors in accordance with the manufacturer's instruction manual. For detection of gases heavier than air, you should position point detectors below the level of exhaust ventilation openings and close to the floor. For detection of gases lighter than air, you should place the detector above the level of exhaust ventilation openings and close to the ceiling.

Because LOS systems can't provide gas concentration measurements, they supplement rather than replace point detectors. While not recommended as the primary means of protecting equipment, LOS systems continuously monitor for the presence of combustible hydrocarbon gas. LOS features should include a wide alignment tolerance and failsafe operation as well as low maintenance and infrequent calibration requirements. LOS detectors also should withstand harsh conditions, including chemical exposure, precipitation and occasional vibration.

To consistently maintain optical alignment of the transmitter and receiver, you should mount LOS detectors to a rigid and stable surface. In addition, careful component placement is crucial because the system requires an unobstructed line of sight between the transmitter and receiver. However, typical LOS detectors are self-monitoring and will alert users should a blocked light beam or some other issue adversely affect detector operation.

#### FLAME DETECTOR INSTALLATION



Figure 2. Proper placement requires avoiding obstructions between detectors and the area of interest.

Before operation, you should calibrate point detectors according to the manufacturer's instructions for the gas type(s) to be detected. Once in use, all point detectors require periodic recalibration using the appropriate calibration method. Regulations may specify the necessary calibration frequency; if not, consult the manufacturer's documentation.

Where possible, you should install remote calibration-initiation and gas lines to simplify the task of calibrating difficult-to-access detectors. When feasible, you should place detectors in locations that aren't too hard to reach.

Unlike point and LOS technologies, both of which require gas plumes to move to active sensing regions, an acoustic leak detector (Figure 1) can respond almost immediately to a pressurized gas leak. Moreover, rain, wind, fog or obstructions may affect its detection capabilities less. However, acoustic detectors can't distinguish between combustible and non-combustible gas leaks.

Because every gas detection technology has benefits and limitations, a common strategy is to combine the technologies and place each in locations that maximize their effectiveness. In many chemical plants, for example, LOS devices work with point detectors to provide optimal protection. In such situations, the point detectors are installed at or near high-risk gas leakage points or accumulation areas to provide gas level information. LOS detectors, on the other hand, often are placed at process unit or site boundaries where they can monitor the perimeter and track gas cloud movement into and out of an area.

As they age, some gas detectors can suffer degradation from dust, solvents and other contaminants in the air. Therefore, they require ongoing maintenance for proper operation and increased longevity. You should follow the specific maintenance instructions for the particular detection device as detailed in its product manual.

#### 4. USE INDUSTRIAL SMOKE DETECTORS

While combustible gas detectors can warn of increased fire risk, smoke detectors pick up early indications that a fire actually has started. Smoke detectors used in hazardous locations differ from ordinary smoke detectors because they must be rated (either "explosion-proof" or "intrinsically safe") for the risks associated with explosive substances.

Hazardous-area smoke detectors spot particles produced by combustion using a variety of technologies, including ionization, cloud chamber, photoelectric light obscuration, photoelectric light scattering and video image detection.

Before embarking on the design of a hazardous-area smoke detection system, you should review applicable standards such as "NFPA 92 Standard for Smoke Control Systems," which addresses the design, installation, operation and testing of smoke control systems. For smoke detectors

to be effective, you should locate and space them based on airflow from sources likely to present fire risks.

As with gas detectors, to simplify maintenance you should place smoke detectors in locations that aren't too difficult to access. Also, you should keep smoke detectors as free as possible of dust, dirt and other substances that could impair their operation. Product manuals for particular models will specify any additional maintenance requirements.

#### 5. ADD FLAME DETECTORS

No fire protection system is comprehensive without optical flame detectors to spot the radiant energy emitted by a flame. Flame detectors employ several sensing technologies, including ultraviolet (UV), IR, UV/IR and multi-spectrum IR (MSIR). When selecting from among these options, you must match the spectral response of the device to the spectral emissions of the fires to be detected.

In addition, you can performance test a flame detector with the fire type to determine its effective detection range. Flame performance testing also can ascertain a detector's coverage area or field of view (FOV). In most cases, the greater a detector's range and FOV, the fewer devices a plant will need to achieve the necessary coverage. As with gas detectors, optical flame detectors require a clear line of sight to the area being protected, so proper placement, i.e., with no obstructions between detectors and the area of interest, is critical (Figure 2).

Because non-fire sources as well as fire emit UV and IR energy, it's important that flame detection systems don't misinterpret non-hazardous situations and set off costly false alarms. IR and MSIR detectors typically differentiate fire from non-fire sources by using optical filters and algorithms that analyze the characteristics of the IR energy detected. In most cases, such analysis can successfully identify non-fire sources. However, if an object or person moves between the non-fire IR source and the detector, the randomly modulated IR energy produced could mimic a fire signal.

To optimize a flame detector's false-alarm-rejection performance, you should limit a detector's FOV to the area that requires flame monitoring. In addition, controlling the detector's FOV by careful installation and aiming will enhance performance. You also can consult the manufacturer for information about detector configurations that can help mitigate the effects of background IR sources.

An easy way to reduce false alarms is to remove sources of intense IR emissions, such as hot objects including fin-fan heat exchangers and hot pipes, from a flame detector's FOV. When this isn't possible, you should inhibit the operation of a flame detector that has an intense IR source within its FOV before personnel begin working near the detector.

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Another way to minimize false alarms is to use multiple devices to monitor the same area to validate flame detection. This type of system must include algorithms capable of handling "voting" circuits (with each detector's interpretation of an event counting as one vote) and making correct decisions based on input from multiple detectors.

#### 6. MANAGE COMMUNICATION AND RESPONSE

A fire protection system must include a safety system controller (SSC) that receives and interprets inputs from multiple detectors and, as required, triggers notification and fire suppression. Look for an SSC that is third-party certified for applicable standards, including those dealing with performance and hazardous locations.

In chemical plants, the SSC provides information about detection device status to the process control system (PCS) to keep personnel overseeing operations informed of important fire-related events. In many cases, the PCS is configured to take actions that help mitigate and control a hazardous situation picked up by the fire system. Because the fire system and PCS are independent of each other, a PCS failure won't affect fire protection functions.

#### 7. DON'T SKIMP ON FIRE PROTECTION

As is the case when considering any new purchase, it's natural to look for ways to reduce costs. However, always bear in mind that cutting the costs of fire protection may increase the risk to your facility and workers. It's critical to follow applicable codes, standards and local regulations when selecting the components of a F&G safety system.

The surest way to know detectors meet safety standards, such as those in NFPA 70 and 72, is to specify equipment with certification documentation. Using certified F&G safety system equipment and having installation and commissioning done by experienced professionals may be the best tip of all when considering the protection of your chemical plant's people and operations from the potential devastation of fire. ●

**AARON PATERSON** is flame product line manager for Det-Tronics, Minneapolis, a part of Carrier Global Corp. Email him at [aaron.paterson@carrier.com](mailto:aaron.paterson@carrier.com).



# Solve Process Problems by Simple Mixing Analysis

A one-to-ten index can serve as a valuable tool to judge mixing intensity | By David S. Dickey, MixTech, Inc.

**MIXING OFTEN** provides the critical process step that converts raw materials into useful products. Mixing and mixing equipment sometimes serve a specific purpose in processes. However, in a general sense, liquid mixing combines different materials and creates or maintains uniformity of composition, temperature, physical properties, chemical reactions or even dispersions. Nonetheless, even greater differences may exist in the processes and, indeed, not all processes improve with better mixing. Yet, the fundamental purpose of liquid mixing, to create greater uniformity through fluid motion, has some fundamental properties.

This article will focus on some of the most common and basic mixing characteristics.

*The equipment.* Regardless of the process, the most common requirement is to suitably adapt existing mixing equipment and tanks. Rarely do process or development engineers get to start with a clean sheet of paper to select or design new mixing equipment. Equipment limitations are most obvious when the mixing setup is more than 25 years old or relies on a mixer that was purchased used. In either of these cases and many other situations, the equipment isn't designed for the current, modified or new process.

*The process.* Requirements change. Perhaps you need to improve an existing process, adapt a process to make new but similar products, or set up a totally new process somewhat akin to an existing one. Regardless, you need good mixing. You always want to avoid a mixing failure in a stirred tank.

If the current process or equipment fails to provide the production needs, something must change. Either the process or equipment may require modification. The first step is to get a good idea of the current mixing conditions and capabilities.

Calculating a mixing index (MI) can give an indication in relative terms. Here, we'll focus on MI calculations for vertically mounted, impeller-type mixing equipment in cylindrical tanks, as represented in Figure 1. To avoid confusion and complicated correlations, the basic equations presented here apply to turbulent mixing conditions. We'll provide definitions and discuss exceptions and alternative conditions as we progress.

We'll use customary units for the terms given in the figure — inches for length dimensions like the impeller diameter,  $D$ , and tank diameter,  $T$ ; revolutions per minute for the rotational speed,  $N$ ; and gallons for the volume,  $V$ . Because we're focusing on turbulent conditions, we'll need vertical wall baffles to control rotational flow with on-center, vertical mixers. Without such baffles, a deep surface vortex usually will result; the vortex provides almost no vertical or radial mixing. Properly positioned offset, angle-mounted portable mixers can create effective mixing patterns without baffles but the following calculations only may approximate their performance.

The MI calculation provides a value between one and ten that gives an indication of mixing intensity. A MI less than one means mixing intensity likely won't enable sufficient

fluid motion to keep the entire tank contents in motion. A MI of ten represents a mixing intensity at or above typical conditions for practical industrial applications. The one-to-ten scale offers an approximate but useful description of complicated mixing flow patterns and local velocities.

#### ESSENTIAL ELEMENT

While mixing results in many situations depend on particular processing characteristics, fluid motion is essential to all of them. Process results, such as blend time, solids suspension, gas or liquid dispersion and heat or mass transfer, may require more-specific conditions to achieve desired results. The MI concept takes the basic fluid-pumping characteristics of a mixing impeller and converts the discharge flow into recirculating motion throughout the stirred tank. While the origin of the MI calculations [1] can be described on the basis of hypothetical assumptions about circulation flow in a stirred tank, the actual purpose of those explanations is to achieve a practical quantification of mixing intensity. In this case, the result is more important than the background explanation.

However, many independent and related studies that have generalized experimental results [2] support the explanation and practical values. Mixing technology is based on empirical results, which means that experimentation, not just calculation, is needed to create and justify the correlations. In many academic and even industrial studies, the details of the experimental methods or measurement equipment affect the exact results. In the industrial world, process variability may make such prescribed conditions difficult or impossible to achieve. The MI is a practical way of generalizing mixing intensity for different industrial processes and mixing impellers.

The definition and calculation of the MI take advantage of the general relationships between impeller power number, pumping number and other experimental measures of mixing performance. Most typical measures of mixer operation have limits or involve different evaluations in different situations. For instance, the power requirements of mixer operation must be matched to motor power capabilities. All impeller power inputs are 100% efficient. The power input by a mixer eventually degenerates into molecular motion, which is heat. However, not all power is effective in accomplishing the fluid motion and process requirements. Obviously, power per volume is a better measure of mixing capability than just power because the same amount of power applied to a tank of liquid will have less process impact in a larger tank. Other measures of process effect, such as blend time or turnover time, can be difficult to use as process objectives. Assumptions of longer times aren't conservative. Longer times mean that less mixing intensity is required; less mixing usually will produce poorer process results.

Another problem with other common measures of mixing, such as differences between flow and shear, is that the type of impeller being considered can affect success. Axial-flow and radial-flow impellers create different flow patterns. Some types of axial-flow impellers can yield better process results in similar applications. To accommodate the effects of different impellers, much of the behavior is reflected in different turbulent power numbers. Power numbers primarily are functions of the impeller geometry and pumping results. In the case of axial-flow impellers, the power number also relates to the pumping number, much like the relationship between lift and drag coefficients on an aircraft wing or propeller blade.

By focusing this basic discussion of the MI on turbulent mixing, the turbulent impeller power numbers effectively are constant values for mixers operating in baffled tanks. The pumping numbers for similar conditions also are constant for turbulent conditions. We can overcome the limitations imposed by the assumption of turbulent mixing by the use of viscosity correction factors, which are part of a longer, more complicated article for another day.

#### CALCULATING MI

Turbulent conditions for mixing exist not only because of low viscosity but also in combination with impeller size and rotational speed. The typical definition of turbulent mixing conditions is based on the impeller Reynolds number,  $N_{Re}$ ,

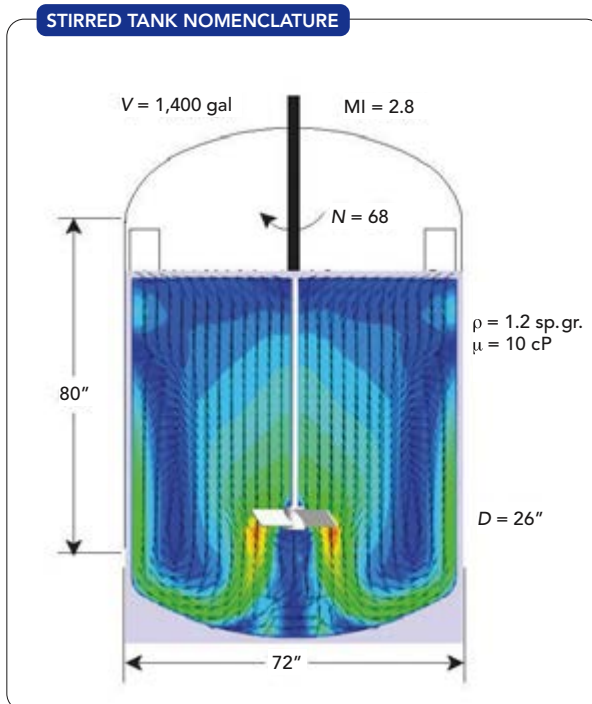


Figure 1. Calculations use conventional units, e.g., inches, revolutions/minute and gallons.

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exceeding 20,000. The Reynolds number is a dimensionless variable that represents a ratio of inertial forces to viscous forces. Turbulence occurs when inertial forces dominate over viscous forces.

$N_{Re}$  is defined and evaluated by:

$$N_{Re} = (10.7D^2N\rho)/\mu \quad (1)$$

where  $D$  is impeller diameter,  $N$  is rotational speed,  $\rho$  is the fluid density (sp. gr.) and  $\mu$  is the fluid viscosity (cP).

You can calculate the MI for turbulent mixing conditions by the following expression:

$$MI = 4.05 \times 10^{-4} (N_p^{1/5} ND^{3/2}) / V^{1/2} \quad (2)$$

This combines the effects of a turbulent power number,  $N_p$ , rotational speed,  $N$ , impeller diameter,  $D$ , and liquid volume,  $V$ . Each variable accounts for the essential factors that affect mixing intensity.  $N_p$  reflects the impeller geometry as it influences the ability and efficiency of the design to pump liquid.  $N$  and  $D$  describe the impeller operation.  $V$  puts the mixer capabilities in perspective relative to the batch size.

The inclusion of  $N_p$  links different impeller types to the same evaluation criterion. A pitched-blade turbine giving a MI of 3.0 should provide the same mixing intensity as a hydrofoil impeller with a MI of 3.0. Typically,  $N_p$  is 1.37 for pitched-blade turbines, 0.30 for hydrofoil impellers, and 3.96 for straight-blade (non-disk) radial-flow turbines. You can use corrected or alternative power numbers for impellers with different numbers of blades, blade angles, blade widths and other dimensions. However, extreme refinement of any factors in the MI calculation isn't practical or important because the MI is no more precise than two significant figures or one decimal place. You might observe a change between a MI of 3.0 and 4.0 in an industrial application but probably won't detect any difference between a 3.2 and 3.3.

The following example will demonstrate a MI calculation for a hypothetical tank. Assume the tank is 72 in. in diameter with an 80-in. straight side and an ASME head on the bottom. The process involves mixing 1,400 gallons of a 10-cP liquid with a 1.2 specific gravity. The mixer in the tank has a 26-in.-dia. pitched-blade turbine turning at 68 rpm.

The first thing we should do is calculate  $N_{Re}$  to check the process is turbulent before we use the turbulent MI calculation.

$$N_{Re} = (10.7D^2N\rho)/\mu = [10.7 (26)^2 \times 68 \times 1.2] / 10 = 59,023 \quad (3)$$

$N_{Re}$  exceeds 20,000, so our example is turbulent.

The next step is to put these same mixing values into the MI calculation.

$$MI = 4.05 \times 10^{-4} (N_p^{1/5} ND^{3/2}) / V^{1/2} \\ = 4.05 \times 10^{-4} [(1.37)^{1/5} (68)(26)^{3/2}] / (1,400)^{1/2} \quad (4)$$

The MI for our example is 2.8, which represents a moderate mixing intensity on the 1–10 scale.

### OTHER CONSIDERATIONS

While the calculation of a MI provides a way to evaluate a mixer in a particular application, not all process improvements depend on just estimating a mixing intensity. Sometimes, even with existing equipment, predicting how changes might alter or improve the MI is important. For instance, suppose you're considering a different impeller type. Switching from a pitched-blade turbine to a hydrofoil impeller may provide more pumping, resulting in greater mixing intensity. However, merely replacing the current pitched-blade turbine with the same size hydrofoil impeller will decrease the MI because of the lower power input by the hydrofoil impeller. The lower power input also will reduce the pumping ability of the hydrofoil for the same diameter impeller.

To do a practical MI calculation for changing from a pitched-blade turbine to a hydrofoil impeller, we must start with an equal power hydrofoil impeller. We must use a hydrofoil impeller with a larger diameter than the pitched-blade turbine to input the same power at the same speed in the same liquid. Because the other factors in the power calculation,  $\rho$  and  $N$ , remain the same, we can calculate the hydrofoil diameter by rearranging the turbulent power for the different impeller types:

$$N_{p,Hydrofoil} (D_{Hydrofoil})^5 = N_{p,Pitched-Blade} (D_{Pitched-Blade})^5 \quad (5a)$$

$$D_{Hydrofoil} = (N_{p,Pitched-Blade} / N_{p,Hydrofoil})^{1/5} (D_{Pitched-Blade}) \quad (5b)$$

Using the conditions from our example MI calculation, we get:

$$D_{Hydrofoil} = (N_{p,Pitched-Blade} / N_{p,Hydrofoil})^{1/5} (D_{Pitched-Blade}) \\ = (1.37/0.30)^{1/5} (26.0) = 35.2 \quad (6)$$

If we now go back to our MI calculation for the equivalent power hydrofoil impeller, i.e., a 35-in.-dia. one, we find the following:

$$MI = 4.05 \times 10^{-4} (N_p^{1/5} ND^{3/2}) / V^{1/2} \\ = 4.05 \times 10^{-4} [(0.30)^{1/5} (68)(35)^{3/2}] / (1,400)^{1/2} = 3.6 \quad (7)$$

This calculation tells us we could expect to see the MI increase from 2.8 with the pitched-blade turbine to 3.6 with

the hydrofoil impeller on the same mixer drive. We should see the effect of the higher MI for liquid blending applications; it also may improve other processes, such as solids suspension. Of course, use of a larger and probably heavier impeller necessitates a check of the mechanical design.

You can rearrange the MI calculation to do some other mixer design calculations such as solving for  $N$  at a desired MI,  $V$ ,  $N_p$  and  $D$ . A different rearrangement of the MI equation also can calculate  $D$  for a given MI,  $V$ ,  $N_p$  and  $N$ .

To account for the effect of viscosity in the MI calculation, you must include an empirical correlation for reduced impeller pumping at lower  $N_{Re}$  in the calculation. You can approximate the effective MI for multiple impellers by doing separate calculations for each impeller using the total batch volume. The square root of the sum of squares of each separate impeller MI will give a reasonable value for the total MI.

Of course, the MI calculation is a simplification of complicated flow patterns in a stirred tank. If the impellers are typical of those used on vertical, top-entering mixers and are at effective locations in the tank, the MI calculations will

provide reasonable estimates of mixing intensity. Don't count on the calculations for accurate direct comparisons of vertical mixers with other geometries, such as off-center, angle-mounted portable mixers. However, comparisons among portable mixers may give reasonable results.

The MI doesn't directly represent other mixing applications, such as solids suspension. However, other applications do need a MI value exceeding 1.0 to expect full liquid motion and may not be practical for MI values greater than 10.0. ●

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### REFERENCES

- Hicks, R. W., Morton, J. R., and Fenic, J. G., "How to Design Agitators for Desired Process Response," *Chem. Eng.*, pp. 102–110, April 26, 1976.
- Dickey, D. S., "Liquid Mixing in Stirred Tanks," *Chem. Eng.*, pp. 24–35, August 2019. (Note: The coefficients in Eq. 15 in that publication are incorrect; use Eq. 2, in this article to calculate mixing intensity.)



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# Are Relief Revisions Reasonable?

Changes made from original design create concern

## THIS MONTH'S PUZZLER

We completed an engineering package for a de-ethanizer system that is part of an overall expansion of a refinery (see figure online at: <https://bit.ly/2ILjYyP>). This involved replacing some lower trays because of fouling and capacity limitations and repairing corrosion in the feed tray and tubes in the air heat exchanger and water condenser. Construction is done. However, the pressure relief system — I did its initial design a few years ago but that has been significantly modified — troubles me.

I noticed the following changes to my design: 1) a block valve was added in front and back of the water (thermal) expansion relief valve (RV); 2) that valve is upside down and someone left the cap at the discharge; 3) the RVs that were located on the reboiler, condensate knockout drum, condensate tank and water condenser have been removed and capped; 4) the pilot RV has been moved from the top of the vessel to the condensate pipe; 5) an isolation valve has been added to a long inlet pipe and the discharge pipe was extended to a duct leading to the flare stack; and 6) the reboiler RV has been replaced by a restrictive orifice on the steam supply (or so I am told by one of the client's engineers working on the project). These changes really concern me, not the least because my name is on the calculations if something goes wrong.

My managers are telling me the refinery is happy and, so, not to rock the boat.

What do you think? What should I do? Should I ask for the new calculations for my files?

### PUT CONCERNS IN WRITING

Based on the limited details shown in the figure, the engineer has every cause to be worried. The refinery will be “happy” right up until the moment something overpressures and explodes and, then, will be most unhappy indeed.

While the additional block valves may not be a problem if they are full bore and locked open, the combination of eliminated relief valves, incorrect installations, and additional inlet and outlet piping pressure drops could conspire to provide inadequate vent relief and pose a very dangerous situation.

As an employee of the engineering firm, the author is in a delicate situation but the risk to life as well as the potential liability to his company and himself force a response. I would suggest he start by reviewing his concerns in detail with his manager and ask for a current piping and instrumentation diagram from the refinery to confirm his suspicions. If the installations are as bad as described, then the concerns have to be raised to the plant *in writing*. It is possible that the revised installation has taken into account all of the changes and the plant is still protected. However, if the protection is inadequate, the refinery likely will be happy to identify the problem before it causes a major incident.

*P. Hunter Vegas P.E., project engineering manager, Wunderlich-Malec Engineering, Kernersville, N.C.*

### REVIEW KEY DOCUMENTS

At the top level, the problem brings up two issues:

1. *Contractual/legal obligations.* If the contract scope is limited to the

work you performed earlier, it may not extend to the changes made by the plant subsequent to completion of your work. However, professional ethics and safety concerns would suggest that you raise the relevant safety concern.

2. *Process safety perspective.* Management of change (MOC) is a vital step and documents should show that MOC had been performed prior to making changes.

Turning to specifics:

- One change involves upstream and downstream block valves on a relief valve (RV). Although this practice is not extensively practiced at plants, offshore and pipeline facilities often install these valves. Of course, they are full port and lock-open (or car-seal open); the plant should have proper procedures for inspection, maintenance and recordkeeping. If this change (installation of block valves) is precedent-setting for that facility, operators should be trained on the isolation and maintenance procedures.

- Regarding capping or eliminating an RV, the need, sizing and installation of relief valves are based on careful consideration of overpressure scenarios (API-520/521; ASME VIII). If an analysis of scenarios shows that the scenario is impossible, then it would be appropriate to eliminate the RV. Experienced engineers consider all operating modes such as startup, normal operation, shutdown or abnormal operations before deciding to eliminate an RV.

- An upside down valve may have been installed to improve accessibility. On the other hand, an upside down installation could lead to dirt and trash build up in the bonnet and generally should be avoided.



- In moving the RV from top of the vessel to downstream condensate pipe, consider the pressure drop in the inlet side of the RV because excessive pressure drop could prevent the RV from protecting the tank. API guidelines suggest inlet pressure drop should not exceed 3% of the RV set point (3% inlet and 10% outlet rule, for a conventional RV).

- For the restriction orifice, you must make sure that all operating scenarios have been considered and have shown that operating pressure will not exceed allowable pressure.

- Because many changes have been made, a comprehensive assessment should be considered to identify potential hazards, *if* no MOCs had been performed for RV changes.

*GC Shah, Consultant  
Houston, Texas*

*Note: Another response appears online at: <https://bit.ly/3nNMgYv>*

## FEBRUARY'S PUZZLER

We replaced our draft-tube baffle crystallizer for borax (Figure 1) six months ago and have suffered a slew of severe problems ever since. Fortunately, the downstream wash-crystallizer can make up some of the production. However, we're under the gun to fix this as soon as possible because we're planning to increase plant capacity.

We're seeing severe corrosion in the propeller; fouling in the draft tube; build-up in the elutriation leg above the steam heat exchanger; fouling in the level measurement float in the settling area; and scaling in the bottoms heater.

Looking at the scant files the corporate engineer left behind makes me concerned. The goal of the project was to increase the output of the crystallizer 50%. This was met in a peculiar way: 1) the volume of the settling area was raised without increasing the agitator power or impeller; 2) the cooling water goes through the same control valve although the coil in the condenser is larger; 3) the volume of the condenser only has been boosted by about 30%; 4) the crystals are larger than desirable, and our product pump is tripping frequently — erosion destroyed the new pump in 8 weeks; 5) now, we're concerned about the feed pump; 6) steam fouling is much worse but we haven't changed the water treatment in the boiler; and 7) the clarifier (the narrow area between the inner and outer wall) has fouled four times in six months.

Corporate has clammed up. However, I am getting help from the company that built the original crystallizer. It says the design of the new unit, which was built overseas, is a mess but can be modified to work.

Is the crystallizer company just bad-mouthing the competition or do you think it can fix the unit? Do you suggest any changes to the setup? Should we go to the fabricator of the new unit to try to get it to address the problems under warranty? What else should we consider?

Send us your comments, suggestions or solutions for

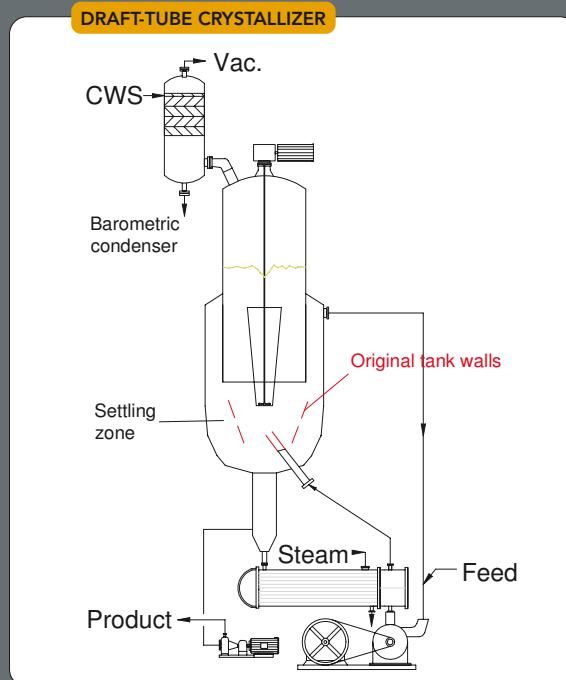


Figure 1. Scale up has led to operational nightmares in a variety of areas.

this question by January 8, 2021. We'll include as many of them as possible in the February 2021 issue and all on ChemicalProcessing.com. Send visuals — a sketch is fine. E-mail us at [ProcessPuzzler@putman.net](mailto:ProcessPuzzler@putman.net) or mail to Process Puzzler, *Chemical Processing*, 1501 E. Woodfield Rd., Suite 400N, Schaumburg, IL 60173. Fax: (630) 467-1120. Please include your name, title, location and company affiliation in the response.

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

# Don't Hobble Your Heat Transfer Fluid

Pay careful attention to temperature limits and fluid condition



Some high-temperature HTFs are solid at ambient temperature.

**A PLANT'S** problems with wiped-film evaporators (WFEs) used for recovery of heat-sensitive distillates spurred a heated discussion when I, the consultant called in to help address the issues, got the process engineering and operations staffs together in a room. The two groups dramatically differed on which problem merited attention first. Process engineering wanted to investigate the WFE speed, recycle system and operating pressure. Operations instead insisted the heat transfer fluid (HTF) for the WFEs deserved priority.

To back up its case, someone from the operations staff stressed that the HTF solidified if its temperature dropped too low. That person then went out and returned with a solid chunk of the HTF. My initial thoughts on looking at the chunk were, first, that it shouldn't be a solid and, second, it shouldn't be dark grey-black.

The first point reveals my lack of experience with HTF systems. Some high-temperature HTFs actually are solid at ambient temperature. This material formed a slurry starting at around 150°F. The high slurry temperature created problems for startup and shutdown but wasn't a defect in the fluid.

However, the grey-black color raised serious concerns. HTFs require filtering, cleaning and even scheduled replacement to ensure they remain effective. This HTF no longer was filtered because all the filters plugged more quickly than they could be changed and so were removed, noted someone from operations.

Further investigation showed the HTF had a manufacturer's recommended temperature limit for extended operations of 752°F and a maximum film temperature of 770°F. The WFEs operated at a process temperature of 805°F, necessitating a hot oil temperature of 810°F. Film temperatures in the hot oil heater weren't evaluated but were even higher.

As a rule-of-thumb for organics, thermal cracking rates roughly double for every 18°F (10°C) rise in temperature. The fluid temperature exceeded the recommended temperature by 58°F (810°-752°). This made thermal cracking rates more than nine times higher than the normal maximum rate. Catalytic reactions from degradation products increase even faster with temperature. The oil sample was black due to extreme HTF degradation. Reduced heat transfer due to the fouling on the HTF side of the WFEs limited their performance.

The current dilemma stemmed from a combination of poor plant design and changes in operating conditions. The original design point exceeded the HTF capabilities. Also, over time, the plant had raised WFE operating pressure to boost capacity. The increased process pressure required higher HTF temperatures to recover the product.

The plant faced a difficult situation. The WFEs relied on conventional HTF systems designed for liquid-phase operation. The HTF had to have a low enough vapor pressure to remain liquid at high temperatures. Investigation revealed that no commercial HTF fluids available met the constraints imposed by the process operating conditions, HTF system capability, and equipment materials of construction and mechanical limits. In fact, the current fluid was the best of a set of unsuitable choices. So, continuing to use that HTF required taking some steps to better handle the severe conditions.

First, HTF filtration resumed. Removing contaminants is critical because many degradation products are catalysts that promote further degradation. However, a reasonable frequency for filter changes is essential to avoid the task getting abandoned as being too much trouble. Achieving a viable frequency necessitated installing larger filters.

Second, the plant reinstated fluid quality monitoring. It had abandoned the practice because the abysmal quality found had made the exercise seem almost pointless. Of course, monitoring only matters if the plant actually acts based on the results.

Third, the plant relied on the results of the quality monitoring to define fluid replacement periods; these, as expected, were much more frequent. Shorter operating periods between fluid changes increased plant capacity by improving WFE heat transfer.

Fourth, replacement fluids were run through a nitrogen stripping step to remove trace oxygen before loading into the system. This helped reduce oxidative decomposition — extending fluid life significantly at these high temperatures.

Fifth, work on a planned plant expansion focused on using different heating technologies for the WFEs being added. The choices investigated were a molten salt system or an electrical heater integrated with the WFE — but that's a discussion for another column. ●

**ANDREW SOLEY**, Contributing Editor  
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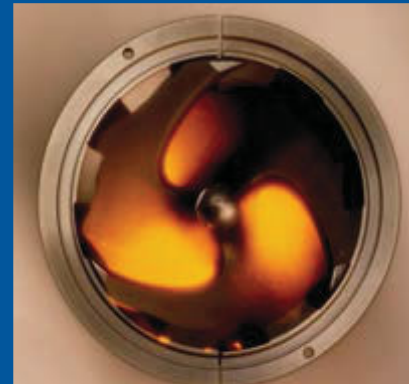
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# Biomass Breakthroughs Beckon

Thermoresistant bioplastic and a catalyst that converts food waste to biodiesel loom ahead



“It could be a game changer for the \$34-billion global catalyst market.”

**SOME PROCESSES** using biomass-based raw materials already operate at commercial scale, others are near (see: cover story, p. 16), while new research gives a hint of what the future might hold.

For example, combining genetically engineered bacteria, kraft pulp and an innovative macromolecular design approach to organic chemistry, researchers at the Japan Advanced Institute of Science and Technology (JAIST), Ishikawa, Japan, and the University of Tokyo have developed what they say is the highest heat-resistant plastic ever based on biomass.

Stable to over 740°C, the novel plastic uses no heavy inorganic fillers and is lightweight in nature.

Producing bioplastics from renewable biological resources is a prerequisite for achieving a circular and sustainable society, but current bioplastics are mostly heat-sensitive aliphatic polymers with limited uses. At the same time, developing aromatic heterocyclic monomers from biomass is problematic because controlling their structure is difficult.

So, the team first genetically engineered bacteria to produce from the renewable kraft cellulosic feedstock two aromatic aminobenzoic acid monomers: 3-amino-4-hydroxybenzoic acid (AHBA) and 4-aminobenzoic acid (ABA).

AHBA was then chemically converted to 3,4-diaminobenzoic acid (DABA). Subsequently, poly(2,5-benzimidazole) (ABPBI) was obtained by the polycondensation of DABA and processed into a thermoresistant polybenzimidazole (PBI) film.

The researchers found that copolymerizing DABA with a small amount of ABA increased degradation temperatures of the PBI film to over 740°C.

Results showed ABA strengthened the interchain hydrogen-bonding of the PBI bioplastic; this was key to its thermoresistance, which the researchers say is higher than any existing biomass- or petroleum-derived plastics, including polybenzazoles.

Further, they believe the bioplastic’s processability enables it to be hybridized with metals and inorganic compounds at temperatures above their melting points without thermally degrading the contacting plastics.

This, in turn, could enable manufacturing engine components that improve energy efficiency for hybrid electric vehicles sensitive to weight. Moreover, PBI bioplastics could be inserted as high-thermoresistant insulators between conducting metals to create high-performance electronic devices, including super-integrated circuits, mass memories, and high-power

motors, opening the door to a new era of lightweight materials.

The work is described in a recent issue of *Advanced Sustainable Systems*.

Meanwhile, researchers at RMIT University’s School of Science, Melbourne, Australia, have developed an ultra-efficient, low-cost catalyst for recycling used cooking oil and agricultural waste into high-value products.

Described in a recent issue of *Nature Catalysis*, the catalyst can make biodiesel from low-grade ingredients containing up to 50% contaminants. The researchers believe it could double the productivity of manufacturing processes for transforming waste such as food scraps — and even microplastics and old tires — into high-value chemical precursors for making medicines, fertilizers, biodegradable packaging and more.

“The quality of modern life is critically dependent on complex molecules to maintain our health and provide nutritious food, clean water and cheap energy,” says RMIT’s Adam Lee. “These molecules are currently produced through unsustainable chemical processes that pollute the atmosphere, soil and waterways. Our new catalysts can help us get the full value of resources that would ordinarily go to waste — from rancid used cooking oil to rice husks and vegetable peelings — to advance the circular economy. And by radically boosting efficiency, they could help us significantly reduce environmental pollution,” he adds.

Lee’s team synthesized a micron-scale ceramic sponge with a hierarchically porous framework in which the macropores are selectively functionalized with a sulfated zirconia solid acid coating and the mesopores with magnesium oxide solid base nanoparticles. Molecules initially enter the sponge through large pores, where they undergo a first chemical reaction (transesterification) and then pass into smaller pores where a second (condensation) reaction occurs.

It’s the first time a multi-functional catalyst has been developed that can perform several chemical reactions in sequence within a single catalyst particle; it could be a game changer for the \$34-billion global catalyst market, Lee believes.

The next steps are scaling up the catalyst fabrication from grams to kilograms and adopting 3D printing technologies to accelerate commercialization. ●

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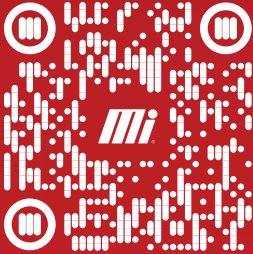
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