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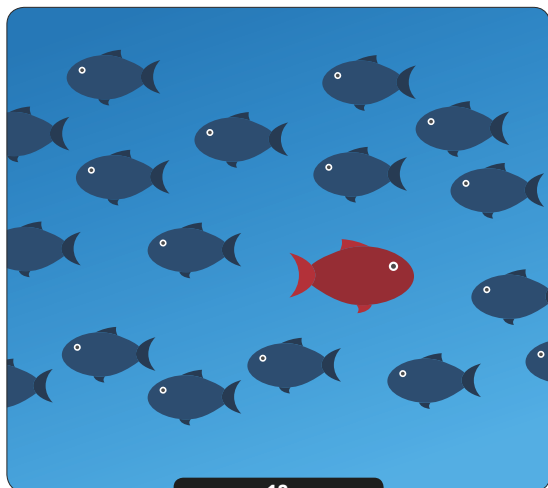


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Folio Editorial Excellence Award Winner

A Petrochemical Centennial Nears

The first plant to make ethylene from ethane started up in January 1920

THE ORIGIN of a significant portion of today's chemical industry traces back more than a century to the pioneering work of an organic chemist at the Mellon Institute of Industrial Research in Pittsburgh, Pa. In the early 1910s, George Oliver Curme, Jr., and coworkers developed a method to produce hydrocarbon gases by subjecting a petroleum fraction, gas oil, to a submerged high-frequency electric arc. Their process promised a source of acetylene cost-competitive with that from calcium carbide. The route also yielded ethylene.

As World War I raged, the U.S. government, seeking an alternative to ethanol dehydration for producing ethylene (to make dichloroethyl sulfide for mustard gas), became interested in the idea of using the electric arc process to convert gas oil to ethylene, and approached Curme. Instead, he suggested using ethane because it requires less energy to crack.

This led to work at the Mellon Institute to develop a process to make dichloroethyl sulfide from ethylene dichloride derived from ethylene. Success prompted the start of construction, in the summer of 1918, of a small "commercial" ethylene plant at the Linde Air Products site in Buffalo, N.Y. However, before the plant was fully completed, the war ended — and, with it, demand for dichloroethyl sulfide.

That could have marked the end of the story. However, Curme conveyed his vision to executives at Union Carbide and Carbon Corp. (which had a stake in Linde):

"Starting with a plentiful supply of ethylene and acetylene, and the necessary by-products obtained in the manufacture of these substances, a huge chemical industry can be built up capable of absorbing thousands of tons of products annually. The Union

Carbide and Carbon Corporation with control of the Linde process, the Carbide process, and with its knowledge and control of electric power projects, is in an exceptional position to exploit this field."

A review of whether to continue the program began late in 1918. Fortunately, Curme's vision of an aliphatic chemical industry convinced the executives to press on with the work. Linde was given responsibility for the project. The first production of ethylene occurred at Linde's Buffalo plant in January 1920.

Unfortunately, fire destroyed the plant later that year. Rather than rebuilding in Buffalo, the company sought out a location with abundant supplies of natural gas, and settled on a site near Charleston, W. Va. In mid-1920, Carbide and Carbon Chemicals was formed to take over the project. Curme was named chief chemist of the new company. He eventually became vice president of research at Union Carbide Corp. and retired in 1955.

These details as well as an extensive review of the genesis and growth of Union Carbide appear in "A History of the Union Carbide Corporation from the 1890s to the 1990s," a 1998 book by Robert D. Stief. You can access the book online at <http://bit.ly/31rNOFM>. It's an interesting read.

By the way, Stief claimed the formation of Carbide and Carbon Chemicals marked the birth of the petrochemical industry. That strikes me as an entirely reasonable contention. What do you think? ●



Formation of the company marked the birth of the petrochemical industry.

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Rethink How You Select Your **Gas Analyzer**



In 2018 **Chemical Processing** completed a study called **“Gas Analytics: Study Finds ROI, Accuracy, Proof are Key Factors”** which indicated that 89 % of process engineers would be willing to change the technology of their gas analyzer.

The 200 process engineers surveyed indicated that their main barriers to changing technologies were:

- Uncertainty about the benefits
- Concern about implementation and maintenance
- Lack of references to build stakeholder acceptance



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Should You Use a Filter or a Centrifuge?

Follow a simple procedure to make the correct choice

YOUR COMPANY has developed a new product and now it's time to go from the laboratory to small-scale production. Your chemists have created a slurry and have separated the product most likely using laboratory filters or maybe a laboratory centrifuge. These units are great for demonstrating the effectiveness of the new product. However, they may not produce the same product quality in full-scale operation. So, it's sensible to take several steps before firming up the process flow diagram (PFD) and making equipment selections.

The chemists likely have provided you with all the most common fundamental data such as particle size, density and other physical properties of the slurry. (Don't just view the researchers as a source of data; they also sometimes can offer valuable insights for your scale-up efforts — see: "Talk to a Chemist," <http://bit.ly/30puZcK>.) You may want to consider refining the product through a variety of drying methods or even liquid/liquid extraction, especially if the desired material is a liquid. However, the most common choice for separation usually involves either filtration or centrifugation.

HOW DO YOU CHOOSE?

Several experimental tests will lead you to the most appropriate type of unit for the separation. These tests, done in a step-by-step sequence, can narrow the selection to just a few pieces of equipment, which can reduce the amount of time needed to select a manufacturer of the appropriate device. Most of these experiments don't require any specialized test equipment and can be run by almost anyone.

Step One. Look closely at the overall behavior of the slurry and ask yourself the following questions:

- How fast do the solids settle in calm liquid?
- Do the solids form a cohesive cake or does it behave like jelly?
- What gravitational force is needed to form a cohesive cake and what's the solids content of the cake?
- How fast does the slurry filter and what is the minimum liquid content?
- What wash rate or cake quality could be achieved after the cake is formed?

One well-defined procedure was published by Edward Davies in 1965 ("Selection of Equipment

for Solid/Liquid Separations," *Trans. I.Chem.E.*, Vol. 43-8, pp. T256–T259). Most of this procedure can be conducted in a tube centrifuge, Buchner funnel and a graduated cylinder. While running these tests, it's important to look at the particles after filtration to determine if they shear or break easily. A simple microscope suffices to observe if this will be a concern in equipment selection.

Step Two. Determine the scale and nature of the processing, i.e., production rate, and whether batch or continuous. Also, check whether some suitable equipment exists in your current operations; if so, this may allow you to campaign the product or utilize an already installed device. However, don't treat availability of such a unit as an overriding factor in equipment selection. Every device behaves in a very predictable manner. I've never seen a filter or centrifuge that wasn't doing what it was supposed to do. However, I've seen a lot of devices that weren't suitable for the product they were handling. While it's tempting to try to use an existing device, doing so isn't always a good decision.

Step Three. Finally, before developing a PFD, determine the quality and suitability of using any filtrate or wash liquid and how to treat it. In the case where the product is the liquid phase, downstream processing of the solids will be important. Retention of some of the samples from the first step is an option but a small-scale test on real-world equipment is better. Try to select a manufacturer that offers your top three choices as determined in the first step. If the tests don't produce acceptable product, that vendor should be able to evaluate your other selections without any prejudices. (Conducting tests at a vendor facility also can prove valuable when using pneumatic conveying — see: "Run a Pneumatic Conveyor Test," <http://bit.ly/2HiA0Bo>.)

Don't neglect another important variable — the human element; operator acceptance of the chosen device is an important factor in its successful use. So, if possible, include relevant operators in the selection process and any on-site testing. Their acceptance can make or break your new product. ●

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I've never seen
a filter or
centrifuge that
wasn't doing
what it was
supposed to do.

Make Your Outage a Success

Follow some pointers to cope with unexpected work and stress



Line up extra craftspeople that you can bring in if necessary.

I'VE SURVIVED numerous stressful outages. So, let me share seven valuable tips.

First, line up extra craftspeople that you can bring in if necessary. By this, I mean have boilermakers available from companies other than the one hired to do the turnaround, and arrange for additional scaffolders, electricians, etc. The foremen managing these extra troops shouldn't come from your primary contractor. Your primary contractor's foremen will be swamped meeting scheduled goals.

As an example, during a 15-year internal inspection of a low-pressure vessel, we discovered enough cracks to tie up boilermakers from the primary contractor for eight days. This was unexpected and blew our schedule. We had to postpone work on other tanks until the next outage and set aside some projects. Knowing tank inspections were involved, we should have planned to have appropriate auxiliary staff on call to handle the other tanks and projects. In this case, we should have lined up extra staff including code inspectors and dye penetration technicians as well as foremen.

We learned our lesson after one turnaround from hell; on a similar project three months later, such preplanning enabled us to finish a day early!

Second, managers usually are inefficient in making decisions. They easily can burn through the clock, leaving little time for engineers and workers to implement changes. This process also ties up key people. So, break up tasks into smaller pieces and only involve those who must decide. Publish a daily report of progress.

Why not create protocols for decisions? For example, use vessel inspectors to estimate remaining service life and inspection frequency but also plan in advance what actions to take. This way, you can avoid delays from decision-making.

Speaking of protocols, consider cleaning and isolation. While these topics merit discussion during design of a pipe route, I can name dozens of pipe runs that apparently were expected to run forever. Proper isolation can include a block and bleed, i.e., three valves — two blocks and a bleed in the middle; two spectacle blinds and a bleed; or even a spectacle and a bleed for safe fluids like water. You regularly should review pipeline isolation and correct design errors during plant outages.

Third, ensure communication among operations, projects, process and contractors is as seam-

less as possible. You not only need radio channels dedicated to different departments but also access to those channels by everyone involved in the outage. A problem with having multiple channels is that critical people may not be listening to the correct channel. So, you need monitors who can page them or beepers for key people. You don't want a crew costing \$500/hr waiting for an operator to sign a work permit.

I've seen shutdowns where engineers responsible for project work weren't given radios. Instead, they scrambled around on foot, logging miles around a facility and dashing back and forth between constructors, their foreman offices, on-site meetings, off-site meetings, warehouses, etc. This results in delays, exhaustion and mistakes. It didn't help that cell phones were banned. Let's face it, if a facility is cleaned and purged, excluding cell phones due to static electricity risk doesn't make sense.

Fourth, establish responsibilities and assign those responsible the resources required to get the job done. If an engineer needs approval to buy gaskets, let alone major equipment, foremen in short order will bypass that engineer.

Fifth, while planning for discovery work seems impossible, make a concerted effort. Scaffolding can pose a particular problem. Vessel inspections require internal and, sometimes, external scaffolding. Failing to keep up on scaffolding resources can cause days of delays — so can lack of skilled boilermakers, electricians, instrument technicians and vessel inspectors. Also, plan for adequate production support, spare parts, tarps, blanks, valves, pumps, e.g., for removing storm water, etc.

Sixth, think about how to most effectively use higher level personnel such as engineers, foreman, operators, contractors, etc. Break down job assignments so such people aren't crushed and, conversely, take advantage of any idle time by allocating additional work or having them fill in gaps, chase equipment deliveries, do hole watches (confined space entry), or even grab water for thirsty welders in a tank.

Lastly, try to avoid scheduling outages when large process plants and refineries using your constructors, scaffolders and engineering firms are doing turnarounds. ●

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Hybrid Membranes May Challenge Distillation

Metal-oxide-infused membranes promise a low-energy option for chemical separations

A POLYMER-BASED membrane infused with a metal oxide network may provide an attractive alternative to energy-intensive distillation, say researchers at the Georgia Institute of Technology (Georgia Tech), Atlanta. The infused membrane separates chemicals better than the untreated membrane and can withstand harsh chemicals without degrading, they add. Moreover, incorporating the treatment into standard membrane manufacturing is straightforward, requires minimal investment in new equipment, and adds little to membrane cost, the researchers claim.

“In practice, using them could produce a 90% reduction in energy cost,” notes associate professor Ryan Lively.

“After placing the pre-fabricated membrane inside of our reactor, we simply expose it to metal-containing vapors that infuse themselves inside the membrane material,” says assistant professor Mark Losego. “This process is called vapor phase infiltration, and it creates a uniform network of metal oxide throughout the polymer membrane. We call it a ‘hybrid’ membrane.”

The team tested the membrane using harsh chemicals such as tetrahydrofuran, dichloromethane and chloroform, and found it remained stable for several months; pure polymer membranes dissolve in minutes.

“Some chemicals that need to be separated are very similar in terms of their size, shape and other properties, which makes them even harder to process using membranes,” Lively explains. “These new hybrid membranes are much more selective.” In the tests, the hybrid membranes separated aromatic molecules that differed in size by as little as 0.2 nanometers. An article in *Chemistry of Materials* contains more detail.

Future research includes fine-tuning the oxide infusions and making new types of hybrid membranes capable of separating a variety of other chemicals.

“Our infiltration process uses essentially the same chemistries as chemical vapor deposition (CVD). ... our initial results are promising, and further optimization of this chemistry would likely be the most productive first step. The Al₂O₃ chemistry is also amongst the least expensive. However, other chemistries may generate additional value beyond membrane stabilization, including improved separation performance or integrated chemical catalysis,” note the researchers.

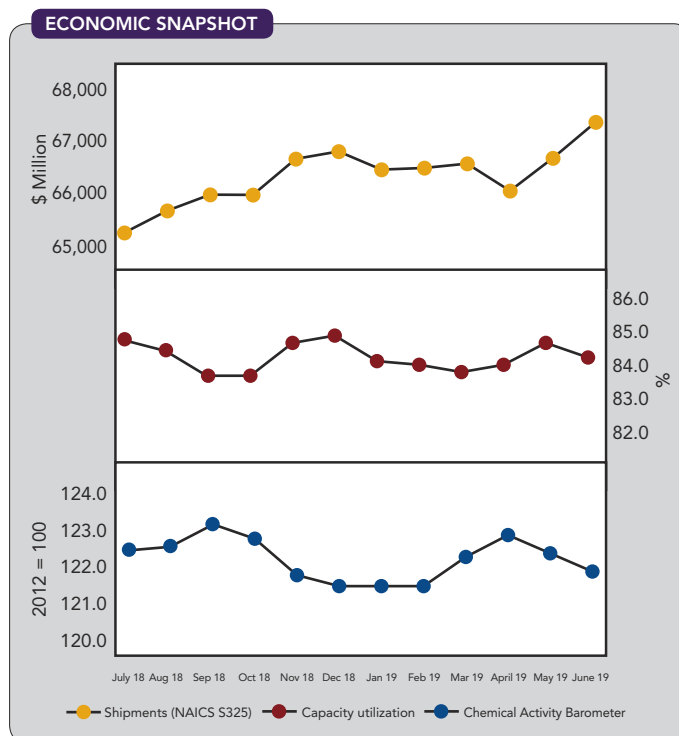
Lively and Losego continue: “As we explore new infiltration chemistries and polymer membrane chemistries, we expect to further refine the separation capabilities of these materials to the point that they

can address some of the most challenging molecular separation problems.”

“At its simplest level, the vapor phase infiltration process requires a vacuum pump with a valve, a vacuum ‘chamber,’ and a valved precursor chemical source. ... While this description is certainly oversimplified, the main point here is that we believe this process has the potential to be directly applied to existing membrane technology without much disruption to upstream membrane module production. It could be a value-added, end-of-the-line add-on process,” they explain.

It’s too early to estimate the cost of the vapor phase infiltration treatment, they say; however, just a few cents in chemical precursors modify these membranes. “Importantly, this technology can be applied to pre-fabricated membrane modules, which we believe will facilitate scale-up (or ‘number up,’ in this case) as the technology can be easily added onto the end of existing commercial manufacturing networks,” they add.

The team believes commercialization is possible within 3–5 years. “Optimization of membrane performance, precursor usage, and process time is all still necessary. Longer term reliability testing also is needed,” they note. ●



Shipments rose but capacity utilization and the CAB slipped. Source: American Chemistry Council.

Reaction Research Gets A Boost

A NOVEL screening process removes the role of chance in discovering new catalysts and their associated reactions, report chemists at the Institute of Organic Chemistry at Münster University, Münster, Germany. Their two-step process can identify previously unknown interactions between catalysts and molecules, say the researchers.

The first step examines whether a potential substrate interacts at all with a catalyst. In the case

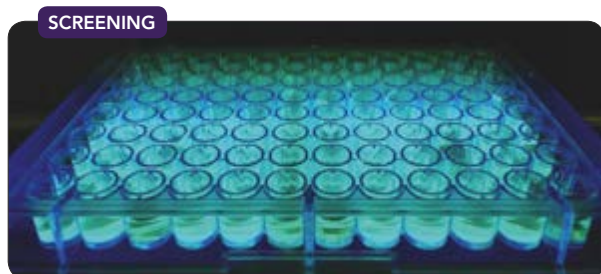


Figure 1. This evaluation looks at impact of a photocatalyst on a variety of possible substrates. Source: Felix Strieth-Kalthoff.

of photocatalysts (Figure 1), which the team found particularly well suited to the new technique, emission quenching detects such interactions. However, these interactions don't constitute reactions. So, the second step looks for the presence of reactions when a reaction partner and a catalyst are present. Combining the two screening steps enables identification of both partners in a new reaction.

"This two-dimensional strategy enables us not only to find new catalyst/substrate interactions but also to actually discover new reactions — including some we hadn't previously expected," explains Frank Glorius, a professor of organic chemistry at the Institute.

So far, the chemists have discovered and further developed three previously unknown reactions, including a photochemical cycloaddition that transfers simple, flat molecules called benzothiophenes to complex three-dimensional structures. From an energetic point of view, that reaction shouldn't be possible, they note.

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Photochemical process expert Dirk Guldi at the University of Erlangen, Erlangen, Germany, and colleagues from the Leibniz Institute of Surface Engineering, Leipzig, Germany, carry out the detailed analysis of the reactions. They use ultrafast spectroscopy to observe and investigate the individual steps in a reaction, including the key activation step.

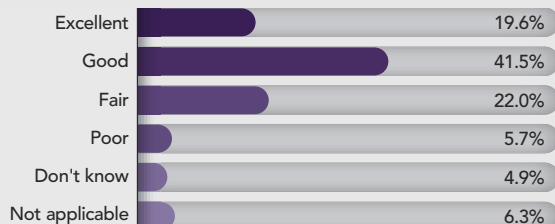
“This greater understanding will allow the development of new processes and catalysts,” stresses Guldi.

“The transformations reported in our study — and further analyzed and learnt about by using high-end mechanistic tools — were based on energy transfer utilizing visible light. Based on more powerful catalysts and improved mechanistic understanding, we are currently trying to develop more visible-light-mediated reactions of this kind,” comments Glorius. “The field is developing rapidly and many reactions are waiting to be discovered, or developed,” he adds.

The team is enthusiastic about developing smart screening strategies and already has exciting unpublished results, says Glorius. “In addition, recently we

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have also started to use machine learning methods to analyze the data the screening provides.”

Making the screens very focused could enable their use for solving specific industrial problems, he feels. ●



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Why Are They Doing That?

Two cases highlight changes that could have become significant and unnecessary expenses

IN THE February 2019 Energy Saver column, I asked readers if they had examples of entrenched operations or operators blindly following outdated procedures, (see: “Why Continue to do That?” <http://bit.ly/31OIViH>). In this month’s column, I cover two of the responses.

CASE ONE

Art Krugler shared an experience from 1951, early in his career. He was a new chemical plant engineer and relief supervisor on the graveyard shift. His plant’s large tunnel dryer, 80-ft long, dried an extruded organic sulfur compound. Air entered through side blast gates, circulated over steam coils, and exhausted with evaporated water from the organic compound.

The dryer formed a bottleneck in the process; an urgent need existed to increase throughput by 25%. To meet this need, the company planned to extend the dryer by 40 ft. This, in turn, required moving grinding, sifting and bagging facilities 40 or 50 ft, as well as extending the plant building and relocating several other major items of equipment. The direct cost of the proposed modifications ran to millions of dollars, quite apart from the cost of lost production during implementation.

During one of his night shifts, under orders to keep production at maximum, Art opened two partially closed blast gates, and was surprised to find the product wetter. After quickly closing the gates, he then spent the rest of the shift closing all the rest, stepwise, except the first. By the end of the shift, production increased by 30%! Closing the gates eliminated most of the air from the dryer. Without the air, heat from the steam coils evaporated moisture from the product. Furthermore, removing the air increased the heat transfer coefficient, which improved the drying rate.

Like many energy-saving initiatives, Art’s modification provided numerous additional benefits. In this case, it increased capacity and eliminated the cost of the revamp project. In addition, the benefits came immediately compared to the revamp’s four-month lead time. Sadly, he didn’t receive a pat on the back from management, let alone a reward — although Art comments it would have been fun to listen in on the discussion the morning after his shift!

CASE TWO

Brad Buecker, a fellow *Chemical Processing* con-

tributor (see his most recent article on page 40, “Plants Benefit from Better Cooling Tower Treatment”), provides the second example. Several years ago, he and a colleague were called in to investigate an air-cooled heat exchanger (ACHE) that wasn’t meeting startup performance guarantees at a power plant in the Los Angeles area. The ACHE was part of a closed-loop water cooling system for air compressor intercoolers; the water temperature entering the ACHE could reach 120°F. The main run of the cooling system utilized ductile iron pipe, with carbon steel for the branch lines.

The engineers on site opened some fittings on the ACHE and found black deposits. They assumed the deposits were iron, and contacted chemical cleaning firms for bids. However, Brad and his colleague asked them to wait until they could inspect as well. After they arrived, one of the engineers brought in a chunk of the material from a witches’ hat strainer on the main circulating line. The black deposit appeared to be organic in nature, not iron. Dropping the deposit into a cup of the gasoline confirmed this, as it immediately dissolved. This probably saved \$500,000 to \$1,000,000, by avoiding a chemical cleaning that wouldn’t have worked with reagents selected for iron.

So, where did the organics come from? The company’s standard materials guidelines called for mastic-coated, cement-lined ductile iron. Once the plant came up to full power and the closed-loop cooling water reached maximum temperature, the heat disintegrated the mastic material, which then quickly fouled constricted spots in the system, most notably the ACHE heat exchanger elbows.

The company did, and still does, maintain an accurate list of lessons learned from projects; this one was at the very top. They were scheduled to install the same piping on another plant in the Los Angeles area, where construction had just started, but were able to make corrections before any pipe had been laid. Well-established chemistry is available to protect iron and steel piping in both closed and open cooling water systems, without resorting to coated materials. ●

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Sadly, he didn’t receive a pat on the back from management.

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EPA Proposes PBT Chemicals Rule

TSCA regulation recognizes environmental and biological issues posed by five chemicals

AFTER MANY years of study, the U.S. Environmental Protection Agency (EPA), industry stakeholders, and the scientific community at large well know that chemicals that are persistent, bioaccumulative, and toxic (PBT) behave differently in the environment and in biological systems than non-PBT chemicals. Congress acknowledged this in updating the Toxic Substances Control Act (TSCA) in 2016 by specifying special provisions under TSCA Section 6(h) for PBT chemicals. In June of this year, the EPA proposed a rule implementing TSCA Section 6(h) review that elicits important insights on how the EPA intends to review such chemicals. The rule is a blueprint for its consideration of PBTs for years to come.

PBT chemicals are known to remain in the environment and biological settings for long periods of time and thus pose unique challenges for chemical producers, users and regulators. In light of these attributes, TSCA Section 6(h) requires the EPA to propose regulatory action by June 22, 2019, on chemicals from the 2014 update of the TSCA Work Plan that meet the PBT requirements under TSCA. The proposed rule must address the risks presented by the chemicals and reduce exposure “to the extent practicable.”

The EPA identified five PBT chemicals that meet the statutory criteria: decabromodiphenyl ether (DecaBDE); phenol, isopropylated phosphate (3:1) (PIP (3:1)) — also known as tris (4-isopropylphenyl) phosphate; 2,4,6-tris (tert-butyl) phenol (2,4,6-TTBP); hexachlorobutadiene (HCBD); and pentachloro-phenol (PCTP). The EPA proposes restricting or prohibiting certain actions with respect to four of the five chemicals — DecaBDE; PIP (3:1); 2,4,6-TTBP; and PCTP. Affected entities would be required to maintain, for three years from the date the record is generated, business records that demonstrate compliance with the restrictions, prohibitions and other requirements.

Importantly, the proposed rule includes hazard summaries for each of the five PBT chemicals. The EPA “did not perform a systematic review of the literature to characterize the hazards of the five PBT chemicals, and instead performed a limited survey of the reasonably available scientific information.” The agency states that “[d]ue to Congress’ direction in TSCA to expeditiously regulate PBTs on the 2014 Work Plan and because risk evaluations were not required by Congress, EPA prepared a fit-for-purpose summary of the hazards presented by the five PBT chemicals.” The proposed rule summarizes reasonably

available hazard information. The EPA notes hazard statements “are not based on a systematic review of the available literature and information may exist that could refine the hazard characterization.”

The proposed regulation is significant for any entity making or using these chemicals. The EPA largely will refrain from regulating commercial uses of the chemicals and instead rely on other laws such as the Resource Conservation and Recovery Act (RCRA) and the Occupational Safety and Health Act (OSH Act) concerning areas falling under their respective scope to address potential exposure issues. In deferring to other statutory authorities to address potential exposure situations that may pose a risk, the EPA is likely to elicit strong opposition from stakeholders who prefer a more restrictive regulatory approach. The EPA’s reliance upon other federal authorities is an important and recurrent theme in its TSCA implementation approach and, in our view, is a reasonable interpretation of the law. The EPA also has proposed specific exceptions for certain uses of these PBTs, and readers will want to support the EPA’s decisions in this regard.

Another aspect that will be interesting to watch play out is the EPA’s approach to and the forthcoming comments on the requirement in TSCA Section 6(h) (4) that EPA’s Section 6(a) regulation “reduce exposure to the substance to the extent practicable.” Interestingly, EPA uses an extent practicable argument in part when explaining its proposal not to regulate in areas otherwise covered by RCRA and the OSH Act. The EPA conducted letter peer reviews of exposure and hazard information for the five PBT chemicals, and also accepted written comments on the charge questions and other documents to be considered by the peer reviewers.

Stakeholders making or using these PBT substances should review and participate as appropriate in this important rulemaking. How the EPA regulates PBT substances will significantly impact manufacturing and chemical processing operations for years to come and it’s important that EPA develop an enduring and legally defensible framework for doing so. The EPA welcomes comments on building its approach to PBT chemical review and regulation. Stakeholders making or using these chemicals, or other chemicals likely to be designated as PBT chemicals, are urged to engage in this initiative. ●

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Regulation will significantly impact manufacturing and chemical processing operations for years to come.

Equipment changes
often can cut consumption
considerably

Think Differently About Water Conservation

By Seán Ottewell, Editor at Large

WATER OPTIMIZATION efforts often focus on achieving the highest possible level of recycling. However, many plants also should consider a complementary approach that targets cutting the water use of specific unit operations. When well planned and executed, this can produce substantial savings, as recent projects by BHS-Sonthofen, Suez Water Technologies and Solutions and DuPont Water Solutions show.

Processes that use washing and clarification technologies are ripe for optimization, advises Barry A. Perlmutter, president and managing director of BHS-Sonthofen Inc., Charlotte, N.C.

“Processes which use washing technology such as belt filters [Figure 1] can make savings of over 30% in water use by switching to counter-current washing. You can recycle the filtrate with no change in the quality of the washing process,” he says.

As an example, he cites a recently completed project for a company that was using 762 kg/h of demineralized water in a once-through washing process. Using counter-current washing in a new process reduced this to 518 kg/h.

“Here, a 2-m² vacuum belt filter was installed. Counter-current washing technology added approximately 7% to the capital cost for the project. The overall operating costs for water usage were reduced by over 30%,” he notes.

However, success in this and other water optimization projects relies on thorough laboratory testing by BHS, he emphasizes. “Lab testing for counter-current washing requires a lot of patience as filtrates must be recovered and kept in

separate beakers. This is crucial to determine both the water savings and final product quality.”

Most clients believe that the savings in the volume of water used more than offset the added capital expenditure involved, e.g., for piping, pumps and control, he adds.

Turning to clarification processes, Perlmutter notes that using plate or candle filters sometimes enables achieving almost 100% water recovery.

He cites two recent projects. In both, customers attained a complete water balance by removing solids from the mother liquor and returning them to the final product while also recycling all the water. “With what is now effectively ZLD [zero liquid discharge], they are making ongoing savings in terms of water use,” he stresses.

The first company installed two vacuum belt filters, each 73.5 m², and two pairs of candle filters for clarification. The first pair, each 12.5 m², removes solids from the mother liquor; the solids get returned to the slurry feed tank. The other pair, each 5 m², recover solids from the product wash water; these go to the final product dryer. The water in both cases is reused.

The second customer, a refining company, reduced water use ten-fold after installing two 20-m² candle filters and a 4-m² pressure plate filter. The cake wash water from the candle filters serves as wash water for the regeneration of ion exchange resins. “This eliminates the use of fresh water and minimizes the dilution of the amine in the scrubbing process,” Perlmutter explains.

REPLACING METAL CARTRIDGES

Opting for an alternative to backwashable metal cartridges for water scrubbing and clarifier effluent concentrating also can save water, he adds.

He cites a case where the wet scrubber water purge goes to a clarifier for primary removal of large catalyst solids; the clarifier overflow discharges to an oxidation tower with the effluent from the tower pumped through the effluent filter and heat exchanger prior to discharge.

The flow rate is 46 m³/h with a solids concentration of 200 ppm. The particle size is below 1.0 micron. The filtrate specification for discharge is less than 15 ppm.

Initially, the site planned to use backwashable metal cartridges but found their low dirt holding capacity and need for frequent backwashing, with the wash water then sent back to the clarifier, made them uneconomical.

Because this process required a concentrated slurry rather than a dried cake, BHS installed two 25-m² candle filters. The candle filter technology provides clear filtrates to less than 1 ppm as well as less backwash to the clarifier because the candles are “cleaned” with compressed gas, not liquid.

Customers constantly want to reduce water use further while at the same time improve product quality — which poses a two-fold challenge to a filter vendor, notes Perlmutter. First, it must rely on filter media suppliers to produce finer grades of media with smaller pores — yet with thinner fibers to main-

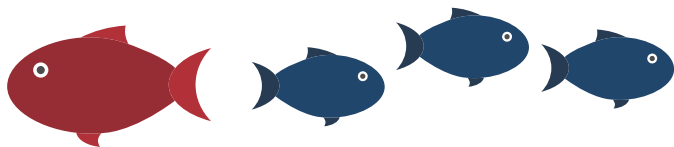
tain permeability. Second, the vendor must figure out how to use these finer, very thin and flexible materials in the filtration equipment without damaging the media during the installation. “This requires new designs to hold the media in place and avoid possible bypass of the media by the solids,” he explains.

SAVINGS WITH SLURRIES

Many processes involve slurries. Typically, plants opt for rubber-lined centrifugal pumps to move these slurries. However, as Todd Loudin, president of Flowrox, Linthicum,



Figure 1. Boxes on top of structure feed wash devices on belt filter. Source: BHS-Sonthofen.



Md., counseled in his article “Save Water When Handling Slurries,” <http://bit.ly/2Mhuo9C>, using a different type of pump can significantly pare water consumption. This, he explains, is because centrifugal pumps typically only can cope with streams containing up to about 30% solids while other options such as peristaltic pumps can tolerate more concentrated slurries.

As an example he cites the case of having to move 100t/h of a solid through a process. A 30%-solids slurry suitable for a centrifugal pump will require 233 t/h of water. In contrast, a peristaltic pump can handle a slurry containing 60–80% solids; providing a 65%-solids slurry for the pump would call for only 54 t/h of water. This translates to about 2 million gal/y for the centrifugal pump versus 500,000 gal/y for the peristaltic. Moreover, the extra water consumed by using the centrifugal pump adds to the burden on reclaiming and reconditioning operations.

In addition, for slurries requiring thickening later, the higher solids concentration permitted by peristaltic and other pumps may translate into savings in downstream filtration equipment, he notes.

DEMINERALIZATION DILEMMA

Water issues can arise gradually in ion exchange systems, cautions Gregoire Poirier-Richer, a senior boiler product applications specialist at Suez Water Technologies and Solutions, Gatineau, Quebec. “Resin fouling is devious because it builds up over a long period of time and its effect on water quality and system efficiency is very gradual. Operators get used to a sub-optimal process and the related cost is not as obvious as an equipment failure that has a drastic impact on production and high repair cost.”

A project completed earlier this year by Suez at the ammonia production facility at a fertilizer plant in North America (Figure 2) illustrates what can happen. The fertilizer company couldn’t produce enough makeup water from its ion exchange demineralization plant, which long had suffered with capacity and quality problems.

The ion exchange demineralization process included primary strong acid cation (SAC) and strong base anion (SBA) trains, followed by mixed bed polishers.

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AMMONIA PLANT



Figure 2. Issues with ion exchangers limited makeup water supply. Source: Suez.

Compliance with minimum water quality limits required a higher frequency of regeneration of the ion exchange resins — with the associated costs — and then treatment of the excess rinse water subsequently produced.

The fertilizer plant’s steam system operated at 1,500 psig and, so, required extremely pure feedwater. However, the demineralization system had run for many years without any performance assessments. It turned out the conductivity of the produced water leaving the SBA train, instead of being the desired $>5 \mu\text{mhos}$, was closer to $50 \mu\text{mhos}$.

A whole host of problems ensued. For example, the mixed bed polishers needed daily regeneration, which was more frequent than the design specification, and the SBA regenerations required excessive washes to achieve the appropriate conductivity.

At the same time, the quality of rinse water coming to the SBAs directly from the SACs implied a very fast depletion rate for the SACs.

A shortage of treated water also loomed. The excessive time spent on regenerations due to extended rinses mandated taking multiple trains offline simultaneously, despite the plant being designed to operate with only one train offline at a time.

Analysis by Suez determined the system at best was operating at 35% of design capacity and the high frequency of regenerations was costing over \$400,000/y in extra acid and caustic.

In addition, the facility risked breaching containment and environmental regulations as it struggled to store the excess water.

One of the main problems turned out to be organic material made up of large anionic molecules from the degradation of surrounding vegetation that found its way into the facility’s raw water.

Highly attracted to the anion resin, these organic molecules act as a “glue” both on and within the beads. Besides reducing exchange capacity, they absorb some of the



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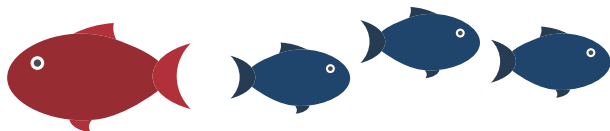
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caustic used during regeneration. This, in turn, slowly elutes from the glue, giving a steady stream of high conductivity water — and, hence, necessitating the very long rinse times.

Suez's answer was to implement a brine squeezing process in which sodium chloride brine and a caustic so-

lution, along with specialty dispersants, are passed multiple times through the ion exchange resin beads.

Each brine squeeze extracts organic material from the beads. Usually after five such procedures, the anion resin is deemed clean.

After the implementation, water

conductivity out of the SBAs consistently was below 2 µmhos and regenerations were extended from one per day to twice per week — a 70% reduction in regenerant usage.

This significant decrease in primary anion effluent conductivity also drastically cut the load on the mixed bed polishers, reducing their regeneration frequency from once per day to twice per month.

The project has saved the company \$320,000 in resin replacement costs so far, while freeing operators from the constant hazardous task of managing regenerations and enabling them to focus on value-oriented projects, states Suez. In addition, the lower frequency of regenerations and shorter rinse times significantly pared the volumes of raw water required and wastewater discharged. The volume of water saved to date is estimated at 4.4 million gal.

GOING BEYOND CLARIFICATION

The River Brazos provides freshwater to an ethylene production facility in Freeport, Texas, along with local farmers and communities. However, two factors promise to put increasing pressure on this supply: a predicted 47% rise in demand from users in the Brazos basin in the coming decades; and increasingly unpredictable weather patterns in Texas over the last decade, which many blame on climate change.

"For example, just five months after Hurricane Harvey hit the Texas Gulf Coast and caused record flooding, almost 40% of the state faced moderate-to-severe drought conditions," notes Andrea Lima, business development manager, DuPont Water Solutions, Corpus Christi, Texas.

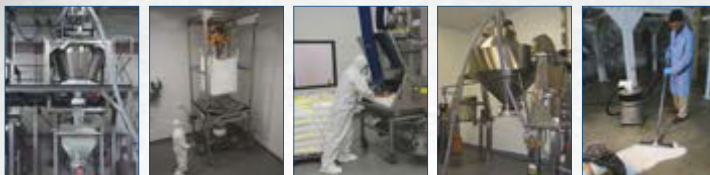
She also points out that if the effects of climate change persist in the way that estimates currently predict, a 2°C rise in global temperature could lead to a 10–30% decrease in annual water discharge in the Brazos River.

Then there's the issue of the feedwater itself, which Lima describes as notoriously variable in terms of turbidity.

The raw water entering the ethylene plant's treatment system has an average

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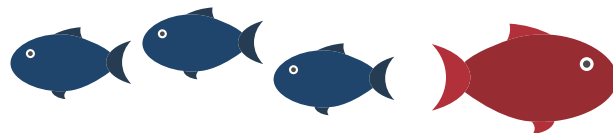


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nephelometric turbidity unit (NTU) of 50 and an average pH of 8.8. The temperature of the feed water averages 24.3°C but spans a range from 7.5°C to 37.8°C. The total organic carbon of the feed water averages 5.0 mg/L while alkalinity averages 135 mg/L as calcium carbonate.

The previous onsite water treatment plant relied solely on clarification and struggled to consistently provide the required treated-water quality targets, including a turbidity limit of less than 1 NTU.

“Conventional technology, like clarification, is often not able to tolerate significant and rapid water quality changes, such as an increase of solids and decrease of alkalinity often associated with rainfall,” explains Lima.

So, to achieve greater consistency, the plant in April 2017 started up a new 23-million-gal/d water treatment plant. At the heart of this, following clarification, is a fully automated filtration process utilizing DuPont IntegraFlux SFP 2880XP ultrafiltration (UF) modules with a 0.03-micron pore size.

The new system effectively removes solids, requires lower pressure and produces consistent higher-quality water than traditional clarification alone.

“While the raw water entering the new system has an average turbidity of 50 NTU, the clarifier system is typically able to provide UF feed water of less than 3 NTU. The UF membrane system has consistently produced filtrate water with less than 0.1 NTU, with an average of 0.01 NTU,” she adds.

The rated capacity of each of the 12 skids is 1,600 gal/min but the average flow to each skid over a 12-month period was closer to 1,400 gal/min. This lower flow rate resulted in reduced flux, which together with membrane performance, allowed for lower fouling potential as evidenced by consistently low transmembrane pressure (TMP). The TMP has stayed below 6 psi — well below the 30 psi maximum TMP — which indicates the backwash and mini-clean-in-place procedures are working properly to keep the membranes clean.

After one year of operation, permeability had dropped only minimally from the initial permeability range of 10–12 gal/ft²/d/psi. Today, the system operates in the range of 9–11 gal/ft²/d/psi and reduces the plant’s freshwater use by 1.3 billion gal/y.

“The consistent water quality produced by the UF system, even

after Hurricane Harvey hit the Texas Gulf Coast, left no question that membrane filtration can handle water quality upsets. The plant’s strong performance has become a success model for other sites looking to achieve similar water optimization results,” concludes Lima. ●

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DEFTLY DEAL WITH DANGEROUS DUST

KNOWING THE STANDARDS AND REGULATIONS AS WELL AS CONTROL OPTIONS IS CRUCIAL | By David Steil, Matt Caulfield and Brian Richardson, Camfil Air Pollution Control

CONTROLLING TOXIC and combustible dust is a common yet serious challenge in chemical processing. Everyday operations like mixing, drying, conveying and blending create dangerous dusts that can become airborne, endanger air quality and pose fire and explosion hazards.

Each facility has unique dust issues based on the materials handled and operations involved. Every chemical processor, though, must comply with U.S. Occupational Safety & Health Administration (OSHA) regulations to protect its employees from exposure to airborne dusts as well as National Fire Protection Association (NFPA) standards to provide a safe working environment.

OSHA REGULATIONS

A company must control toxic chemical dust emissions in the indoor workplace atmosphere to comply with OSHA's established permissible exposure limit (PEL) for workers. If no legal limits apply, then the firm must define in writing, implement and measure its own environmental safety plan to comply with OSHA's general duty clause (which mandates

a workplace environment free of recognized hazards).

OSHA 1910 — Occupational Safety and Health Standards is a broad, general standard that covers most industries. It's a comprehensive and complex standard with 20 subsections. OSHA PELs include limits on airborne concentrations of hazardous chemicals in the air for general industry in 1910.1000 — Air Contaminants. They are listed by chemical name in Tables Z-1, Z-2 and Z-3. Most OSHA PELs are 8-hr time-weighted averages, although there also are ceiling and short-term exposure limits. Many chemicals include a designation to warn against skin contact.

OSHA 1910.22 — Walking-Working Surfaces is a housekeeping standard that requires all places of employment, passageways, storerooms, service rooms and walking-working surfaces to be clean, orderly, dry, sanitary and free from hazards. This means that a manufacturer must prevent dust from accumulating on these surfaces.

OSHA 1910.134 — Personal Protective Equipment (PPE) covers requirements to minimize occupational diseases caused by breathing air contaminated

with harmful dusts, fumes, mists, gases, smokes, sprays or vapors and coming into physical contact with these dusts. It recommends accepted engineering control measures to mitigate these risks as a first step before relying on PPE.

REDUCING WORKER EXPOSURE

One of the best options for keeping hazardous dusts away from personnel is a dust collection system with high-efficiency primary and secondary cartridge-style filters. It's preferable to capture chemical fumes and dust at their source — by incorporating a hood or extraction arm into the process machinery — to prevent them from expanding throughout the plant. Source capture is extremely effective and requires the least energy and capital investment.

You should isolate the captured dust from the rest of the facility and contain it in a specific area (ideally one kept under negative pressure). Send the extracted air either directly into a local collector or, via ducts, to a collector located remotely (Figure 1). In some cases with proper HEPA filtration, you can safely return the filtered air back into the facility to

create a push/pull airflow pattern to improve contaminant control.

A chemical manufacturing facility also may require special options or accessories to improve the safety and reliability of the system. A site can use bag-in/bag-out filters and contained hopper discharge options to limit exposure and cross-contamination of collected material when performing filter and dust removal maintenance.

FILTERS AND FILTRATION MEDIA

Select primary filter media for each application based on the dust particle size, flow characteristics, quantity and distribution. If the dust is toxic and the primary filtration system doesn't use a HEPA filter, install a secondary HEPA filter downstream. Secondary filters prevent hazardous dusts from discharging to the atmosphere; they can forestall contamination of return air ducting and the associated costs of cleaning hazardous dust leakage.

A wide, uniformly pleated filter allows the collected dust to release from the filter, keeping the resistance lower through the filter for a longer time. When the pleats of the filter media

are tightly packed, the dust collector's reverse pulse cleaning system won't eject the dust that has settled between the pleats. Tightly packed pleats raise the resistance of the air through the filters and diminish airflow, thus shortening filter life and increasing energy usage.

The choice of pleated media usually depends on dust type, operating temperatures and the level of moisture in the process. Pleated cartridge filters generally rely on one of two basic categories of media:

- Nonwoven cellulosic blend media is the most economical choice for dry dust collection applications at operating temperatures up to 160°F (71°C).
- Synthetic polyester media or polyester/silicon blend is a lightweight media that can handle dry applications with maximum operating temperatures ranging from 180°F (82°C) up to 265°F (129°C). These filters are washable and can recover from a moisture incursion — but aren't intended for wet applications.

For applications considered a fire risk, opt for standard and nanotechnology filter media treated with a flame

retardant. Use conductive or anti-static filters where conveyed dusts generate static charges that require dissipation.

Combustible dusts demand special care because they can cause a fire or explosion if ignited. Dust collectors minimize the amount of combustible dust that can collect on floors and other surfaces, and contain the dust in one area. However, the dust collectors



Figure 1. Positioning the collector in a location removed from the work area often makes sense.

themselves can pose a fire or explosion hazard if they aren't designed correctly or equipped with the proper explosion or fire protection controls. Cartridge filters with anti-static media also suit explosive dust applications, enabling conformance to NFPA requirements and lessening the risk of ignition sources due to static electricity charges.

High-efficiency dust collection systems also use self-cleaning mechanisms that regularly pulse dust off the filters, allowing units to run longer between filter change-outs. Applying a layer of nanofibers on top of the base filter media (Figure 2) promotes surface loading of fine dust and prevents the dust from penetrating deeply into the filter's base media. This translates into better dust release during cleaning cycles and lower pressure drop readings through the life of the filter.

APPLICABLE REGULATIONS

In the United States, combustible dust issues fall under the scope of three key entities, each with its own particular area of responsibility:

- NFPA, Quincy, Mass., sets safety standards regarding combustible dust, and amends and updates them on a regular basis. NFPA's standards aim to prevent an explosion, vent it safely and ensure it won't travel back inside a building. Most insurance agencies and local fire codes mandate following NFPA standards. Sometimes, though, the authority having jurisdiction (AHJ) specifies an alternative, perhaps even more stringent, safety approach.

ENHANCED FILTER MEDIA



Figure 2. Top layer of nanofibers improves dust release during cleaning and lowers pressure drop.

- OSHA, Washington, D.C., together with local authorities, enforces NFPA standards. OSHA's Combustible Dust National Emphasis Program (NEP) outlines policies and procedures for inspecting workplaces that create or handle combustible dusts. OSHA began rulemaking in October 2009 for a general industry standard for combustible dust but has yet to issue a proposed rule.
- U.S. Chemical Safety and Hazard Investigation Board (CSB), Washington, D.C., is an independent federal agency responsible for investigating industrial chemical accidents. The CSB probes into combustible dust explosions, sifting through evidence to determine root causes and then publishes findings and recommendations.

RELEVANT NFPA STANDARDS

A good starting point for sorting through the standards is NFPA 652 — Standard on the Fundamentals of Combustible Dust. This standard applies to all facilities and operations that deal with combustible dust.

NFPA 654 — Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids is an all-encompassing standard on how to design a safe dust collection system.

NFPA 68 — Standard on Explosion Protection by Deflagration Venting focuses on explosion venting on devices and systems that vent combustion gases and pressures resulting from a deflagration within an enclosure, for the purpose of minimizing structural and mechanical damage.

NFPA 69 — Standard on Explosion Prevention Systems covers explosion protection of dust collectors when venting alone is enough.

NFPA 70 — National Electrical Code encompasses everything related to the installation of electrical equipment across all industries and all types of buildings and defines combustible dust as particles that are 500 microns or smaller and present a fire or explosion hazard when dispersed and ignited in air.

MITIGATING COMBUSTIBLE DUST

Before taking steps to address issues posed by combustible dust, you first must conduct two crucial evaluations: a dust hazard analysis (DHA) and a dust characteristics analysis.

Dust hazard analysis. The owner or operator of any facility where combustible dust exists must perform a DHA to identify the hazards and then create a plan for managing the hazards and provide training for anyone affected by them. An internal team or an independent consultant can conduct the analysis — but, either way, the AHJ ultimately must review and approve the findings.

The first step in a DHA is determining whether the dust is explosive. NFPA classifies dusts according to their explosi-

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"Tackle Combustible Dust Risks," <http://bit.ly/2YQedH1>

"Stop Explosion Propagation," <http://bit.ly/2YRmaM8>

"Dust Explosion Standard Gets Significant Revisions," <http://bit.ly/2U23Tpq>

bility, that is, their K_{st} value, which is the normalized maximum rate of explosion pressure rise measured in bar m/s.

NFPA terms any dust with a K_{st} above 0 as explosive. Class ST1 dusts have a K_{st} below 200, Class ST2 dusts range from 200 to 300 K_{st} , and Class ST3 dusts exceed 300 K_{st} . As a rule of thumb, dust with a K_{st} approaching 600 is so explosive that it requires wet collection methods. If OSHA determines that even a very low K_{st} dust is present in a facility with no explosion protection in place, a citation will result, per OSHA's NEP policy.

It's also important to know other combustible dust properties such as P_{max} (the maximum explosion pressure of a dust cloud), P_{red} (the maximum pressure developed in a vented enclosure during a vented deflagration) and the MIE (minimum ignition energy). You can determine these via ASTM E 1226-10 — Standard Test Method for Explosibility of Dust Clouds.

Your dust collection equipment supplier will need the K_{st} and P_{max} values to correctly size explosion venting or suppression systems. Failure to provide this information may increase your costs because the supplier will have to use worst-case estimates of the K_{st} and P_{max} values or may even refuse to provide the equipment.

Dust characteristics analysis. It's also crucial to analyze other dust attributes to determine the best dust collection system and filters for your operation. Key properties include particle size, dust shape, specific gravity, moisture level and abrasiveness. Reputable equipment suppliers will conduct tests to gather these data and work with you to specify the best system or your application.

EXPLOSION PROTECTION

Many types of explosion protection devices and systems can help dust collection systems comply with NFPA standards. Passive systems react to the event, with the goal of controlling an explosion to help keep employees safe and minimize equipment damage.

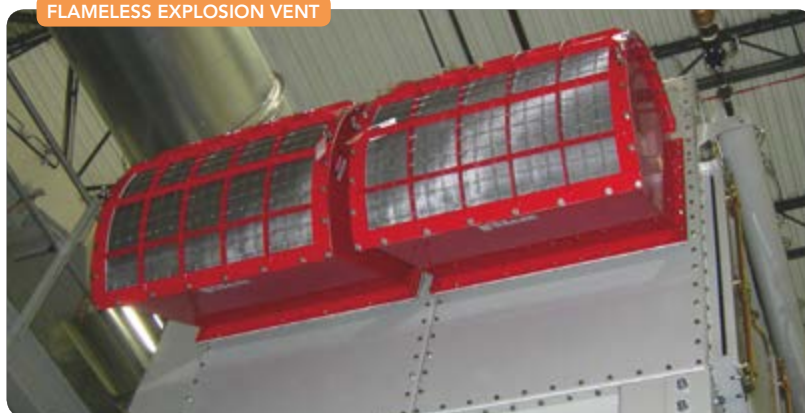


Figure 3. Installed over an explosion vent, device extinguishes flame front so it doesn't exit.

Active systems detect and respond prior to or during the event, with the aim of preventing an explosion from occurring. An active system involves more-expensive technology and typically requires recertification on a regular basis.

Passive devices include:

- **Explosion vent.** This device opens when pressure inside a collector reaches a predetermined level, thus allowing the excess pressure and flame front to exit to a safe area. The vent is designed to minimize damage to the collector and prevent it from fracturing in the event of a deflagration, thereby reducing the safety hazard. Understanding the pressure capabilities of your collector is important in the specification and calculations of vent sizing. Comparing vessel enclosure strength to the maximum pressure for the vented enclosure (P_{red}) and vent burst pressure are key to effective deflagration protection.
- **Flameless vent.** Designed to install over a standard explosion vent, a flameless vent (Figure 3) extinguishes the flame front exiting the vented area, stopping it from leaving the device. This allows use of conventional venting indoors where it otherwise could endanger personnel or ignite secondary explosions. You still must establish a safe area around the flameless vent due to the release of pressure and dust/gases.

- **Passive isolation flap valve.** Installed in the inlet ducting of a dust collection system, this valve utilizes a mechanical barrier to isolate pressure and flame fronts caused by the explosion from propagating further through the ducting. The mechanical barrier, activated by the pressure of the explosion, reacts within milliseconds.
- **Back draft damper.** This device, positioned in the inlet ducting, features a mechanical barrier that's held open by the process air and slammed shut by the pressure forces of an explosion. When closed, this barrier isolates pressure and flame fronts from propagating further up the process stream.
- **Flame front diverter.** This unit redirects the flame front to atmosphere and away from downstream piping. Typically used between two different vessels equipped with their own explosion protection systems, it eliminates "flame jet ignition" between the two vessels that could overpower the protection systems installed.

Active devices include:

- **Chemical isolation.** Placed in either inlet or outlet ducting, a chemical isolation system is designed to react within milliseconds of detecting an explosion. Typical components include an isolation canister, explosion pressure detector(s) and a control panel. This system creates

a chemical barrier that suppresses the explosion within the ducting, eliminates the propagation of flame through the ducting and minimizes pressure increase within connected process equipment.

- *Chemical suppression.* Intended specifically to protect the dust collector itself, chemical suppression often is used together with isolation when it's not possible to safely vent an explosion or where the dust

is harmful or toxic. The system detects an explosion hazard within milliseconds and releases a chemical agent to extinguish the flame before an explosion can occur.

- *Fast-acting valve.* Designed to close within milliseconds of detecting an explosion, this valve can be installed in either inlet or outlet ducting. It creates a physical barrier within the ducting that effectively isolates pressure and flame fronts from either direction, preventing them from propagating further through the process.
- *High-speed abort gate.* Fitted into the inlet or outlet ducting of a dust collection system, this device diverts possible ignition hazards from entering the collector, preventing a possible explosion from occurring and stopping flame and burning debris from entering the facility through the return air system. A mechanical barrier diverts air to a safe location. A spark detection system located far enough upstream to provide sufficient response time activates the abort gate.

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HEAD OFF HYDRAULIC SYSTEM HEADACHES

Understand the factors that affect performance and reliability

By Amin Almasi, mechanical consultant

HYDRAULIC SYSTEMS find wide and varied use at process plants — because they offer an efficient and cost-effective way to create movement and do work. These hydraulic systems must provide high performance, robustness, reliability and availability. However, the design, purchase and operation of hydraulic units usually pose challenges.

A vast array of pre-manufactured hydraulic devices and actuators are available. Configuring systems with these components nearly always requires contending with budget, space, weight and other constraints. Success usually hinges on developing a simple and failsafe configuration using reliable components from a reputable source. Here, we'll look at practical pointers and useful guidelines to deal with challenges and solve design and operational problems.

HYDRAULIC PUMPS

A fixed or variable displacement pump supplies fluid (usually a hydraulic oil) that acts on a component like a cylinder (Figure 1) in the hydraulic circuit to do the assigned work. Typically, a gear, vane or piston pump handles this duty, with the choice depending on operational requirements, performance and budget. Usually, the system should have two pumps, one operating and another on standby.

The cost of electricity or fuel to operate a hydraulic pump set over its entire life span generally exceeds by many times the cost of the pump package itself. Therefore, correct sizing so the pump and driver work most of the time around their best efficiency points is extremely important. Optimum sizing of both the pump and its driver can save a sizable amount of money over the life of the package.

First, you must calculate the pressure and flow of the hydraulic system and then select the pump. The torque, speed and power requirements of the hydraulic pump determine the sizing of the driver; this requires finding the maximum torque required at the highest-pressure level of the hydraulic

application. Provide enough margin — say, 15–20% — when sizing the pump and its driver.

Electric motors with the same power rating can have different pull-up torques. So, first, calculate the power rating. Then, select a motor based on vendor performance curves that provides the required torque with some margin. The sizing and selection process usually is straightforward because electric motor drivers generally have a starting torque that far exceeds running torque.

Undersizing of hydraulic pumps or their drivers is common. Oversizing poses issues, too, particularly energy waste because the motor operates at below its best (peak) efficiency.

Some hydraulic pumps use engines as drivers. Diesel, gas or gasoline engines have a much flatter torque/speed curve than electric motors; they deliver roughly the same torque at high speed as at low speed. This means an inter-



Figure 1. This heavy-duty double-acting unit awaits repair and refurbishment.

nal combustion engine may develop high enough torque to drive a loaded pump during normal operation but not enough to accelerate it to operating speed (during startup). Consequently, with all other factors being equal, an engine that drives a hydraulic unit requires a higher power rating than that of an electric motor. Sometimes, the power rating of the engine driver is 1.7 times or even more than that of the electric motor. In addition, engines always are more expensive than electric motors and need many other auxiliaries and accessories.

Hydraulic systems nearly always use a pair of positive-displacement pumps. So, a set of relief valves is essential to protect the system against over-pressurization and potentially dangerous failures. These valves also are used to unload the system when starting up a pump or putting one on standby. Vibration and noises can pose challenges and deserve consideration.

OPERATING PRESSURE

Most engineers today prefer higher operating pressures (sometimes as high as 400 Barg) for hydraulic piping, cylinders, actuators and devices to achieve compactness, light weight and economic savings. As a very rough indication, increasing the

pressure to 200 or 250 Barg from 100 Barg can reduce costs by around 20–35%. However, some systems are better off in the medium-pressure range of 80–150 Barg. Each application usually has an optimum pressure range.

High pressure can require very specific and expensive technologies for devices and pose sealing complications, potential leakage and other problems. In fact, above certain levels, costs may rise with pressure. In general, hydraulic systems with pressures above 350 Barg demand great care.

In high-pressure hydraulic systems, the energy converters fail to transform a portion of the compression energy into useful work. The energy waste mainly causes heating of the hydraulic fluid.

KEY COMPONENTS

Every hydraulic system requires a fluid reservoir or tank. As a rough indication, you should size the reservoir volume to provide 4–10 minutes of pump flow, allowing hydraulic fluid to settle in the tank but recirculate enough for stable temperature and to keep it clean. Also consider hydraulic actuator drain-down and working volume changes. Installing baffle plates in the reservoir to separate return and supply lines enables dirt and air to settle before fluid

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reuse. In addition, the reservoir needs an air breather/filter to allow fluid volume to change and to filter any incoming air. Suction lines from the reservoir to the pumps demand great attention. Use large-diameter short piping for low fluid velocity. Pumps should have a positive head or be primed before first startup. Putting in a suction filter (suction strainer) isn't necessarily a good idea. While the filter might improve supply conditions, it can restrict pump supply if not maintained.

Install a pair of pressure filters (one operating, the other on standby) to stop contamination reaching components in the circuit. A cheaper alternative is a filter with a bypass valve. Either way, provide an indicator, such as a differential pressure sensor, to show when the filter element needs replacing.

As already noted, systems generate heat that is absorbed by the hydraulic fluid. This often necessitates coolers to keep the hydraulic fluid within the specified temperature range (whose high limit usually is set to avoid fluid breakdown or damage to seals). The cooling and filtration system comes in one of two general set-ups: an online configuration where the system is installed downstream of the pump set and upstream of the control and actuators; or an offline arrangement where fluid passes through an independent cooling and filtration system

and then goes back to the reservoir. (Use of the later system assumes the hydraulic fluid in the reservoir is clean and cool.)

The hydraulic system requires appropriate controls for adjusting pressure and temperature. This calls for suitable instruments, sensors and valves.

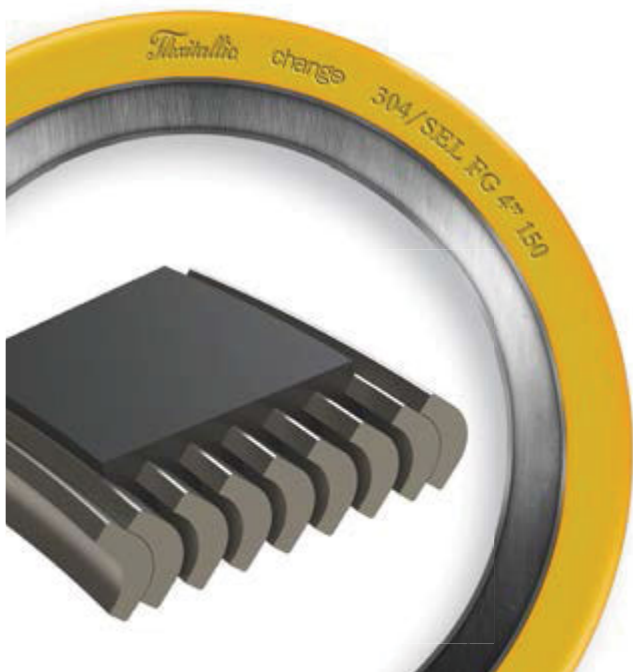
PIPE SIZING

For estimating and approximate sizing, the standard flow velocity method of pipe sizing may suffice. However, final sizing of the piping and inline components of a hydraulic system requires a better method.

First, decide upon the overall allowable pressure loss and then distribute pressure losses in different parts of the hydraulic system. Many factors and parameters affect this, making a general rule infeasible. Instead, engineers often must decide what loss is tolerable, based on limitations in heat dissipation as well as requirements to achieve desired work output, system efficiency, overall cost, etc. Of course, the aim is to minimize overall pressure drop; any rise in the pressure drop leads to lower overall efficiency and larger coolers. Many systems can attain a suitable operating temperature range only with a low pressure drop. Performing an optimization can avoid specifying too large piping, hoses and valves, which incur added costs and problems.

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ACCESSORIES AND AUXILIARIES

The requirements and specifications of key components and devices of a hydraulic system generate little disagreement. However, no such consensus exists for so-called accessories and auxiliaries, such as isolation valves, which may play an important role in the operation, reliability and maintenance of some hydraulic systems. Isolation valves (usually ball valves) are needed to ease operation, maintenance or future relocation. They can protect personnel during maintenance and stop syphoning of hydraulic fluid when items are changed or removed.

Many hydraulic devices and actuators are sensitive to back pressure. However, adding an isolation (ball) valve usually is acceptable in critical battery limits, provided the installation fittings incur minimum pressure drop and don't represent a significant restriction or pressure loss to the system.

Overall, the piping and hose length and numbers of fittings are key considerations. Besides suitably sized components, the circuit should have minimum possible length. Use full-bore (full-port) ball valves to reduce pressure drop and equip them with a locking device to prevent accidental closure.

Accumulators usually play an important — indeed, critical — role in many hydraulic systems. Generally, a pair of accumulators are fitted and pre-charged with hydraulic fluid from the pump when operating; they provide backup hydraulic force for transient cases, e.g., a pump shutdown (either deliberate or due to unexpected power loss), change-over from one pump to another, or other reasons. At such times, the accumulators will provide pressurized hydraulic fluid for a short period of time ranging from 15 seconds up to one or two minutes, with the accumulator sized accordingly.

A hydraulic system may include many different auxiliaries and accessories such as a manual drive, manual drive engaging/disengaging system, lock assembly, adjustable limit stops, anti-rotation device, mechanical position indicator, etc.

CENTRAL VERSUS INDIVIDUAL SYSTEMS

You can opt either to install a centralized hydraulic system to handle all actuators and devices in a package or unit; or multiple individual and independent hydraulic systems, each to serve one or a few specific services.

A centralized hydraulic system often can offer clear benefits such as higher efficiency and easier handling of peak fluctuations. However, selecting optimum pressure is critical, and sizing of all items assumes considerable importance because different devices and subsystems can affect each other. In addition, when the distances are long and the system contains many different actuators, subsystems and consumers, you should consider all the extra costs, challenges and inconveniences a centralized system may incur.

For instance, the hydraulic fluid may travel through long lengths of piping with many bends. This impacts costs, system rigidity and overall reliability — and may lead to considerable energy loss. However, the larger piping surface area helps dissipate the heat generated by the losses, which sometimes is a positive point.

On the other hand, individual hydraulic systems may offer flexibility and other benefits.

No general rule exists for making the choice between central or individual configurations. You must evaluate your specific system to decide.

MAINTENANCE AND OPERATION

Contaminated hydraulic oil is the bane of hydraulic systems. Indeed, contamination and dirt likely account for more than 75% of all problems and failures in such systems. So, cleanliness is of paramount importance when installing and maintaining components and items.

Pay particular attention to the first hours and days of operation. Change the initial set of oil filter cartridges soon, say, approximately 24–60 hours after the startup. Then, you usually should swap out the filters every 500–1,500 hours of operation. Most of the time, the first change of hydraulic oil should get replaced fairly soon, say, approximately 100–400 hours after the startup. Subsequent hydraulic oil changes then should occur every 2,000–4,000 hours of operation.

The state of the hydraulic oil is a good indicator of the hydraulic system's health. Therefore, you always should perform routine sampling and oil analysis. Obtain an oil sample at every filter change and compare it with the previous samples to detect any changes. Monitoring hydraulic oil characteristics and contamination provides a powerful way to pre-empt operational problems and reliability issues.

AMIN ALMASI is a mechanical consultant based in Sydney, Australia. Email him at amin.almasi@gmail.com.



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Consider Turnkey Analyzer Shelters

Offsite assembly and testing can save time and money while improving safety

By Joe Goh, Yokogawa Corporation of America

CHEMICAL PLANTS often rely on process analyzers to meet environmental regulations, optimize their processes through on-line continuous monitoring and improve personnel safety. These analyzers typically reside in shelters located close to the processes and units being monitored. Frequently, operating companies opt to build these analyzer shelters onsite but this can be a time-consuming and expensive undertaking.

A better approach in many cases is buying a turnkey analyzer shelter with all analyzers, ancillary components and equipment installed and tested. Once delivered to the site and set in place, such a unit only requires connection to utilities and the processes. Large shelters with many analyzers and other complex requirements gain the most from offsite construction but smaller and simpler shelters also can benefit, especially when the necessary analyzer and assembly expertise isn't available onsite. However, you must consider logistical and installation issues to decide if a turnkey approach is realistic.

Before getting into specific points about turnkey units, let's first look at what an analyzer system consists of and how it's designed, assembled and tested.

THE NEED FOR SHELTERS

Analyzer reliability and measurement precision often depend on stable climate conditions. In addition, not all analyzers are suited for installation in hazardous locations. A shelter (Figure 1) addresses these issues by offering a protected and climate-controlled environment. Warm climates require air conditioning systems, which may also provide shelter ventilation and purging. Cold climates need a forced-air heating system along with insulation. The bottles supplying gas to the analyzers may be mounted inside the shelter or in heated external cabinets. Larger installations sometimes use a split shelter, with one side for analyzers and the other for the sample gas conditioning system.

Modern analyzers generate large amounts of data, requiring routing of discrete signal and networking wiring to common



Figure 1. Analyzers usually must reside close to the monitored operation — and this dictates the shelter site.

data junction boxes, sometimes with fiber optic patch panels for transmission of large amounts of data. These junction boxes and patch panels are typically mounted on the outside of a shelter.

Proper shelter design accounts for many factors including ambient conditions, corrosive atmosphere and regulatory requirements as well as weight and size considerations. The shelter must maximize accessibility while minimizing costs and should provide space for growth and maintainability.

Sample systems are an integral part of a shelter design and require custom engineering for each application. Rain shields

are strongly recommended to cover external portions of sample systems and bottles for protection against ultraviolet light and weather.

The interior atmosphere of a shelter often requires monitoring to detect the presence of hazardous gases using combustible analyzers, toxic gas (H₂S, etc.) sensors and oxygen deficiency analyzers (common when analyzers use nitrogen). These detectors typically activate local warning lights and horns, and also send a signal to the plant's main control room. Emergency ventilation sometimes is necessary for a toxic or O₂ deficiency event, along with shutoff of the sample system.

A shelter typically requires a supply of power and, in some cases, an uninterruptible power system. In addition, instrument air is necessary for the operation of some analyzers, such as gas chromatographs (GCs), and, in some cases, for purging analyzer enclosures. The shelter may also require nitrogen, steam and water, along with calibration and support gases such as burner or actuation air, flush nitrogen and vortex coolant air.

Header and manifold systems simplify plumbing throughout the shelter for shared

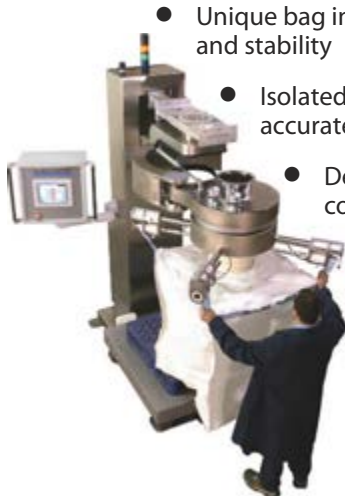
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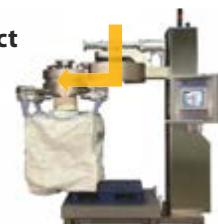


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gases, instrument air, steam and GC carrier gases. Waste recovery headers handle venting of gases, with check valves provided if vents tie into plant processes such as flare gas systems. Similarly, a shelter sometimes needs a liquid recovery system, consisting of a storage tank, return pump(s) and associated piping.

Analyzers may be wall or rack-mounted; sufficient space must be allowed between analyzers for wiring, plumbing and maintenance access.

Managing all these design details throughout an analyzer shelter project can pose difficulties due to the wide diversity of hardware suppliers. Factory acceptance tests may take place at the analyzer manufacturer, after installation or both.

SAMPLE SYSTEMS

The sample handling system includes portions of the process itself, the sample extraction nozzle and probe, the sample transport system, the sample conditioning system, the fluid pathway through the analyzer and the sample disposal facilities.

Figure 2 depicts an installed analyzer shelter along with the main interfaces to plant processes and utilities. Samples extracted from the process and conditioned go to the ana-

lyzer, with exhaust effluent from the conditioning system returned to the process.

Process gas sample streams may go to different analyzers, necessitating switching so each stream gets routed through

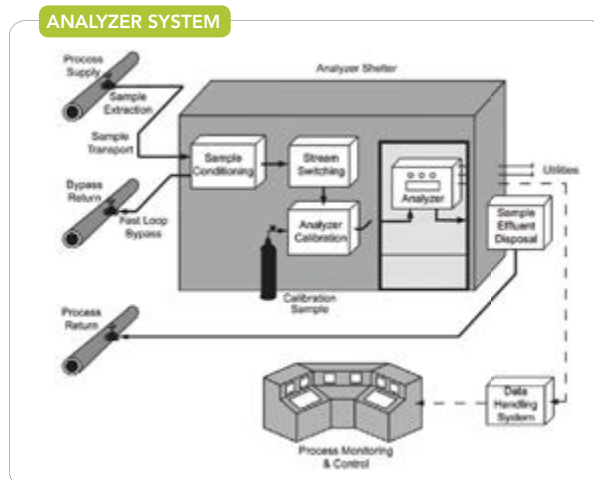


Figure 2. Elements include the instrument as well as a sample system and data communications.

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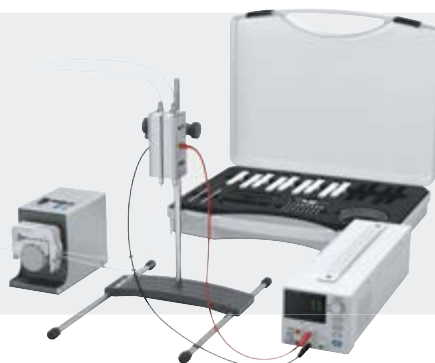
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the analyzer calibration system and then to the analyzer. Effluent exiting the analyzers returns to the process through the sample effluent disposal system.

Sample conditioning prepares the gas samples drawn from the process to ensure compatibility with analyzer requirements. The sample delivered to the analyzer must be representative of the process and provided to the analyzer on a timely basis. This is best accomplished by limiting the distance from the sample point to the analyzer and, if needed, by keeping the sample line at similar conditions to the process, for example by heat tracing the sample transport system.

You must control the sample pressure, temperature and flow rate to reduce particulates, comply with analyzer constraints and preserve the gas or liquid phase to prevent a mixed-phase sample from entering the analyzer.

You also, of course, must ensure sample systems are safe to operate and adhere to relevant codes and regulations. You must select materials for system components that are compatible with the process sample's constituents, including materials that don't allow reactions, permeation or absorption because these actions may change the sample composition and degrade system integrity.

OFFSITE ASSEMBLY ADVANTAGES

An analyzer shelter houses delicate instruments and demands great care during assembly. Fabricating the shelter offsite and then transporting it to a plant may offer significant benefits.

Fabrication requires many specialized tasks such as bending, routing and installation of tubing. Offsite facilities have design and installation specialists on hand who perform these tasks on a regular and routine basis, skills rarely found with general mechanical and electrical construction crews.

Offsite construction allows testing of analyzers as part of the entire assembly, instead of in isolation prior to shipment to the site. This can reveal issues at interfaces between the analyzers and other systems such as sample conditioning, stream switching and effluent disposal.

An offsite facility dedicated to designing and assembling analyzer shelters can work much more quickly and efficiently than general construction crews working on site. Site installation activities are limited to setting the shelter in place and making connections to the process, utilities and control systems.

Minimizing onsite construction activities provides time and money savings because it's much simpler and easier to construct a shelter offsite than in a plant, especially if the work must be performed during normal operation. Even if onsite shelter assembly can take place during a shutdown, activities during these periods are always hectic, so it's best to do as much work as possible early and offsite.

Moreover, minimizing onsite construction activities reduces the likelihood of incidents. It's much safer to assemble a shelter offsite, particularly if the final installation area is classified as hazardous, often the case in chemical plants and facilities.

Offsite construction eases detection and resolution of any compatibility issues with analyzers from different suppliers. For example, some types of Ethernet-based outputs aren't compatible.

Performing a thorough factory acceptance test offsite prior to delivery can address these and other issues. In some cases, such a test can include introducing sample gases, which might not be possible in an operating facility due to safety concerns in hazardous areas. Plant personnel can witness the test, allowing them to suggest changes and improvements.

SIZE CONSIDERATIONS

Offsite assembly and testing of a shelter isn't always feasible, though. Analyzer shelters can be quite large (Figure 3), presenting a number of transport and installation problems and costs. Shipping restrictions and availability of a path to the installation point on the site may limit shelter size.

Shipping restrictions vary from one locale to the next, with transport costs rising along with shelter size. For

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SHELTER SHIPMENT



Figure 3. The cost and feasibility of transporting an analyzer shelter and installing it at the site can pose limitations.

example, shelters wider than 12 feet may require escorted transportation, greatly increasing costs and adding to delivery time. Shipping can incur other substantial costs, including for any necessary shelter crating. Overseas shipping may be prohibitive in terms of time and money because it involves transport to a dock, loading onto a ship, transport on the ship, unloading at a dock and transport from the dock to the plant.

A shelter arriving at a plant requires a clear path from the receiving location to the installation point. Typically, a shelter is trucked to a location near the installation point, then lifted by a crane and set in place. This last step isn't always practical due to the presence of overhead obstructions; it also may be cost prohibitive, particularly if the crane lift has to span a long distance or excessive height.

Finally, shipping and installation always pose the potential risk of damage. Insurance may cover the cost of damage but rarely the costs incurred by a delayed schedule, which can be substantial.

CONSIDER BOTH OPTIONS

Analyzer shelters are complex to design, construct and test. They require many different construction trades, along with a high level of technical expertise for testing and other activities. If shipping and installation is possible and not cost prohibitive, offsite shelter construction often makes the most sense.

You should evaluate both approaches in all instances. Pay particular attention to the expertise and experience of the offsite construction vendor, especially with respect to the goals of the intended application. It's best to visit the vendor's facility as well as to obtain detailed information and references for similar projects performed for other chemical companies. It's always a good idea to contact these customers to evaluate vendor performance and gather information to improve design, construction, test and installation activities. ●

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Plants Benefit from

Better Cooling Tower Treatment

New chemistry enables two facilities to dramatically reduce corrosion and fouling

By Brad Buecker and Ray Post, ChemTreat

OUR EARLIER article “Improve Your Cooling Tower Treatment,” <http://bit.ly/2Z3k0Et>, stressed the critical role that chemical treatment of cooling water systems plays for minimizing microbiological fouling, scaling and corrosion, and discussed a polymer chemistry that is replacing phosphate/phosphonate treatment. In this article, we look at two real-world examples of the benefits of that chemistry and point out the importance of not viewing corrosion inhibition in isolation.

But first, here’s a bit of background on the polymer chemistry. The original goal behind its development was to provide a more environmentally sustainable alternative to phosphates in cooling systems. The available formulations have flash points >200°F, aren’t U.S. Dept. of Transportation regulated and don’t contain California Proposition 65 materials. These products, typically applied at a dosage of 100 mg/L, have an LC₅₀ (lethal concentration) on the common U.S. Environmental Protection Agency aquatic marker organisms in the range

of 1,000–10,000 mg/L. In many cases, the chemicals can be formulated at mild pH values, making them less hazardous to handle than products with extreme pH values.

FIRST EXAMPLE

A large Southeastern industrial complex was using a polyphosphate corrosion inhibitor program. Influent water to the plant enters a large open pond and then goes to a settling clarifier. Chlorination takes place in the clarifier, with its discharge, approximately 4,000 gal/min, dosed with the corrosion inhibitor. After servicing a number of once-through cooling heat exchangers, a recirculating cooling tower and other process cooling needs, a portion of the water recycles back to the pond.

The phosphorus in the return water provided ample nutrients to support robust algae and microbiological growth, which in turn increased the biocide chemical treatment costs and fouled intake screens. Figure 1 shows the condition of the pond during the summer of

2014 when the phosphorus-based corrosion inhibitor program was in use. Similar to natural water systems with phosphate loading, the water has a deep, opaque green color.

The total phosphate concentration in the pond was 3–4 mg/L. Despite the presence of the polyphosphate corrosion inhibitor, mild steel corrosion rates in the hot return of the once-through cooling water averaged a barely acceptable 8–10 mils/yr (mpy).

To reduce biological growth, the facility converted the corrosion inhibitor program to 0.5–1.0 mg/L zinc in mid-September 2014. Corrosion rates on the zinc program dropped to an average of 2–4 mpy and the condition of the pond water improved considerably. Efforts to further reduce corrosion using higher levels of zinc alone led to some fouling of high temperature heat exchange surfaces.

At the end of May 2017, the site switched to a ChemTreat FlexPro non-phosphorus and non-zinc corrosion inhibitor program, which has the further advantage of being non-fouling. The inhibitor was applied at a concentration of 5 mg/L as formulated product. The initial corrosion coupon result was 3.4 mpy, comparable to that of the zinc corrosion inhibitor. Corrosion rate meter results in the clearwell supply water are in the 0.1–0.3 mpy range, the best ever achieved on any program in this application.

The appearance of the pond greatly improved after the conversion to non-phosphorus programs, as expected based on experience with phosphorus reduction in natural water bodies. Figure 2 shows the pond in the summer of 2017 after the switch. The total phosphate concentration is approximately 0.1 mg/L as PO₄. With only the minimal natural phosphate loading in the source water, the pond water is crystal clear.

The elimination of zinc from the program deserves mention. Increasingly, discharge of some transition and

heavy metals, including zinc, is coming under tightened scrutiny and regulation. However, removing zinc can have a downside because it protects galvanized cooling tower materials from corrosion. This is one of many aspects to consider in the design and chemical treatment of new cooling towers.

SECOND EXAMPLE

A Gulf Coast natural gas liquids (NGL) fractionation plant separates raw or “Y-grade” NGL into its major components, principally ethane, propane, butane and higher condensates. Separation process economics require efficient cooling. Fractionation plants often use wet surface air coolers (WSACs) in which the process fluid in a closed-loop bundle is cooled by spraying open-loop water over the outside of the tubes while drawing



Figure 1. Phosphorus in return water fostered substantial algae and microbial growth.



Figure 2. Switch to non-phosphate treatment program led to dramatic improvement in water clarity.

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air across the bundle to provide evaporative cooling. The heat exchanger coils are hot dip galvanized.

The plant relied on a phosphate-based treatment program for the open cooling water loop. This allowed considerable deposits of calcium phosphate and calcium carbonate to accumulate on the hot tube surfaces and water spray nozzles. The WSAC units were first cleaned for one month while the unit was in service by circulating a proprietary pH 6.5–7.5 cleaning chemistry containing the corrosion inhibitor to avoid damaging the galvanized tubes. Figure 3 shows thermal images of the water sprays and the tube bundle before and after cleaning. They indicate removal of most deposits and significantly improved water flow and spray coverage after the cleaning.

Similar cleaning took place on a depropanizer cooled by a conventional evaporative cooling tower. The system was so heavily scaled that both water flow and heat transfer were severely restricted, impacting production. Because this system didn't contain galvanized surfaces, the cleaning process was more aggressive, briefly reaching a pH of 4.0. A FlexPro

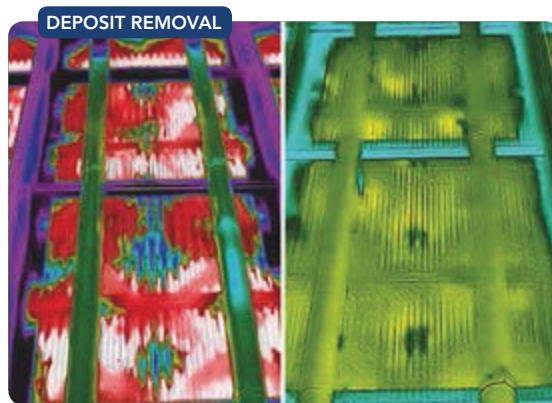


Figure 3. Thermal images show state of WASC tube bundles and sprays before (left) and after (right) cleaning.

formulation was employed during and after the cleaning process to control corrosion. The cooling water flow was slowly restored over a period of ten days. Depropanizer approach temperatures decreased sharply during the initial ten days of cleaning and held steady for four weeks on the non-phosphorus treatment program. The previous phosphorus-based program then was reinstated. Approach temperatures rose rapidly on the phosphorus program until it was replaced permanently by FlexPro after one week. The system has remained on the non-phosphorus program without fouling since late January 2017. Mild steel corrosion rates typically are <1 mpy, which is considered excellent by industry standards. The plant has credited the program for increased production of approximately 2,500 bbl/d by maintaining clean heat transfer surfaces.

OTHER IMPORTANT CHEMISTRY

The passivating corrosion inhibitor chemistry described above has had many successful applications. However, no corrosion inhibitor treatment program typically can stand on its own without good control of other variables. First and foremost, proper microbiological control is paramount. Microbes, if allowed to grow and form colonies on cooling water surfaces, will render the corrosion inhibitor ineffective at the deposits. Furthermore, the microbes themselves can produce metabolic byproducts such as acids or hydrogen sulfide that will attack metals. Interestingly, evidence indicates that the efficacy of the non-phosphorus corrosion inhibitor increases with greater free available halogen concentrations, and a 0.5-mg/L residual as opposed to, say, a 0.2-mg/L residual can enhance microbial control and corrosion inhibitor performance. Operating at higher halogen residuals may require feed of a reducing agent such as sodium

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bisulfite to the cooling tower blowdown to comply with discharge permit regulations.

Application of the inhibitor to an existing system with rusted pipe sometimes poses difficulties because the rust will absorb the chemical. Achieving proper treatment efficiency may require cleaning older system pipes and other equipment.

Cooling water impurities can influence polymer performance. High iron content in the water may necessitate increased biocide residuals to defeat some microorganisms. Chloride isn't problematic but high levels of sulfate may reduce effectiveness. (The reverse basically is true for phosphate/phosphonate programs.)

This points up the need for comprehensive water analyses to determine applicability of any treatment method. And, of course, impurities in the plant makeup will "cycle up" in cooling towers to concentrations several times greater. This impacts heat exchanger materials, too. For instance, some materials suitable for once-through cooling, such as 300-series stainless steels, may become unacceptable at the higher impurity levels. Fortunately now, with the development of advanced passivating chemistry, some flexibility in materials selection has returned. Even so, materials selection demands care during plant design. Spending a bit extra upfront on durable materials is far better than suffering process outages later due to corrosion of poorly selected metallurgy.

LOOK BEYOND PHOSPHATES

Phosphorus is an essential nutrient for algae growth and exhibits undesirable consequences in the aquatic environment. Fortunately, phosphorus isn't absolutely essential to the control of corrosion or scale formation in cooling water systems. In fact, phosphorus has numerous limitations as a corrosion inhibitor. Moreover, its use in cooling systems presents many of the same issues as in the natural environment, including challenges regarding microbiological control, the potential for fouling heat transfer surfaces, inability to passivate lightly rusted surfaces, and little or no ability to control corrosion on alloys other than mild steel. As the two examples here illustrate, non-phosphorus corrosion inhibitors offer important performance advantages, such as the ability to protect stainless steel, as well as environmental benefits. In addition, ongoing development of non-phosphorus cooling water treatment chemistries promises to increase their value. ●

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This article is based on "The Development and Application of Non-Phosphorus Corrosion Inhibitors for Cooling Water Systems" presented by R. Post and R. Kalakodimi at the World Energy Congress, Atlanta, October 2017.

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The right level instrument won't necessarily resolve process issues

THIS MONTH'S PUZZLER

We're having trouble measuring the solids' level in our forced-circulation crystallizer that feeds storage bins. The product is a solid with a dielectric constant of about 2.7; however, some impurities have constants of about 12 and others about 5. Screw conveyors transport the water-logged solid to bins feeding re-dissolvers that are the next step in purification. We have difficulty controlling the water content from the crystallizer; excess water flows into the bins. We have used tuning fork contact probes but always have suffered issues related to fouling. Problems included overflows of the bin and grossly inaccurate indicated levels. Out of desperation, we've switched to guided radar for continuous measurement.

Is guided radar the right choice? Why do you think the tuning fork probes failed? Can you suggest other options for reducing errors in solid measurement?

MOISTURE IS YOUR ENEMY

The problem statement doesn't discuss the scheme for controlling moisture content of the solids leaving the crystallizers. I assume that solids' level in the crystallizer is a part of the control system to regulate moisture level of solids.

As far as the level sensing is concerned, tuning fork probes are prone to plugging and so are best for dry powder applications. They would not be a suitable choice for this application.

For crystallizer solids' level, consider guided wave radar (GWR), pulse radar or ultrasonic probes. Each of the techniques has its own pros and cons. For example, wide variation in the dielectric could affect signal quality of GWR and, hence, accuracy. With digital systems and their algorithms and diagnostics, you can make adjustments to account for variation in the dielectric constants. In addition to variation in dielectric, you also need to consider issues such as moisture condensation, internals of the crystallizer — they could interfere with the signal — and dust. Some vendors offer systems to remove condensation from the horn of the GWR.

Ultrasonic sensors, though not affected by dielectric variations, have their own limitations such as probe plugging and limits on solid particle size. Some vendors state particle size should exceed 0.1 in.

Consider ancillary issues such as the nozzle size required for installing the level sensor, power requirements, and aligning the level transmitter with your current distributed control system.

Also, think about looking into your moisture removal system in the crystallizer.

*GC Shah, senior advisor
Wood Group, Houston*

DON'T BLAME THE MESSENGER

Too often instrumentation is called upon to fix production problems that actually have their root in a bad design. If you can't work around a unit operation problem, then build in spares you can readily switch to when the inevitable failure occurs. Instruments have nothing to do with this type of solution.

Guided wave radar is an excellent replacement for tuning forks. However, neither option will work well if you don't address the process inconsistency issues.

The dielectric constant is adequate for measurement but the issue about the impurities concerns me. One vendor said that GWR works down to 1.4. Also, wet polar compounds have high dielectric constants and are easier to measure. I wonder how well the instrument can be tuned to measure solids if it detects wet solids better than dry ones.

In addition, solids' buildup on the instrument could be a problem. While still wells are used with liquids, there really isn't a good option for wet solids.

*Dirk Willard, consultant
Wooster, Ohio*

NOVEMBER'S PUZZLER

As a process control consultant, I was brought in to fix a blending problem with a set of static mixers installed to replace an agitator (Figure 1). The four static mixers are supposed to blend ingredients together before sending them to a feed tank for a packaging line. The liquid ingredients range from 0.3 cP to 250 cP; there're also some solid ingredients that make up about 1% of the final volume added. The plant hired me specifically to tune the loops for precise control.

According to the production manager and maintenance engineer, the startup with the new controls was a disaster. They were expecting tuning to solve all their problems. They are refusing to pay me.

In confidence, an operator revealed to me that the plant used to blend these ingredients in a baffled agitated tank by batch; the blended stream goes to the feed tank for packaging lines. However, when the agitator gearbox failed, the maintenance engineer reckoned he could save money by abandoning the agitator in place and replacing it with static mixers — despite the quality control manager's protests that not using the agitator would make

achieving six-sigma results hard. It doesn't help that some ingredients are solids.

The materials that pass through the static mixers go to the feed tank. That small unbaffled tank has a tiny agitator (for the size of the tank); the tank oscillates like a bobble head.

Should I admit I blew it? Should I have investigated the quality control problem a little more before accepting the job? Is there anything else you can recommend to fix this problem?

Send us your comments, suggestions or solutions for this question by October 11, 2019. We'll include as many of them as possible in the November 2019 issue and all on ChemicalProcessing.com. Send visuals — a sketch is fine. E-mail us at ProcessPuzzler@putman.net or mail to Process Puzzler, *Chemical Processing*, 1501 E. Woodfield Rd., Suite 400N, Schaumburg, IL 60173. Fax: (630) 467-1120. Please include your name, title, location and company affiliation in the response.

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

BLENDING SYSTEM

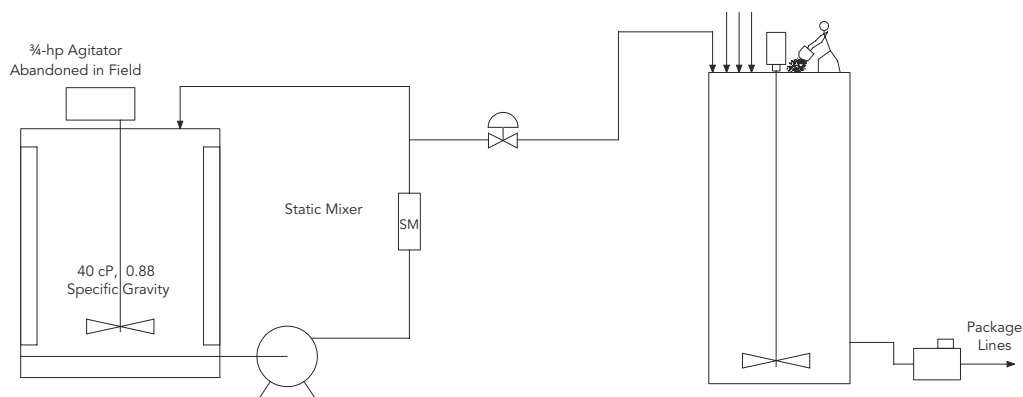


Figure 1. Replacing an agitator with static mixers stirred up problems.

Treat Your Reciprocating Compressor Right

Pay attention to the load the device must contend with at startup



Consider two common methods for starting up at no load.

IT'S BEST to start up a reciprocating compressor at no or very low load. This reduces torque requirements — and, thus, the need for higher-torque motors — as well as improves machine reliability. So, let's look at some methods to reduce startup load.

Figure 1 shows a schematic of a two-stage reciprocating compressor system. Each stage has both a suction knock out drum to protect the compressor from liquid in the feed and an aftercooler to reduce the process temperature. The first-stage aftercooler helps prevent excessive temperature into the second stage suction. While operating, the compressor system uses both a flow control recycle line plus suction valve unloaders on the compressor stages to control compressor capacity.

Two common ways of starting up reciprocating compressors at no load use the normal-operation capacity controls to decrease the starting load to zero. These methods are total recycle through the recycle line, and running at zero load with the inlet valve unloaders open.

Operating with the recycle flow valve in Figure 1 fully open reduces the discharge pressure to the suction pressure, minimizing the torque at startup. (Each stage may have its own individual startup line rather than the common line shown.)

Using the recycle line to decrease load means the entire flow is cooled through the after-coolers. Compressor suction temperatures stay within normal operating ranges. This configuration requires the product check (no-return) valve to seal well. If that valve doesn't seal, reverse flow from the discharge can enter the system.

The flow control valve then is closed until discharge pressure rises enough to force flow forward. Net

capacity can be smoothly increased to prevent excessive torque changes on the machine and motor.

The other option uses valve unloaders on the suction of the compressors to drop the capacity to zero load. Valve unloaders prevent isolating the cylinders from the feed. When the compressor enters the compression stroke, feed is forced back into the suction rather than being pressurized and moved forward.

Valve unloaders can lead to heating of the suction gas. For the limited duration of a startup, this rarely is severe. If present, cylinder cooling jackets usually suffice to deal with this heating.

On a double-acting compressor cylinder, simple valve unloaders allow stepping capacity up from 0% to 50% and then from 50% to 100%. While not as smooth as a recycle line, even the 50% capacity step dramatically reduces startup torque loads.

We recently came across a third method of starting up reciprocating compressors: lowering compressor startup load by dropping the feed density. This involves fully closing the feed isolation valve of the compressor at startup. The small gas volume left in the line between the valve and the compressor leads to a drop in suction pressure. The resulting low gas density in the cylinder suction translates into low load. Once the machine is started up with blocked feed, the feed valve gradually is opened to move into normal operation.

We don't recommend blocked-inlet startup because it poses several problems. First, the system is pressurized to process conditions for a fraction of a second. During this time, the compressor and motor must deal with the full startup torque. Depressurizing the inlet piping to a lower-than-normal pressure before startup can reduce this load. Second, the cylinder and valve temperatures

can rise dramatically. So, this approach only suits compressors with cylinder coolers and, even then, generally should be avoided.

A good startup plan for a reciprocating compressor can save money and improve reliability by reducing startup torque. Using a recycle line, if present, generally is the most effective method. Inlet valve unloaders are also a good choice. ●

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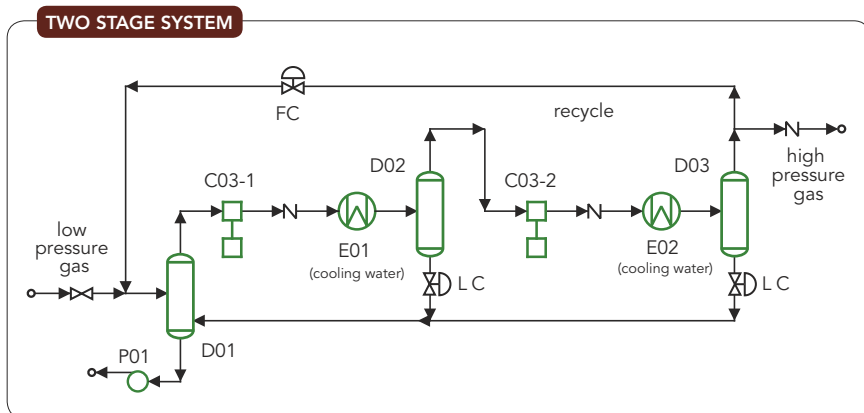


Figure 1. The recycle line in this reciprocating compressor setup provides a means for no-load startup.



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reduce cost, weight and space, says the company. The Bonomi 723/724 Series wafer ball valve, due to its compact size, uses less steel, which translates to lower cost. The valve's



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Technology Simplifies Complex Mixtures

Combined experimental and data processing techniques help analyze petroleum fraction



They managed to assign a record-breaking number of 244,779 molecular compositions within a single sample.

AN ADVANCED mass spectrometry (MS) technique developed by chemists at the University of Warwick, Coventry, U.K., has broken a world record for the number of molecular compositions identified in a single sample of petroleum.

Known as operation at constant ultrahigh resolution (OCULAR), it combines experimental and data processing techniques that allowed the chemists to characterize the most-complex sample they have ever worked on — a non-distillable heavy petroleum fraction. They managed to assign a record-breaking number of 244,779 molecular compositions within a single sample of the fraction.

Identifying the elemental composition of such molecules can provide valuable data for research, determine the mixture's viability for use in the petrochemical industry, or even “fingerprint” a complex mixture such as oil or environmental samples, say the chemists.

To date, Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS) has represented the state-of-the-art, offering the highest performance in terms of both resolving power and mass accuracy. However, very complex mixtures have always posed a serious challenge to the technology.

The Warwick chemists start with an analysis of a sample of heavy petroleum in solution using FT-ICR MS. Then the molecules in the sample are ionized, excited and detected using a Bruker solariX FT-ICR MS to determine the mass-to-charge ratios.

What they are doing is effectively “filtering” the ions that go to the FT-ICR cell for detection. This means they have plenty of ions per peak, but not so many in total to cause the problems traditionally associated with complex samples. This allows them to build a complete data set in stages — and to detect the very “weak” (i.e., low abundance) compounds, too.

Key here is the ability to keep the resolving power the same for each segment being analyzed. Then, an algorithm looks at the segments to find the best place to overlap them. It ultimately stitches them together in one very complex data set. The approach opens new doors, particularly for complex samples.

Diana Palacio Lozano, from Warwick's Department of Chemistry, notes: “This method can improve the performance of a range of FTMS instruments, including high and low magnetic field FT-ICR MS instruments and [ion trap mass analyzer] Orbitrap instruments. We are now able to analyze mixtures that,

due to their complexity, are challenging even for the most powerful analytical techniques. This technique is flexible as the performance can be selected according to the research needs.”

The heavier oil's extraordinarily complex elemental composition now explains its low volatility. The high complexity of heavy oils can interfere with catalysis and affects extraction, transport and refining processes. The OCULAR technique also is powerful enough for samples requiring the highest performance to assign compositions based on mass accuracy or fine isotopic patterns.

Principal investigator Mark Barrow says: “The OCULAR approach allows us to push the current analytical limits for characterizing the most complex samples. It significantly extends the performance of all FTMS instruments at no additional cost and works well with developments in the field, such as newer hardware designs, detection methods, and data processing methods. OCULAR is highly versatile, the experiments and processing can be adapted as needed, and the approach can be applied to many research areas, including energy, healthcare and the environment.”

Examples for analysis and potential applications include energy, for example petroleum and biofuels; life sciences and healthcare, e.g., proteomics, cancer research, and metabolomics; materials such as polymers; and environmental analysis, including “fingerprinting” oil spills by their molecular composition.

The Warwick chemists now are applying the methodology to other sample types within their laboratory, such as petroleum and bio-oils/biofuels, and reviewing ways to further develop their OCULAR approach.

“The non-distillable sample we tackled was one of the most challenging we have ever tried to analyze, and the OCULAR approach made the difference between getting no useful data and producing the most complex petroleum spectrum to date,” he says, adding, “So we soon realized the methodology would hold promise for industry and can be particularly useful for the heaviest and most complex samples.”

Although he couldn't go into details, Barrow revealed that industry has already expressed interest in the method and its results. ●

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