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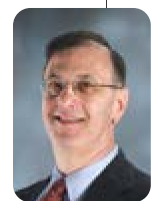
Folio Editorial Excellence Award Winner

Consider Covid's Subtler Impacts

It may prompt some rethinking about process equipment and careers



THE QUEST for diagnostics and vaccines for Covid-19 has spurred some ancillary and less widely appreciated impacts. For instance, as this issue's article "Disposable Equipment Makes Lasting Gains," p. 30, notes, single-use equipment is playing an important role in such developments because of its benefits, such as faster set-up and lower capital cost. While use of such disposable equipment has shown continuing growth for some time, the current efforts promise to foster even more uptake.

Another result of the pandemic, I certainly expect, is a greater awareness and interest by chemical engineering students and graduates in the opportunities to use their technical training in careers involving bioengineering. While work in the pharmaceutical industry may come to mind first at the moment, such careers span a broad range of fields.

So, the timing of a new publication by the Institution of Chemical Engineers (IChemE), Rugby, U.K., is particularly propitious. "Chemical Engineering Careers in the Bioeconomy," released in late April, contains career profiles of more than twenty chemical engineers in diverse roles and at various career stages in a variety of industries.

James Winterburn, chair of the IChemE Biochemical Engineering Special Interest Group, provides an apt foreword:

"... Each one of these career profiles demonstrates the impact made by chemical engineers across the breadth of the bioeconomy, including water, energy, food, manufacturing, and health and wellbeing.

"As chemical engineers we must continue to support, be encouraged and evolve our knowledge to encompass new advances in engineering biology, synthetic biology and industrial biotechnology. I hope that this booklet provides inspiration to students who decide to study chemical engineering; to the professionals who work in engineering; to the companies operating in the biosector interested in the skills a chemical engineer can bring to their operation; and to the public, to help develop their understanding of the role that chemical engineering plays in society."

More students may consider careers involving bioengineering.

Ten profiles cover people working in the area of health and wellbeing; five focus on engineers in the energy field; four on those in bioprocess design and manufacturing; one on someone in the water field; and, another, in food and nutrition. Most work in the U.K., but some are based in Ireland, Canada, New Zealand and China. Four are women. The people are at a variety of career stages, from first jobs to executive positions.

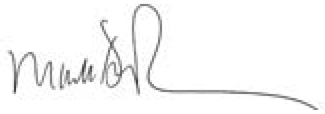
Each profile includes answers to about a dozen questions. These address basic points such as the person's educational background and current job responsibilities but also delve into what it takes to do the job and its greatest challenges, what the person considers the similarities and differences from other chemistry- or process-related industries, what sets the biosector apart as a good place to work, and what tips the person can offer for someone considering a career in the sector.

You can download a copy via https://bit.ly/2WdqUc8.

Winterburn ends his foreword:

"As demonstrated by the career profiles presented here, a career in chemical engineering is a journey, and there are many different doors to open and many different roads to exciting new opportunities."

I couldn't agree more.



MARK ROSENZWEIG, Editor in Chief
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Upgrades Enhance Your Site Visit

Recent changes to ChemicalProcessing.com aim to improve your experience

You've probably noticed some changes.

FREED-UP TIME that otherwise would go for commuting, shopping, etc., before the pandemic, can prove a powerful resource. I, for one, have finally addressed some unglamorous but much-needed chores such as purging junk drawers. I've also devoted time to looking for ways to make your visit to ChemicalProcessing.com more efficient.

Over the last few months you've probably noticed some changes. Cosmetically, we've updated our font as well as the spacing of our copy. One reader took notice and sent me an email to thank us for making it easier on the eyes. She even said the new font feels more welcoming. I agree.

You'll also notice larger images throughout the site. This was made possible by making our site wider. How? Well, our programming team centered our site and removed the edges — the result is a roomier feel. We've also added large feature images at the top of article pages (e.g., see sample at left). This change helps us marry our print issue to the web version. Part of the wonderful experience of reading a magazine article usually is having an image visually set the stage for the text. The enlarged images help us make our online presence as pleasant as thumbing through the hard copy. We've also removed the cumbersome "next page" button. Now, you simply just keep scrolling. And once you've finished the piece, you'll find a listing of related content — hand selected by our editors — right at the bottom should you wish to delve further.

We've also updated the homepage. Industry News is now located at the top of the page so you can get an immediate glimpse into what's happening in the chemical industry. Right underneath is our Online Exclusives section that covers content such as our webinars, the Comical Processing Cartoon and our Ask the Experts forum. If you scroll down, you'll notice we've added an area to highlight our Twitter feed. Keep scrolling and you'll reach our Be Sure To Read section. Currently, we've added a COVID-19 Coverage area. This page features everything related to the coronavirus, including how the chemical industry has rallied to help people stay safe. You can access it here: ChemicalProcessing.com/home/covid-19.

MEET THE *CHEMICAL PROCESSING* EDITORIAL BOARD

The editors of *Chemical Processing* meet with members of the editorial board four times a year to discuss best practices, key trends, developments and successful applications. We've published many articles based on the board's recommendations. See who sits on our board at http://bit.ly/CPEditBoard

The bottom of the homepage has a section that features the Chemical Reaction blogs as well as multimedia, news, products and white papers. The footer — that area in our signature cranberry color — gives you access to everything that lives on the site. It essentially provides a site tree of our entire online presence: contact information, editorial calendars, Comical Processing cartoon gallery, polls, eHandbooks, etc. Don't worry, we still have the hamburger menu at the top of the page. To refresh your skills with our menu bar, you can read "Check Out Site Upgrades, Top Content On *Chemical Processing*." (https://bit.ly/2yO802r).

Something that I've been meaning to do but never had the extra time for was adding transcripts to our Process Safety With Trish & Traci podcast series. Now, you can read the full transcript of each podcast. Moreover, it includes links to several things Trish and I talk about — thus giving you a more-robust safety resource. You can read the transcripts by following this link https://bit.ly/2WoG8Le.

The COVID-19 pandemic has changed nearly everything we do. Turning challenge into opportunity is what our industry does best. If you see an opportunity for us to make the site even more useful, please let me know. ●

TRACI PURDUM, Senior Digital Editor
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ChE Students: Take a Broader View

A job in industry requires much more than chemical engineering

Don't fall for the fallacy that reactors are solely our domain.

"ISN'T THAT mechanical engineering work?" the intern asked, implying it wasn't something a chemical engineer should do. Not wanting to appear condescending, I said, "No, writing pipe specifications is necessary..." This episode underscored to me once again the importance of chemical engineering students broadening their education. Specialization is a luxury in this world of shrinking staffs.

Many chemical engineering students lack an appreciation of mechanical engineering. For that matter, most probably think chemistry is boring and maybe even irrelevant to them. The plain truth is that the chemical engineering learned in school will form only a part of what most jobs demand. Indeed, the areas we consider chemical engineering — and, thus, ours alone — are pretty small.

Consider this: our specialties consist of separation and reactors. And, if you think about separation, many methods involve myriad mechanical and electrical details. Take solid/liquid separation. There's filtration, centrifugation, cyclones, settlers, crystallization, leaching, floatation — and that's just reading through the table of contents in "Handbook of Separation Techniques for Chemical Engineers" by Philip Schweitzer. None of these methods are truly unique to our business. For example, civil engineers commonly deploy sand filters, settlers, flotation devices and even cyclones in water treatment. As for centrifuges, try installing one without the expert advice of an experienced electrical engineer!

Now, you'd think that distillation is one technique that is exclusively ours. Given the thermodynamics involved, I would tend to agree with you. However, the heart of the distillation column is the reboiler, unless you're operating directly on steam or another heat source. Even then, the boiler is in the wheelhouse of the mechanical engineer, as are the reboiler and condenser.

That takes us directly to a subject I like to call fluid flow. The equipment involved, which I dub "movers" in my hard drive library, includes fans, pumps, compressors and ejectors. Mechanical engineers play a key role with such equipment. As for fluid flow itself, other than rheology, mechanical, aerospace and even civil engineers largely are in command. Where chemical engineers still dominate is when fluid flow design extends into the field of mass and heat transfer. Thus, distillation, extraction, crystallization and evaporation are solid niches.

Isn't gas/liquid separation also a safe spot in our vocation? Generally, yes — but really only with hydrocarbons. The oil industry spent millions of dollars making it easier to model species with simple C-H, C-C bonds. The trouble is that you're back in the laboratory if C-S, C-O, C-N and other bonds are involved. I work with formaldehyde, methanol and the products created from formaldehyde — and depend upon data developed by DuPont when it built a plant 80 years ago. I wouldn't trust anything I could calculate using Peng-Robinson or even-more-advanced models of physical or chemical behavior. Besides, these advanced models rely on the same old laboratory data I'm using now. Many times, I've gone back to the laboratory to develop data for a calculation. In other words, if you considered chemistry class useless, think again.

Also, don't fall for the fallacy that reactors are solely the domain of chemical engineers. Civil engineers generally design digesters, which are an important part of wastewater treatment. Their design and operation are based on biochemistry. Those reactor models bear a striking resemblance to the ones for pharmaceuticals.

Some chemical engineers have moved into the field of instrumentation, which you might think really is a niche for electrical engineers. However, electrical engineers often do instrumentation badly. They don't understand fluids, chemistry and the branch fields of corrosion and materials. Getting involved in instrumentation means learning electrical engineering on the side.

So, the takeaway here is to broaden your skills. If there's any profession where specialization is the bane of survival, it's chemical engineering.

Getting back to the intern assigned to do the pipe specifications — that task not only will broaden her experience but also will help her develop research skills. Many different people likely will give her advice or make specific requests. So, she'll have the useful challenge of sorting out what's the most-suitable pipe specification and presenting her conclusions so they're accessible at a glance. ●

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Bioproducts Promise Better Biofuel Economics

Extracting modest levels of compounds may enable parity with fossil fuels

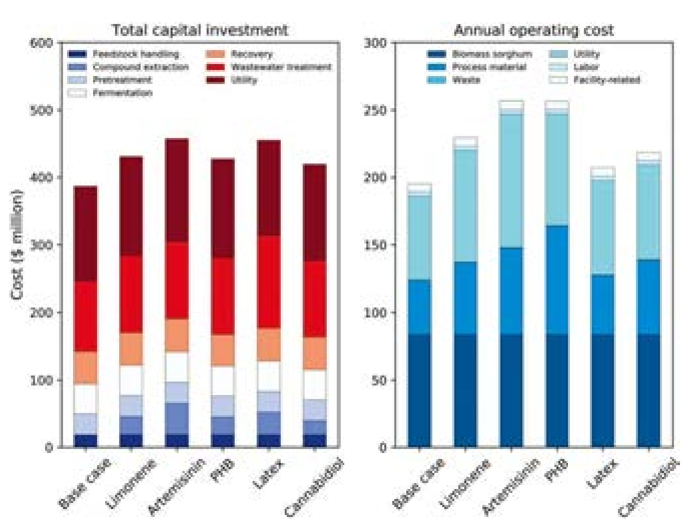
BIOFUELS COST-COMPETITIVE with fossil fuels would result if crops produce a valuable chemical that can be recovered economically, note researchers at the Department of Energy's Lawrence Berkeley National Laboratory and Joint BioEnergy Institute (JBEI), Berkeley, Calif. The researchers now have determined exactly how much of such a bioproduct that plants would need to create to make the process of extracting it worthwhile.

Using bioproducts that plants already economically produced, Corrine Scown and Patrick Shih of JBEI designed and simulated what it would take to extract these bioproducts in the context of an ethanol biorefinery. In this setting, after extracting the valuable bioproduct from the plant, the remaining plant material would be converted into ethanol.

This approach helps determine how much bioproduct that plants must produce to make extraction worthwhile, and the amount needed to reach a target ethanol selling price of $2.50 per gallon.

Results showed that a harvest of 10 dry metric tons of sorghum biomass from an acre of land would require recovery of around 130 pounds of limonene from that biomass to meet the target. That represents an accumulation of limonene at just 0.6% of the dry weight of the biomass. An article in *The Proceedings of the National Academy of Sciences* provides more detail.

BIOMASS PRODUCTION



This ethanol-production-facility simulation highlights the total operating cost and capital investment for nonengineered biomass sorghum feedstock. *Source: The Proceedings of the National Academy of Sciences.*

"The researchers in our Feedstocks Division were surprised by how modest the target levels were," says Scown. "The levels we need to accumulate in plants to offset the cost of bioproduct recovery and drive down the price of biofuels are well within reach."

In addition to sorghum, the team is working on switchgrass as well. "Some bioenergy crops are less genetically tractable than sorghum, which could make them more difficult to engineer for this purpose …," notes Scown. "One might ask, 'Why not do this with corn?' We often model corn stover (the biomass residue leftover after grain is harvested) as a bioenergy crop. It is possible, but there is a risk of negatively impacting the 'primary' product (in this case, the grain)," she adds.

The team next plans to apply the economic analysis to other potential coproducts. "The goal now is to take what we've learned and start doing modeling more specifically focused on products that our colleagues are engineering plants to accumulate. There are a variety of compounds we are going after, so I'm not sure which ones we'll do first, but stay tuned," comments Scown.

"The exciting part of this research is that there is a huge range of targets that could be great bioproducts …," adds Shih. "We looked at a structurally diverse set of compounds that also represent a wide range of low to high value compounds. I would hesitate to say there is an 'ideal' compound to go after, but taking into account the market size is important."

Engineering efforts specific to the accumulation of bioproducts in high-yield bioenergy crops are limited but this is an active area of research, notes JBEI's, Jenny Mortimer. "… There are a number of technical bottlenecks, such as plant transformation efficiencies, co-expressing multiple genes in specific tissue types, as well as regulatory issues. A lot of progress has been made in model systems grown in controlled environments …, but I think we're at the beginning of understanding how this works in the field. Muconic acid is a good example of a target compound," she says.

Forage Genetics International is working with JBEI on current and future developments. "They are collaborators on improving traits in sorghum, and have also licensed some of our technologies," concludes Mortimer.

Catalyst Makes Ammonia Process Greener

A NEW catalyst consisting of CaFH doped with ruthenium nanoparticles does away with the high temperatures, pressures and energy consumption associated with the current Haber-Bosch process for making ammonia, say its developers at the Tokyo Institute of Technology, Tokyo. The scientists note its lower energy demands reduce the carbon dioxide emissions from the use of large amounts of fossil fuels. They add the development raises the possibility of an environmentally sustainable Haber-Bosch process, opening the door to the next revolution in agricultural food production.

The catalyst — a solid solution (i.e., a solid mixture containing a minor component uniformly distributed within the crystal lattice of the major component) of CaF_2 and CaH_2 that is formed at low temperatures — produced ammonia from nitrogen and hydrogen gases at 50°C. The reaction involved an activation energy of 20 kJ/mol, which the scientists, in a recent article in *Nature Communications*, describe as extremely small and less than half that reported for conventional catalysts.

After conducting spectroscopic and computational analyses, the scientists proposed a possible mechanism by which the catalyst facilitates ammonia production. They suggest its performance stems from the weak ionic bonds between Ca^{2+} and H^- ions in the solid solution and the easy release of hydrogen atoms from H^- sites. These then desorb from the ruthenium nanoparticles as hydrogen gas. The resultant charge repulsion between trapped electrons and F^- ions releases electrons that attack the bonds between the nitrogen atoms in nitrogen gas and, so, promote the production of ammonia.

The next step in the development is to improve the new catalyst's performance, says Michikazu Hara, a professor at the Institute of Innovative Research at the university. "For example, its surface area is only 30 m^2/g, so we want to increase this," he explains.

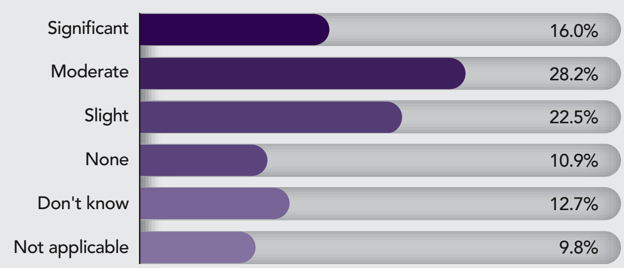
This work initially will take place in the current mL-scale reactor but catalyst tests in a pilot plant will occur at some point, he reckons.

"We will also develop other new catalysts on the basis of the knowledge obtained in this work — probably aimed at methane conversion into methanol, biomass conversion to value-added chemicals and polymers, and the efficient electrolysis of water," Hara adds.

While the effort has yet to attract interest from industrial fertilizer manufacturers, Hara notes the team has been working closely with the local government, which manages Ogata-Mura, a 9,000-ha (>22,000-acre) plot of reclaimed land where agricultural innovations are tested.

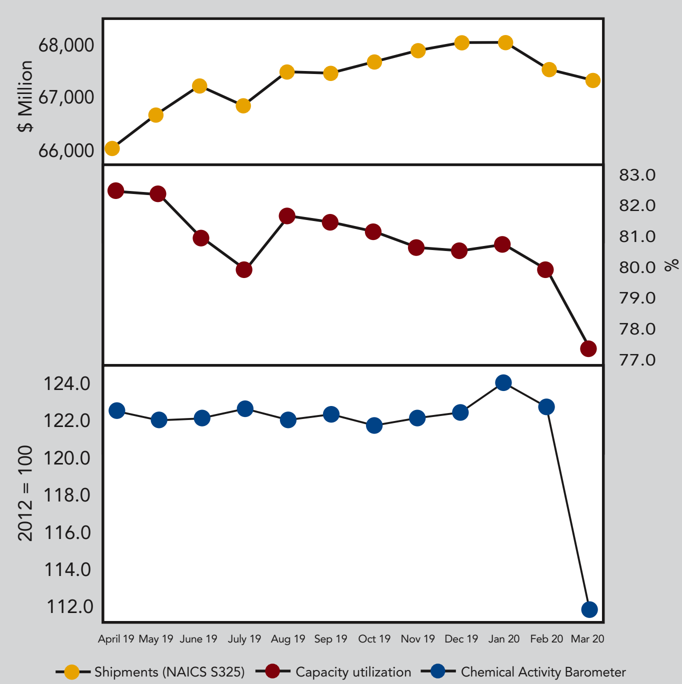
TO PARTICIPATE IN THIS MONTH'S POLL, GO TO CHEMICALPROCESSING.COM.

How much progress has your site made in taking advantage of the Industrial Internet of Things?



Almost half of respondents report their sites have made moderate or better progress.

ECONOMIC SNAPSHOT



All three metrics continued to drop, reflecting the impact of curtailed economic activity. *Source: American Chemistry Council.*

Combat Low Rate, Low Efficiency

Production cutbacks in continuous processes boost energy consumption

Most flow control systems are inherently inefficient.

THE CORONAVIRUS-INDUCED economic slowdown and the recent gyrations of oil prices have many refineries and chemical plants running at reduced throughputs. The impact on profitability and employment has become headline news. However, much less has been said about the impact on energy efficiency.

Energy intensity is the amount of energy used per unit of production — i.e., Energy Intensity = Energy Consumption/Production.

Low energy intensity corresponds to high energy efficiency; as the equation makes clear, this is achieved with low energy consumption and high production rates. This simple fact produces many ramifications — one of the most obvious is the adverse impact of cuts in production rate.

Chemical plants and refineries are designed to run at maximum efficiency at their nameplate capacity. As production falls in continuous processes, energy consumption doesn't drop proportionately. Many reasons for this exist, with the majority linked to control methods, equipment constraints, and leaks and losses.

Most flow control systems are inherently inefficient. Two common examples involving centrifugal pumps illustrate this point. In so-called "bypass control," the flow rate to the downstream consumer is regulated by recycling fluid from the pump discharge either to the pump suction or to a feed drum ahead of the pump. When the flow required by the downstream consumer declines, the recycle flow increases. However, the flow through the pump and, hence, the pump's energy consumption remain essentially constant. Because energy consumption stays the same while production goes down, energy intensity increases.

In the second example, "throttle control," a valve in the pump discharge line adjusts the flow. The valve closes to reduce the flow. This imposes backpressure on the pump, which has to deliver a higher discharge pressure. This, in turn, demands more energy per unit of flow. In addition, both the pump and its driver (usually an electric motor) move away from their design points to new operating points, which are invariably less efficient. The result, once again, is an increase in energy intensity — although the increase isn't usually as large as it would be with bypass control.

In contrast to these examples, variable speed control can, in some cases, reduce energy intensity as flow rate goes down. However, this is typically more expensive to implement.

Control systems also can cause a rise in energy intensity as throughput drops in distillation columns. The flows of reflux streams and stripping steam often are set based on nameplate throughput, then held constant. Consequently, when feed rates drop, there isn't a commensurate fall in energy consumption. Modifying flow control systems to maintain a constant reflux ratio or stripping steam ratio — or, better, to keep product specifications constant using online chemical analysis — can correct this problem.

To overcome minimum turndown limits in distillation columns, boilers, furnaces, and other equipment requires energy and minimum flow restrictions in piping. For example, as a distillation column reaches its turndown limit, it may make sense to increase its reflux ratio to maintain liquid and vapor traffic instead of reducing it, as discussed in the previous paragraph. When boilers reach their turndown limits, many sites either vent steam or, alternatively, deliberately use steam inefficiently within their processes to avoid a visible vent. When a flow rate approaches the minimum limit in a pipe, prudence may dictate recycling fluids, which increases pumping costs.

Heat losses through piping and vessel walls, steam leaks, and condensate are insensitive to throughput, so they become a larger percentage of energy consumption as production falls, causing energy intensity to rise.

With the exception of some of the simpler control issues, resolving most of these problems usually requires significant investment. However, in some cases, operating changes also can provide improvements, especially where multiple pieces of equipment run in parallel. For example, it may be possible to shut down one process train in a multi-train plant, one or two pumps or fans in a large cooling water system, or one or two boilers in a large steam system. However:

- The operating changes must not compromise safety or reliability.
- You must consider system interactions. For example, shutting down a cooling water pump eliminates the energy use in that pump, but the reduction in flow may adversely affect the energy intensity of equipment that uses the cooling water (e.g., refrigeration units). ●

ALAN ROSSITER, Energy Columnist
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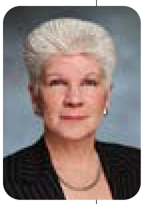
Talk to Your Supply Chain

Exchanging information clearly and frequently with all stakeholders is essential



It's a mistake to overlook the EPA as a critical supply chain stakeholder.

MUCH ATTENTION now focuses on COVID-19 and subsequent supply chain disruptions; here, we tackle supply chain communications and ways to optimize them. The Toxic Substances Control Act (TSCA) requires such communications, as do evolving best business practices. Managing supply chain communications effectively, and strategically optimizing the commercial interactions and exchanges of information they elicit are essential business practices.

As demand increases for more information about chemical components to which workers and downstream customers may be exposed, federal and state regulators have stepped up efforts to compel the disclosure of chemical ingredient information to supply chain partners. Other initiatives urge voluntary disclosure of such information as a matter of good product stewardship and corporate governance, motivated in part by the business community's desire to exert more control over the timing, optics and content of such disclosures. TSCA amendments enacted in 2016 also have enhanced the need for and the opportunities available to manage supply chain communications smartly and in a way that offers considerable commercial value.

The new TSCA requires a high degree of communication among chemical value chain partners. TSCA Section 8 reporting obligations are a case in point. Current chemical data reporting (CDR) requirements are extensive and include chemical identity, where the chemical is produced, manufacturing information, and certain processing and downstream user and use details. While the legal standard that applies to providing this information is "known to or reasonably ascertainable by," sophisticated entities appreciate that it is in the manufacturer's best interests to provide accurate, high-quality information, given that the U.S. Environmental Protection Agency (EPA) relies upon CDR information for regulatory prioritization purposes.

Revisions to TSCA Section 5 (new chemicals) have also heightened the need for enhanced communication among supply chain entities. The utility of a new chemical, and thus its commercial success, in part will reflect its ease of use in commercial settings without regulatory restriction.

Since the TSCA was amended, the EPA must make one of three alternative determinations under Section 5. If the EPA determines available information is insufficient to permit making a reasoned evaluation of the chemical's health and environmental effects or the chemical may present an unreasonable risk or it has substantial production and exposure, the agency will issue a Section 5(e) order that sets out the control measures it deems necessary to protect against the unreasonable risk. Standard Section 5(e) provisions can include specific use prohibitions, restrictions on consumer use, no releases to water, worker protections, limits on production volume, prohibitions on domestic production, prohibitions on formation of respirable forms, and recordkeeping requirements. Clear communication between the chemical innovator and the downstream processor or user prior to the submission of the premanufacture notification can, in some instances, avoid a Section 5(e) order entirely.

EFFECTIVE SUPPLY CHAIN COMMUNICATIONS

For stakeholders wishing to embrace a business strategy focusing on developing and curating proactive supply chain communication, here are a few suggestions:

Identify and prioritize stakeholders/suppliers. Know your customers and accommodate their needs. A new chemical notice requires information from entities throughout the supply chain, and accurately portraying its conditions of use is critical to understanding commercially feasible regulatory controls. The only way to elicit this information is to know your customers' manufacturing operations, intended uses, and appetite for regulatory control.

Include the EPA in your list of stakeholders. Chemical producers often overlook the EPA as a critical supply chain stakeholder. This is a mistake. Let the new chemicals staff in on important product rollouts so that both parties can anticipate the regulatory trajectory, resource needs, and data development requirements.

Communicate often and clearly. Ensuring your customer base is aware of regulatory requirements with the products you manufacture and how they can address those requirements are considerations as important as the product itself. Routine, candid communication is foundational to all relationships, and commercial relationships forged by the TSCA are no exception.

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Shaft Seals Protect Quality, Predict Maintenance Issues

Offering support to the customer throughout the lifecycle of the seal generates advancements for all.

FACILITIES ARE constantly tasked with improving productivity and equipment reliability levels. An often-overlooked opportunity is found in rotary shaft seals. They don't just simply prevent leaks, they play an important role in efficiency, quality and maintenance.

Chemical Processing discussed the design considerations and benefits of seals with Paul Wehrle, chief engineer, Woodex Bearing Co., MECO Seal, Georgetown, Maine.

Q. What factors affect the selection of low-pressure reactor shaft seals?

A. It could be a reactor first and then at the end of it, it's a dryer, or it is a dryer and there's no reaction other than removing moisture. It's the terminology that varies throughout different industries across the world. I think vacuum application is the buzzword versus low pressure or reactor. Reactors outside our capabilities are at high pressure, over 4 bar. Low pressure may imply a small positive pressure or inert gas blanket, measured in inches of water or 1 to 2 psig. What factors affect it – with regard to the selection of seals? What are the actual minimum and the maximum pressures during the process and how do pressures vary over time? Is it only at atmospheric pressure when not in a vacuum state? During various pressure cycles of the batch, is the shaft rotating? If not, what is the pressure when static? Sometimes assumptions miss these variables, causing missed opportunities for MECO's solution.

Consider how deep a vacuum is desired and the material transformation. How does material behave within the reactor over time? Is it liquid, then light and fluffy or dense and sticky, or dense and lumpy, then granular? Are the shaft, drive and agitator sized with a safety factor included to minimize flexing? The vessel design and shaft seals are important for equipment longevity, product quality and batch consistency.

Another factor: What is the acceptable rate of vacuum loss without the vacuum pumps? There are many points where you can have loss of vacuum, including the shaft seals, doors, manways, valves, inlet ports, instrumentation probes and chopper seals, to list a few. The typical guideline we target is a loss of ¼ in. (6 mm) of Hg/minute. Equipment size and integrity play a role in the value. We fit split seals on new and used vacuum dryers with shaft sizes between ø1.5 in. (40 mm) to ø16.5 in. (420 mm).

We also consider the pressure rating of the vessel. We are requested to seal vessels with positive pressure ratings of 1 or 2 bar. Both are common ASME welding certification standards offered by a fabricator. Was the vessel originally designed for different service and now repurposed? Using the actual upper pressure limit of the application and not the vessel rating is best when using MECO polymeric face sealing technology.

Additionally, with used equipment, agitators, connecting arms and the main shaft are often repaired in the field by welding. These repairs increase shaft runout — something our seals tolerate, but this influences the seal barrier fluid consumption and maximum vacuum containment. Sometimes a new vessel is best.

Q. What issues too often are under-appreciated with such seals?

A. Shaft seals should provide consistent product quality and cycle time per batch with trendable metrics repeated. You can predict preventative maintenance for service versus having a setback in the middle of the batch or weekend.

We all have setbacks. Ours emerge from gradual wear and are noticed in the trends. A hard-face mechanical seal is lubricated with a fluid film protecting the brittle faces and often unsplit. A catastrophic failure results when hard-face seals lose their fluid film. In contrast, MECO seal faces are self-lubricating, bearing-grade polymeric materials, fully split, malleable and operating in contact. You don't have to worry about the vacuum pulling the fluid film away from our sealing interface. We use the vacuum as our friend. It helps close our sealing interface. So a vacuum condition is natural for us. It's a negative that's a positive. Additionally, we tolerate the shaft runout. That's not the case with traditional packing boxes — another common seal used on vacuum vessels — that need continual maintenance.

Q. What are some of the common errors when working with and selecting these shaft seals?

A. As discussed a little earlier, sometimes we receive the ASME pressure rating on the vessel for maximum pressure. For example, someone might tell us it's a full vacuum to a 30 psi or 2 bar application, but in reality the vessel is rated for 30 psi and the highest it's ever going to see in the process is only 7 psi. Sometimes this eliminates our ability to propose a solution, especially on larger shaft diameters. Or we over-design for the higher pressure, overloading our polymer seal faces and reducing the lifecycle. That is a challenge that we encounter and will continue to, but it opens discussion — the key for long-term success and partnerships.

Reliability engineers and rotating equipment specialists have a strong background using hard-faced mechanical seals from their experience in the pump world. This experience is different than other low-shear process machinery. Pumps are equipped with smart technology and typically rotate between 1,150 to 3,600 rpm. At those speeds, the bearings and impeller balance must be sound. The smart technology tells the controller, “Hey, there's a valve closed, don't turn on,” or, “You can't be pumping from that tank — it's empty.” So the pump remains idle, protecting the seal. Batch operation process machinery often turns at 5 to 100 rpm and doesn't have all of these advantages protecting the seals. However, we both must operate with the equipment's idiosyncrasies and process setbacks in the batch-production environment. Working with the reliability engineers and the project engineers and sharing these differences in equipment is important when comparing hard-face seals, packing boxes and our polymeric seals.

For instance, when you are retrofitting, concentricity is important in a vacuum application more so than in a positive-pressure application. Otherwise, you get this teeter-totter effect with the rotary seal faces as the shaft rotates. Pump construction and speeds rarely permit seals to tolerate this mounting condition and still function — ours do.

Q. Are there any other special design considerations?

A. Occasionally, we place a barrier ring in front of the seal and sweep a little compressed gas along the shaft. This reduces product migration along the shaft in abrasive conditions and extends lifecycles.

Batch operations have moments of non-steady-state or upset conditions. Stopping, starting, loading, emptying and change of material characteristics are some causes. They introduce a moment in time where a bit of process material may enter the seal cavity. It's not going to cause a problem, but over time that bit increases; if it's trapped inside the seal cavity, it then spins around and may transform into a setback. We advise clients to plumb a trap off a port underneath the seal cavity to collect debris.

The operator should periodically open the plumbing and inspect. It is helpful after known upsets or on preventative-maintenance schedules. This extends service life and provides another trendable metric.

Additionally, the plumbing size chosen for the gas barrier fluid, the regulator output range and pressure gauge scale all have important influence on the life and performance of the seal.

Reviewing the application for explosion hazards is important. We incorporate static discharge brushes, grounding

MECO EP TYPE 3 SPLIT SEAL

A ø5” MECO EP Type 3 split seal on a cylindrical plow blender in service at temperatures approaching 500° F under full vacuum, drying calcium carbonate.

connections, a pressure relief valve and thermal sensor ports for the various hazards such as explosive powders, gases or vapors in the reactor. A risk assessment is done to determine the needed features, and EU ATEX certification is available.

Q. How can you ensure maximum service life for the shaft seals?

A. “Seals fail three ways,” was shared with me years ago. They fail in shipping, at startup, or when there's some catastrophic event like a bearing failure, bent agitator or loss of barrier fluid. The first two we control far more than the other. We control the packaging to assist the shipping carrier and we support the installation. The installation is complete when the diagnostics are met using the barrier-fluid readings. Plus, we offer field support, consultation over the phone, e-mail or video. Support is available before, during, after and ongoing for the mutual quest to extend runtime.

If investing in shaft seals, inspect your bearings, drive and end-wall condition before the installation. Trend your process and seal metrics. Utilize the plumbing trap under the seal discussed earlier. For any seal, maximize the concentricity of the seal to the shaft. Maximize seal perpendicularity to the shaft and seal flatness against the machinery end-wall.

Q. Is there anything else you wanted to add?

A. Offering support to the customer throughout the lifecycle of the seal generates advancements for all. Enhancements are a continuing endeavor for us. Sharing insights leads to longer service life. Communication is the vehicle for building a strong partnership with forward momentum for all.

Process Automation Opens Up

Ongoing effort aims to improve operational flexibility and asset performance

By Mohan Kalyanaraman, Don Bartusiak, Steve Bitar, Bradley G. Houk and David L. DeBari, ExxonMobil Research and Engineering, and Brandon Williams, CPLANE.ai

NO TREND in the past thirty years likely will revolutionize chemical processing as much as the imminent implementation of "digital transformation" technologies and practices. This transformation encompasses a proliferation of Industrial Internet of Things (IIoT) sensors and actuators, a flood of time-series data, and exponential growth in computers directly participating in plant operations. However, one central concept — low-cost implementation of change — will drive the real power and productivity benefits of digital transformation, namely, the ability to make rapid, iterative and data-driven innovations to plant operations at a fraction of the cost previously possible. This demands overcoming the restrictions to innovation created by closed proprietary systems.

Numerous factors are driving this need: global markets and competition make laggards in innovation unsustainable; changing environmental laws and sensitivities require new tools for compliance; and reimagined capital budgets consider operational flexibility and profitability not only efficiency and safety.

Digital transformation and asset performance maximization place a call on business systems, cloud and computing architectures, and process automation and control systems that operate manufacturing plants. Major global industrial and chemical companies are collaborating with leading process automation vendors and system integrators to accelerate this revolutionary change in automation through the adoption of The Open Group Open Process Automation Standard (O-PAS).

To fully benefit from the immense power of new digital tools such as artificial intelligence, machine learning, cloud computing, data analytics and edge computing, the chemical industry must adopt an open standard like O-PAS to accommodate and implement continuous change. Such a move will enable operating companies to affordably upgrade equipment in-situ, rapidly reconfigure production to respond to sudden market opportunities, and continually apply improved algorithms with deterministic results. Moreover, it will allow working within system constraints such as keeping human/machine interfaces and operational procedures usable by current and new workers, aggressively implementing digital security, and never compromising operational safety. O-PAS, the second version of which has just come out, provides a critical standards framework to address all these factors and many more.

THE CURRENT SITUATION

Since the 1970s, the state-of-the-art for process control and business information systems at process plants has consisted of a multiple-level hierarchy of interconnected computing devices, sometimes called the Purdue Model. This hierarchy (Figure 1) has the process control systems as Levels 1 to 3 and the business systems as Level 4 and 5.

The process control systems, usually described as distributed control systems (DCSs), monitor and control manufacturing processes. A DCS typically consists of operator and engineering stations, controllers, input/output (I/O) modules and application servers. Such control systems generally remain in service for a long time, often for decades, even as the surrounding business network and enterprise systems (Levels 4 and 5 in Figure 1) are upgraded. The closed proprietary nature of Level 1–3 systems provides a significant obstacle to change at those levels.

However, for legacy systems installed in the 1980s and 1990s, obsolescence of components is a real problem. Obtaining hardware and patching the software to keep the systems running are increasingly difficult; loss of institutional memory and programming skills for legacy systems compound the problem. Opting to "rip and replace" the installed system is very expensive and time consuming, affecting both productivity and profitability. Moreover, closed systems don't allow for ease of access to data that complex algorithms use to generate actionable operational insights that can boost productivity and truly drive a digital-enabled organization. The concept of a layered hierarchy of access seems increasingly at odds with the emerging trend of open access to data and trends in digital enablement.

Security was an afterthought in legacy systems; the majority of security measures focused on physical access controls. As networking and computing technology improved, strong business drivers emerged for interconnecting these networks to allow centralized process control and sharing of information across the enterprise. The convergence of once-isolated control systems with information technology (IT) networks has introduced new security risks, exacerbated by lack of encryption and authentication technologies as well as availability of open-source information regarding industrial control system architectures, operations and vulnerabilities.

In addition to the technical issues, legacy systems pose an inherent business problem by strongly favoring incumbent suppliers. The closed proprietary nature of the interfaces enables those vendors to control access and affords them "vendor lock," whereby they gain a recurring revenue stream for provision of exclusive services.

AN ALTERNATIVE MODEL

Given the limitations of the current approach to process control, what should an alternative model encompass? It should contain four major elements that can provide a framework for creating an improved automation system.

1. *A distributed, modular, extensible and scalable platform* that lowers the cost, complexity and operational risk associated with expansion or online replacement (to deal with component

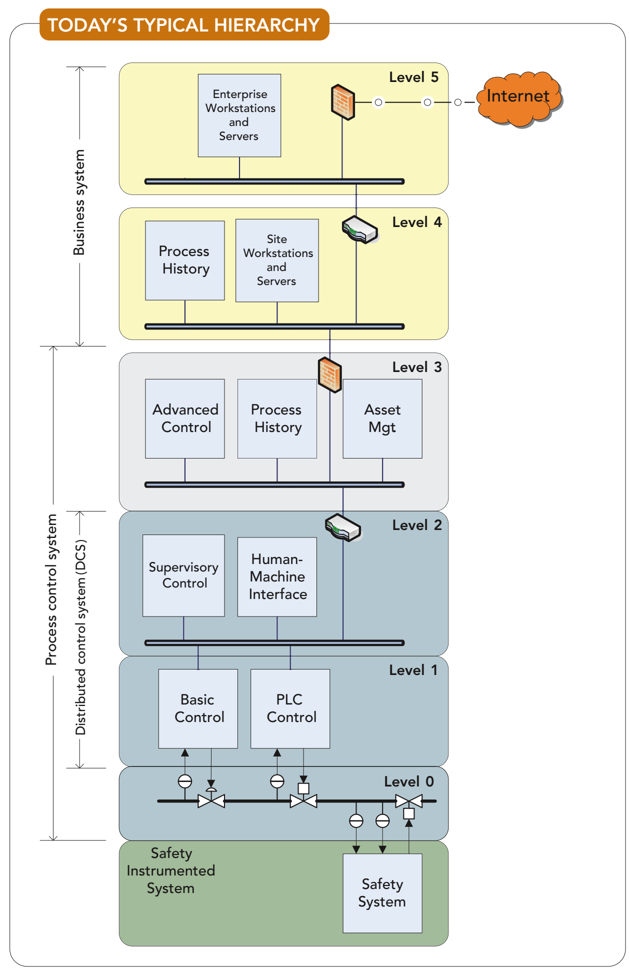
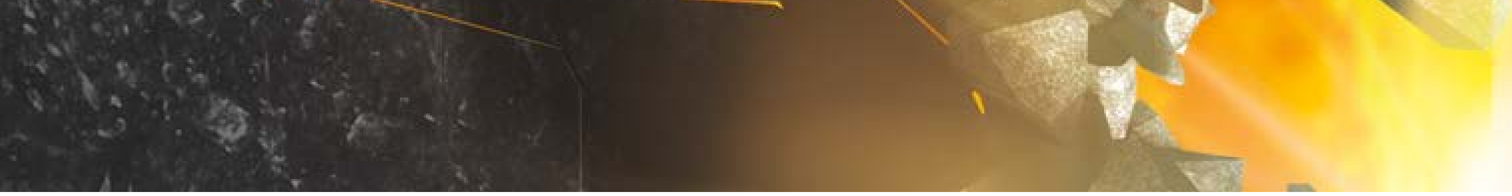


Figure 1. Manufacturers generally deploy process control and business system hardware in five levels.



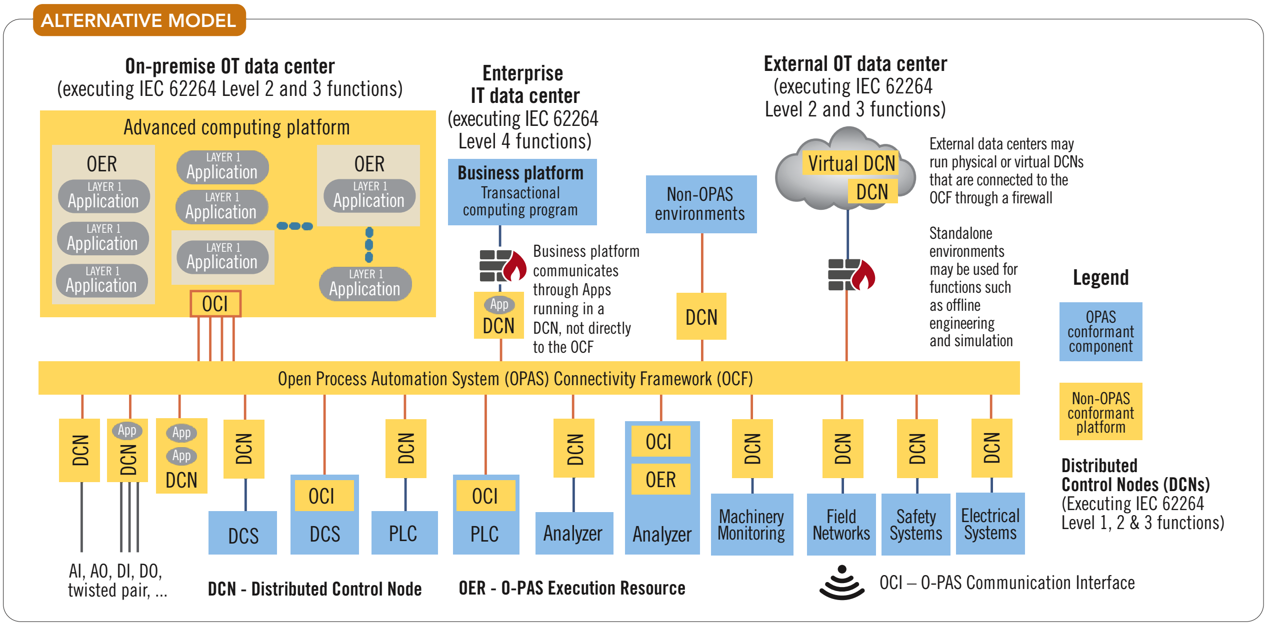


Figure 2. Unlike current proprietary control systems, an open one based on O-PAS readily integrates multiple vendors and enables easy upgrades.

obsolescence or to open up new opportunities), and that exploits the increased computational power in endpoint (edge) devices to improve application capability and effectiveness. In this new platform, the applications could access data at any of the control nodes as needed, unlike the traditional model.

2. *Standards-based open interoperable architecture* that offers the freedom to choose any procurement strategy, allows owners to preserve custom software for the lifetime of the plant asset, provides incentives for software developers to create and sell directly to asset owners, and enables integrators to connect different hardware and software components without modification.

3. *Designed-in security* using a standards-based secure architecture that allows asset owners to protect against known risks, detect abnormal situations and evolve with emerging threats.

4. *A less-complex and more-productive user environment* realized via technologies such as plug-and-play field devices, flexible notification capability and an enterprise-wide asset information portal. These would enable workforce empowerment and innovation through use of industry standard tools for creating applications.

Figure 2 shows a reference architecture to illustrate what the future might look like.

The Open Process Automation Reference Architecture flattens the design, eliminating the hierarchical nature, and attempts to ensure data are always available to the desired user with the minimum overhead. An important aspect of the new architecture is the concept of a distributed control node (DCN) as the edge device connected to the field wiring. Many functions of today's DCS and programmable logic controller (PLC) systems might migrate to the DCN. The DCN will include I/O signal processing as a minimum, with the potential to have expandable computing capability. Depending on the functional requirements, the DCN could host regulatory controls, more-advanced control applications and, eventually, advanced optimization and analytics applications. The future world includes the capability to run the latest applications directly at the edge, if required for data latency or availability. This allows for future-proofing as new possibilities open up on how plants are operated and monitored.

A real-time bus provides the data backbone to connect the DCN and all components in the system. For brownfield applications, gateway devices would allow integration of legacy devices into the new architecture. A high-availability advanced computing platform supports the system and provides the computing power to host applications that don't need to run at the edge. Examples include abnormal event detection, procedural automation, advanced control and process optimization. In the new architecture, data are readable from the source in the DCN to either a local enterprise-level IT data center or to external data centers with proper security authentication and based on trust as defined in the standards-based security protocols. This allows for true business control of operations and, thus, fosters the success of digital initiatives.

THE ROLE OF OPAF

The Open Group Open Process Automation Forum (OPAF), www.opengroup.org/forum/open-process-automation-forum, has a broad scope, encompassing today's DCSs and PLCs for the continuous and hybrid process industries. Its core work is to define the standards for an open, interoperable, secure process automation architecture. The Forum is using a "standard of standards" approach to minimize re-work and avoid "reinventing the wheel." The Forum will

select the best available standard from existing applicable industry standards. When no applicable standard exists, the Forum will work with standards-development organizations to generate a standard. The ultimate goal is to create a thriving marketplace of software and hardware components that use standards-based open interfaces to allow for easy integration, interoperability and more innovation.

Open automation does *not* require open sourcing. The published standard provides public exposure of software and hardware interfaces and data definitions but a supplier need not reveal the inner workings of its hardware or software component nor does an end-user divulge applications it has developed.

Joint workshops held between end-users and suppliers led to development of a set of quality attributes (QAs) — nonfunctional system characteristics that influence system quality and drive architectural decisions. These QAs serve as touchstones in guiding the work of the Forum. A few key QAs are: interoperability, modularity, interchangeability, conformance, securability and portability. The Forum considers the QAs of safety, resilience and maintainability as fundamental to any O-PAS product, so these aren't called out separately.

A KEY DIFFERENCE

Unlike other standard-development activities, the Forum isn't just a technical effort. In addition to a technology working group (TWG), the forum has created a business working group (BWG) to establish viable business practices and procedures to conduct business in the new open environment. The BWG's role includes reducing impediments to commercial success and providing guidance to the TWG. It has published "The Open Process Automation Business Guide," https://publications.opengroup.org/g182, that defines the ecosystem roles in the new business environment and offers a roadmap for suppliers, end-users, service providers and system integrators about the value proposition and benefits to the participants.

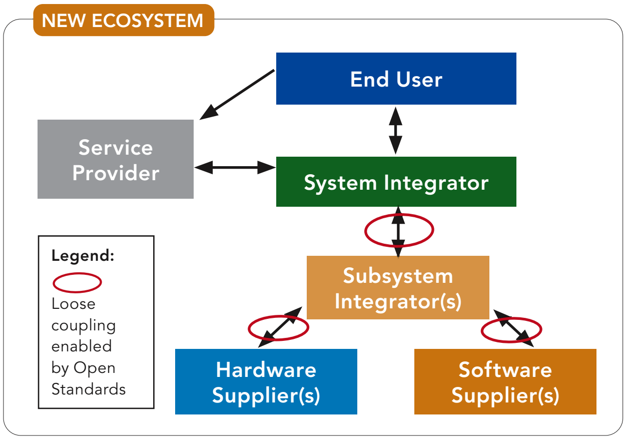


Figure 3. Exploded view shows interconnections between roles of end-user, systems integrators, hardware, software suppliers, subsystems integrators and service provider.

An important part of the task of the Forum's Certification Work Group is to develop a policy for conformance and certification and to maintain a registry of conformant products. For a component to be registered and discoverable, it must conform 100% to the published standard. Outside accreditation laboratories, selected by The Open Group Certification Authority based on the standard, will verify conformance.

The TWG is charged with developing the standards. Specialist subcommittees handle security, interoperability, technical architecture and portability, among other components. In addition, an Enterprise Architecture Working Group manages the use-cases and translates the business guidance into technical requirements to guide development of standards. The Forum has partnered with a variety of industry associations and standard-development organizations such as the International Society for Automation (ISA), OPC Foundation, NAMUR, CSIA, FieldComm group, PLC Open and others consistent with the "standard of standards" approach.

THE NEW ECOSYSTEM

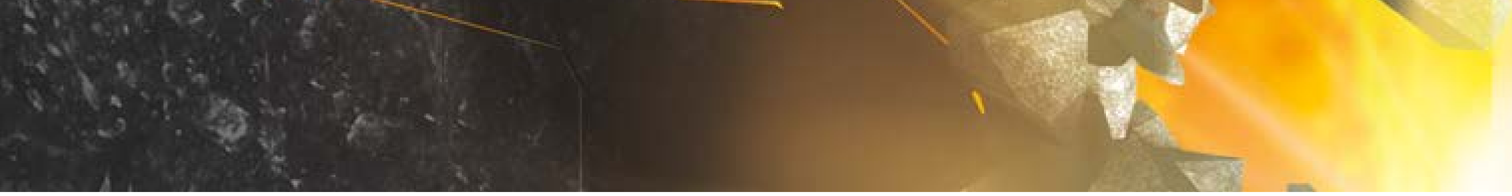
In the traditional model of automation procurement, the DCS vendor configures its available offering of proprietary hardware and software components to meet end-user specifications. The resulting package reflects the special relationships between the vendor and component suppliers, with integration issues handled by the DCS vendor using proprietary interfaces.

By contrast, in the new ecosystem model, a systems integrator (SI) assembles a system to meet end-user specifications using cost- or performance-advantaged O-PAS-certified hardware and software components. This should ease integration and reduce development cost because there's a loose coupling that enables the different components to work together, facilitated by certified and standards-based interfaces that allow for stitching together the system quickly and efficiently.

Standardization of interfaces lowers the barrier to entry. Therefore, additional specialist hardware or software suppliers can compete, allowing for more innovation. The new ecosystem explodes the monolithic role of the DCS vendor into different constituent roles such as systems (and subsystem) integrator, hardware and software suppliers, and service provider (Figure 3). It's important to note that the new ecosystem model is a role-based model. So, a supplier may serve as a SI or service provider for a given project. It also allows for more players to enter and perform the role of an integrator, increasing competition. Accountability for system performance rests with the systems integrator or SI, as spelled out in Section 4.1 of the Business Guide.

BROAD GUIDELINES

The Forum is advancing an entire supplier/buyer ecosystem of traditional DCS vendors, SIs, digital technology providers and process manufacturers toward an open business model. Consequently, the OPAF also establishes business practices for how



this open marketplace should operate, unlike traditional technology standards from groups like ASTM International or the Institute of Electrical and Electronics Engineers.

Operating companies implementing systems containing O-PAS-certified components benefit from the capability for continuous process improvement through rapid application of the latest available hardware and software. Once adopted, software applications and system configurations are portable and reusable across systems, reducing total cost of ownership. In addition, end-users gain access to a more-competitive market of offerings and minimize customized development associated with proprietary components. Solution providers also benefit from access to new market opportunities, continued relevance to existing and prospective customers, and reduced development costs due to the entry of smaller specialized suppliers that add value and innovation.

Through the Forum, each incremental definition of the O-PAS technology is matched by business guidelines for use-cases, industry involvement and detailed certification procedures for conformance. Forum members are working to provide the vision, understanding and framework for end-users to make intelligent and strategic decisions about future plant operations and designs. The entire process automation ecosystem is moving forward together.

For example, these changes in ecosystem allow for new business models to evolve similar to the changes in the enterprise IT business (e.g., software as a service) and transference of owner-controlled operation to a "tolling" model reflecting the desired level of owner involvement.

RELATED CONTENT ON CHEMICALPROCESSING.COM

"Open Automation Efforts Advance," https://bit.ly/3fkwbWW

"Plant Pioneers Use of Automation Concept," http://bit.ly/2HCyntc

TECHNICAL COMPONENTS

The O-PAS Standard includes eight parts:

- Part 1 — Technical Architecture;
- Part 2 — Security Aspects;
- Part 3 — Profiles;
- Part 4 — Connectivity Framework;
- Part 5 — System Management;
- Part 6 — Configuration Portability;
- Part 7 — Physical Platform; and
- Part 8 — Application Portability.

Here, let's take a high-level look at three wide-interest aspects: cybersecurity, communications and system management.

Cybersecurity is an O-PAS imperative and of upmost importance to OPAF members. Managing security (Part 2) in a highly distributed environment such as in O-PAS requires consideration of security in all elements of the technical architecture (https://publications.opengroup.org/s184), including the physical and communications platform, operating system, system management services and applications. The security specification is based on the broadly accepted ISA/IEC 62443 Security for Industrial Automation and Control System standards. An O-PAS environment may consist of thousands of O-PAS-conformant components from multiple vendors. Version 1 focuses on providing O-PAS-conformant components from a product supplier that can be made secure in a system configuration (see: "O-PAS Version 1 Explained," https://bit.ly/2YBPt3V).

The Connectivity Framework (Part 4) defines the information models and transport protocols for communicating data using Open Platform Communications Unified Architecture (OPC UA). Version 1 describes the necessary OPC UA security and services to ensure interoperability for OPC UA clients and servers and the services for client/server actions and for publish/subscribe communication. The "Version 2 Preliminary Standard," https://publications.opengroup.org/p201, which

came out in late January, adds standard information models for DCNs, signals, alarms and function block applications.

System Management (Part 5) uses the Distributed Management Task Force Redfish standard. Version 1 focuses on providing system management of compute node hardware (e.g., chassis, board, and cooling information for hardware with and without a baseboard management controller). Version 2 extends system management by operations-technology-specific DCN information including runtime, metrics and sensor interfaces, as well as in-band operating systems information and metrics.

Version 2 of the standard (https://publications.opengroup.org/i201m), which was published in January 2020, addresses portability of configurations. Version 2.1, scheduled for publication in the second half of 2020, extends definitions for information exchange models and standard interfaces that support some event processing, and standards-based application processes. Version 3 will focus on application portability.

CURRENT STATUS

Since its inception in January of 2017, the OPAF has grown to include more than 90 companies from around the world. Each iteration of the standard will undergo testing in real-world scenarios both to guide development of the O-PAS as well as to demonstrate feasibility and viability. Because "seeing is believing," OPAF held its first interoperability workshop in June 2019 based on Version 1 of the standard. The second workshop is planned for the third quarter of this year (but may be delayed depending upon Covid-19 travel restrictions). Companies evaluating design and purchasing decisions should review "O-PAS Certification Policy," https://publications.opengroup.org/x201, which was published in February.

Separately, some member companies have developed an active "test bed" to prove out and refine O-PAS-compliant technologies from multiple vendors.

Key success factors for the activity are a critical mass of input from end users and consensus among members in the ecosystem. The adoption and success of O-PAS standard will significantly impact automation and process control in the continuous and hybrid process industries by expanding innovation while improving security, flexibility and productivity — maximizing asset performance. Don't let your company be left behind. ●

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Successfully Start Up Your Pilot Plant

Avoid ten common problems that compromise commissioning | By Richard Palluzi, consultant

THE COMMISSIONING of a newly constructed piece of equipment always is challenging. The task is even more daunting in a research environment because the operation is more novel, the process information and operation less defined, and the equipment performance often not as certain. Compared to a plant startup, the commissioning of a pilot plant unit generally is less well organized and certainly less fully staffed.

Based on my experience, here are the ten most common problems that afflict the commissioning of pilot plants:

1. *Lack of a commissioning plan that lists in detail all the known tasks that must be done before operation.* Most pilot-plant commissioning plans exist only in a researcher's mind. The few that do get documented usually are shallow, cursory and full of logic gaps and missing elements. So, it's hardly surprising that startups then take so long and go so poorly. A good commissioning plan should detail every task, and estimate the resources involved and the time required. It should assign each task to a specific person and set a target date. This sort of commissioning plan, while tedious to develop and time consuming to write, is critical to the success of the whole process.

2. *Failing to review the design for commissioning problems before construction is complete.* Many difficulties are blatantly obvious beforehand. Common examples include a flow meter that lacks a valve for calibration, a level sensor that has no way to see the level for calibration, a pump that has no means for venting, and a heat trace line that has few temperature indicators to confirm proper operation. All these and dozens more miscues are painfully common. An experienced pilot plant designer should conduct a detailed review of the proposed design prior to completion to develop a good commissioning plan well in

CONSIDER TAKING A COURSE

The University of Wisconsin offers a course "Pilot Plant Design, Construction, and Operation" that provides further information on commissioning pilot plants, laboratory units and research equipment in general. For more details, go to https://bit.ly/2xkJiGe.

advance of when the unit is finished. The number of small but time-consuming issues likely detected will amaze you; more importantly, addressing them during construction will save large chunks of commissioning time. These get overlooked during the design process because it has a different focus. You must look at the unit through another lens to catch all these small but important gaps. Few should exist in a well-designed unit by an experienced designer. Rarely will none arise.

3. *Trying to commission a unit using personnel part time.* My experience repeatedly has shown that when a group assigns personnel to the effort part time the startup takes inordinately longer. A team available only half time takes 3–4 times longer to complete the task than a full-time team. Yes, there will be days where time is lost for meetings, personal commitments and the odd crisis. However, an organization will suffer poorer results and a disproportionately longer commissioning time if it doesn't find ways to commit the team full time. Otherwise, people on the team must remember where they were, pick up the tools and documentation, coordinate with the others involved (who may not be available at that moment) and get started again.

4. *Having totally unrealistic expectations about the required resources and probable schedule.* Most plans for pilot-plant commissioning grossly underestimate the effort involved and the time needed. I've seen plans that assume that leak-testing a brand new pilot plant will take a day, installing all the insulation will require another day, and performing all the calibrations will consume a day or perhaps two. In reality, each of these — and dozens more items — took significantly longer. Moreover, no contingency is allotted for problems. Understaffing exacerbates the underestimating. A task takes much, much longer because the necessary resources aren't available at all, not available for long enough or not even planned to be available. This invariably leads to other problems due to resources having been committed elsewhere or other efforts now taking precedence. In addition, management pressure, based on totally unreasonable expectations from the badly underestimated plan, becomes intrusive and often disruptive.

5. *Not reading the instruction and installation manuals in advance.* Pilot plants always involve new equipment — either a novel unit for which there's little actual operating experience or new in the sense that the organization has no familiarity with it. All too often, no one looks at the manuals until the equipment has problems. Only then does the need for different installation or calibration become apparent. Sadly and all too often, that's also when it's discovered that the equipment doesn't really suit the unit's specific operating conditions. All should have been addressed in advance.

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6. *Not considering the downside risk, particularly for new processes, designs or equipment.* What if the brand new particle analyzer doesn't work? What if the gas chromatograph (GC) doesn't seem to give an accurate analysis? What if the pump clogs? Questions like these make researchers uncomfortable. They think to themselves: "If you keep asking what if everything fails, we'll never get any research done!" Yet the effort to determine a fallback position in the event of a problem can save incredible amounts of time. Identifying another GC on-site to send a batch sample or an on-site expert in this type of analysis can save days if the problem arises. Leaving room for a larger pump in case the chosen less expensive or faster delivery model doesn't work as expected can prevent large amounts of costly rework. Adding the valve, gage or thermocouple during construction is so much faster and cheaper than doing so during commissioning. Occasionally this effort also highlights the often overlooked problem that one key piece of equipment is essential to the unit's proper operation. So, if the particle analyzer has no fallback, testing it in advance to verify it will work in your application may avoid incredible problems later.

7. *Not systematically checking out the unit's safety logic.* Without a logic matrix that shows all the inputs and how they will affect all the outputs, checking out safety (and operating) logic is very hit or miss. It's too easy to overlook simulating a given failure mode to confirm that the unit operates properly. (I once wound up standing in a pool of water after we decided to see what happens if someone pushed two buttons — one opening a drain to a bucket and the other starting the feed — at the same time. The senior operator commented, "Glad that we found that out with water.") Developing these logic matrixes is tedious and time consuming; checking them is even worse. However, they are critical to ensuring a safe commissioning.

8. *Failing to allot time for all the necessary documentation and reviews.* Completion of operating and emergency response plans often are casually dismissed as "ongoing"

or "as time permits." Setting up a preoperational safety review, updating the required databases and completing all the organization's forms take time and effort — and must have resources and time allotted. I've seen too many units ready to operate but held up for weeks for completion of these items. This usually stems from no one starting early enough or devoting sufficient attention (and resources) to them because the effort involved was never truly assessed.

9. *Not listing all the tasks, even the minor ones, that must be completed as part of the commissioning.* Making or ordering the valve tags, tracing all the piping, mounting all the signs, ordering the feedstocks, getting the gas cylinders, finding enough sample bombs, and numerous other small less-than-glorious tasks need doing. Most commissioning plans fail to address these chores, which then, invariably, fall by the wayside and are forgotten until they — needlessly — become critical path items. The commissioning plan must include every task, no matter how unglamorous and trivial. (How often have you walked to your car for a crucial trip only to have to scurry back to get your keys or your phone?)

10. *Failing to approach task in an organized and logical manner.* Checking loops haphazardly as they occur, failing to ring out all the thermocouples, calibrating equipment only when you think about it and many other tasks are approached too casually. Nothing goes as fast as something planned well and organized effectively. It takes discipline to tediously check all the inputs to a computer in order but it saves so much time and effort when a problem arises and you can know that "well it is wired right so that's not the problem."

If you take deliberate steps to avoid these ten problems, you'll experience a smoother commissioning. ●

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Gain Insights from **Diaphragm Seals**

A failed seal on a pressure sensor may shed light on unrecognized process conditions

By Nathan Stokes and Pat Goettig, Emerson

THE SENSING element of a pressure instrument must contact the process fluid, ideally as close as possible to the measurement point of interest. However, direct contact between the process fluid and the instrument potentially raises multiple issues:

- Loss of containment. A mechanical gauge using a conventional impulse line can blow out the tube, releasing the contents. Even an electronic transmitter can fail, sending process fluid out through the conduit.
- Instrument durability. Exposed parts must withstand process conditions, which may involve temperature extremes, corrosion and erosion.
- Process downtime. Performing service or calibration may require a shutdown for removal or access.

Therefore, many pressure instrumentation installations rely on diaphragm seals to keep the process fluid where it belongs while delivering accurate and repeatable pressure measurements across a wide variety of operating conditions.

This type of remote diaphragm seal withstands the pressure and other attributes of the process fluid including its temperature and corrosiveness. The remote diaphragm seal moves in response to the system pressure and transfers that action to a fluid-filled capillary line that goes to the pressure transmitter. The remote diaphragm seal becomes the process containment point. Let's examine how this works in greater detail.

DIAPHRAGM SEAL

Figure 1. Such a seal uses a large diaphragm to transfer pressure to a fill fluid and prevents problems caused by process fluid directly contacting the instrument.

A VERSATILE APPROACH

Diaphragms can serve as remote seals (Figure 1) in many pressure measurement applications that can accommodate their physical size. They can support gauge, absolute or differential pressure (DP), which extends potential use to flow and level measurements. Generally, a remote diaphragm seal is installed via a threaded or flanged connection, with available sizes ranging from ¼-in. NPT to 4-in. ASME flange.

The diaphragm surface area and stiffness determine the amount of pressure applied to the fill fluid, which must correspond to the process pressure so the instrument reacts correctly. Because it directly contacts the process, the remote diaphragm seal must be chemically compatible with the process fluid to avoid corrosion and other problems.

If specialized alloys are necessary, only the remote seal assembly must be made of the costly material — unlike conventional impulse lines that require the material for their valves and fittings.

The fill fluid also must suit the anticipated temperature range. This rarely is a problem because a wide selection of specialized oils are available; some resist boiling even at very high temperatures. Where the process temperature is high but the ambient temperature is low, a fill fluid that can withstand the high temperature may become too viscous to transmit pressure accurately if it must go far from the process heat. In such cases, inserting a second diaphragm between the remote seal and the transmitter allows use of a second fill fluid (Figure 2), more appropriate for the lower ambient temperature, for the leg attached to the transmitter. This expands the thermal range of the setup and avoids any need for heat tracing.

In many respects, a remote diaphragm seal's greatest advantage is that it protects the instrument from the process. The remote seal bears the brunt of high pressures, high temperatures and corrosiveness. Others benefits include:

- Suspended solids and viscous fluids cannot clog impulse lines.
- Smooth and flush surfaces improve cleanability and other hygienic characteristics.
- Simpler impulse lines between the transmitter and remote seal reduce maintenance of wet and dry legs.

These benefits extend the capabilities of DP technologies for applications such as flow and level measurement.

REMOTE DIAPHRAGM SEAL FAILURES

After discussing all the advantages of remote diaphragm seals, we also must recognize that they can fail. Getting responsive and accurate readings requires thin diaphragms to transmit pressure. While the fill fluid provides even support, the diaphragms remain susceptible to corrosion; so, careful material selection is essential. Actual field failures, if analyzed appropriately, can provide important insights because the information gained can reflect on both the process and the equipment. Therefore, using the proper examination methods to analyze a failure is crucial for determining the true root cause.

The most common cause of failure involves an instrument being pushed beyond its design limits. This can occur for a variety of reasons. For example, the process fluid is more corrosive or erosive than expected. This can stem from a difference in chemistry, inclusion of abrasive solids, increases in fluid velocity and other factors. Consequently, the service life of the diaphragm declines.

These cases often reveal things about the process that operators didn't realize or fully understand. However, in many cases determining the root cause depends on sophisticated testing methods. A vendor, through its analysis capabilities, often can help in pinpointing the culprit.

Most failures associated with remote diaphragm seals involve the diaphragm itself at the point of contact with the process fluid. Drawing on a wide collection of sophisticated tools is critical to determining failure mechanisms. Some are observational while others attempt to recreate circumstances of the failure. The most frequently used tools and methods include:

- Scanning electron microscope (SEM) — aids in determining material failure due to mechanical stress from corrosion or physical damage;
- Energy-dispersive x-ray spectroscopy (EDX) — ascertains via composition analysis if material failure stems from specific chemical exposure;
- Fourier-transform infrared spectroscopy (FTIR) — identifies presence of organic contamination and decomposition;
- Cross-section examination with high-powered microscopes — locates potential material fractures or porosity;
- X-ray fluorescence (XRF) — verifies plating materials and associated thickness;

EXTENDING TEMPERATURE RANGE

Figure 2. Process and ambient temperatures differing markedly may require use of a second fill fluid and, thus, an intermediate internal diaphragm.

- Positive material identification (PMI) — confirms material(s) of construction;
- Temperature effects testing — performs tests at specific temperatures or over a range of temperatures to reproduce field symptoms; and
- Performance accuracy testing — checks performance at zero, full scale or a specific pressure to duplicate field symptoms.

Now, let's examine five actual cases to see how these methods can work together to identify problems and suggest solutions.

CASE 1: HYDROGEN PERMEATION

A chemical plant installed a Rosemount 2051T pressure instrument in combination with a Rosemount 1199 remote diaphragm seal made of Type-316 stainless steel in a process slurry application. After six months of service, the site reported that the instrument indicated a pressure exceeding 3 bar-g when no process pressure was applied. It also observed obvious bulging of the remote seal diaphragm although no leakage of fill fluid was seen.

Our lab verified both the false pressure indication and bulging. PMI showed that all the materials used in construction of the remote diaphragm seal assembly were correct. Failure analysis testing using gas chromatography indicated the presence of hydrogen gas in the fill fluid. It caused the increased pressure — but how did the hydrogen get there?

Single hydrogen atoms in the process fluid were able to diffuse through the stainless steel diaphragm. While this may sound impossible, Type-316 stainless steel is permeable at high temperatures; other specialized materials, such as Alloy C-276, are even more permeable. Once on the other side of the diaphragm, some of the hydrogen atoms combined into hydrogen molecules, which no longer could escape. Many factors, including high temperature, high pressure and galvanic corrosion, can accelerate the permeation rate.

The recommended solution was coating the diaphragm with gold plating or AbrasionShield (one of our SensorShield coatings) to reduce permeability.

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CASE 2: FILL FLUID VAPORIZATION

Another chemical plant installed a Rosemount 3051S pressure instrument in combination with a Rosemount 1199 remote diaphragm seal in a polyurethane production unit. The fill fluid was Silicone 200. After seven months of service, operators noticed a pronounced reading drift when operating at a temperature of 365°F (185°C) and applied pressure below atmospheric.

When returned to our lab, the equipment appeared to be fully intact. However, discoloration of the instrument housing suggested extended periods of high temperature exposure. At atmospheric pressure, the assembly functioned as expected. Next, because the unit was used in a deep vacuum, a 0.44-psia (3-kPaa) vacuum was applied. Nothing odd happened initially until the assembly was tapped to provide a physical shock. Then, the reading immediately began to climb significantly. What could ccount for this reaction?

Operating at 365°F routinely in a vacuum situation using Silicone 200 fill fluid put the operation at the point where the vapor pressure curve for the fill fluid begins to climb steeply. Under these conditions, gas bubbles form in the fluid due to the high heat and vacuum pressure, distorting the reading. Eventually, some of the gas will re-dissolve but, like shaking a can of soda, a mechanical disturbance can cause the bubbles to re-form.

The recommended solution was changing to a fill fluid with higher temperature resistance to avoid potential for vaporization inside the capillary lines.

CASE 3: PROCESS INDUCED MECHANICAL DAMAGE

A third chemical plant installed a Rosemount 3051L single remote diaphragm seal assembly with a Type-316 stainless steel diaphragm. After an unspecified period of operation with a 50% solution of sodium hydroxide, the diaphragm began to leak.

Examination with our SEM clearly showed the diaphragm had sustained heavy damage from particle abrasion, with sodium chloride deposits in multiple locations. EDX analysis also indicated chlorine attack but the process shouldn't contain chlorine.

The process creates sodium hydroxide by electrolysis of sodium chloride, which also can result in unreacted chlorine. Chemical analysis suggested the diaphragm erosion was caused by unreacted sodium chloride crystals in the fluid combined with attack from the residual chlorine. Standard Type-316 stainless steel was inadequate for this application.

So, we recommended changing to a higher nickel alloy (e.g., Alloy C-276 or Duplex 2205) for the diaphragm to provide added strength or using an abrasion-resistant coating such as AbrasionShield.

CASE 4: INVISIBLE CORROSION

A chemical plant installed a Rosemount 3051C pressure instrument in combination with a Rosemount 1199 remote diaphragm seal with a Type-316 stainless steel diaphragm filled with Silicone 200 fluid. After about one month in hydrocarbon service operating at 400°F (204°C) and 130 psi (900 kPa), the facility reported a loss of fill fluid from the diaphragm face.

Visual inspection in our lab confirmed the leak. PMI verified the correct specified material for the diaphragm. SEM examination indicated a crack near the outside edge of the diaphragm within the heat-affected zone where the diaphragm was welded to the frame. Analysis by EDX determined that exposure to chlorine in the process had caused the crack.

We suggested changing to a higher nickel alloy (e.g., Alloy C-276) for the diaphragm because the site couldn't rule out continued exposure to chlorine.

CASE 5: DRIFTING LEVEL READINGS

Another chemical plant installed a Rosemount 3051C DP pressure instrument in combination with two Rosemount 1199 remote diaphragm seals for a level measurement application. The purchase order specified threaded seals with 0.006-in.-thick diaphragms and 16.4-ft (5-m) capillary lines on each side (high and low) in a balanced configuration. The setup was field calibrated and ranged for 0–50 in. (0–1,250 mm) H_2O. During the first month of operation, it exhibited an unacceptable amount of drift.

The site returned the complete assembly to our lab for performance testing and, if necessary, failure analysis. In the lab, it performed within expected tolerances across the full measurement range at temperatures between -40°F and 185°F (-40°C to 85°C). No failure was detected.

The lab analysis concluded that no specific problem existed but the components didn't suit the application. The requirement of 0.006-in.-thick diaphragms, twice the normal thickness, wasn't necessary. The combination of these stiff diaphragms, the long capillary lines and the fluctuations in ambient temperature caused a high degree of fill fluid expansion, distorting the reading. Ultimately, the components were re-specified.

UNDERSTANDING PROBLEMS AND SOLUTIONS

Three causes account for more than three-quarters of remote seal failures (Figure 3), with process-induced corrosion just edging out fill fluid as the top culprit. As the cases just discussed indicate, sometimes finding the source of the problem isn't easy. Corrosive chemical components turn up in situations where they may not be expected; so, in some cases, analysis yields critical information about the nature of the process that might not be discovered otherwise.

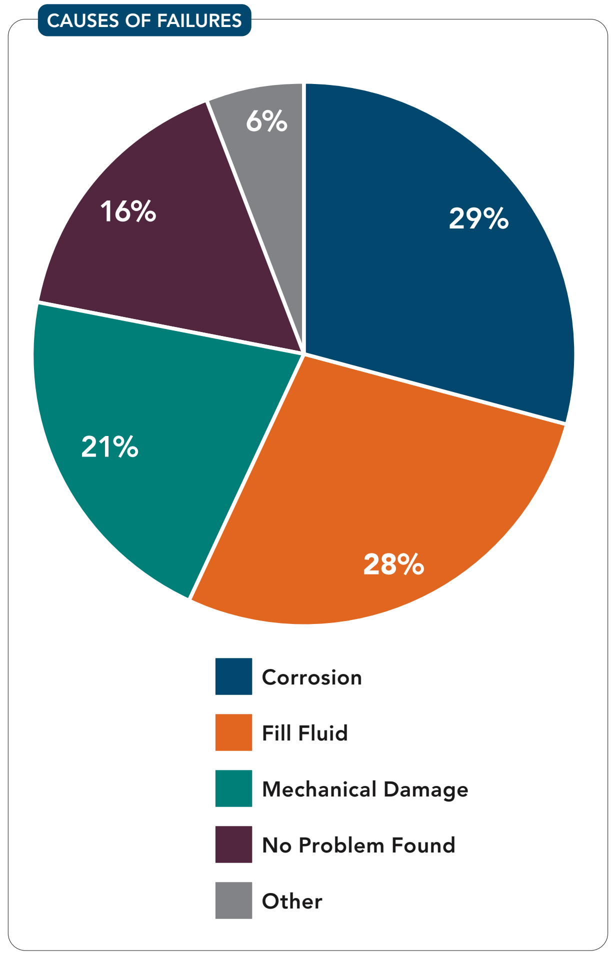

Figure 3. Corrosion and fill fluid problems, usually related to temperature, account for well over half the failures of remote seal systems.

At the same time, incorrect specification of instrument components can result in short service life or poor performance.

To ensure you get a suitable system, take advantage of all the resources available from manufacturers during the product evaluation and specification stage. In the event of an actual failure, the vendor also can help you pinpoint the root cause and, thus, improve measurements and processes. ●

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Figure 1. Chinese developers are relying on single-use bioreactor to produce possible vaccine for Covid-19. *Source: Sartorius Stedim Biotech.*

Disposable Equipment Makes Lasting Gains

The pandemic and technical developments are bolstering uptake

By Seán Ottewell, Editor at Large

SINGLE-USE EQUIPMENT can provide processors with a number of benefits — including faster plant set-up and turnaround between batches, improved product flexibility, reduced capital expenditure and quicker time-to-market for products. That's why such equipment is playing a significant role in the development of diagnostics and vaccines for Covid-19, note various vendors. However, the growing popularity of single-use devices long predates the pandemic and will continue increasing afterward, they stress.

"The flexibility of single-use facilities to be used for multiple different processes, depending on demand, is relevant in both rapid development and streamlined manufacturing," says Melisa Carpio, global technology consultant, cell culture technologies, Sartorius Stedim Biotech, Bohemia, N.Y.

The importance of rapid development was brought into sharp focus on March 25 when Sartorius announced that CanSino Biologics, Tianjin, China, in conjunction with the Institute of Bioengineering at the Academy of Military Medical Sciences, Beijing, was using its Biostat STR single-use bioreactor system to bring what at that stage was the first vaccine candidate against Covid-19 to clinical trials (Figure 1).

Opting for the single-use bioreactor cut the amount of time needed to prepare the vaccine to several weeks from several months. The project also built upon experience gained during a similar 2017 collaboration between the two Chinese organizations and Sartorius. In that case, a Biostat STR50 bioreactor system featured in the development of a recombinant vaccine against the Ebola virus — the first registered Ebola vaccine in the world.

Today, Sartorius offers standard bag designs for the most-common processing configurations. It also provides configured-to-order and engineered-to-order options for custom designs that can range from simple, such as dual redundancy for sensors like those for pH and dissolved oxygen, to more complex, such as modified dip-tube lengths for microcarrier cultures.

"Over the years, we have had to adapt to the trends of the bioprocessing industry, like adding ports and patches for process analytical technologies (PAT), as in our BioPAT Viamass, Trace and Spectro. In addition, bag designs have been modified to allow for connectivity to cell retention devices like alternating tangential flow filtration for use in intensified processing," Carpio explains.

The company's latest version of Biostat STR, generation three, has a fully configurable control tower that can work with any bag holder size from 50–2,000 L. The bags feature a traditional top-drive motor and an impeller design comparable to stainless steel ones, and suit multiple cell types in a range of applications including high density, microcarrier and perfusion cultures.

"It comes with standard configurations that can be upgraded easily to adapt to process or application changes. In addition, as other features like additional PAT tools become available, the new STR has been designed to accommodate them mostly via software upgrades, with no changes needed to the hardware," she adds.

The main challenge single-use bioreactors face today is the large number of batches needed to meet annual demands of traditional fed-batch processes.

"However, with higher titre processes and process intensification, volume requirements for commercial cell culture bioreactors are trending towards lower volumes. According to Bioplan's "2019 Biomanufacturing Report" [BioPlan Associates, Rockville, Md.], the greatest demand was for 1,000-L single-use bioreactors, followed by 500-L, and then 2,000-L," Carpio notes.

The company also has launched its first 3D-printed single-use part — a port integrated into the Flexsafe STR bags used with the new BioPAT Spectro platform.

"It's a flow-cell-based design that allows for non-invasive, at-line samples to be taken and it decouples the measurement from disturbances such as gassing and stirring caused by process conditions. It also benefits from a shielded design so that any interference from ambient light is eliminated," comments Carpio.

ATTENTION TO AUTOMATION

Thermo Fisher Scientific, Waltham, Mass., which also is involved with several biopharma companies working to develop a vaccine for Covid-19, sees automation of single-use equipment as an important focus. Its new HyPerforma TruBio Discovery software system, based on Emerson's DeltaV platform, meets bioprocessors' demands for reduced risks associated with technology transfer and manufacturing, says vice president and general manager Steve Lam.

"We are able to offer small- to mid-size research and process development (PD) labs a cost-effective, yet robust control platform that can be easily employed during tech transfer and scale-up. Our customers are embracing this solution because our open architecture approach allows them to not only use pre-existing hardware but to also adopt new equipment and peripherals on the same platform, while taking advantages of reduced operator training as they move from R&D to PD to manufacturing," he explains.

Meanwhile, development continues on the company's new HyPerforma DynaDrive single-use bioreactor (SUB). Work started last September and the first of the new bioreactors, a 50-L model (Figure 2), is due for release later this year. Three other sizes, up to 5,000 L, should reach the market in early 2021.

"The new bioreactor technology is designed to meet changing demands as the market is maturing and increasingly looking to adopt single-use technologies in current good manufacturing practice (cGMP) facilities," notes Lam.

The DynaDrive SUB currently is going through extensive internal and customer testing. "Early data from testing has shown excellent mixing times and volumetric mass transfer coefficient (kLa) data, and cell densities well over 200 million cells/mL can be achieved," comments Lam. That coefficient often is used to compare the efficiency of bioreactors and as an important scale-up factor.

The company is making major investments in bioprocess container (BPC) chambers and their final assemblies at its three main manufacturing sites in Cramlington, U.K.; Millersburg, Pa.; and Logan, Utah, as well as expanding manufacturing capabilities in the Asia Pacific region with new BPC centers in Suzhou, China, and Singapore. "As single-use technology adoption continues, it is important to us to bring the manufacturing process closer to our customers," Lam adds.

NEW BIOREACTOR

Figure 2. Line of units, ranging from 50-L to 5,000-L capacity, is aimed at current good manufacturing practice facilities. *Source: Thermo Fisher Scientific.*

MORE DEVELOPMENTS

For its part, Cytiva, Marlborough, Mass., is collaborating with both Sona Nanotech, Halifax, N.S., and Avacta, Wetherby, U.K., in the development of Covid-19 test technology.

The company has observed an increase in the adoption of single-use equipment across clinical and commercial production over recent years as several biologics developed using single-use systems have moved through clinical-scale manufacturing and on to regulatory approval and commercial production.

The 2019 BioPlan report cited a 15–20% increase in respondents indicating their biomanufacturing systems were single-use/disposable, compared to a similar survey in 2017, points out Chor Sing Tan, Cytiva senior consumables application leader.

"Most of the new single-use technology equipment and enabling technology focuses on improvement of features and reliability to meet the industry drives toward a connected, continuous and closed manufacturing. Thus, either in standard or through custom engineering solutions, suppliers have introduced modular hardware and plug-and-play automation approaches to the second generation of single-use bioreactor and mixing systems," he says.

More-robust sensors are emerging, too, overcoming past challenges

MODULAR PRODUCTION

Figure 3. Off-the-shelf, prefabricated manufacturing facilities now are available for Biosafety Level 2 operations. *Source: Cytiva.*

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with short shelf life after gamma irradiation, measurement drift, and issues with fiber optic and wireless connections to transmitters.

"Today, they are mostly used to monitor common parameters including pH, dissolved oxygen, flow rate, temperature and pressure. However, outstanding monitoring challenges remain, including total cell density, viable cell density, foam detection, glucose and lactate concentrations," he explains.

3D printing is coming of age, too, he notes. It already manufactures some downstream equipment including chromatography columns and surface plasmon resonance devices for measuring biomolecular interactions, and also helps the company's product development team create rapid prototypes of single-use components for engineering testing.

The company continues development of its FlexFactory configurable single-use platform and KUBio off-the-shelf modular, prefabricated manufacturing facilities (Figure 3). It now offers two KUBio modules for Biosafety Level 2 (BSL-2)-classified operations. "We have looked into different viral vector processes and been able to create a large-scale solution, KUBio BSL-2, and an indoor module solution, KUBio box, for viral vectors," comments Johan Rosenquist, global operations director KUBio, Uppsala, Sweden.

"Both are designed according to BSL-2 class with unidirectional flows and the corresponding HVAC/air pressure technologies. Collaborations with industry specialists such as Pharmadule and Germfree are important in order to develop solutions and help biopharma manufacturers access the market faster," he adds.

In fact, Cytiva and modular plant specialist Pharmadule Morimatsu, Nacka, Sweden, are currently finishing the installation and commissioning of 54 modules for a KUBio facility being built at the Lonza Biologics plant in Guangzhou, China.

Meanwhile, operation of a FlexFactory bioprocessing platform already has begun at Clover Pharmaceuticals, Chengdu, China. In addition, work continues with the company's FlexFactory platform at Bayer's $150-million cell-culture technology center in Berkeley, Calif., that will initially house two 2,000-L single-use bioreactors with room to double this if needed in the future.

LARGER INTEREST

"In the last three years, we have seen significant uptake of our large-scale single-use solutions, which enable improved economies of scale and lower cost of goods versus the standard 2,000-L bioreactor-based processes," says Brady Cole, vice president, equipment solutions, for ABEC, Bethlehem, Pa.

Last September, for example, the company added a 6,000-L custom single run (CSR) bioreactor to a product line

LARGE SINGLE-USE UNIT

Figure 4. Chinese manufacturer has opted for 4,000-L disposable units at new commercial manufacturing facility. *Source: ABEC.*

that already included bioreactors up to 4,000 L, fermenters up to 1,000 L, and liquid mixing systems up to 5,000 L. Delivery of significantly more capacity per unit area of floor space is a key metric in high-value, multi-product biopharmaceutical facilities, Cole notes.

By way of example, he cites WuXi Biologics, Wuxi, China. Two years ago, it selected ABEC's 4,000-L CSR disposable bioreactors (Figure 4) for a new commercial manufacturing facility in Wuxi. The Chinese company has pioneered the use of multiple disposable bioreactors for commercial manufacturing and the new CSRs enabled it to raise global manufacturing capacity to more than 100,000 L.

At a time when improving titers (g/L of product) can drive bioreactor size reductions, Cole says many applications remain at titer levels where large-scale single-use bioreactors are optimum. "Also, higher titers generally drive larger equipment for the downstream process," he adds.

ABEC long has treated customization as key, first with stainless steel equipment decades ago and now with single-use technologies. It provides this via its flexible manufacturing platform (FMP). Launched last September, the FMP brings together the company's scalable single-use products and its legacy stainless-steel technologies into one platform. "Importantly, we are the only supplier with a fully agnostic view when it comes to single-use implementation, since we can provide single-use, stainless steel, or hybrid solutions. Which we supply depends entirely on a customer's specific needs," Cole stresses.

In terms of single-use sensor technology, ABEC regularly integrates pH and dissolved oxygen sensors in its bioreactors and fermenters. It also is tracking developments in optical density probes and efforts to prolong the limited shelf-life of some sensors.

The company also has built on its long experience with mixing/gas-transfer technology to adapt its stainless-steel low-shear mixers to single-use format using different materials of construction. "Different cultures have different shear sensitivities, so, again, we customize mixing to individual customer processes," says Cole.

"At the end of the day, the single-use versus stainless-steel decision is case-by-case depending on multiple technical and business considerations such as bioreactor titer, production quantities needed, number of different products to be produced, time-to-market goals, regulatory considerations, geographic location, and so on," he concludes. ●

New Catalyst Provides Competitive Edge

World's largest coal-to-chemicals plant gains sizable economic benefits

By Christian Librera, Clariant Catalysts

A SIGNIFICANT drop in the purchase price of methanol on the global market, from a high of \$400/ton in 2018 to the current value of less than \$250/ton, has put considerable pressure on producers' margins. In China, methanol makers must contend with an additional issue: most are located inland while the majority of methanol-to-olefin (MTO) plants are sited in coastal areas with easy access to low-cost imported methanol.

To further compound the problem, approximately half of the methanol produced in China goes for MTO production — which is forecast to slow down considerably in the next five years. According to the latest figures, the overall methanol compound annual growth rate is expected to drop from the 10.6% experienced from 2014–2019 to 4.3% from 2019–2024. This undoubtedly will result in overcapacity and lower the operating rate of methanol plants from a current level of approximately 93% to 80% by 2023. To remain competitive, methanol producers in China urgently require innovative solutions for improving their cost base.

ADDRESSING A MAJOR CHALLENGE

China Energy Corp. is the largest coal-to-chemicals company globally. It owns and operates a world-class coal-to-liquids plant in Yinchuan, Ningxia Province (Ningxia Coal Industry Co. Ltd., NCIC), that produces methanol that serves as feedstock for the company's methanol-to-propylene (MTP) unit. However, methanol supply had not kept up with its demands. The company needed a reliable way to quickly improve productivity and decided to upgrade to the MegaMax 800 methanol synthesis catalyst (Figure 1). NCIC selected the new catalyst because of

METHANOL SYNTHESIS CATALYST

Figure 1. New catalyst is delivering higher productivity and selectivity for Chinese producer.

its higher activity, which was expected to increase methanol yield with no rise in feedstock consumption, and improve overall productivity of both the methanol and downstream MTP plants.

Clariant developed the MegaMax 800 catalyst specifically to provide higher activity, up to 40% better than previous catalyst generations, and superior selectivity towards methanol production — even at very low reactor temperatures and pressures. Depending on the facility's design and processes, a producer can expect to increase methanol capacity by as much as 10%. This results in greater carbon efficiency and methanol yield while reducing synthesis gas consumption. Moreover, the catalyst is exceptionally robust, easily tolerating demanding daily operation and protecting against process upsets.

SUBSTANTIAL SAVINGS

Loaded and started-up at the NCIC plant in August 2018, the new catalyst achieved an anticipated operation load of 102% after just two months. Even though it currently is running at variable capacity, the 1-million-ton/yr methanol plant is experiencing considerably higher yield at lower energy and feedstock costs. Compared to operation with the previous catalyst, synthesis gas feedstock consumption has decreased by 40 million m^3/yr. Assuming a unit cost of 0.4 RMB/m^3, the plant annually should save around RMB 16 million (approximately $2.3 million).

The facility also is reporting noticeably lower formation of byproducts such as ethanol in the crude methanol product. This reduces steam consumption for the downstream distillation unit and, thus, adds to the plant's total profitability. Based upon its 1-million-ton/yr design capacity, the methanol unit likely will save 238,000 tons of steam annually, which equals RMB 6.73 million (nearly $1 million) in financial value to the company. Following the successful installation of the catalyst, Clariant also recommended reducing the steam drum pressure from 2.2 to 1.85 MPa, allowing the plant to benefit from the catalyst's low temperature activity at constant feedstock consumption.

A SIGNIFICANT SUCCESS

In the coal-to-chemicals industry, the greater the competition, the greater the need for innovation becomes. In the face of increasing price pressure on methanol and its own growing demand for the chemical, NCIC has succeeded in swiftly enhancing its process and cost efficiencies through collaboration with Clariant and use of the MegaMax 800 catalyst.

After only about one year since use of the catalyst began, the company already is profiting from its superior performance — and benefits are expected to grow. The successful results are particularly significant for Clariant because NCIC is the first adopter in China for MegaMax 800 using Air Liquide's Lurgi LP methanol technology. Clariant is committed to continuously advancing its state-of-the-art methanol catalysts and processes to maximize production efficiency and reliability for its customers. ●

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Deter a Dust-Up

Problems in making pigments pose political as well as technical issues

THIS MONTH'S PUZZLER

I am a new graduate now working as a production engineer at an extrusion plastic manufacturer and would like to make a good start. I manage a process to produce paint pigments and would welcome some tips on optimizing the operation (Figure online at https://bit.ly/2Xcmy4o).

From what I've gathered in a few weeks, we have bouts of clogging in the paint spray nozzles at the extruder. We also see far more fines in the screen than corporate engineering considers appropriate. We change bags every couple of weeks, which seems too often; the bags are tossed in drums as toxic waste.

Laboratory results show a lot of dust collected on the coarse product. Dust sometimes appears to get through the baghouse to the blower. I see dust on the duct connections to the blower and at the outlet to the atmosphere. One operator complained that dust clogs the product container nozzle of the grind collected at the screen.

I talked to several managers and engineers. The production manager said not to worry about it because the plant always has run this way. Someone in corporate engineering suggested digging through the files, hinting this wasn't the first design for the system. The plant safety manager isn't worried about the dust but the corporate manager is concerned because exposure to this pigment is a problem in Europe. Can you suggest anything I should look at to reduce downtime and improve product quality?

DUST OFF OLD FILES

Let's see: a dust problem in the product, an undertow of politics (corporate engineering is concerned but plant production isn't), a potential safety and environmental problem, and a reliability issue.

Someone in corporate engineering hinting that this wasn't "the first design for the system" is a big clue. However, with the production manager unconvinced there's a problem, you won't make any headway if you can't justify at a least a 25% rate of return (four-year payback).

Let's consider routine things to eliminate: divide the system into before and after the hammer mill. The first step is to review maintenance logs and perform sampling.

Samples are crucial, so you will need funding for sample analysis. If you can't get that, give up — the politics are against you. Get samples from the feeder, the top (after the air lock) and bottom of the hammer mill, the cyclone discharge, the fines and coarse product, and the dust in the dust collector. You should, at least, have the product dust samples. You're looking for particle size distributions — where they change and how. Keep in mind that round particles are an anomaly in nature and uniformity invariably means you missed something. Sample at regular intervals for a few months. Also, identify the dryness of the compressed air from utility records; review more than a year's worth.

Now, consider maintenance. What was the system shut down for? Has anything changed since commissioning? Was the process ever fine-tuned? Too often, after equipment is installed, nobody checks the product particle size against the details in the equipment vendor's bid package. Dig into the files; compare the bids in the folders against the

AUGUST'S PUZZLER

We've run our nitric acid purification process (Figure 1) for about ten years. Recently, we shut it down for minor repairs. Less than an hour into the subsequent startup, an explosion occurred. The building was filled with acrid orange-yellow gas. This prompted a unit evacuation. We barely had time to complete the emergency shutdown procedures before the general evacuation. Fortunately, nobody was hurt.

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

actual equipment. Look into typical screening issues, such as tears in the screen, corrosion in the mill, motor failures, etc.

Now, let's consider the hammer mill. Maintenance records may reveal that its motor has been troublesome, e.g., burnouts, clogging or jamming. This could suggest reducing the tip speed of the mill. Seek help from corporate engineering and also contact your local winding shop to ask how many visits they've made. Because the optimum rotation speed may change with what's in the feeder hopper, you may want to look into a variable speed drive so you can optimize the speed.

Dirk Willard, consultant
Wooster, Ohio

AUGUST'S PUZZLER continued

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

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

Send us your comments, suggestions or solutions for this question by July 10, 2020. We'll include as many of them as possible in the August 2020 issue and all on ChemicalProcessing.com. Send visuals — a sketch is fine. E-mail us at ProcessPuzzler@putman.net or mail to Process Puzzler, *Chemical Processing*, 1501 E. Woodfield Rd., Suite 400N, Schaumburg, IL 60173. Fax: (630) 467-1120. Please include your name, title, location and company affiliation in the response. And, of course, if you have a process problem you'd like to pose to our readers, send it along and we'll be pleased to consider it for publication.

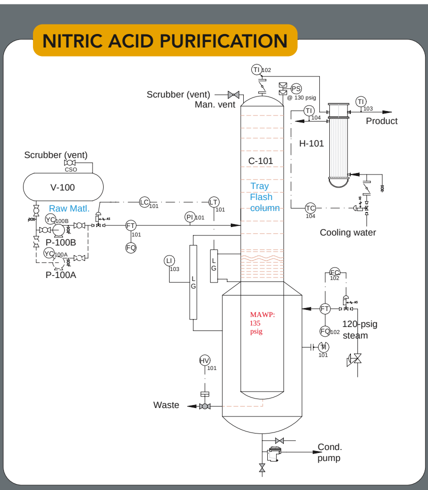

Figure 1. During startup after minor repairs an explosion took place.

Don't Err with Fans

Understand the tradeoffs posed by the various options

Leaks pose different issues in forced-draft and induced-draft systems.

TO MOVE large volumes of air at low differential pressure, plants rely on both forced-draft (FD) and induced-draft (ID) fans. The former push the discharge air from the fan into the process while the latter pull suction air to the fan from the process equipment. Sometimes, FD and ID fans work together in the same equipment; a common example is air supply to the combustion side of a fired heater using both types.

Process/fan interaction and fan mechanics determine the choice of FD versus ID fans for specific situations. Generally, FD fans have backward curving blades while ID fans have forward curving ones. Most fans use constant speed motors and vary capacity with either louvers or variable pitch blades. However, controlling capacity via a variable frequency drive (VFD) to adjust motor speed usually is best. Modern VFDs often are highly cost-competitive in spite of their higher initial purchase price. (VFDs frequently are much more reliable and cheaper to maintain.)

At a constant speed and fan diameter, an ID fan produces a higher speed of air leaving the blade and a greater discharge head than a FD fan. However, at constant capacity, the aerodynamic disturbance from the forward curving blade of the ID fan also creates more noise and vibration. Large ID fans can be very noisy. While efficiencies vary with specific fan shape, ID fans generally are less efficient and require more power than FD fans for the same pressure rise and flow rate. Nevertheless, because of its higher air velocity, the ID fan is favored for large-capacity low-head systems.

Either type of fan can be placed in elevated structures. However, the increased vibration from ID fans will raise structure costs for fans at high elevations.

The forward lean of the blades on an ID fan tend to capture sticky solids more readily than the blades on FD fans. Thus, ID fans may require more frequent cleaning to sustain efficiency and capacity and to avoid balance problems.

While an ID fan will have a smaller diameter for the same capacity and head, its fan assembly normally will cost more. The extra expense comes from the need for a larger motor (because of the fan's lower efficiency) and stronger fan components (due to vibration, power and balancing).

Used by itself, an FD fan pressurizes the downstream process. So, air may leak out of the equipment. For a cooling tower, this only may be a minor issue. However, an FD fan upstream of a heater firebox can lead to leaks of high-temperature combustion gas that can damage equipment and pose a safety problem. Heater fireboxes subject to positive pressure require excellent refractory and firebox enclosure maintenance to prevent leaks.

In contrast, an ID fan drops the process pressure below atmospheric pressure. Leaks go into the equipment. On fired heaters, inward leaks of air decrease efficiency because excess air becomes difficult to control.

A so-called balanced-draft system includes both FD and ID fans. Common on fired heaters and solids drying systems, the balanced-draft configuration allows regulating pressure in the equipment to minimize air leaks in either direction and enables good overall flow control.

Some heaters can operate under natural draft without any fans at all. This may require a reduced firing rate. Other heaters must shut down if the fans don't run. The stack may not have enough height to generate draft or mandatory pollution-control equipment imposes such a high pressure drop that operation is not feasible without fans. The ability to run under natural draft is an important consideration in shutdown systems.

For a heater with only one fan service, fan failure causes a heater shutdown or a shift into natural draft operation.

Balanced-draft systems require safety features to allow safe operation or shutdown if one fan motor fails. Most often, the heater has both high-pressure and low-pressure shutoffs. If the ID-fan fails, the high-pressure trip may shut down the furnace completely or shut off the FD fan to prevent the heater from over-pressuring. If the FD fan fails, the low-pressure trip may shut down the furnace completely or shut off the ID fan to prevent the heater from going into too much of a vacuum.

Of course, shutting down the second fan but keeping the heater running only is practical if the heater can operate with natural draft. ●

ANDREW SLOLEY, Contributing Editor
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Flowmeter Boasts Easy Installation

The Optisonic 6300 V2 ultrasonic flowmeter features a stationary, clamp-on design that allows users to measure flow anywhere necessary, all while processes continue. With a viscosity range of up to 200 cSt, it avoids the need for re-greasing due to solid coupling material, and includes a signal converter for enhanced application range, Namur NE107 diagnostics, and integrated thermal energy calculation. The meter suits diameters ranging from ½- to 160-in. and has a process temperature range of -40 to 392°F (-40 to 200°C). It delivers accurate sensor alignment using rail-mounted transducers, and minimized uncertainty through an installation wizard and optimization routine. This flowmeter is constructed as a submersible stainless steel sensor rail (IP 68/NEMA 6P).

KROHNE
1-800-356-9464
www.us.krohne.com

Condition Monitor Banishes Batteries

The Machine Health Monitoring system is designed to deliver real-time, maintenance-free insights into the health of rotating equipment, such as motors, pumps, fans and compressors. The wireless sensor network operates without batteries, instead using power

from low levels of harvested energy, such as from a warm machine surface or dim indoor light. By transmitting vibration, temperature and magnetic field data to the cloud continuously, the system quickly detects machine faults, sending real-time alarms via email and SMS as issues are identified. The sensors require no maintenance, allowing plant personnel to deploy maintenance resources only when and where they're needed.

Everactive
https://everactive.com/solutions

Device Eases Worker Safety Monitoring

The TGX Gateway wirelessly connects lone workers in the field to safety contacts, giving them a lifeline to safety in remote locations. With dual cellular and satellite connectivity, the device reportedly is ideal for locations where wi-fi, Ethernet or cellular alone cannot reliably connect workers to safety contacts. The gateway transmits gas readings and alarm activity from Ventis Pro5 multi-gas monitors to iNet Now live monitoring software. With iNet Now's easy-to-use dashboard and optional text alerts, safety managers can see worker status, location, and current conditions, providing an instant view into remote worker safety.

Industrial Scientific
800-338-3287
www.indsci.com

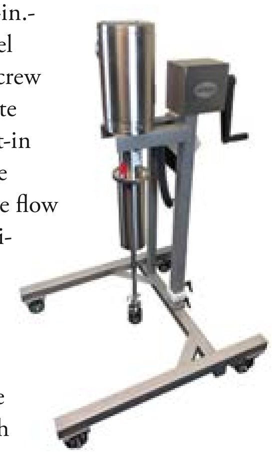
Level Sensor Resists Material Buildup

The GWR-3000 guided wave radar suits all liquids including those with steam, vapor, foam, condensation or those prone to residual buildup. It reportedly is ideal for continuous level measurement in storage vessels, standpipes and separators, for tank metering at tank farms, and interface measurement to detect separation layers. Customized for each vessel, the unit comes with plastic, aluminum or stainless-steel housings and with either a cable or rod sized to a specific length. Both 2-wire 4–20-mA or 4-wire 4–20-mA and Modbus output options make it compatible with existing systems. A variety of CSA and FM approvals meet hazardous location requirements.

BinMaster
800-278-4241
www.binmaster.com

Volumetric Feeder Optimizes Delivery

The VMF-90F volumetric feeder is a self-contained, automated dry chemical addition system. The 0.36- to 3.56-ft^3/hr feed rate has accuracy to within 1% of volume. A 1.5-in.-dia., stainless-steel open helix feed screw optimizes feed rate delivery to a built-in wetting cone. The cone improves the flow properties of additives, especially those not very soluble in water. This reportedly improves additive usage rates, which makes the system more efficient and effective. The wetting cone is designed to regulate flow to ensure all material within the cone is thoroughly mixed and dispersed. A 1.5-in. water eductor sends the solution into the process.



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Tree Research Branches Out

Two projects seek to find sustainable uses for wood products

Collaboration draws on a range of engineering expertise.

TREES ARE big business in Finland. According to the Finnish Forestry Industries Federation, Helsinki, the country manufactured 9.5 million metric tons of paper and paper board in 2019 — however, this is down 10% compared to the previous year.

In recent years, Finland has been looking beyond the paper industry and investigating how to use natural fibers, such as the cellulose from trees, in applications that currently rely on fossil-fuel-based plastics. These include packaging, hygiene products, building materials, textiles, filters and more.

In April this year, Finland's research, development and innovation organization, VTT, Espoo, launched two initiatives to investigate possible alternative uses.

The first project, "Piloting Alternatives for Plastics," will run for three years. The European Regional Development Fund (ERDF), VTT, and 52 companies from across Europe coordinated by the Regional Council of Central Finland, are funding the €6.7-million ($7.3-million) effort.

Together, VTT and the companies have several pilot projects investigating the challenges involved with scaling up manufacture of new-generation fiber products. The collaboration encompasses engineering expertise from polymer dispersion specialists, pulp and paper manufacturers, engineering consultants, water treatment companies, and pumping specialists.

Based at VTT's technical research center in Jyväskylä, the pilots will have access to novel technologies, including what the organization says is the first research environment in the world to utilize a foam-forming process.

Some of the same companies were involved in an earlier €3.6-million ($3.9-million) project to investigate the possibility of using foam-forming technology. The process uses tiny bubbles of air mixed to a water/fiber suspension to expand the use of natural fibers in the production of recyclable and lightweight products.

According to VTT, this work overcame the problems that foam causes in paper mills, allowing them to improve resource efficiency. However, it also showed that foam-assisted forming technology introduced opportunities to develop new types of sustainable wood fiber products.

"In this [new] project, we are creating a new understanding of bio-based fiber networks and how, by tailoring them, we can produce new types of recyclable materials that do not burden the environment," says VTT vice president Jani Lehto.

The challenge now, he adds, is to select the most interesting from a range of raw material and manufacturing options, and to reduce the time it takes to scale the laboratory results to commercial production levels.

The companies involved can then use this information to develop and tailor their own specific processes.

VTT's second initiative involves using nanocellulose-based films and hydrogels to support the capture and identification of very small microplastic particles before they enter waterways.

"Nanocellulose has a mesh-like, porous structure and a large surface area. In the water, powerful capillary forces are generated in this structure, allowing particles to be transported inside the mesh and bound there," says VTT research professor Tekla Tammelin, pointing out that 1,000 L of seawater can contain up to 8.3 million microplastic particles.

The method provides a way to catch microplastic particles of a size the human eye can't detect — those with a diameter of only 100 nm.

"Nanocellulose structures can be used to identify and analyze these particles and to obtain information about their behavior at an earlier stage. We can determine the concentration of particles in water and analyze, for example, whether particles are released into drinking water from plastic bottles," she notes.

VTT pioneered the identification of microplastic particles using nanocellulose structures as a part of the FinnCERES flagship project, which is exploring new bio-based material solutions. Based at Aalto University, Aalto, FinnCERES is the joint competence center for the materials bioeconomy between the two organizations. It aims to create new businesses based on novel value-added products manufactured from wood constituents that contribute to the renewal of the Finnish forestry industry.

The next step could be to develop new and inexpensive filtration solutions employing the method.

"New filtration solutions would allow particles to be captured where they are generated. The solutions could be utilized, for example, in laundry, where microplastic particles are released from fleece clothing and other synthetic fibers. Similarly, we could develop filtration methods for any industry where there is a risk of microplastics being generated and released into waterways," concludes Tammelin.

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