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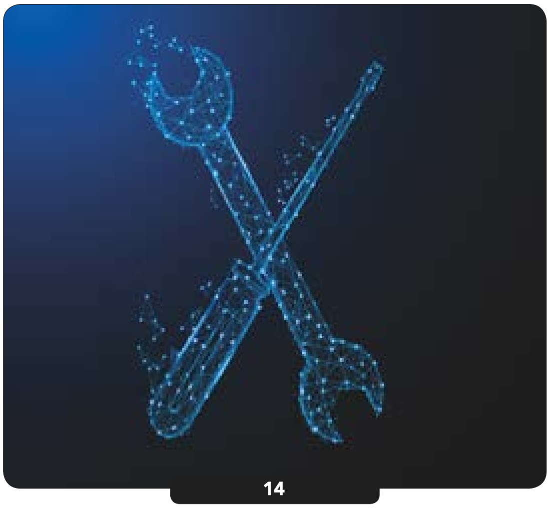

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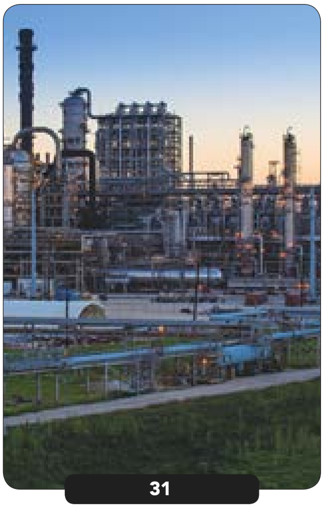

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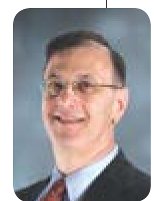
Two Startups Win Novel Contest

Competition focused on five areas related to sustainability



The contest attracted more than 160 submissions from 30 countries.

FOSTERING COLLABORATIVE innovation is the aim of Imagine Chemistry, a contest started by AkzoNobel Specialty Chemicals in 2017. As I noted last year ("Imagine Chemistry Challenge Awards Support to Startups," http://bit.ly/2Xk5gkq), the competition provides an offbeat but effective approach to cultivating relationships with groups developing technology relevant to the company.

AkzoNobel Specialty Chemicals is now an independent company, Nouryon. It ran Imagine Chemistry this year.

"We not only need to create more sustainable products — we also need to become more open and collaborative… No one company has all the answers," explains Renier Vree, Nouryon's CFO.

The 2019 competition focused on five areas: pushing the frontiers of sustainable innovation; performance-boosting nanoparticles; sustainable bio-based surfactants; sensing in demanding chemical environments; and chemistries that don't require labels on products. It attracted over 160 submissions from 30 countries.

Fourteen finalists took part in a late May event in the Netherlands. The judges picked two overall winners to receive joint development agreements (JDAs):

- Sironix Renewables, Seattle, for its plant-based detergent molecule that serves both as a surfactant and chelating agent, eliminating need for co-formulated chemicals, and that provides enhanced performance in hard water. It garnered two JDAs, one from Imagine Chemistry partner Unilever for consumer personal care products and another from Nouryon for applications outside that area.
- Ionomr, Vancouver, B.C., received a JDA from Nouryon for its hydrocarbon ion-exchange membranes and polymers for electrochemical systems. These represent a fundamental shift from the perfluorinated sulfonic acid chemistry now used, and offer both markedly reduced toxicity and environmental impact.

Six other groups also won awards:

- Ingu Solutions, Calgary, obtained a supply agreement from Nouryon for its miniaturized inline sensors to detect leaks, defects and deposits in pipelines.
- RISE — Research Institutes of Sweden, Borås, Sweden, got a research agreement to further develop vinyl functionalized reactive additives for commercially available metal oxide nanoparticles.
- Intelligent Fluids, Leipzig, Germany, garnered a research agreement with Nouryon plus support from ICOS Capital for its cleaning agents that use physical effects rather than toxic solvents.
- Cambridge Carbon Capture, Cambridge, U.K., gained support from Lux Research for its technology that captures carbon dioxide and converts it to a solid byproduct with various commercial uses.
- Arenal Process Control Solutions, Pijnacker, the Netherlands, obtained chemical research support from Nouryon for its ultrasonic and thermal sensors for real-time process monitoring.
- The University of Sheffield, U.K., and Entomics Biosystems, Cambridge, U.K., won chemical research support from Nouryon for their work to use black soldier fly larvae to make surfactants.

Imagine Chemistry was planned as a three-year trial. Nouryon now is assessing the program and how best to continue it. This, for instance, may involve replacing the single multi-faceted annual competition with multiple ones, each focused on a specific technical area and taking place at different times, says Marco Waas, global director RD&I and technology.

I strongly urge other chemical makers to emulate this astute approach to collaborative innovation.

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Evaluate Different Facets of Crystal Phases

Knowing more about a crystal than just its solubility is important

The crystal phase may be important in drying, transport and storage.

IF YOU have a crystallizer or are planning to install a crystallization process, then you know the importance of solubility curves. Yet, it's amazing how many plants run without such curves or use ones that are ancient, perhaps many decades old. Empirical data underpinned the development of these old-time processes, which probably will run forever without any changes — at least we hope so. However, hope isn't a strategy or a plan. Something such as a raw material will change or customers will want a different particle size distribution.

This is when I show up asking for data such as a solubility curve, and pose a lot of questions about the crystals and the process. Even plants that have a curve are stymied when I ask about potential crystal phases such as polymorphs or solvates. The concern I have for crystal phase isn't limited to the crystallization process; this physical property may be important in drying, transport and storage of the chemical.

I can't emphasize enough the need to look very hard for the existence of these phases along with any temperature sensitivity. Any heat flux that shows up during temperature changes is a concern. We were developing a new pharmaceutical and in the final stages of getting U.S. Food and Drug Administration approval when the solubility of a batch changed dramatically; we even saw a slight shift in the x-ray pattern. When I asked about polymorphs, the team responded that it didn't think any existed. However, one chemist said she may have seen one. Molecular modeling identified six potential polymorphs; two were robust. The problem was resolved by avoiding a temperature region that allowed one of these polymorphs to form.

I've mentioned phase in previous columns (e.g., "Get a Solubility Curve," http://bit.ly/2JR2P5M). Here, let's look at some tools for identifying polymorphs and solvates to help you avoid or address production problems, or allow you to produce a more desirable product:

Molecular modeling. This is a theoretical method and computational technique that attempts to mimic the behavior of molecules. Many advances have occurred in this technology. Hand calculations can define simple systems. The common feature of molecular modeling is the atomic level description of the molecule. You can treat atoms using molecular mechanics or by explicitly modeling electrons using a quantum chemistry approach. I ran some rather crude computer programs over 20 years ago to identify the polymorphs in the pharmaceutical problem cited above.

X-ray diffraction. This method will identify structural differences of a material. By measuring the angles and intensities of a diffracted beam, a chemist can produce a three-dimensional picture of the crystal. It's important to look at material produced under different conditions to identify the most stable crystal form and any polymorphs.

Differential scanning calorimetry. Many variations of this technique exist but the basic idea is to identify phase changes as a sample is heated. The amount of energy absorbed or released may indicate a polymorph or solvate.

Raman and infrared spectroscopy. Raman spectroscopy is a technique to observe vibrational, rotational and other low-frequency modes of a chemical. It can identify molecules that have a slight variation in structure. Infrared is another method that can serve for quantitative analyses of unknown substances or to determine the structural properties of known substances.

Microscopy. It's amazing what you can learn from looking at your product under an optical microscope. However, a scanning electron microscope or a transmission electron microscope will reveal differences in the surface or composition of the sample and help identify structural distinctions that indicate the presence of different chemicals.

Drying rate or critical moisture. Often solvates or polymorphs dry differently due to altered heat capacity caused by their distinct structure.

The most important conclusion you can reach by using these methods is the identification of the most stable form of the chemical. If that form is the most effective product (e.g., the drug that works the best), the additional information about when an unstable form occurs will allow you to always make the desired product. If an unstable form is more effective, then these data will allow you to tailor your process to avoid the stable product. ●

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Produce Proper Pipe Specifications

Include adequate detail and appropriate background information

THE PRESSURE to get the ammonia refrigeration pipe specifications done quickly was palpable. However, I've learned that, even on rush jobs, being correct is more important than being fast. Getting one complaint about late delivery beats facing never-ending gripes if the work is filled with errors.

I've written many pipe specifications. So, let me share some learnings.

First, it's important to realize the specifications must consider regulations and the desires of the operating company and engineering firm. Generally, give the maintenance staff's needs — improved reliability and reduced inventory — high priority. After all, they must maintain what you've specified.

Second, don't count on regulations for clear guidance. To prepare my ammonia pipe specifications, I had to sift through several standards for material-specific instructions for valves. Generally, organizations such as the American National Standards Institute, the American Society of Mechanical Engineers (ASME) and the International Institute of Ammonic Refrigeration don't provide comprehensive details you'll need for a pipe specification. The Chlorine Institute does a better job of defining valves suitable for chlorine service.

Next, let's dig into the weeds a little. Take, for example, hoses, a part of everyday plant life. Yet, organizations don't publish specifications. The State of California provides a comprehensive guide I found useful; it requires a 500-psig test annually. Most companies won't bother with the risk of poor documentation and just toss the hose.

In the ammonia pipe specification, I accepted nylon as the inner and outer material for hoses smaller than 1½ inches but said larger hose required braided stainless steel for the outer wall. This made sense to me because, for a given wall thickness, larger diameter pipe and hose must defend a bigger area than a smaller hose. You won't find considerations such as these in regulations or standards.

Another issue is the use of lap flanges. These consist of two parts, a flange and a stub that's welded onto the pipe. I worry a sloppy workman can compromise connection integrity. While these flanges may be useful in some low pressure applications, they tend to leak when subjected to thermal expansion or vibration. You certainly don't want them on a 450-psig chlorine railcar. Design engineers should avoid them.

Now, let's consider the structure of a pipe specification. Break it into two parts — engineering and tables. The engineering section supports the structure of the entire document while the tables section is meant for handing to constructors for use by their fabricators.

For engineering, provide the following sections: 1) scope; 2) delivery, storage and handling; 3) codes and standards; 4) related documents (process and instrumentation drawings, etc.); and 5) special topics. In addition, if any changes exist from past work at the plant, include a separate engineering design report.

The delivery, storage, and handling section merely should send the reader to a particular specification for ensuring items are delivered to the fabricators intact and in order. Don't just count on having a specification for this; review it and add to this section if it's insufficient.

Be as specific as possible with codes and standards. Quote sections and even cite crucial passages. Confirm that each passage applies.

Special topics include ones like corrosion allowances, use of alternative materials (e.g., stainless steel instead of carbon steel), welding practices, incompatible chemicals or procedures, acceptable ASME pressure class and unique inspection requirements.

The table is the heart of the pipe specification. Columns should cover in order: item, notes, size, pressure rating, type of end connection and description. The description should reference an ASTM standard. Items include valves, gaskets, pipe, fittings, tubing, flanges, hose and fasteners (bolts, studs and nuts). If you discourage the use of some items like valves, explicitly say why.

Add copious numbered notes to the bottom of the table. Fabricators must know the reason for the choices in the table. You want to convince them to make the right choices.

Painting and insulation are crucial but keep in mind that ASME B31.5, Paragraph 538.2 requires pressure testing of bare uninsulated pipe. After testing, B31.5, Paragraph 520.1.6 mandates application of a "weather-resistant" coating to all "parts." However, this doesn't mean painting flange bolts; don't do that. Sherwin-Williams recommends greasing the bolts to provide a protective coating.

Don't think of pipe specifications as mundane boiler plate. It's your chance to inspire safe construction practices.

Break a specification into two parts — engineering and tables.

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Greener Epoxide Production Beckons

Electricity from renewable sources could power new synthesis method

PRODUCING EPOXIDES — used to manufacture numerous everyday products — requires extreme temperatures and pressures, and generates carbon dioxide emissions. So, researchers at the Massachusetts Institute of Technology (MIT), Cambridge, have created a more-sustainable approach using electricity. Their process takes place at room temperature and atmospheric pressure, eliminates carbon dioxide as a byproduct, and promises lower-cost production.

The team uses electricity to split water into oxygen, protons and electrons, and then attaches the oxygen atom to an olefin, a precursor to epoxides.

Olefins and water react only when an electric voltage is applied. So, the MIT team designed a reactor with an anode that breaks water down into oxygen, hydrogen ions (protons) and electrons. Manganese oxide nanoparticles act as a catalyst for this reaction, and for incorporating the oxygen into an olefin to make an epoxide. Protons and electrons flow to the cathode, where they are converted into hydrogen gas. An article in the *Journal of the American Chemical Society* highlights the process and its results.

Thermodynamically, this reaction only uses about 1 volt of electricity and doesn't generate any carbon dioxide. Using renewable sources to make the electricity to power the epoxide conversion could further reduce the carbon footprint, believe the researchers.

The researchers have used the process to create an epoxide called cyclooctene oxide; they now are working on adapting it to other epoxides.

"We select targets based on the carbon footprint and energy footprint of chemicals. This means that key targets in addition to epoxides include ammonia and olefins. We are developing, for instance, a room temperature and ambient pressure route by which renewable electricity can be used to convert nitrogen into ammonia fertilizers," says Karthish Manthiram, an assistant professor of chemical engineering at MIT, who lead the project.

Presently, about 30% of the electrical current goes into the conversion reaction, but the researchers hope to double that to make it more efficient.

"Our preliminary technoeconomic analysis indicates that doubling the Faradaic efficiency is necessary to make the process competitive," notes Manthiram. This will require developing anodic catalysts which facilitate selective transfer of oxygen-atoms from water to olefins to generate an epoxide.

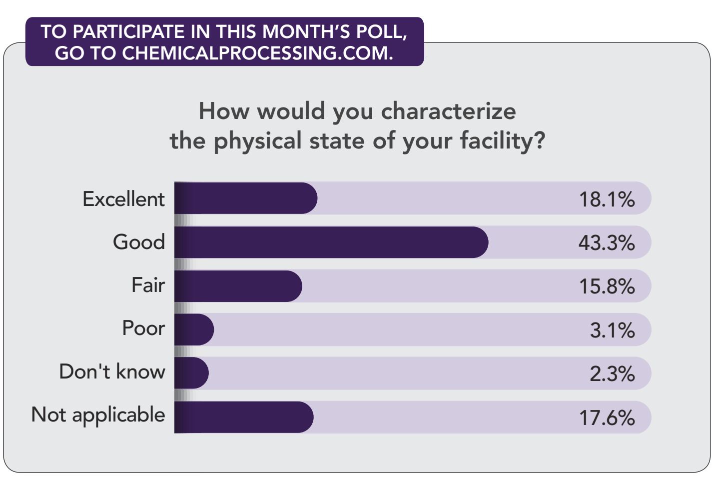
"Achieving higher energy efficiency will necessitate creating more efficient catalysts for the cathode, which conducts hydrogen evolution, and developing cell architectures which minimize the distances for ion transport," he adds.

The researchers plan to continue developing the technology in hopes of eventually commercializing it for industrial use; the team is in early-stage discussions with companies interested in the process.

If scaled up, the researchers estimate the process could produce ethylene oxide at a cost of $900/ton, which includes credit for the current U.S. market price for byproduct hyrogen, versus $1,500/ton using current methods. That cost could be lowered further as the process becomes more efficient. In addition, its hydrogen byproduct can be used to power fuel cells, further enhancing the process' economic viability.

The system is relatively robust to perturbations and conducive to ramping up and down rapidly because the process runs at ambient conditions, says Manthiram. "This means the reactor can be dynamically operated to follow renewable electricity generation, to operate when the sun shines and the wind blows," he explains.

However, Manthiram points out that key challenges for successful scaleup are developing energy efficient reactor architectures, and selective and robust catalysts tolerant to impurities. "This is the focus of our ongoing efforts in our lab. This is still early-stage research, but translating this to understand the scale-up constraints is essential for continued development," he notes.



Most respondents consider their sites to be in good or better state.

Needles Point to Improved Water Splitting

A NEW needle-like hybrid catalyst offers a route to cheap and sustainable hydrogen production, believe researchers at the Technical University of Munich (TUM), Munich, Germany. They have created a stable yet flexible semiconductor structure they claim splits water four times more efficiently than previously possible. The reaction takes place at ambient temperature and pressure.

The new material consists of a fibrous, inorganic, double-helix compound made of tin, iodine and phosphorus (SnIP) that then is encased in a carbon nitride shell.

The team, led by Tom Nilges, a materials science professor at TUM, and Karthik Shankar, a professor of electrical and computer engineering at the University of Alberta, Edmonton, found that a 30/70% ratio of SnIP to carbon nitride gave the best catalytic performance. Knowing that a large surface area improves catalytic efficiency, the researchers then split the fibers into thinner needle-like strands, some with diameters of only a few nanometers (Figure 1).

Catalyst synthesis is a simple process that takes place at temperatures of around 400°C, say the researchers; the resulting fibers are both robust and flexible, they add.

"We are currently working on lab scale. Upscaling must be realized and stability tests carried out over a longer period of time before any pilot-scale work could be planned," notes Nilges.

The catalyst's water-splitting capabilities can be further enhanced, he believes. "We need to adjust the amount of material in the core shell to improve the hydrogen production. This work will last some more years and requires funding."

The team now is investigating other hybrid materials, including phosphorus/titanium dioxide (TiO_2) and SnIP/TiO_2, which also show good promise as water splitters.

It already has synthesized hybrid semiconductor/TiO_2 nanotube photocatalysts. An upcoming article in *ACS Applied Nano Materials* will describe a simple low-cost synthesis route that results in loading the cavities in 100-µm-long TiO_2 nanotubes with easily accessible fibrous red and black phosphorus.

The researchers then use a vapor transport technique to create heterojunctions (i.e., the interfaces that occur between two layers or regions of dissimilar crystalline semiconductors) between phosphorus and TiO_2 that enhance both charge separation and effective visible light absorption — and also give improved water-splitting performance.

These projects effectively demonstrate the conversion efficiencies of nanostructured hybrids, believes Nilges. He foresees potential opportunities in optoelectronic applications such as photodetectors, photovoltaics, photoelectrochemical catalysts and sensors.

NEEDLE-LIKE FIBERS

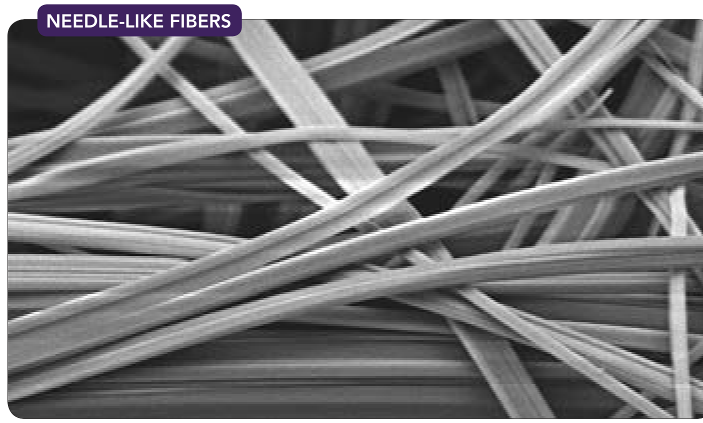
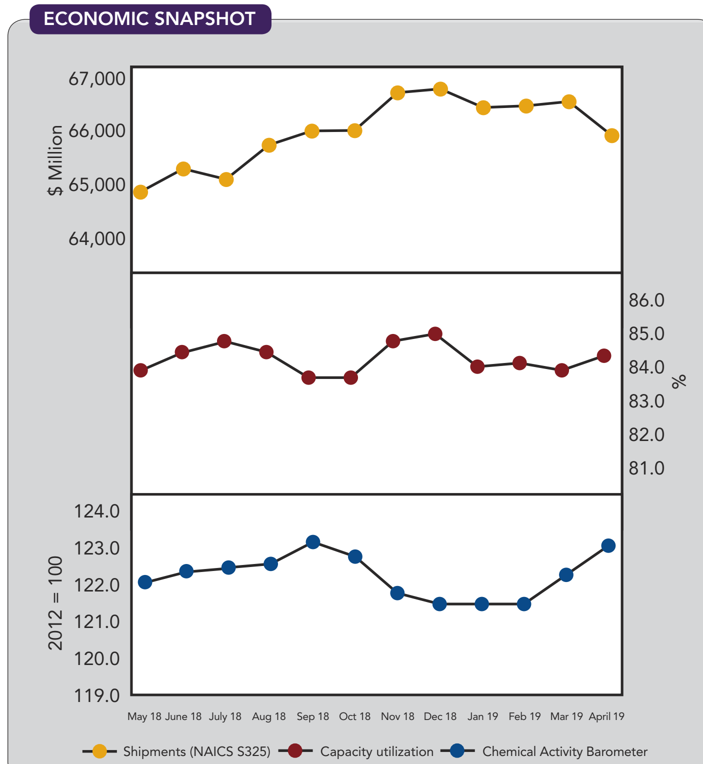


Figure 1. Thin strands provide greater surface area and, thus, higher catalytic efficiency for water splitting. *Source: TUM.*

ECONOMIC SNAPSHOT



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

Take the Heat Off Pinch Analysis

Composite curves help determine proper heat transfer and energy savings

Pinch work shouldn't be an isolated activity.

PINCH ANALYSIS is a powerful tool for designing energy-efficient heat exchanger networks. It has been widely used for preheat trains in oil refinery crude units and fluid catalytic cracking (FCC) units, ethylene plants, and other large chemical and petrochemical systems (1).

We all learned as children that heat flows from hot objects to cold ones. This simple concept is the basis of the hot and cold composite curves (Figure 1), which represent the overall heat release and heat demand of a process as a function of temperature.

The hot composite curve is the sum of all the heat sources (or "hot streams") within the process, defined by their heat load and temperature level. The cold composite curve is the corresponding sum of all the heat sinks (or "cold streams"). We plot these curves together on a single temperature-enthalpy graph (as in Figure 1), from which we can see heat can be recovered within the process wherever the hot composite curve is above the cold composite curve — that is, heat can flow from a higher-temperature part of the process to a lower-temperature part. The heat flow takes place in heat exchangers, whose sizes increase as the temperature difference decreases. We therefore specify a minimum allowable temperature difference, ΔT_{min}, to ensure the equipment size doesn't become too large.

HOT AND COLD COMPOSITE CURVES

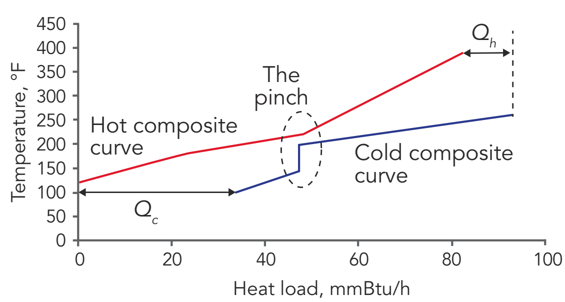


Figure 1. The curves represent the overall heat release and heat demand of a process as a function of temperature.

Most composite curves show a pinch where the vertical separation of the curves approaches and eventually reaches the ΔT_{min} value. The pinch divides the process into two distinct regions:

- Above the pinch, some heat integration is possible (where the hot composite curve sits above the cold composite curve), but there is a net heat deficit, and an external utility heat source (Q_h) is required.
- Below the pinch, some heat integration is possible (where the hot composite curve sits above the cold composite curve), but there is a net heat surplus, and an external utility heat sink (Q_c) is required.

If we allow heat to flow from the region above the pinch, where a deficit of heat exists, to the region below it, where a surplus is found, both the deficit and the surplus will increase, so we need more hot and cold utility duty to satisfy the process heat balance, and more energy is consumed. This leads to the pinch principle: Don't transfer heat across the pinch.

Composite curves and the pinch principle are the best-known elements of pinch analysis. Other tools and techniques include heat exchanger grid diagrams, grand composite curves, and algorithms to evaluate heat exchanger network area and capital/energy trade-offs.

Pinch analysis was initially developed for new plant designs. The technique must be modified for retrofit work, since a revamp must account for existing equipment and plot space. The simplest approach is to identify major inefficiencies (i.e., places where heat crosses the pinch) in the existing heat exchanger network, and then find ways to eliminate — or at least reduce — them.

A wide range of pinch software is now available; engineers in many organizations conduct pinch analyses, at least at a basic level. Specialized consultants, typically in small companies, as well as some larger engineering companies, carry out most of the advanced pinch analysis work. However, pinch work shouldn't be an isolated activity. Rather, it should be integrated into broader process design, energy management or process improvement programs.

REFERENCE

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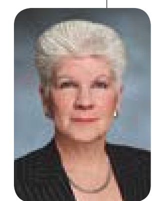
EPA Aims to Clarify Enforcement Action

Policy seeks to foster cooperative goals and coordination between federal and state agencies



The policy is a significant improvement over earlier memoranda.

ON MAY 13, 2019, the U.S. Environmental Protection Agency (EPA) released a draft policy titled "Enhancing Planning and Communication Between the EPA and the States in Civil Enforcement and Compliance Assurance Work." The guidance sets expectations and procedures for enhancing planning and communication on civil enforcement between the EPA and state agencies implementing federal environmental programs. As enforcement issues are always of key concern to businesses, the policy offers important insights into a little understood area.

The concept of "cooperative federalism" is uniquely vague to most business entities, especially in the all-important area of enforcement. The EPA's FY 2018–2022 Strategic Plan places cooperative federalism and compliance as fundamental priorities. In a prior October 30, 2018, enforcement policy, the EPA outlined key principles, including general deference to the states in state-implemented programs, effective communication between the EPA and the states, clear standards of review and a clear process for elevating issues. The draft policy intends to improve upon and update the earlier enforcement policy to ensure EPA Regional offices and state environmental agencies develop appropriate and agreed upon cooperative enforcement goals.

Fundamental to the policy's effectiveness is communication. The policy stresses the need for every Regional EPA office to meet as appropriate with each state agency in its region. The regional office must have procedures in place to inform the state's leadership of any work-sharing arrangements, collaboration or issues between the state and the EPA on compliance assurance work to ensure "no surprises."

Strategic planning is essential and should include awareness of state environmental compliance problems; national, regional, and state compliance priorities; emerging issues; and how to optimize state and EPA combined resources to meet these needs.

Another key element of the policy relates to the concept of coordination. Facility inspection planning should focus on avoiding duplication. Cooperative inspection planning helps the EPA and the states meet their respective goals efficiently while ensuring the same facility won't inadvertently be inspected by the EPA and a state. The EPA regions should provide states with advance notice of inspections, and EPA regions and states "should invite each other to participate in inspections where there is value in both entities participating." In situations where the EPA has the lead, EPA regions "should share information requests with a state concurrently with sending them to the recipient."

Joint enforcement planning is similarly outlined in the policy, with a focus on coordination. Where the EPA believes enforcement is warranted, there should be a discussion of which entity should bring the action. Where a state opts to take the lead, the EPA and the state should discuss how to proceed, being especially mindful of the need to maintain confidentiality.

The policy outlines in detail the roles in implementing authorized state programs. The EPA's policy is generally to defer to the states as the primary implementer of inspections and enforcement in authorized programs. Exceptions to the rule include certain actions involving violations of the National Compliance Initiative (initiatives involving matters where national consistency is key); emergency situations where a substantial threat to human health or the environment exists; cases where a state lacks resources to undertake an action; cases involving multiple states or regions; significant noncompliance that a state hasn't addressed in a timely way; criminal violations; or situations that involve federal or state owned or operated facilities.

If you've ever wondered why an EPA Regional office rather than a state enforcement agency is bringing an action or conducting an inspection, reviewing the draft policy should help. The policy is a significant improvement over earlier memoranda, is clearly written, and provides a straightforward delineation of the respective roles of EPA Regional enforcement personnel versus state enforcement agencies within the regions. While the EPA retains much discretion, the policy is deferential to state agencies and mindful of the core principles of "cooperative federalism." The enforcement area is among the most sensitive to state or regional variation, and the policy appropriately reflects significant deference to state and local priorities.

Comments on the policy wrapped on June 12, 2019. The EPA will soon issue a final policy that, in all likelihood, won't vary significantly from the draft as it is well written and makes a lot of sense. ●

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MAINTENANCE GETS SMARTER

MORE INSIGHTFUL DATA AND BETTER ANALYSES BOOST UPTIME

By Seán Ottewell, Editor at Large

PLANTS INCREASINGLY are turning to machine learning (ML) and artificial intelligence (AI) to recognize precise patterns in sensor data. The technologies ease differentiating between normal and abnormal equipment behavior and also detecting specific patterns that lead up to failures — and, so, enhance capabilities for predictive maintenance.

Meanwhile, advances in sensor technology are reducing both procurement and implementation costs and, thus, spurring greater adoption. "It's now economically feasible to roll out shadow sensing technology in both greenfield and brownfield applications to capture high fidelity data in volumes that were unachievable several years ago," notes Jim Chappell, vice president, information solutions for Aveva, Chicago.

The incentive for adopting predictive maintenance is compelling, stresses Mike Brooks, senior director, APM Consulting, Aspen Technology, Bedford, Mass. "A European customer tells us that 15% gross margin losses are attributable to unplanned maintenance. Even best-in-class approaches 4–5% losses."

He also points to a large automation company's finding that 63% of scheduled maintenance is unnecessary and such work often causes more damage than if the equipment were left untouched. He cites the experience of a large oil company: out of five automatic tank-gauging systems, the only one giving little trouble at all didn't get regularly scheduled maintenance and inspection; the other four, subjected to regular planned maintenance, constantly broke down.

"So, the spend in maintenance today is in searching for wear-and-tear conditions while the problem is in process-induced failures caused by operating equipment outside safety and design limits: incorrect setpoints, pumps running dry and cavitating, compressors affected by liquid carryover, and so on," he emphasizes.

"People talk about the IIoT [Industrial Internet of Things] like it is an initiative. The initiative is always to improve operational excellence. The technology is how you do this. The most important thing you must solve is improving equipment uptime. Mtell, Aspen's predictive and prescriptive technology, is borne out of operations and maintenance — so stopping the breakdown of machines is right at the heart of what we do," he adds.

Now in its fifth generation, Mtell uses small pieces of software called anomaly and failure agents. The anomaly agents constantly monitor to detect irregularities while the failure agents recognize a pattern of behavior that leads to the breakdown of a single machine or process.

"They can tell you what will happen, when/why it will happen, and what you can do to avoid or mitigate the outcome. Mtell lets 'Joe Normal' solve very complex problems without having to understand how it works," explains Brooks.

Mtell allows users to scientifically decide on the most appropriate maintenance schedule, he underscores: "This is important because refiners and chemical plant owner/operators tell us they spend 200% more on maintenance than they should but cannot realistically determine which preventive maintenance routines to cut back on."

Brooks cites the example of refiner and fertilizer manufacturer Borealis, Vienna, which had applied expensive vibration systems and reliability-centered maintenance techniques on the hyper-compressors at one of its refineries but still was losing millions of dollars' worth of production annually.

Aspen found the root cause of the problem to be issues with packing seals and poppet valves. Such problems now are flagged with 30–50 days' notice. This has enabled the refinery to avoid unplanned shutdowns; the new technology also has completely eliminated false alarms.

Another example is from Saras, Sarroch, Italy, which operates a 300,000-bbl/d refinery and 575-MW integrated gasification combined cycle plant. As part of the company's digitalization initiative, it wanted to employ prescriptive maintenance to reduce unplanned downtime.

Aspen used Saras' existing condition data and maintenance records to build agents for a subset of compressors and pumps. The failure agents accurately predicted two valve events: a high outlet temperature failure with 39 days' lead time and an instrument failure with 25 days' lead time that would have led to a valve replacement. They also identified numerous process equipment failures such as oil leaks on pumps. Here, the agents achieved a 91% detection accuracy with 30 days' lead time, reports Brooks.

The next step for Aspen is culling data from similar process equipment at different sites to find non-variable conditions common to them all. "This way we can solve bigger and more challenging problems. We call this 'transfer learning' and expect to do a lot more things like it in the future," says Brooks.

RETHINKING STRATEGY

To remain competitive, chemical companies must take a more holistic approach to digital technology and look beyond traditional techniques for increasing margin, counsels Chappell.

"Many companies today focus on the gains achievable through process optimization. However, a single critical asset failure in a chemical manufacturing application can wipe out years of savings from process optimization," he cautions.

Aveva's answer to this is to combine its process simulators with ML, an approach that enables modeling a wide range of assets and processes — including the dynamic periods when processes are starting up or in transition.

To do this, the company's Predictive Asset Analytics technology uses a patented algorithm called OPTiCS that applies advanced pattern recognition and ML technology. For systems with lower levels of historical repeatability, high noise or that use process-driven problem solving, Predictive Asset Analytics uses a predictive algorithm plugin called KANN.

"This algorithm allows users to create models that predict future values for signals. It uses artificial neural network technology and allows users to create operational profiles with a specific set of inputs and outputs, testing how the outputs will evolve in the future through data playback and 'what-if' analysis," he explains.

Predictive Asset Analytics learns an asset's unique operating profile during all loading, ambient and operational process conditions. Existing machinery sensor data are input into the software's advanced modeling process and compared to real-time operating data to determine subtle deviations from expected equipment behavior and alert if necessary. Once an issue has been identified, the software can assist in root-cause analysis and provide fault diagnostics to help the user understand the problem reason and significance.

"Within the chemicals industry, rotating equipment such as compressors, turbines and pumps have traditionally benefited the most from predictive analytics technology. Some of Aveva's larger customers have (conservatively) estimated over $34 million savings for individual avoided 'catches,' and total avoided costs at over $100 million each," notes Chappell.

Companies using Aveva's technology include Covestro, BASF, Air Liquide and Abu Dhabi National Oil Company (ADNOC). The latter firm has installed Aveva's enterprise visualization and integration technologies, including predictive and prescriptive analytics, at its Paronama digital command center in Abu Dhabi (Figure 1). ADNOC uses the center to monitor, control and optimize the performance of the entire end-to-end value chain across its 16 operating companies.

A major remaining challenge is the cleansing and curating of existing big data to make them suitable for and useful in predictive and condition-based modeling software, he says.

"Over time, we anticipate a shift in maintenance strategies from the traditional cost-centric approach to a more revenue-centric approach. Combining cloud, edge, IIoT and predictive analytics enables companies to develop revenue streams through maintenance-as-a-service programs," he adds.

Predictive analytics also is advancing rapidly as well, with anomaly detection no longer the state-of-the-art, says Chappell. "To stay cutting-edge, software must predict the future."

So, Aveva's ongoing developments focus on leveraging deep learning to forecast the remaining useful life of an asset and, from there, provide prescriptive guidance for maintenance and remediation.

THE VALUE OF EXPERTS

The digital revolution is catalyzing improved outcomes using advanced analytics, stresses Michael Risse, vice president of Seeq, Seattle, citing the company's rapidly growing list of commodity and specialty chemicals customers as proof. "The drive to gain better insights from existing data is absolutely there, and Seeq is working on spreading awareness."

Rather than a black box technology that tries on its own to recognize patterns in data, Seeq enables subject matter experts (SMEs) to define what's important to them or what they're looking for. To this, they can add context based on experience and other data sources, such as manufacturing execution and laboratory information management systems, and investigate to identify precursors to asset failure or degraded production.

"When SMEs put these efforts into action, in the form of monitoring and analyzing incoming data, they are able to accurately predict failures and prescribe mitigations," he says.

They can build predictive models that are adaptable over time as plant conditions change — an interactive approach that actively promotes sustainability in the predictive analytics, rather than a one-time optimization effort, Risse adds. The benefits of such an approach include improved asset uptime and proactive rather than unplanned and costly reactive maintenance.

As an example, Risse cites a global analytics program instigated in late 2017 by Abbott Nutrition, Lake Bluff, Ill. One of the pilot studies that Seeq conducted managed to identify the root causes of why some clean-in-place (CIP) runs took longer than others — typically leaking valves and instrumentation failures —highlighting those parts of the CIP process that Abbott should focus on to make further production improvements.

New sensors and more data rarely are the issues these days, Risse is quick to point out. What users want is faster, meaningful insights from the data they already have stored in process historians: "For all the fancy talk about AI and ML, the number one tool for finding insights in process data is the spreadsheet, a 30-year-old innovation. What the spreadsheet lacks in capabilities, it makes up for in terms of accessibility by the SMEs who have experience/expertise in the plant. Whatever the future may hold in terms of AI and ML, it must maintain that level of ad hoc self-service access for SMEs."

COMMAND CENTER

Figure 1. Facility in Abu Dhabi controls and optimizes, including via predictive and prescriptive analytics, operating company's entire end-to-end value chain. *Source: Aveva.*

PUMP CAVITATION

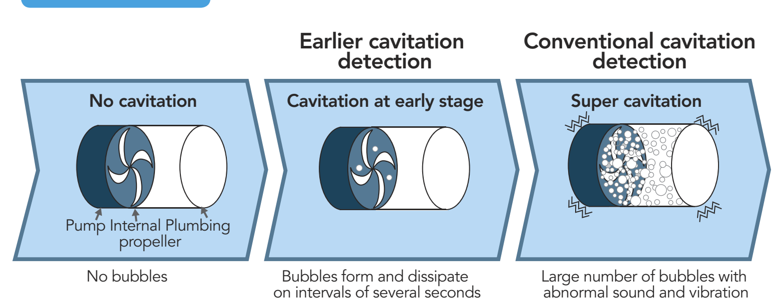

Figure 2. Different pressure transmitter detects data that enable machine learning to predict the onset of cavitation. *Source: Yokogawa.*

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FASTER DETECTION

Meanwhile at Yokogawa, Tokyo, efforts are focused on using its technologies to drill down and better identify and understand individual equipment issues, for example, cavitation in pumps.

"Rather than relying on sound and vibration, we have devised a method to measure cavitation accurately in a different way by monitoring minute pressure changes. This ability to detect very low levels of cavitation has been further enhanced by ML analysis," notes system products marketing specialist Masaru Kimura.

The system detects the minute pressure fluctuations caused when cavitation bubbles pop (Figure 2) using the oscillation value parameter on the company's DPharp differential pressure transmitter.

"By using the data detected by this system for ML, it becomes possible to construct a model for detecting signs of cavitation. Usually, the most important barrier in machine modeling analysis and modeling is the collection of labeled-learning data but the cavitation detection system can be used to automatically create it. The data can then be used to construct a prediction detection model of cavitation," he explains.

This, in turn, does away with the need for operators who are experts in cavitation, and allows equipment changes to be made while minimizing reductions in operating load.

"The system has only just been released and already we have received feedback from field trials showing it can help extend asset life and improve efficiency by reducing or eliminating operating losses," he adds.

Kimura sees the chemical industry as a very important market because its cavitation issues are more pronounced than those of other sectors. As sensors become more accurate and data collection and processing faster, he also believes other phenomena will become measurable, enabling further reductions in customers' asset maintenance costs. ●

CHOOSE THE RIGHT FAN

Understand the various factors that require consideration

By Amin Almasi, mechanical consultant

MANY OPERATIONS at process plants require propelling gas forward. Centrifugal fans commonly handle that duty. Unfortunately, engineering, operations and maintenance teams largely ignore fans, frequently forgetting or overlooking them. This lack of attention often results in design, manufacture and installation of fans without the quality and provisions necessary for reliable long-term performance.

A centrifugal fan consists of a wheel with blades on its circumference and a casing to direct the flow of gas into the center of the wheel and out toward the discharge. The configuration and details of these components affect the gas movement as well as the efficiency and reliability of the fan. Often, fans generate relatively low differential pressures — as a rough indication, below 1.1 Barg. Blowers usually can achieve higher pressures than fans, say, for instance, 1.1 Barg or above. (For information on centrifugal blowers, see: "Make Success with Centrifugal Blowers a Breeze," http://goo.gl/zORhMk.) Compressors can achieve much higher pressures. Centrifugal fans usually operate against pressures of 0.1 to 0.8 Barg but some operate at 0.9 Barg or even a little more.

Commonly used centrifugal fans typically run at speeds between 800 rpm and 4,000 rpm, although high-speed fans exceed these limits. Some fans feature a gear system as an integral part of the machinery to increase speed. Other high-speed fans are directly driven, e.g., by high-speed electric motors. A high-speed impeller/wheel, whether gear- or direct-driven, can rotate very fast, say, up to 6,000 rpm or even more.

Some fans are multi-stage devices, accelerating gas as it passes through each stage. In single-stage fans, gas doesn't take many turns; hence such units are considered more efficient. One usual characteristic of fans — which can be a disadvantage in some applications — is that gas flow tends to drop drastically as system pressure increases. Fans most often are used in services that aren't prone to clogging. Blowers are a better choice when some degree of clogging is expected because they can produce enough pressure (say, more than 1.5 or 2 Barg) to blow clogged materials free.

SELECTION AND OPERATION

Any fan selected should meet capacity and pressure stipulations, operational specifications, desired machinery size, weight and cost, as well as ruggedness and reliability requirements. Many small fans are overhung models but this design isn't possible for medium- and large-size devices. Lots of fans, particularly medium and large units, are between-bearing (BB) models. In this type, the wheel or impeller assembly is located between bearings; the bearings usually are mounted on independently supported pedestals and protected from the gas stream. As a rough guideline, opt for a BB fan if impeller diameter exceeds 0.5 m or driver-rated power tops 90 kW. High-speed, say, over 2,000-rpm, fans in any size need special care and preferably should have a BB configuration. Usually, low temperature gases (say, below -10°C), high temperature services (above 160°C) and challenging gases (toxic, flammable, corrosive, erosive, hazardous, etc.) demand very careful selection, special materials, specific seal systems, bearing protection and a BB design. In addition, each particular service poses its own set of considerations and requirements. For instance, reduced speed is desirable for erosive service. Services subject to fouling deposits require special attention. Fouling can cause rotor unbalance that impairs fan performance; therefore, a smart rotor-dynamics configuration, insensitive to some degree of unbalance, makes the most sense for these services.

WHEELS AND BLADES

A fan wheel consists of a hub to which a number of blades are attached. The blades can be arranged in different ways; we'll look at the main ones: forward-curved, backward-curved and radial.

Forward-curved blades arch in the direction of the fan wheel's rotation. Such blades are especially sensitive to particulates. They provide a comparatively low noise level and generally find use for relatively small gas flows with a relatively high increase in pressure.

Backward-curved blades arch against the direction of the fan wheel's rotation. Smaller fans may have backward-inclined blades, which are straight, not curved. Larger machines use backward-curved blades with properly selected and shaped curvatures. These models provide good operating efficiency. Units with backward-curved blades of one form or another commonly serve in many applications. Such fans can handle gas streams with different characteristics and specifications such as those with low to moderate particulate loadings, etc. They easily can be fitted with wear protection but certain blade curvatures can be prone to solids' build-up. Backward-curved wheels often are heavier than their forward-curved equivalents because they run at higher speeds and require stronger construction. Backward-curved fans can have a high range of specific speeds. They are the most common units for relatively high pressure, medium flow applications. However, they also find use in a wide range of size, flow and pressure services.

Radial fans have wheels whose blades extend straight out from the center of the hub. Radial-bladed wheels often are favored for particulate-laden gas streams because they are the least sensitive to solids' build-up on the blades. However, they frequently generate greater noise and lower efficiencies. Radial blades appear in fans running at high speeds, low volumes and relatively high pressures, e.g., ones used in industrial vacuum cleaning, dust collecting, pneumatic conveying and similar systems.

Ideally, a fan should come with wheels or impellers that provide the highest efficiency consistent with the application. Backward-curved fans are more efficient than radial-blade ones and, therefore, are suitable alternatives for medium- and high-power ratings.

Forced-draft-fan wheels/impellers often come with backward-inclined or backward-curved blades. Induced-draft-fan impellers may be radial, backward-inclined or backward-curved, depending upon the gas environment. Induced-draft-fan blades usually are used in small fans, say, those below 0.7 m in diameter; induced-draft fans aren't common for large applications.

PERFORMANCE AND RELIABILITY

Operation at part load is very common for fans, so turndown and operating range are important. As an indication, plants often desire a turndown of 60% or less of the rated flow. This usually is provided using a variable speed drive (VSD), an inlet guide vane (IGV) system or a combination of the two. Some services have relied on other turndown systems such as a bypass, pressure reduction at suction, etc., but VSD, IGV or VSD+IGV commonly are specified because they are more efficient and more reliable. Surge or other instabilities are major

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factors limiting the minimum achievable capacity. The fan performance curve (pressure versus flow) preferably should show a continuously rising characteristic from the rated capacity to the surge. Note that many fan curves just plot theoretical values. Instead, strive to get performance curves corrected for the particular job gas at the specified conditions and based on performance tests of actual equipment at the shop or site performance tests at a very realistic configuration.

Shaft seals need great care because many fans have suffered seal problems or failures. In general, seal selection/configuration and seal maintenance/operation have been challenging. Many different seal systems for fans exist — e.g., labyrinth type, floating bushing, close-clearance annulus, honeycomb type, etc. Choose a type and model of seal that minimizes leakage from or into the fan over the range of specified operating conditions and during periods of idleness. Select a seal that can handle all foreseeable operating conditions, including those during startup and shutdown as well as any special operating modes expected. Many applications rely on double seals. For instance, fans in processing applications (except air services) with negative pressure at the shaft seals usually should have double seals. A seal for a critical service (such as toxic, flammable, etc.) generally requires provisions for a centralized buffer gas injection to minimize leakage.

Bearings are critical components in fans. Indeed, bearing problems have caused many trips. Hydrodynamic radial and thrust bearings have been popular because of their high reliability and theoretical indefinite life. They are common in large fans, say, above 150 kW. These bearings also are used in many fans in the medium range of size and power rating as well as those in critical applications. Insist on hydrodynamic radial and thrust bearings for challenging services such as high-speed ones, those for high temperatures (say, above 150°C), etc. Tilting-pad bearings have been used in high-speed fans. These bearings should be self-aligning and preferably supported on near-rigid pedestals independent of the fan housing to ensure that vibration, differential thermal movements or other forces from the fan housing don't affect them.

However, many manufacturers still use rolling-element bearings for small and some medium fans. Rolling-element bearings have limited life and relatively low reliability. Manufacturers of many of these fans can't use hydrodynamic bearings without changing their designs. Hydrodynamic bearings need more space and auxiliaries, an expensive oil lubrication system and numerous other provisions that make such a fan expensive and challenging. When you must opt for a fan with rolling-element bearings, take a few important steps. First, specify a high rated life, say, above 90,000 hours or 100,000 hours, for the bearings. (Some users have requested and gotten vendors to accept 140,000 hours!) Think about access and maintenance provisions for the bearings. Regardless of bearing type, getting to all bearings preferably shouldn't require dismantling ductwork or the fan casing. Overhung models should have provisions for supporting the rotor during bearing maintenance.

Many fans need circulating lubrication oil for their bearings. Filtering and cooling this oil before it goes to the bearings is essential. Provide a full-flow dual filter set with replaceable elements and suitable filtration degree (preferably 10 microns or less). Ideally, locate the filter set downstream of the coolers. Ensure the flow and conditions of the lubrication oil suffice to properly lubricate and cool the bearings. As a rough indication, keep the rise in oil temperature through the bearing and housing to less than 30°C. For most oils, the bearing outlet oil temperature should be below 75°C. Very small fans or blowers may use grease instead of oil to lubricate bearings. Temperature limits also usually apply. For grease lubrication, restrict the maximum bearing housing temperature to less than 75°C, preferably under 70°C. Don't allow oil or grease to leak outside the bearings; equip bearing housings with replaceable seals (usually, multistage labyrinth-type) and deflectors, both made of non-sparking materials.

All fans in even moderately high temperature services, say, handling gases above 150°C, preferably should have special provisions for cooling the bearings, i.e., properly configured oil, water or other cooling. For these hot services, the fan manufacturer should perform a thermal analysis for the bearings and seals taking into account the heat conducted by the shaft in these hot gas applications to optimize the cooling systems, lubrication oil system and overall thermal management.

Many fans use gear units or have integral gearing; these machines require a carefully selected lubrication oil and a proper lubrication oil system. Where a common system supplies oil to different pieces of equipment, such as a fan, a gear and an electric motor, select an oil whose characteristics are the optimum balance for all these applications.. ●

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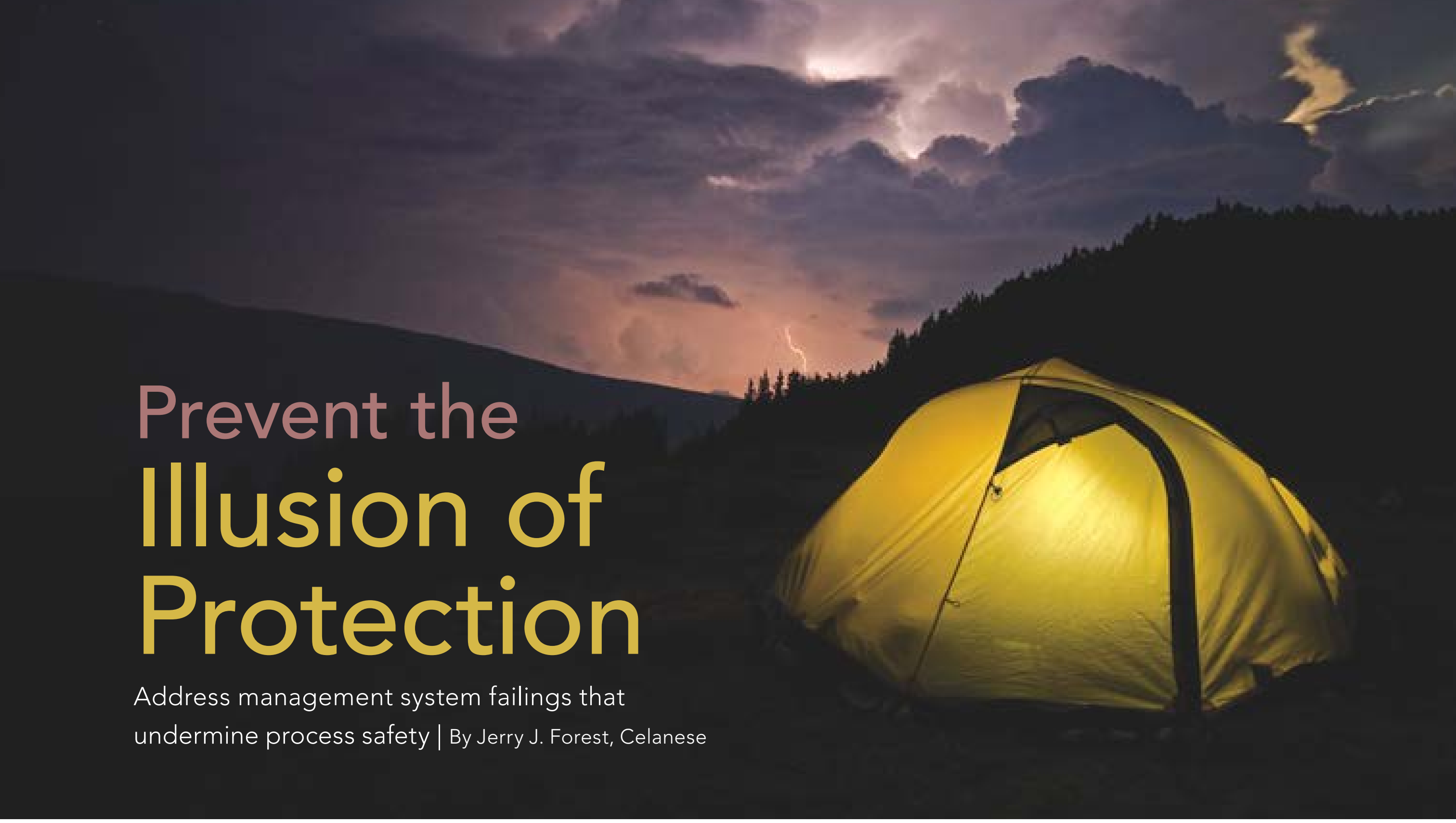


Prevent the Illusion of Protection

Address management system failings that undermine process safety | By Jerry J. Forest, Celanese

THE SWISS cheese model familiar to many safety professionals clearly illustrates that when weaknesses in barriers align, hazards can manifest [1]. If these barriers are selected via a risk-based methodology, the probability of failure is calculable. Because many companies use some type of semi-quantitative risk matrix and require mitigation of risks to a category level commensurate with a very low probability of failure, multiple barriers rarely should fail at the exact same time.

Yet, our experience in industry is that most large consequence process safety incidents occur due to coincidental failures of multiple layers of protection (LOPs). A likely reason for this is that, while these layers are assumed independent — and, thus, give the illusion of protection — they actually aren't because they fall under the same management system. A weak management system can be a common cause of the multiple failures.

This article examines the elements of an integrated process safety management system. It describes one system that can be created and used to prevent the illusion of protection.

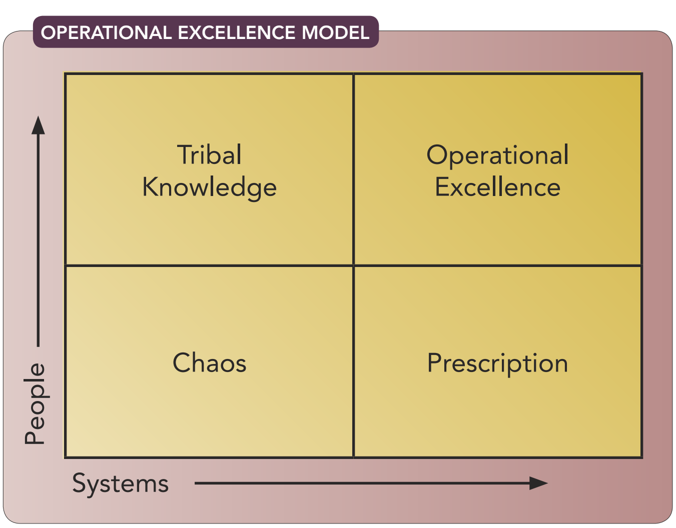


Figure 1. People and systems both play key roles in achieving success.

WHAT IS A MANAGEMENT SYSTEM?

Since the Center for Chemical Process Safety (CCPS) issued its 20-element risk based process safety element model, a clear distinction has existed between *process safety* and the process safety management (PSM) regulation of the U.S. Occupational Safety and Health Administration (OSHA). The former term is defined as: "A disciplined framework for managing the integrity of operating systems and processes handling hazardous substances by applying good design principles, engineering, and operating practices" and is in place to prevent incidents [2]. The later term refers to the rule that regulates industry. The two shouldn't be used interchangeably. Similarly, PSM shouldn't be confused with a management system. PSM simply consists of the 14 elements that OSHA regulates in covered processes.

Common characteristics used to describe management systems include a combination of people and systems, as illustrated in Figure 1.

Weak systems executed by weak people lead to chaos. Strong people can provide a strong management system. However, if that system isn't documented, the organization will lose knowledge when people leave. Similarly, a management system only made up of procedures either leads to people blindly following them without critical thinking, or ignoring the procedures. An effective management system requires knowledgeable people executing the necessary process safety elements with discipline to produce repeatable results. This type of system leads to operational excellence and continuous improvement.

CCPS's Vision 20/20 describes the characteristics of a vibrant management system as "all employees must clearly understand their role in managing process safety." Furthermore, the management system: "is documented, accessible, and easily used; defines how operations are conducted at the workplace; promotes safety in design, operations, and maintenance; and is agile and continuously improved" [3].

With these characteristics in mind, a management system is: "a formally established set of activities designed to produce specific results in a consistent manner on a sustainable basis" [4]. Definition of these activities is the next logical step in creating a management system.

The past 20 years has seen the development of several process safety models, including those published by CCPS, the American Chemistry Council, the American Petroleum Institute, OSHA, the U.S. Environmental Protection Agency and the European Union [4]. The comprehensive model developed by CCPS appears in "Guidelines for Risk Based Process Safety" [5]; it's summarized in Table 1 and used for discussion purposes here.

The CCPS model includes 20 elements categorized into four pillars (Table 1). These pillars — management commitment; understanding hazards and risks; management of risks; and learning from experience — make up the key elements of an effective management system.

INTEGRATING MANAGEMENT SYSTEM ELEMENTS

The illusion of protection arises when the various process safety elements aren't connected in a management system. The selection and use of safe operating limits (SOLs) illustrates the importance of interconnectivity of process safety elements in a management system [6].

Selecting SOLs requires choosing appropriate process safety information (PSI) to understand the hazards of a process. This enables identifying high risk scenarios as a hazard identification and risk assessment (HIRA) process proceeds. The team might assign SOLs to those scenarios that operator action — taking into account equipment design and the dynamics of the process — could prevent [7]. Once selected, the SOLs become part of the PSI.

The SOLs then must be documented and accessible. In addition, operators must receive initial and then refresher training. One way to integrate these parts of the management system is to transfer the information gained with PSI and HIRA to standard operating procedures (SOPs) and operator certification/recertification materials. Critical alarms often accompany SOLs; therefore, attention to alarm management is crucial to ensure the distributed control system's configuration aligns with the HIRA results. This process should be documented. Because failure to act on an SOL could lead to significant consequences, preventative maintenance of instruments that measure the deviations from normality deserves serious consideration.

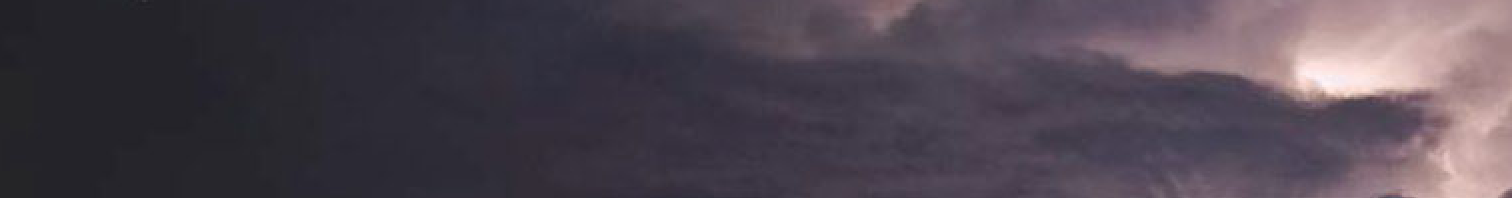
Auditing ensures each of the elements described above are interconnected and working as intended. The risk associated with changes to anything in this process must be evaluated through a management of change procedure. Finally, any of these elements can fail without the common tie-in of management commitment and review. Figure 2 illustrates how each of the process safety management system elements are interconnected.

The management system unites the process safety elements. Without integrating these elements, the barriers and LOPs identified in the HIRA only are an illusion of protection. If those LOPs aren't considered in building competency, documented for ease of access, taken into account for equipment maintenance and other elements of the process safety management system, it's easy to understand how this common failure mechanism can occur.

CCPS PROCESS SAFETY MODEL

Commit to Process Safety	Understand Hazards and Risks	Manage Risks	Learn from Experience
Process Safety culture	Process knowledge management	Operating procedures	Incident investigations
Compliance with standards	Hazard identification and risk analysis	Safe work practices	Measurements and metrics
Process Safety competency		Asset integrity and reliability	Auditing
Workforce involvement		Contractor management	Management review
Stakeholder outreach		Training Management of change Operational readiness Conduct of operations Emergency management	

Table 1. Its four pillars include a total of 20 essential elements.



BUILDING A MANAGEMENT SYSTEM

There are many ways to design a management system. Companies that have ISO certification may have management systems documented following the International Organization for Standardization requirements. "Guidelines for Implementing Process Safety Management" [4] also describes how management systems are built.

When building a management system, adhere to some important best practices:

- Document roles and responsibilities for all levels of the organization.
- Keep written procedures simple and short, and include instructions and requirements, not descriptions.
- Group similar requirements together. For example, list all training requirements in one document rather than dispersing them through several.
- Include instructions in the system for maintaining uniformity in the documents.
- Establish an approval process for changes.
- Develop formal auditing protocols to ensure that elements of the management system are being followed.

With these items in mind, adopt a three-tiered approach for the management system.

Tier 1. In this tier, documents describe *how* a company or a site does business. For process safety, the Tier 1 document might detail CCPS's 20 elements of process safety, the high requirements for each, and how every element is addressed. Some elements only might have a Tier 1 requirement. This gives individual sites or units the flexibility to comply with the higher level requirements commensurate with applicability.

Tier 2. Here, documents cover aspects requiring more prescription. They describe *what* is required. For example, a Tier 1 requirement might be that each process undergoes a HIRA review once every 5 years. Because this element is essential to understand the hazards and the risks of a process, the Tier 2 document describes specifics of the HIRA, such as team composition, methodology, minimum PSI used, reporting and approval — to name a few.

Tier 3. In this tier, documents describe *who* is responsible for *what*, and *how* it gets done. Let's consider, for example, incident investigation. The Tier 1 document might mandate reporting of all incidents. Tier 2 might have more prescriptive requirements, such as an incident must be reported within 24 hours, categorized (with instructions provided on how to classify), and communicated in a certain way. A Tier 3 document describes who reports incidents and how they report them. This might differ among sites or even units at a site. (Incident investigations often reveal deficiencies in Tier 3 documents that need addressing.)

Success of such a tiered management system depends upon strong ongoing management support. It also requires adequate training for all involved, auditing for effectiveness, and periodic

INTEGRATED MANAGEMENT SYSTEM FOR SAFE OPERATING LIMITS

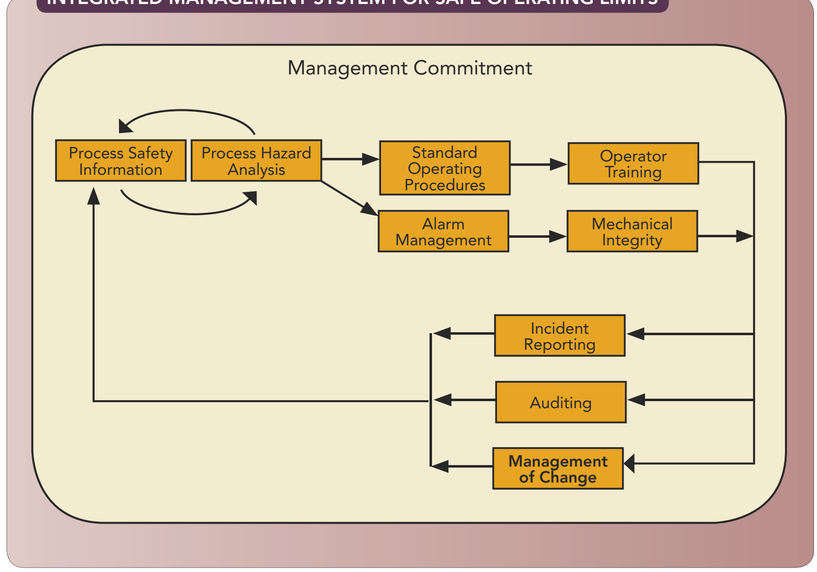


Figure 2. Failure to properly integrate elements can lead to the illusion of protection.

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management review and continuous improvement.

FORESTALL FAILINGS

The CCPS 20-element process safety model, if used properly, provides a basis for effective protection against incidents. You can't just pick and choose portions. Rather, the various process safety elements must share an intimate connection. This connection is made possible by a functioning and vibrant management system that: "is documented, accessible, and easily used; defines how operations are conducted at the workplace; promotes safety in design, operations, and maintenance; and is agile and continuously improved" [3]. Without this vibrant management system, we only have the illusion of protection. ●

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ADDITIONAL READING

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USE DYNAMIC SIMULATION TO IMPROVE PROCESS SAFETY

A digital twin can help spot and combat risks during design and operation

By Timothy Herbig, Bluefield Process Safety

PROCESS UPSETS at many chemical plants can quickly turn dangerous. Dynamic simulation can give engineers and operators the power to reduce potential process upsets or non-routine situations.

Long accepted for its strength in training, dynamic simulation can provide additional far-reaching value for enhancing safety. By using a digital twin as a double for the existing process (Figure 1), dynamic simulation offers a protected environment in which to practice safe deployment of process strategies and justify further safety improvements. Unfortunately, myths about such simulation (see sidebar) frequently thwart its application.

As facilities attempt to achieve their safety risk tolerance by performing a layers of protection analysis (LOPA), simulation can help determine how to improve the individual risk factors involved in reaching the defined tolerance. (For details on how to avoid coincident failures in layers of protection, see "Prevent the Illusion of Protection," p. tk, url tk.)

A wide variety of chemical plants can benefit from dynamic simulation. Here, we'll use examples from ammonia production. Ammonia facilities often choose to perform shutdowns during process upsets because there's so little time, minutes at best, to react to potentially hazardous situations. While many process plants don't require as aggressive a response to conditions, an ammonia facility provides an ideal environment to illustrate the value of dynamic simulation.

IMPROVED RESPONSE TO NON-ROUTINE SITUATIONS

Research shows that in stressful environments, such as during non-routine and emergency situations, operators make more errors than under routine circumstances. The goals of simulation include improving safety by reducing stress and preparing operators to perform non-routine tasks often enough so they feel more routine. Carrying out simulated tasks at an operator station, as if in real life, improves response time by invoking muscle memory in ways that learning via pen and paper or classroom instruction can't.

Operator response time is a factor in a LOPA. If performed often and well enough, a task can be considered routine rather than non-routine; this, in turn, could lower the risk factor of a process area.

At an ammonia plant, a loss of feed water can create a low level within the steam drum, which may lead to water being reintroduced to a hot drum, causing catastrophic vessel failure. In this case, during simulation, operators might find a low level inside the steam drum and practice implementing a course of action to fix the cause, loss of feed water.

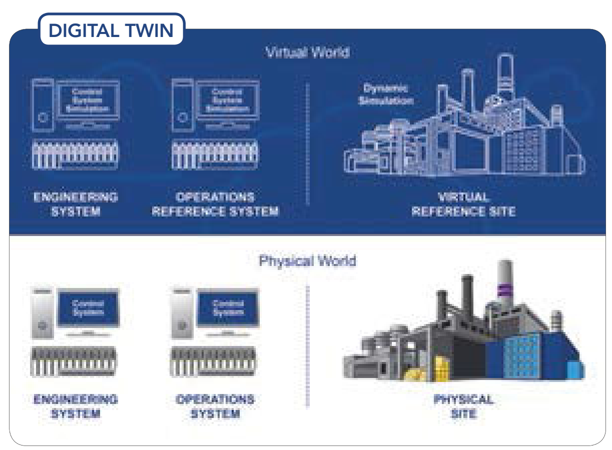

Figure 1. An identical replica in the virtual world allows testing process changes and providing hands-on training and real-world results without affecting the actual plant.

After using dynamic simulation during training, the response of personnel becomes more accurate and faster, thus enhancing the independent layer of protection (IPL). Because the team acts safely and quickly, the safety instrumented system (SIS) activates less.

Actually, a dynamic simulator opens up a number of opportunities related to operator performance.

Train on a digital twin instead of the real plant. Training on a live, working control system is less than ideal because of risks to the process and the associated stress in the learning environment. By training on a digital replica of the process — including devices, control system, and higher networks and systems — operators know how to work with the system interfaces. The simulation doesn't affect the live process in any way.

Create a solid baseline of performance. Using dynamic simulation, a facility can establish a minimum acceptable performance for operators in given situations. Ammonia plants, which often are located in remote locations, usually face a shortage of experienced operators. Simulation enables training all operators to the same baseline level as well as evaluating how quickly they detect a situation, how much time they need to respond, and how long it takes for the action to produce results. After baselines are set, trainers can benchmark operators over time until tasks are performed to achieve desired safe outcomes.

DON'T FALL FOR COMMON MYTHS

Five myths too often impede the wider use of dynamic simulation:

1. *Low-fidelity simulation is useless.* Low-fidelity simulations aren't exact replicas of the real system. However, in creating a LOPA, a near replica could provide enough proof that a person would know what to do in certain situations.
2. *Simulation is just for startup.* When kept current, simulations are valuable during skill re-evaluation. For example, alarms change over time and responding to them is critical, so keeping those current in the simulation is important.
3. *Testing individual sensors and assets is enough.* Facilities that don't test assets together in the system put themselves at risk. Simulation brings all devices together to verify, for example, that voting works as designed.
4. *Use experienced operators to train new ones.* As operators perform tasks, they inadvertently might modify procedures. If included in training, such shortcuts can compromise approved safe procedures. Training through simulation preserves the approved procedures.
5. *Alarm hitting and tripping are the same.* High-level alarms don't necessarily need to stop the process. With enough practice, personnel can recognize situations and be ready to respond before a higher alarm trips and stops the process.

Design structured training. In an emergency, each person plays a role in de-escalating the situation. A dynamic simulator enables the trainer at the facility to educate every operator in standard plant procedures to execute that person's emergency role — and then to evaluate the operator's skills over time. The skillsets themselves can be evaluated to ensure they're effective in emergencies.

Save time during refresher training. Simulation can expedite operator review of updated safety situations. Ammonia plant startups have many hazardous simultaneous activities and can benefit from, for example, compressing tank-fill time so operators learn skills without waiting for the fill.

Provide proof to safety evaluators. Under many circumstances, safety evaluators that go into a facility must weigh the soundness of performance reviews provided to them. A simulator can document how operators performed during training, giving the evaluators more confidence they have an accurate report of abilities.

SAFE DEPLOYMENT OF PROCESS STRATEGIES

Plant staff must be sure of the changes they make to improve process safety. By combining LOPA and simulation, personnel can detect weaknesses in design and refine process areas.

LOPA WORKSHEET

LOPA: References

Bluefield Process Safety Poj. No.: 170XX
ABC Chemical Corp.
Location: St. Louis, MO, USA
Unit: Cooling water tower

LOPA Rev.: A
LOPA Rev. Date: 05-2018
Facilitator: Timothy Herbig

Initiating Cause Opportunity	Frequency
Error during high-stress, non-routine task	1
Error during routine or low-stress task	0.1
Failure executing routine written procedure	0.01
Failure executing special written procedure with check	0.001
Failure of lockout/tagout procedure	0.001
Routine event	1

Figure 2. In this project, a non-routine task contributes ten times more than a routine one to the ultimate risk results.

For example, while performing a LOPA on a section of the simulated facility, engineers might find conditions that either are unsafe or non-optimized. Digging further into the simulation and experimenting with designs, they might identify ways to improve that area of the plant.

An ammonia process can be vulnerable to many deviations, such as low level on jacket water or turbine over-speeds. While these conditions themselves don't pose a danger to the work site, if not reacted to properly, their consequences can injure or kill employees who operate the process. Personnel can safely test, via simulation, proposed responses to ensure they do what they should. Key in all these activities: the live process remains unaffected until the updates are polished and safe.

When considering dynamic simulation to help ensure design and deployment of safe processes, keep in mind a variety of opportunities.

Perform alarm evaluation. A team can affect safety meaningfully by designing an alarm strategy that reduces, for example, nuisance alarms so that an operator only sees significant alarms, i.e., ones that demand action. For instance, during an ammonia plant startup, alarms frequently are set to align with nameplate as recommended by the manufacturer. However, the nameplate often eventually gets exceeded as a facility continues to improve operations and systems through debottlenecking. Dynamic simulation enables re-evaluation of potential events in the plant environment so they cause fewer alarms. Without simulation, that re-evaluation requires a great deal of time and can fall to the bottom of the to-do list.

Match the fidelity of the simulation to the need. The area of the plant that most needs improvements in safety may not require a high-fidelity simulation. Indeed, in safety analysis, setting the fidelity at a low level sometimes may suffice, thus saving some costs and time.

Conduct regression testing. With a valid simulation of the existing process, an engineering team can set up tests to compare proposed and existing conditions to ensure that changes won't create unsafe conditions. Using simulation, this testing

can be largely automated and easily documented for record and compliance purposes.

Test the SIS. By simulating the SIS together with the distributed control system, a site can confirm that, if the SIS were called upon, the systems would act together as they should. Or it can see where changes are necessary to improve response and safety.

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JUSTIFICATION OF SAFETY IMPROVEMENTS

Simulation can give the safety team tools to prove how process or equipment changes can enhance safety, quality and production time. Simulation also provides an opportunity to test the effectiveness of safety system IPLs.

For instance, the design team might notice that a process change can offer a provable four hours of better production or save several hours in a startup. Further investigation might show how to improve an area's safety integrity level (SIL) rating.

An ammonia plant's SIS often is programmed aggressively to shut down the process for a variety of situations that could, but don't always, pose dangers. Although an SIS responding unnecessarily can result in a substantial expense, the SIS must act just in case. Many facilities would benefit if their teams could realistically evaluate potentially hazardous situations before programming the SIS to activate.

To improve safety and avoid situations where the SIS must activate, many teams perform a LOPA. Combined with dynamic simulation, a LOPA worksheet (Figure 2) helps them determine the most effective deployment of layers of protection. After using simulation to analyze the potential problems, teams can add layers of protection or adjust the process to avoid the potential problems. Then they can re-simulate the revised process to evaluate the solutions.

Dynamic simulation can perform a valuable role in several ways.

Avoid over-engineering. A LOPA that indicates a facility needs double redundant block valves may lead to significant

over-engineering. In general, over-engineered safety systems aren't necessarily safer; they're just over-engineered. Simulation could check, for example, whether loss of lube oil pressure requires a SIS response at an ammonia plant before a facility incurs the added expense of extra engineering and maintenance. Facilities need the least complex systems that implement the process safely. Simulation can show where alternative technologies or people, rather than systems, can handle unique and complex tasks.

Set the IPL accurately. Simulation allows a team to test the automation IPL and reduce system errors. In fact, the testing might indicate the facility has more IPLs than required, enabling elimination of those that aren't needed — thus maintaining safety while avoiding unnecessary costs. Of course, the opposite also might occur — testing might show the need for more IPLs, thus saving the facility from potentially dangerous conditions.

Verify human factors. A well-designed simulator can confirm that human factors in a process and system are proper and need no additional capital expense. For example, does the operators' human/machine interface (HMI) enable them to respond more quickly and efficiently by giving them easy navigation and information at their fingertips, or is it bulky and obstructive to the point of actually reducing their effectiveness? Simulation allows testing new systems well in advance of their implementation and reviewing by all interested parties rather than just their designer.

ACHIEVE A SAFER REALITY

As the ammonia applications highlight, use of dynamic simulation in many process situations can save time and money toward creating a safer facility. In addition, dynamic simulation prepares a team to go online with fewer errors by helping them understand and reduce the risks and training them for the hazards that could happen.

As teams design the process and before they implement the physical design, dynamic simulation can tell them if they are improving the LOPA results. If other design options are on the table, the team can try those ideas before moving ahead. ●

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ACKNOWLEDGMENT

The process simulation team at Emerson Automation Solutions provided support and technical information for this article.

Refinery Improves Cybersecurity

By Mark Littlejohn, Honeywell Industrial Cybersecurity

Site bolsters defenses by using managed security services

THE PORT Arthur, Texas, refinery of Total Petrochemicals & Refining USA wanted to address today's rising security threats while allowing its staff to keep focusing on production. The facility, which has a capacity of 169,000 bbl/d of transportation fuels, processes crudes with conversion capabilities centering on coking, fluid catalytic cracking and reforming technologies. The site is part of the Refining-Petrochemicals Americas Segment of Total S.A., La Défense, France.

The refinery worked with Honeywell to achieve an enhanced cybersecurity posture; this is the first effort of its kind within Total Petrochemicals & Refining USA.

Total's approach — teaming up with a recognized cybersecurity specialist — made good business sense. The company realized that refinery personnel are very knowledgeable in plant processes but often don't have the resources and skills to maintain the ongoing security posture of the process control network (PCN).

Yet, cybersecurity now is a pressing concern. Bad actors increasingly have targeted industrial control systems (ICSs) since the discovery of Stuxnet in 2010. As recently as March 2019, a ransomware attack forced a large aluminum producer to move to manual operations. The discovery of more and more industrial exploits has pointed up that even common practices like using USB drives to maintain an ICS can enable bad actors not only to propagate malware but also to take over machine commands.

For industrial sites, specific cybersecurity vulnerabilities can include:

- Lack of security policy and procedures;
- Undocumented or undiscovered ways to gain access to the industrial process network from the public Internet;
- Access points that span the business local area network to the PCN;

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- Out-of-date anti-virus software;
- Obsolete firmware and operating systems that can't be maintained with security updates and patches;
- PCN architectures implemented without network segmentation and other security design considerations; and
- Incomplete or infrequent backup processes.

As part of the lifecycle management of the control system, Total's engineering staff consulted with Honeywell's cybersecurity experts to perform a complete site audit to identify security vulnerabilities and develop a strategy to mitigate threats. Total corporate representatives met with Honeywell specialists to define and implement an approach to updates, patching and other cybersecurity activities that allowed the plant to improve site security while still focusing on its core refining processes.

Key to implementing an effective cybersecurity program was supporting the small in-house automation department at Port Arthur responsible for overseeing a relatively large PCN consisting of approximately 120 servers and workstations.

A RANGE OF SERVICES

In approximately 2011, Honeywell's Managed Industrial Cybersecurity Services began supporting the Total team. The services have helped to reduce the risk of security breaches and manage the security posture of the process control infrastructure. Honeywell provided skilled industrial security engineers to support the ongoing maintenance and monitoring of the site's industrial cybersecurity.

Honeywell's cybersecurity services for the Port Arthur Refinery include:

- Honeywell Secure Connection, featuring encrypted communication to protect data even through the site's corporate network;
- Automated patching and anti-malware services to ensure ongoing updating of all computers with the latest security protections;
- Continuous monitoring and alerting services to check the performance and health condition of the PCN, including controllers, servers and workstations; and
- Intelligence reporting services to transform system statistics into actionable trends.

When a facility like the Port Arthur refinery launches Honeywell's Secure Connection, an authenticated, encrypted virtual private network is established. Various Honeywell and Total entities can connect to this network to help the refinery address security or general maintenance issues. Having a secure means of remote connection and maintenance also can help reduce downtime and troubleshooting related to any issues.

MEDIA MONITORING

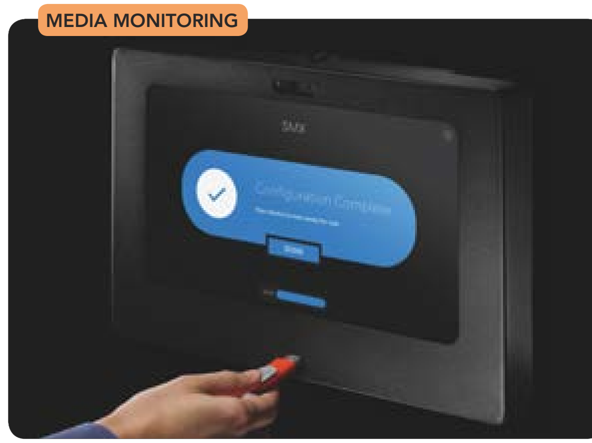

Figure 1. Site has installed special system that checks USB devices.

Honeywell provides a dedicated site support specialist as part of Total's services agreement. This person assists with patch and anti-virus automation, security and performance monitoring, activity and trend reporting, advanced monitoring and co-management, and secure access.

With the support from Honeywell, the Port Arthur refinery has greater visibility into the cybersecurity and system conditions of its PCN architecture.

Total now has added Secure Media Exchange (Figure 1). This checks USB devices entering and exiting the facility. It automatically updates threat intelligence and includes human response capabilities to help detect and stop malicious USB actions.

Future plans include expanding the scope of Honeywell's services to cover additional assets such as analyzer networks and safety systems. Total also wants to provide global users on its business network with safe and secure access to cybersecurity information when needed.

Honeywell's suite of technology infrastructure services has helped Total secure the various aspects of its distributed control system. It includes an array of security defenses integrated to protect the network, workstations, applications and process equipment.

This approach results in enhanced operating system security, stability and reliability, ultimately contributing to improved production and safety for complex industrial facilities. ●

MARK LITTLEJOHN is Houston-based director, managed security services, for Honeywell Industrial Cybersecurity. Email him at mark.littlejohn@honeywell.com.

Don’t Pull Your Punches with a Knockout Drum

Fixing mist eliminator and transmitter issues demands significant steps

ELIMINATE THE IMPULSE LEGS

Consider the following points:

1. Impulse legs to the pressure transmitters are plugging frequently. Eliminate impulse legs altogether by using pressure transmitters with diaphragm seals and capillaries. (Some vendors call them remote diaphragm seals.) [Ed.: for information on such seals, see “Rethink Distillation Column Pressure Measurement,” http://bit.ly/2x214KR.] Thus, the process stream containing particulates does not come in contact with the capillary. The diaphragm is bolted onto the tank nozzle. The diaphragm senses pressure, which is transmitted to the pressure transmitter. This arrangement should reduce, or even eliminate, the frequent plugging problem.

2. The diaphragm arrangement should give relatively trouble-free operation. However, if you experience problems with deposits sticking on the diaphragm, provide an isolation valve for the diaphragm, so that it can be cleaned and put back in service.

3. Capillaries use a fluid to transmit a pressure signal to the transmitter. In an extremely cold or hot environment, the fluid may not work effectively. Specify to the pressure transmitter vendor the range of ambient temperatures expected. In these situations, you may need to provide a means to maintain temperatures in the working range of the capillary fluid.

4. The problem statement does not specify size distribution of particles in the wet gas. However, if there are particles roughly 10 micron or above, you might consider passing the wet gas through a cyclone separator and then to the knockout drum that contains the mist eliminator. The key is to reduce particulate load to the mesh pads.

5. You also can get cyclonic action by introducing the wet gas stream tangentially in your knockout drum. However, at this stage, such a change may be difficult because it requires installation of a new nozzle followed by pressure-rating certification.

6. Separation efficiency of mist eliminators rises sharply with increasing velocity — until you reach an upper limit where re-entrainment will severely affect efficiency. Thus, there is an operating range of velocities where the mist eliminator is effective. Ensure the velocity of wet gas through the mist eliminator is within the design range.

7. Although chemical species shown in the wet gas are not highly corrosive, if you have older vessels made of, say, carbon steel, you may have corrosion; this could cause the mist eliminator’s plugging. During the next turnaround, take samples of the deposits in the mist eliminator.

8. The problem statement does not indicate any problems with the TOX. However, it seems to me that with considerable droplet carryover in its feed the TOX could experience flame stability problems.

GC Shah, senior advisor
Wood, Houston

ANSWER SOME KEY QUESTIONS

This actually is a two-part problem. The first is fairly simple but the second will require time and personnel resources.

The first problem — the impulse line plugging — can be easily solved by installing capillary pressure transmitters, thus eliminating impulse lines and, therefore, plugging.

Installing two transmitters is

THIS MONTH’S PUZZLER

We installed a new knockout drum with a better mist eliminator (Figure 1— online at http://bit.ly/2Iqz0ac) to replace a drum that was giving us problems. The new drum, like its predecessor, is at the inlet of two thermal oxidizer (TOX) systems. “Flow is controlled by a pressure transmitter downstream of the mist eliminator,” notes the production foreman. Operations had project engineering install two redundant transmitters in the old drum. However, the impulse tubing for both transmitters plugged so often that the TOX systems downstream tripped on low pressure every few weeks. Those systems run at 2 psig at the inlet with the trips set at 0.5 psig. The pressure drop across the mist eliminator is about 0.3 psig when clean and about 0.5 psig when dirty, according to the manufacturer; our maintenance engineer says 0.75 psi is more like it. We installed two redundant transmitters on the new drum and their impulse lines also suffer from plugging: six months after the new drum was installed, the TOX systems have started tripping again.

Our grizzled, old maintenance engineer is disgusted. He hoped this problem would be solved by now. He says we should have included a steam purge in a manifold and the mist eliminator; he drew up a sketch in a few minutes when I asked his opinion on how to address the problem (see the figure). The young engineer who ran the project didn’t see a need for it, figuring the improved mist eliminator would do the trick.

What do you reckon that we should do to solve the problem? Why do you think the mist eliminator failed to work effectively to prevent fouling of the impulse tubing? Can you suggest a better way to control the TOX systems or reduce the tripping? Is it possible to improve the performance of the mist eliminator?

puzzling. If one impulse line plugs, what would keep the second from plugging?

The line purging approach, while a good idea for keeping the impulse lines free of plugging, seems to be introducing vapor back into the process downstream of the mist eliminator.

The second part of the puzzler is more difficult, mainly because there are not enough data to attempt to solve the problem. This initiates a few questions:

1. Why was the previous knockout drum replaced? Industrial tanks usually will last longer than the engineer who orders them. It may get to the point that no one will remember who requisitioned it in the first place.
2. Was any tank wall corrosion found in the replaced tank?
3. If the answer to the second question was yes, was the new knockout drum made of corrosion-resistant material or coated to prevent oxidation?
4. What were the parameters of the mist-laden gases entering the mist eliminator (temperature, density, viscosity, etc.) and what were the "others?"
5. Have provisions been made to clean or backwash the mist eliminator? The mist eliminator functioned acceptably for six months and then seemed to require cleaning; notice the increase in pressure drop with age.
6. Has the mist eliminator been installed properly? The sketches indicate it is installed perpendicular to the knockout drum. Would it be better to install it horizontally so that the liquid condensed and the material clogging the impulse lines would drip back into the knockout drum? This would require a change to the internals: fixtures would have to be installed in the drum to hold the mist eliminator and isolate the downstream gas/vapor from the rest of the tank.
7. Finally, because TOX operation is shutting down "every few weeks," this is not only an operation's problem but also increases costs and reduces company profits. Therefore, I recommend putting together a team that includes a chemist, a metallurgist, a chemical engineer, and operation's personnel to thoroughly examine the process and determine the root cause or causes of this problem.

Stephen Curyk, consultant
Lago Vista, Texas

CHANGE THE CONTROLS

First of all, pressure doesn't control flow as the operator described. Pressure control valves being called flow control valves is typical; however, proper flow control would be a good idea. I would suggest an insertion-type device, i.e., a pitot tube, annubar or perhaps even a target. This could give you real flow measurements to aid in a material balance because vent flows feeding TOX systems tend to get forgotten in plant balances.

By redundant, I assume that operations switches back and forth between the transmitters. Or do they run them together? It probably won't matter because the tubing comes from the same tubing bulkhead nozzle into an 8-in. blind flange. Both tubes will foul at the same time.

The maintenance engineer is on to something. Purging with steam may unplug the impulse lines but it also will cause additional condensation downstream; check flow capacity of the liquid discharge nozzle and pipe from the knockout drum to the TOX fan. Also, if there are agents in the gas stream that will react with steam or impurities in the steam, then corrosion or plugging in the TOX systems could be a problem. Maybe, pulses of steam would be okay but compressed air probably would make more sense. Perhaps a non-fuming, less likely to precipitate acid such as acetic or inhibited hydrochloric acid might do a better job of cleaning the tubing. Another idea would be to build the tubing so it can be disassembled quickly without interfering with plant operation.

Alternatively, you could locate the transmitter diaphragms on the drum flange directly; it's a low-pressure vessel (ASME: ≤ 15 psig), so modification is okay but follow ASME construction practices anyway. I like the maintenance engineer's idea of separating the pressure taps, so long as they are not too far apart. Note that different instruments always will produce different readings even if on the same tap.

Steam might work well to clean the mist eliminator. Nitrogen is too expensive at up to $3/100 ft^3 of liquid in cylinders at 230 psig; air could be a fire hazard because flammable liquids are present. Steam may provide the added benefit of possibly dissolving some of the solids into the steam condensate. The temperature of the steam coming out of the regulators won't be saturated, so be mindful of the temperature limit on the mist eliminator materials.

Dirk Willard, consultant
Wooster, Ohio

SEPTEMBER'S PUZZLER

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

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

Send us your comments, suggestions or solutions for this question by August 12, 2019. We'll include as many of them as possible in the September 2019 issue and all on ChemicalProcessing.com. Send visuals — a sketch is fine. E-mail us at ProcessPuzzler@putman.net or mail to Process Puzzler, *Chemical Processing*, 1501 E. Woodfield Rd., Suite 400N, Schaumburg, IL 60173. Fax: (630) 467-1120. Please include your name, title, location and company affiliation in the response.

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

Ensure Satisfactory Sampling

Drawing representative streams from pressurized systems demands care

Temperature drops during sampling can create their own problems.

WHEN ACCURATE, online analyzers often give the best information on process compositions. However, such analyzers generally are expensive and delicate as well as time consuming and costly to maintain. So, plants tend to install a minimum number of them. Instead, most facilities send samples to a laboratory for monitoring and troubleshooting. Permanent sample installations with flow-through loops provide the most consistent method for gathering samples (see: "Get Valid Samples," http://bit.ly/2Eqlnmh). Flow-through loops also may be costly, though, and pose their own problems.

Troubleshooting frequently requires taking samples from rarely used locations. Samples from pressurized systems typically go into cylinders, often called sample bombs. These sample cylinders come in two main types: constant volume and constant pressure.

Most engineers are familiar with constant volume cylinders. They are fixed in place with valves at both ends. The downstream side of the cylinder may be vented to atmosphere (if safe) or coupled to a closed disposal/vent system. In use, the inlet and outlet valves are opened, and flow continues into the cylinder until adequate purging has taken place. Then, the outlet valve is closed, followed by the inlet valve. The sample now is in the constant volume cylinder.

When using constant volume sampling, a significant pressure drop can occur across the inlet valve. Consider the situation with a separator drum (Figure 1). Attempting to take a constant volume sample of the drum feed, if it's a pressurized liquid, may result in flashing across the cylinder inlet valve and, thus, two-phase flow going through the cylinder. In such a case, possible liquid/gas phase separation likely will render the sample unrepresentative. In addition, the laboratory will find the sample very difficult to handle.

One solution is to take samples of the streams downstream of the drum and then use separate analyses of the gas and liquid samples along with their flowrates to calculate the feed composition.

The gas sample is relatively straightforward. However, the downstream liquid still may flash — you may not have prevented the problem, just moved where it arises.

If you're dealing with a hot system, using a sample cooler on the liquid may drop the temperature enough to prevent flashing. This enables a constant volume cylinder to sample correctly.

Temperature drops during sampling can create their own problems for both gas and flashing liquid sampling. In some systems, the pressure drop across the inlet valve can lower temperature significantly. With sufficient moisture present, the cylinder valves may freeze open.

One solution to these sampling difficulties is to use a constant pressure cylinder. This type of cylinder has an internal piston. A fluid acting on one side of the piston raises the pressure to that of

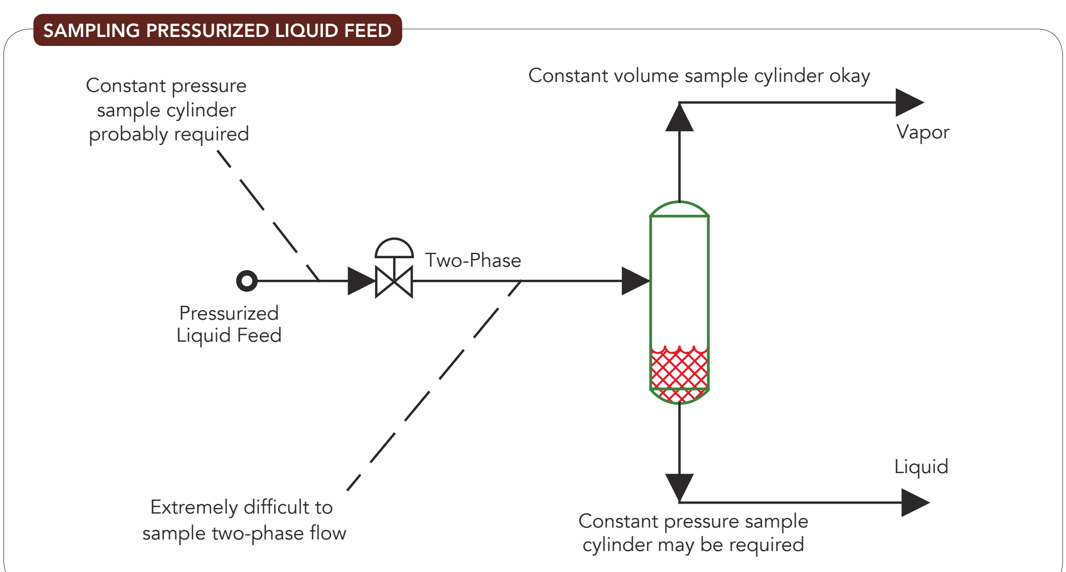

Figure 1. Flashing due to pressure drop across the inlet valve may lead to an unrepresentative sample.

the sampling system. The cylinder is attached to the process and the valves are opened; then the pressurizing fluid is gradually released until the cylinder is full. This type of approach would work for sampling the upstream liquid as well as the downstream liquid. The pressurizing fluid often is nitrogen or another gas inert to the process that doesn't affect the analysis if it leaks into the sample.

Pressurized cylinders must include a rupture disc. If the sample is full of liquid, even a small temperature increase can cause extremely high pressures due to density changes. Pressurized cylinder samples should include a vapor cushion to cope with these pressure changes. However, such a cushion doesn't negate the need for the rupture disk, or for careful sample handling on the way to the laboratory. Additionally, because the cylinder typically is at high pressure at all times, the rupture disc protects against other sources of over-pressure.

One disadvantage of the pressurized cylinder is that it normally isn't subjected to a purge step with free flow through the cylinder. So, any impurities present in the cylinder remain. These can come from more than just the cylinder itself. If normal operation through the sample point is low or no flow, surface contaminants and solids may build up. Taking a sample can push these into the cylinder.

If you must make low concentration (ppm or less) tests, take at least two samples, one after the other, with pressurized cylinders. Fill these sample cylinders slowly. Low entrance velocities will help avoid pushing surface contaminants into the samples. If the first sample gives a higher concentration of interest than the second, surface contamination probably is the culprit. In such a case, continue sampling until only small changes occur in the concentration between consecutive samples.

(For pointers on sampling systems for online analyzers, see "Choose the Right Sampling System Transport Line," http://bit.ly/2QdgAzx, "Consider Flow Regime's Impact on Sample Analysis," http://bit.ly/2EBrc2f, and "Check Sample System Pressure Drop," http://bit.ly/2EBrc2f.)

ANDREW SLOLEY, Contributing Editor
ASloley@putman.net

Nitrogen Generators Start Up Fast

NGMs 1–3 membrane technology units offer a highly efficient, compact and simple on-site system for low-flow N_2 requirements, with the added benefits of minimal maintenance and operational costs, says the company. With three models to choose from, the generators feature fast start-up time, taking only a few seconds to produce nitrogen at the outlet, resulting in maximum uptime assurance and ontinuous nitrogen availability 24/7. The generators offer zero performance loss at high ambient temperatures and very low service requirements. The units consist of one or multiple high-performance membrane modules combined to achieve the nominal inlet flow, ensuring maximum compressed nitrogen output for the minimum input of compressed air.

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Siemens Corp.
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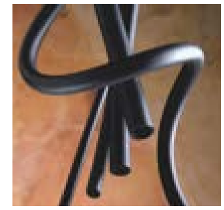

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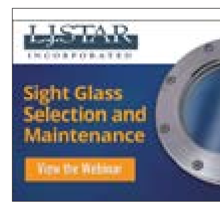

Improperly specified, installed or maintained sight glasses can represent the weakest link in a processing system. Watch this tutorial webcast from the process engineers at L.J. Star to see how others are specifying and maintaining sight glass installations in their facilities.

L.J. Star, https://www2.ljstar.com/l/12112/2019-06-11/7gs9h4

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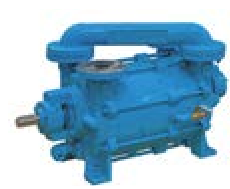

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Singapore Gets Closer to Zero Waste Goal

New research facility uses slagging gasification technology to convert waste to energy

Waste poses a serious challenge because the island country has only one landfill site.

IN 1970, Singapore generated just under 500,000 tons/yr of solid waste. The country's massive growth in population and industrial activity since then has seen this rise to 7.7 million tons/yr, with the figure forecast to grow further in coming years.

However, disposal of this waste continues to pose a serious challenge because the island country has very limited land stock and only one landfill site.

The National Environment Agency (NEA) plans, develops and administers Singapore's hazardous waste management systems and has implemented a four-point plan to help the country reach its target of generating zero waste. This involves waste minimization/prevention; recycling; waste-to-energy (WTE) technologies/volume reduction; and landfill.

Currently, the island recycles 4.63 million tons/yr of solid waste. Incinerators reduce the rest by up to 90%. The heat recovered from these units creates steam used to generate electricity — meeting up to 3% of Singapore's needs. Ash and other non-incinerable wastes go to the Tuas marine transfer station for barging to Semakau landfill for final disposal.

Now, the country has taken another important step towards its zero-waste goal with the commissioning of a WTE research facility at Tuas South on the campus of Nanyang Technological University (NTU). NEA contributed S$12 million ($8.8 million) of the overall S$40 million ($29 million) cost of the facility, which is slated to operate for 10 years.

The plant turns municipal waste from the NTU campus into electricity and other useful resources. It's also a double first for the nation in technology terms as it combines slagging gasification technology with biomass charcoal as auxiliary fuel.

The facility can treat 11.5 tons of waste daily. This waste is sorted, shredded and transported via a conveyor and bucket lift to the top of the furnace tower; biomass charcoal helps maintain the molten slagging layer at the base of the furnace at 1,600°C.

The waste is dried and gasified as it moves down the furnace. About 85% of the waste converts to syngas — mostly carbon monoxide and hydrogen. This flows to a secondary combustion chamber where it's burned to heat a boiler to produce steam. The steam then drives a turbine that generates electricity for the campus.

Meanwhile, 12% of the material leaves the bottom of the furnace as slag, a glass-like material that has potential as a construction material, and metal alloy granules that can be recycled.

The exhaust flue gas from the boiler is then treated with slaked lime and activated carbon and passed through a bag filter before being discharged as clean gas to atmosphere.

Disposable fly ash makes up the remaining 3%.

In Singapore's context, slagging gasification technology has potential to complement the current mass burn technology as it can treat diverse mixed-waste streams that can't be handled by the incinerators because they typically operate at around 800°C.

According to NTU president professor Subra Suresh, the research facility's use of university waste is well aligned with the NTU smart campus vision and will be a living testbed for advanced technology-enabled solutions aimed at tackling some of the most pressing challenges Singapore and the world are facing. "It will enable our scientists to scale up promising ideas from lab prototypes into practical engineering solutions for sustainable waste management," he adds.

The plan now is for NTU scientists and engineers from the university's Nanyang Environment and Water Research Institute (NEWRI) to spend several years collaborating with industry and academic partners on various research projects aimed at developing and testing emerging WTE technologies.

The research facility is designed specifically to simplify test bedding of new technologies in a plug-and-play style. Municipal solid waste also has the capability to process diverse feeds such as incineration bottom ash and sludge.

Provisions exist for evaluating the cleaning and upgrading of syngas to run a gas engine or turbine for higher energy recovery efficiencies, utilization of slag in engineering applications, novel flue-gas-treatment modules for reduced emissions, low-grade heat recovery and using a gas separation membrane to extract oxygen from air. These technologies, if proven successful and implemented, could enable more energy and materials to be recovered from waste, thereby prolonging the lifespan of the Semakau landfill. ●

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