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Ponder Harvey's Hard Knocks

A safety guru provides perspectives in the aftermath of the hurricane

Resuming normal operations after the storm poses serious challenges.

AN INVISIBLE rabbit may come to mind to people of a certain age when they hear the name "Harvey." James Stewart saw that 6-ft 3½-in. "púca" (as it's known in Celtic folklore) in the 1950 film of the same name. However, everyone now likely will associate "Harvey" with something not at all entertaining — the hurricane that devastated the Texas Gulf Coast.

The storm battered plants but didn't wreak widespread havoc. Most incidents weren't too severe — minor upsets, extensive flaring and unplanned releases of chemicals — notes Dr. Sam Mannan, Director of the Mary Kay O'Connor Process Safety Center at Texas A & M University and presenter of *CP*'s popular ongoing series of process safety webinars. (For details on these webinars, see "2018 Webinars Address Process Safety," p. 9.)

The notable exception occurred at Arkema's plant in Crosby, Texas. There, flooding took out the backup power for the refrigeration system that cooled nine containers holding unstable organic peroxides. This led to their decomposition and ensuing explosions at three containers that generated large amounts of noxious black smoke. Arkema, in consultation with authorities, then conducted a controlled ignition of the six remaining containers.

That incident had a bright spot of sorts, notes Mannan. While Arkema's prevention and mitigation steps didn't suffice, at least its response seemed appropriate and showed a high degree of coordination between Arkema, local emergency responders and other government agencies, he says. This avoided loss of life and major injuries, Mannan believes.

Now, as chemical makers and refiners strive to resume normal operations, they face serious challenges, he adds. "Getting these production facilities back online is a very complex problem. In addition to making sure that all employees are available... there is a need for a large number of additional specialized manpower... Additional care and inspections are needed to make sure that equipment or storage that may have been compromised by Harvey does not result in undesirable outcomes."

Harvey and other recent incidents, e.g., explosions at West, Texas, and Tianjin, China, underscore the importance of knowing about hazardous materials present in communities, Mannan stresses.

"We need to have a national dialogue and develop some consensus with regard to location of sites near sensitive population zones. Currently, we do not have any requirements either at the federal level or local level to lay out guidelines and enforce these guidelines... As much as possible, we also must select the location of hazardous materials' sites away from areas that are prone to extreme weather.

"Finally, we must have a national tracking system (database) for hazardous materials' incident surveillance. There is presently no reliable means for evaluating the performance of industry in limiting the number and severity of accidental chemical releases. There also are limited data with which to prioritize efforts to reduce the risks associated with such releases. Without this information, there are no means to measure the effectiveness of present programs or to guide future efforts. An incident surveillance system also could be used to improve planning, response capability and infrastructure changes," notes Mannan.

Harvey undoubtedly will come up at this month's Mary Kay O'Connor Process Safety Center International Symposium. A wider and ongoing dialogue followed by concrete actions, as Dr. Mannan suggests, ultimately may enable us to address the issues properly rather than hoping someone will pull a rabbit out of a hat. ●

MARK ROSENZWEIG, Editor in Chief
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2018 Webinars Address Process Safety

Successful series expands to six presentations next year

We've put together a program of six webinars on process safety for 2018.

AS I am working on this column, the United States is cleaning up from two major hurricanes: Harvey and Irma. Harvey hit the heart of the chemical industry on the Texas Gulf Coast at the end of August and many plants were forced to shut down for several days. As Editor Mark Rosenzweig notes in "Ponder Harvey's Hard Knocks;" p. 7, that hurricane led to one event that sullied the chemical industry's reputation. Moreover, Harvey raised some issues that operators of all plants should contemplate very seriously.

The need for process safety in the chemical industry is always paramount. Technical knowledge and effective approaches for eliminating or addressing hazards are crucial. Our cover story "Reduce Process Safety Events," p. 20, provides some proven pointers from Dow Chemical, a company with an admirable track record.

CP long has focused on process safety (see: "Here's a Safe Bet," http://goo.gl/P8XsDN). In line with that focus, this year we introduced our Process Safety Series webinars. Visit http://goo.gl/m1F75E to access on-demand versions of the four topics: Leadership In Process Safety, Enforcement and Operational Discipline, Process Safety Competence, and Failure to Learn.

Dr. M. Sam Mannan, PE, CSP, DHC, Regents Professor and Director, Mary Kay O'Connor Process Safety Center, worked with the editors of *Chemical Processing* to create this series, and served as the expert presenter.

We are expanding the program for 2018, for a total of six webinars. Dr. Mannan will again serve as the expert presenter. I will be the moderator.

Here's a rundown of the 2018 lineup (all webinars are free and take place at 2 p.m. ET):

Safe Work Practices — February 8: Safe work practices are a set of guidelines on how to perform a specific task that may not always be done in exactly the same way. These practices help to mitigate hazards identified through the hazard-management process. Safe work practices should include lock-out/tag-out, decontamination of equipment, hot-work permits, confined-space entry, control of access, shift handover and simultaneous operations. Integrating risk assessment and risk management principles is essential.

Management of Change — April 21: Process changes handled incorrectly have led to a number of catastrophic incidents. Governmental regulations and industry standards mandate a well-defined administrative procedure for management of change (MOC) as a key element of a process safety management system. This webinar summarizes the diversity of implementation practices in industry and the traps and shortcomings encountered in establishing and maintaining effective MOC programs. Some of the issues addressed include: scope, policy development, change and replacement-in-kind, size of MOC programs, emergency and temporary changes, MOC record management, audits, MOC software and MOC program awareness training.

Impact of Facility Siting on Preventing Incidents — June 14: The layout of process buildings and equipment can determine the cost and complexity of a plant site and significantly impact the safety of its operation. Building inherent safety into a site can reduce both the cost and complexity. Optimum facility siting minimizes the risk of losses throughout a site's lifecycle and builds an even safer work environment.

Implementation Challenges for Inherently Safer Technologies — August 16: We must create a culture of learning from incidents. Populating incident investigation teams with the appropriate diversity of disciplines and depth of experience and worker training is a must. Training should be carefully designed and continuously updated. In high hazard industries, training devices may provide the only exposure workers get to certain hazardous conditions or potential emergencies; accordingly, such training should be especially rigorous and thorough.

Runaway Reactions — October 22: This webinar will give an introduction to chemical reactivity and the evaluation of potential hazards posed by the reactivity of industrial chemicals. It will provide a basis for evaluating chemicals to ensure safe and economical operation of plants.

Dust Explosions — December 4: Such explosions are a very complex phenomenon. Simulating the boundary conditions of an industrial-scale event in a laboratory is very difficult. Therefore, discrepancy exists between experimental methods, tools and approaches. This discrepancy has prevented development of a reliable tool/model for scaling-up laboratory observations to industrial applications. Obtaining adequate knowledge of dust properties requires consulting several sources of information and learning the history of previous incidents.

Early registration for these webinars begins Dec. 1. Email me at tpurdum@putman.net, and I will be sure to send you the registration link when it's available.

TRACI PURDUM, Senior Digital Editor
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Stop Stupidity with Relief Devices

Discourage use of back-to-back devices and check each valve carefully

All engineering problems have their roots in design.

HAVE YOU ever done a double-take when looking at an inspection photograph? I certainly did when an engineer at a valve manufacturer sent me an inspection photograph and asked, "See anything wrong with this picture?"

"Yeah," I replied.

Someone had installed two expansion relief valves back-to-back on the body bleed of a twin-seated plug valve used for isolation in our gasoline tank farm. The valve casting safety port was cracked because expansion flow was choked.

"Dumb, really dumb," I remarked. How did this get by?

I fervently believe that all engineering problems have their roots in design. So, let's look at some guidelines for designing relief systems.

First, carefully examine any design involving two relief devices (including rupture discs) back-to-back.

Second, grill anyone who wants to slap in another small device instead of replacing the whole rig with a single larger device. The argument usually made for this approach is that small valves are easier to get and less expensive. However, standards tend to punish this sort of reasoning. According to Section VIII, Divisions 1 and 3 of the ASME Boiler and Pressure Vessel Code and Part 1, Section 2 of API Recommended Practice (RP) 520, you can set a single valve to 10% above the maximum allowable working pressure (MAWP) for all relief scenarios except fire, where 21% is allowed. There's often some confusion with the set pressures of multiple valves — another reason to avoid them.

The Society of Petroleum Engineers (SPE) offers some useful guidelines at http://goo.gl/HxbsNM. Namely, you should: 1) set the smallest capacity valve at the lowest pressure; 2) set the "primary" device, i.e., the first one that opens, no higher than the MAWP; 3) stage valves between a maximum set pressure of 5% above the MAWP and the set pressure of the primary device; and 4) also apply rules 2 and 3 for the fire case but use a maximum set pressure of 10% above MAWP for that case. It also recommends minimizing chatter — but chatter is unavoidable with multiple valves.

In effect, using multiple devices restricts the operating pressure for the system. Why? Because unless a relief valve has a soft seal, it will start to open at about 80% of its set pressure to ensure full flow at 110% of the set pressure.

Suppose you have a MAWP of 150 psig. For a single relief valve, the set pressure is 165 psig and the maximum operating pressure is about 80% of that, around 132 psig. With two valves, the first valve opens at 150 psig while the second must open at 157 psig; so, the maximum operating pressure is only 120 psig. This not only is restrictive but could be expensive if your valves are protected by rupture discs.

Another design concern is the inlet of the relief device. According to API RP 520, Part 2, Section 4.2.2: "The total non-recoverable pressure loss between the protected equipment and the pressure-relief valve should not exceed 3% of the set pressure of the valve except as permitted in 4.2.3 for pilot-operated pressure relief valves." Believe it or not, 10–20% of devices in many refineries break the 3% rule.

Check valves at the inlet and outlet of relief devices have raised some concern. The SPE doesn't seem to have a problem with check valves at the inlet but API RP 520, 6th ed., Part 2, Section 6.3.2(c) excludes check valves, albeit in an off-hand way: "This outlet isolation (valve) shall never be closed while the vessel is in operation." Note the relief devices protect vessels, not pipe. Because check valves, even swing-style ones, could rust closed, you should exclude all from outlet *and* inlet service.

Now, let's consider pipe construction. First, even for a batch system, you should have double-block-and-bleed valves upstream and downstream; install an additional downstream valve for high pressure (>150 psig). Second, for any valves smaller than 3 in., insist upon socket welds to ensure stability.

I plan to cover more aspects of this topic in a future column.

DIRK WILLARD, Contributing Editor
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For additional practical pointers, check out the online roster of Plant InSites columns at www.ChemicalProcessing.com/plant-insites/

Rethink **Process Safety** – Rethink **Gas Analytics**

What happened when one of Asia's largest producers of acrylonitrile butadiene resin experienced an increased safety risk at their flares?

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Heating Promises Better Bioplastics

Researchers find thermal treatment improves bioplastic fibers' robustness.

CONVENTIONALLY PREPARED bioplastic fibers are known for their lackluster resistance to heat and moisture. In addition, producing the material on a commercial scale usually involves solvents and other expensive, time-consuming techniques. Adding a simple step — raising the temperature of bioplastic fibers — resolves these issues, and could allow manufacturers to continuously produce the biodegradable material on a scale that at least approaches petroleum-based plastic, say researchers from the University of Nebraska-Lincoln, Lincoln, Neb., and Jiangnan University, Wuxi, China.

The approach works with polylactic acid (PLA), or polylactide, a component of biodegradable plastic that can be fermented from corn starch, sugarcane and other plants. However, the material's sensitivity to water and heat limits its industrial use. The team knew that stereo-complexation of PLA molecules, i.e., creating a combination of "L" and "D" enantiomers, typically results in a more robust material than one with just the L or D version. However, this process required costly and harmful solvents and agents. So, the researchers took a new approach. After mixing pellets of the L and D polylactide and spinning them into fibers, the team rapidly heated them to as hot as 400°F.

Compared to plastics with only one enantiomer, the heat-treated bioplastic (Figure 1) resisted melting at more than 100°F higher. It also maintained its structural integrity and tensile strength after being submersed in water at more than 250°F. An article in *Chemical Engineering Journal* provides more details on the process.

"This clean technology makes possible (the) industrial-scale production of commercializable bio-based plastics," say the researchers.

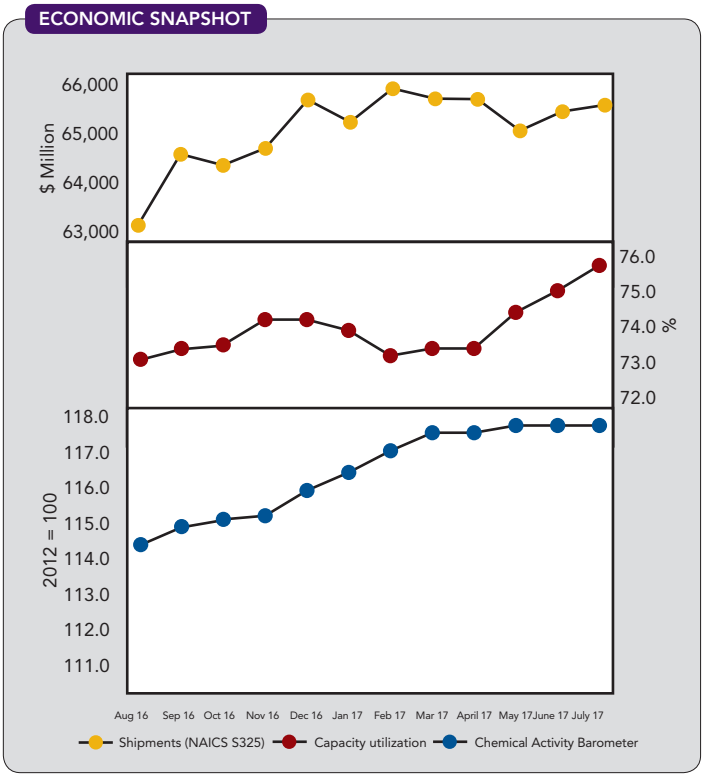
A feasible green manufacturing route could pay off both environmentally and financially, believes Nebraska's Yiqi Yang, who led the research. "So we just used a cheap way that can be applied continuously, which is a big part of the equation," he notes. "You have to be able to do it continuously in order to have large-scale production. Those are important factors."

The team has demonstrated continuous production on a small scale and will next ramp up to further illustrate how the approach might be integrated into existing industrial processes. The approach could be readily incorporated into current continuous industrial-scale production lines, notes Yang. This would involve normal melting, spinning and other fiber/textile facility processes, he says.

Usually, an improvement in one property involves a tradeoff in another property. Yang admits, "We have not studied the degradability of the products yet, but it certainly will slow the degradability of the products," he believes.

"We will need industrial partners to have pilot-scale production. Hopefully, in the next two-to-three years," says Yang.

ECONOMIC SNAPSHOT



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

HEAT-TREATED BIOPLASTIC FIBERS

Figure 1. Nebraska researchers collaborated with colleagues in China to develop a more robust, biodegradable plastic fiber derived from corn starch. *Source: University of Nebraska-Lincoln.*

Amination Catalyst Boasts High Selectivity

A REUSABLE catalyst can produce primary amines from carbonyl compounds with negligible byproduct formation, report Japanese researchers. The catalyst consists of ruthenium nanoparticles supported on niobium pentoxide (Figure 2).

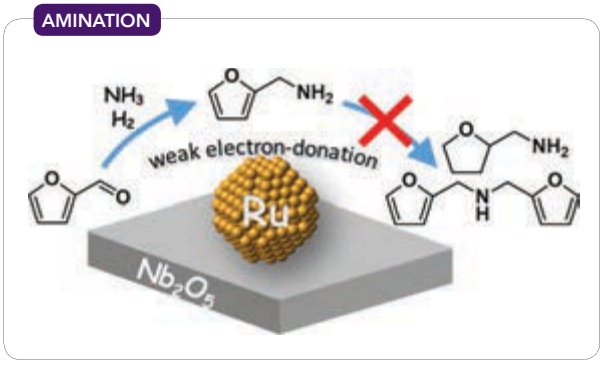


Figure 2. Highly selective catalyst consists of ruthenium nanoparticles on niobium pentoxide support. *Source: Tokyo Institute of Technology.*

The catalyst enables efficient low-temperature reductive amination of carbonyl compounds having reduction-sensitive functional groups like heterocycles and halogens using ammonia and hydrogen as the nitrogen source and reductant, respectively, explain the researchers at the Tokyo Institute of Technology (Tokyo Tech), Yokohama. The superior catalytic efficiency — yields exceed 90% — stems from ruthenium's weak electron-donating properties on the Nb_2O_5 support, they believe. More details appear in an article in the *Journal of the American Chemical Society*.

Michikazu Hara, a professor at Tokyo Tech's Laboratory for Materials and Structures, and his coworkers then investigated the effectiveness of the catalyst for breaking down biomass (in the form of glucose) into 2,5-bis (aminomethyl)furan (AMF), a feedstock for aramid polymers. Teaming the catalyst with a so-called ruthenium-xantphos complex provided a 93% yield, with little or no byproduct

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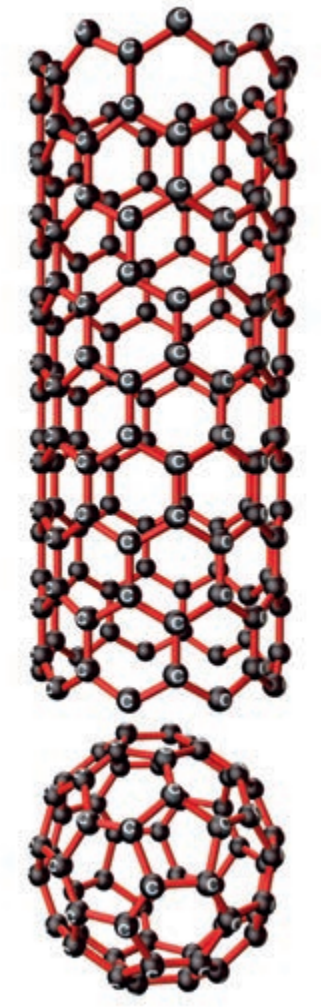

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formation observed. This success in producing AMF promises to spur the development of environmentally friendly aramid polymers, he believes. Moreover, the combination could enable efficient synthesis of other primary diamines from complicated hydroxyl- and carbonyl-groups containing compounds, the researchers note.

The approach also may suit other reactions, says Hara. Many processes require reducing only the functional groups bonded to aromatic rings without the reduction of the aromatic rings, he explains, adding that he welcomes suggestions about reactions to explore. Success for them may hinge on addressing challenges in achieving a further decrease in electron donation and charge control.

Ultimately, the catalyst may foster development of pharmaceuticals, agrochemicals, biofuels and other products, the researchers hope.

Pilot plant trials might begin within five years, Hara believes. These would be conducted by an industrial partner, he notes, adding that several companies already have contacted the researchers.

Availability of the catalyst won't be a barrier to commercial use, he says, because it can be mass produced by an established industrial method.

The researchers now are investigating the use of metals that are less expensive than ruthenium.

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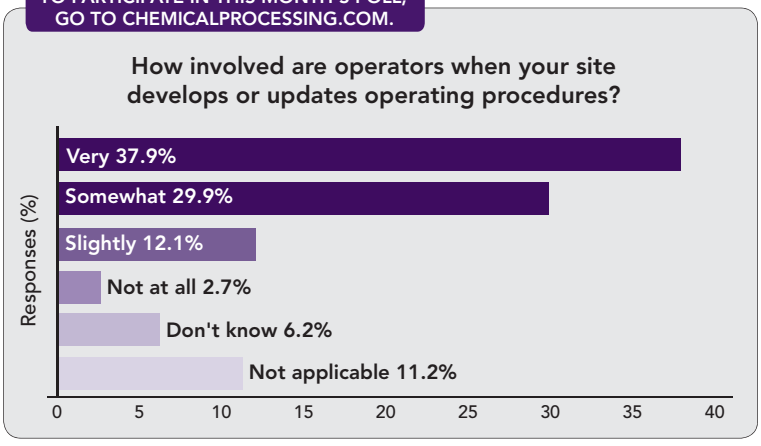

More than two-thirds of respondends report that operaors are somewhat or very involved.

Cast Cold Eyes on Cooling System Interactions

Take a look at the cooling tower, refrigeration compressor and condenser

The results surprised Jake.

PLANT PERSONNEL often asked Jake if they should install variable speed drive motors on their cooling tower fans. He usually replied, "I have normally found that one horsepower saved on the fan requires three horsepower more in compressor power." Jake's experience on multiple field tests and computer optimizations led him to this rule of thumb.

However, in the late 80s and 90s, as the phase-out of chlorofluorocarbons began, refrigeration manufacturers tightened up not only the containment of their equipment but also the performance. Prior to that, power consumption varied within the 0.7 to 1.2 kW/ton range. Steady improvements brought chiller power consumption down in the 0.4 to 0.6 kW/ton range. So, Jake's old rule of thumb probably didn't work anymore.

To check this, Jake first thought about how individual components acted in the system and their constraints. He broke it down to the cooling tower, the refrigeration compressor and condenser. He then identified how these would interact.

For the cooling tower, Jake looked at some readily available samples of manufacturers' curves. For optimal cooling, the fan blades are fixed at an airflow that maximizes the available motor horsepower. The curves are set to correlate to water flow and ambient air wet bulb temperature (WBT). The constraints on the tower include the air's ability to absorb water vapor for the incoming water and the sensible temperature rise of the moist air leaving the tower. As the ambient air WBT increases, the air's ability to absorb more water vapor — as well as the sensible temperature — decreases. Towers are designed with a set approach temperature, typically the difference between the WBT and the exiting water temperature, of 7–10°F. However, as the tower's heat load decreases with high WBT, the approach temperature will fall, but not in proportion to the tower's airflow. So in effect, air power doesn't show full benefit versus the exiting water temperature. At that point, reductions in airflow will result in less power, which won't impact the refrigeration condenser.

In the condenser, the design conditions dictate the design kW/ton. That is but one point on the refrigeration compressor map. The kW/ton can vary considerably, depending on the evaporator and condenser operating conditions. The compressor has to lift the refrigerant gas from the evaporator to the condenser where it is condensed at a temperature largely dependent on the cooling tower exiting water temperature. The lower that temperature is, the lower the lift on the compressor, and the lower the compressor hp/ton. Generally, each 1°F reduction in condensing temperature trims compressor power 1.5 to 2.5%.

The major constraint on the condenser is a minimum pressure drop across the thermal expansion device. This could be a fixed orifice, a float valve or a control valve. Falling below the pressure drop could restrict flow to the evaporator thus increasing refrigerant liquid level in the condenser, a condition known as stacking. This would reduce the surface area in the condenser, raising the pressure and eventually slightly increasing flow.

The second constraint is the compressor operating curve. This can be modified by using inlet guide vanes to change the capability of the compressor to lift the gas. A variable speed drive either with a variable speed motor or a turbine drive also can serve to optimize compressor efficiency.

Jake recognized this analysis was more complicated than his old guidance. He developed a computer model to accurately assess the lowered condenser temperature impact versus the reduced cooling tower airflow impact. He picked several good test candidates where the tower and the condenser were uniquely connected; parallel towers and chillers would make the job difficult.

What he found was it "usually" made more sense to run the cooling tower to minimize condenser temperature and pressure. In his case, the exceptions were high ambient WBT with light loads, off peak season operations where lowering the exit cooling tower water temperature came up against minimum required condenser pressures, and a few others. The results surprised Jake. He attributed it to the advances made in refrigeration equipment efficiencies.

So, start collecting your data on the systems under consideration. Develop a model that looks at the constraints on the chiller as well as the cooling tower. Look at the interactions of the cooling tower, the refrigeration compressor and condenser. Compare your various options and the capital required to the savings achieved. Use this to make an informed decision on how to proceed. Happy energy hunting.

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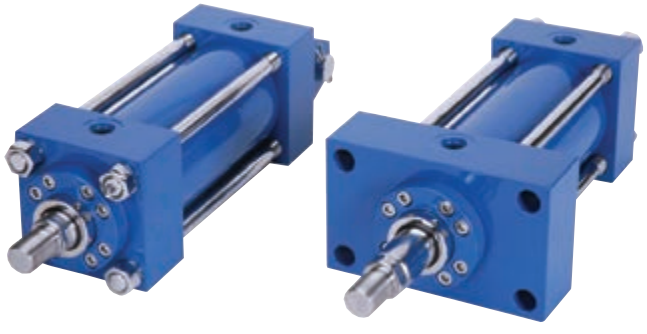

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Successfully Substantiate CBI Claims

Any confidential business information claims that aren't validated may be made public

We offer several useful suggestions in preparing substantiations.

ON SEPTEMBER 15, 2017, the Environmental Protection Agency (EPA) announced that due to the impact of Hurricanes Harvey and Irma, the agency is extending the deadline to submit and claim information as confidential business information (CBI). Manufacturers now have until October 19, 2017, to submit the substantiations required by Toxic Substances Control Act (TSCA) Section 14(c)(3).

BACKGROUND

On January 19, 2017, the U.S. Environmental Protection Agency (EPA) issued an interpretation of the TSCA Section 14 concerning substantiation of CBI claims for information submitted to the EPA. The agency expressed its view that new TSCA requires substantiating all non-exempt CBI claims at the time such information is submitted. The EPA noted that the action will "facilitate [its] implementation of TSCA section 14(g) to review all CBI claims for chemical identity, with limited exceptions, as well as to review a representative sample of at least 25% of other non-exempt claims." CBI claims made as part of an existing submission in the EPA's Central Data Exchange (CDX), such as information claimed confidential in a premanufacture notice (PMN), must be validated by amending the CDX submission. Other information should be submitted using the same mechanism (e.g., substantiate claims made in paper submissions by submitting substantiations on paper). The action was effective as of March 21, 2017, after which any non-exempt CBI claim must be proven at the time of submission. The EPA will consider CBI claims that aren't authenticated to be deficient, resulting in a notice sent to the affected business that it must remedy the substantiation deficiency within 30 calendar days or the information may be made public.

IMPLEMENTATION

The EPA urges businesses to look at the substantiation questions found at 40 C.F.R. Part 2, Section 2.204(e) for guidance on how to meet the Section 14(c)(3) requirements for information not currently subject to regulatory substantiation. The EPA states that the answers to those questions typically form the basis to determine final confidentiality, and that substantiations that don't address those questions "might not provide sufficient information to uphold" a TSCA Section 14(g)(1) determination that the information is eligible for CBI protection.

HELPFUL TIPS

We offer several useful suggestions in preparing substantiations.

Review EPA templates. The EPA provides templates for substantiating CBI claims. These templates are suggested, but not required. If you elect to use a different document to validate CBI claims, be sure to address all the elements in the template files. A substantiation document may itself contain CBI. Be sure to indicate what content in the document is CBI and that such claims are also substantiated, or note any substantiation exemptions that apply. Include a sanitized copy of the document when the substantiation document is submitted to EPA; CDX will require a sanitized copy of any document that includes a CBI claim.

Review prior submissions. If you have not timely done so, review all documents submitted between June 22, 2016, and March 21, 2017, for information claimed as CBI. In each submission, review each data element claimed as CBI in a Section 5 notice, chemical data reporting submission or other type of document, and consider carefully whether the information is truly confidential. The EPA reportedly has found a surprising number of claims thought to be CBI actually have been made public by the submitter on a website or are otherwise publicly available.

Review claims to assess if any are exempt from substantiation. Review the remaining data elements claimed as CBI to assess if any are exempt from substantiation under Section 14(c) and note which subparagraph applies to each such claim. Be sure to identify which data elements are exempt and the applicable exemption listed in TSCA Section 14(c). For data elements not exempt, review each and answer the questions included on the templates, the first of which is to describe the substantial harm to the company's competitive position that would result from the disclosure of that information.

Above all, follow the rules and comply with them consistently. Exercise care in managing CBI claims, assert them prudently, and only when warranted.

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Lynn is managing director of Bergeson & Campbell, P.C., a Washington, D.C.-based law firm that concentrates on chemical industry issues. The views expressed herein are solely those of the author. This column is not intended to provide, nor should be construed as, legal advice.

Part 1

SUCCESSFULLY REDUCE PROCESS SAFETY EVENTS

Other companies can emulate the approach proven effective at Dow

By John Champion, Sheila Van Geffen and Lynnette Borrousch, The Dow Chemical Co.

THE PREVENTION of process safety incidents (PSIs) has received emphasis at Dow for a long time. In 1995, business and corporate environmental, health and safety (EH&S) leadership established formal goals to significantly reduce incidents over the next ten years. These goals provided the platform for driving breakthrough performance impacting employees, customers, communities and the environment. This emphasis yielded a more-than-threefold decrease in PSIs over those ten years (Figure 1).

In 2005, another ten-year goal was established to further reduce the number of PSIs and their severity by 75% and 90%, respectively. As Figure 1 shows, this goal was met in 2011 and sustained through 2015.

This article focuses on some of the key programs that enabled us to break through the plateau we had reached in 2005–2008 and continue to drive us closer to zero. A second article next month will cover other crucial programs.

THE BASIS FOR SUCCESS

Figure 2 illustrates the three foundations of effective process safety programs. These aspects intertwine to form the overall approach to success that we have seen in practice in Dow.

At the base of the triangle, supporting everything we do, is leadership. Leadership support at all levels of the organization is the essential foundation for sustaining success in process safety.

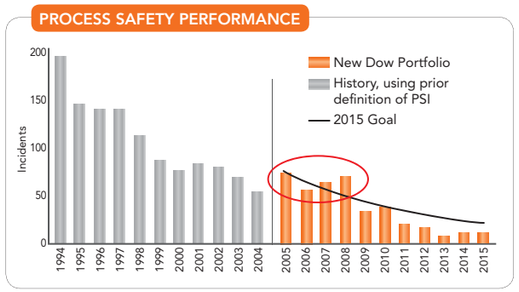

Figure 1. Dow has significantly reduced the number of incidents per year.

Figure 2. An effective process safety program requires three essential elements [1].

CHECK OUT THE FULL PAPER

This two-part series (the second article will appear in November's *CP*) is based upon portions of a paper given at the 13th Global Congress on Process Safety in San Antonio, Texas, in March 2017. The full paper appears in the *Proceedings* of the Congress and also will be published in the December 2017 issue of *Process Safety Progress*.

On the left side of the triangle are the process safety systems that Dow has implemented globally through our operating discipline management systems. These systems include Dow's Process Risk Management Standard (PRMS) and Global Mechanical Integrity Safety Standard (GMISS) as well as our personal safety standards, and many others. Compliance with these internal requirements, which typically go beyond the minimum mandates of regulations, is what enables long-term success.

On the right side of the triangle is operational discipline, i.e., what occurs in the plant on a daily basis. Operating discipline performed successfully enables effective implementation of process safety systems. For example, an inspection protocol established under GMISS for a facility's piping circuits must be properly followed for effective inspections and a decrease in containment losses resulting from mechanical integrity failures. How the plan is executed will determine whether the outcome is successful or not.

LEADERSHIP AT ALL LEVELS

Dow's commitment to continuously improve both personal and process safety performance aligns to corporate core values. Dow established EH&S as its top priority, engaging all employees across a multitude of business and functional sectors. Dow has clear expectations that all employees are responsible for safety, and measures both business and employee performance against achieving safety expectations. Sponsorship of EH&S begins at the board of directors; it is a key aspect of all leadership roles, as underscored by goals, expectations and resource allocation.

Leadership commitment is critical. Operations benefits from leadership support provided by both the business and corporate EH&S leadership and aligned to Dow's common process safety vision. Business and corporate EH&S leadership define the expectations and strategic goals needed to achieve targets. They allocate the resources necessary to


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drive improvements and sustain performance. So, let's highlight a few examples of their direct engagement:

Leadership governance. Ensuring that ongoing support, resources and priorities are properly managed is crucial for achieving process safety improvements. The operations governance team (OGT), led by the corporate EH&S director, is designed to drive business and functional accountability for EH&S performance in operations facilities. It also provides functional oversight and direction regarding alignment to Dow corporate EH&S policies, standards and requirements. The OGT oversees the corporate risk management of facilities to drive EH&S improvements and ensure the operating business and regional teams are managed appropriately in accordance with the corporate risk criteria.

Financial commitment. Substantial corporate capital funding is allocated to supplement business capital to manage overall corporate risk and promote timely completion of process safety projects. These projects are identified and prioritized through various assessments. Corporate-funded projects are co-managed by the business group, process safety and EH&S leadership. These corporate funds are designated as high priority EH&S capital to address targeted risk reduction projects along with high priority personal safety improvement projects.

Facility leadership. Production leaders at the individual facility are expected to demonstrate a competent understanding of the facility's chemistry, technology and process safety risks. One mechanism for validating this knowledge is through the new leader reactive chemicals and process hazard analysis work process. This includes having the person make a presentation to subject matter experts, process safety and EH&S professionals. New production leaders are expected to complete this process within the first 90 days of taking responsibility for a facility; they are not authorized to approve high risk management-of-change reviews until successful completion of the process [2].

Employee engagement. Personnel operate facilities daily with a clear expectation that EH&S is their top priority. All facility employees, including the operators, are expected to set personal EH&S goals aligned to those of their facility.

Key influential leaders focus on driving desired behaviors through continued engagement in field activity and coaching. All employees, regardless of position, are empowered to report issues and take action to keep themselves and the work environment safe. Operations personnel can shut down the plant if they have an EH&S concern, even for a minor leak.

A game plan is only as good as its execution. We achieve our goals not only through the act of setting a target but also in doing what is needed to reach and exceed that target. Therefore, operating discipline is essential for enabling success on a day-to-day basis. Here, we'll look at two operating discipline systems that contribute to Dow's sustained success in process safety. We'll cover three more in Part 2.

CARDINAL RULES

The prevention of large scale accidents that have a low frequency of occurring but high consequences depends upon an acute awareness of worst-case scenarios and the assurance that the protection layers are not compromised. Dow uses cardinal rules to maintain a high awareness of these types of scenarios and help prevent major incidents [3].

Cardinal rules are technology specific; they have been used for some of our processes for a long time. In the last few years, Dow has placed an increased emphasis on ensuring that all technologies have cardinal rules developed and then disseminated all the way to the shop floor. These rules follow the format of the biblical Ten Commandments. They are short statements

SOME CARDINAL RULES FOR ACRYLIC MONOMERS

1	**Never** thaw frozen acrylic acid or methacrylic acid with steam.
2	**Never** remove liquid from a partially thawed container of acrylic acid or methacrylic acid.
3	**Never** sparge nitrogen through aerobic inhibited monomer.
4	**Always** know the inhibitor concentration of a monomer.

Figure 3. This partial list illustrates the clear and concise nature of the rules.

that are expressed in absolute terms like "never" or "always." Limiting the number of these rules for a given technology emphasizes the importance. We consider a maximum of 10–15 effective; any more can dilute the emphasis. Most statements are developed as a result of a significant Dow or industry incident involving the particular technology.

All Dow personnel involved in a technology are required to know, understand and abide by its cardinal rules. Violating a cardinal rule may result (and, in many cases, has resulted) in a significant incident with potential impact to personnel, property and the community. A violation that does not result in an accident is recorded as a near-miss and appropriately investigated. The learnings from the investigation are leveraged across the technology to help prevent recurrence.

An implementation example. The Dow acrylic monomers technology owners formalized their list of cardinal rules in 2010, based on internal and external storage and handling standards that had existed for many years. These standards consist of numerous pages of detailed rules and guidelines for the safe handling of acrylic monomers. Many of the rules and guidelines reflect best practices and learnings from past events, including big and small, internal and external ones. The key benefit of taking an extensive standard and developing a list of cardinal rules is to distill crucial concepts down into short statements that can be more easily hard-wired into people's way of working. Figure 3 shows a few examples of the acrylic monomer rules.

Behind each of the short statements is detail to reinforce the importance of the rule. Such detail includes a description of what could happen (or has happened) if the rule is violated, where in the plant the hazard exists and what minimum safeguards shall be in place. Table 1 provides an example for one of the rules from Figure 3.

Once their development was finalized, the cardinal rules were incorporated into the training program for all personnel who interact with the technology. Operators, engineers, production leaders and others were trained initially on these rules in instructor-led interactive training sessions with the technology experts. Periodic formal refreshers ensure retention. Furthermore, the rules are built into the daily work practices to maintain awareness in everyone's mind. For example, each operating plant control room prominently displays a copy of the rules as do some staff buildings. The rules are frequent topics of safety meetings and even informal discussions.

MAINTAINING CORPORATE MEMORY

Corporate memory is important because bad things can, and have, happened at Dow and in industry: uncontrolled chemical reactions, fires and explosions, mechanical overpressure, building detonation, and more. They can lead to devastating consequences: property damage or destruction, capital losses, environmental impact, and injury or death.

The need to maintain corporate memory gets even more critical as we continue to improve process safety performance. As incidents become less and less frequent, we may become less vigilant over time. Many individuals may never personally experience a serious event during their career. In fact, that is the real goal: to never experience a serious event.

Institutionalizing corporate memory in training can assist in

DETAILS BEHIND A CARDINAL RULE

Cardinal Rule	What could happen?	Where Does the Hazard Exist?	Minimum Safeguards
Never thaw frozen acrylic acid or methacrylic acid with steam.	The use of steam can initiate a thermal, uncontrolled polymerization of the monomer, resulting in potential equipment rupture. *Note that a tank truck exploded in 1976 due to this.*	Freezing can occur in pumps, pipe systems and storage vessels that are uninsulated, poorly insulated, have inadequate heat tracing or inadequate temperature control of heating systems.	1. Well-maintained insulation and heat tracing systems to prevent freezing. 2. Procedures and training on the safe methods that can be used for thawing are critical. 3. Never increase the temperature of the heat tracing system above the maximum allowable temperature. 4. The use of a hot water mixing station requires automatic shutoff capability for high temperature.

Table 1. Background on the hazard, its potential impact and minimum safeguards reinforce the importance of the rule.

preventing significant events and create a continuum of key knowledge. Dow's training includes:

- chemical properties of hazardous materials;
- hazardous scenarios;
- main protection systems and design features; and
- major incident history.

Chemical properties of hazardous materials. The training program details the properties of those chemicals used at the facility. It includes a list of chemicals, how to recognize them, how to respond to exposure, their flammability and toxicity, reactivity hazards and properties of those chemicals that operate at conditions that could be hazardous (e.g., high temperatures and pressure).

Hazardous scenarios. This training covers the reactive chemistry and hazards associated with systems that could be impacted by those working in the process areas, potentially causing a life-threatening event. The content includes the chemicals involved, typical initiating events and the extent of the impact (distance/consequence). It presents scenarios for both normal operations and abnormal situations.

Main protection systems and design features. The training describes the main protection systems and design features that contribute to safety (e.g., no water in the process, no aluminum used in the process, layout and building design). One key focus area concerns what aspects of the protection strategy the operations personnel can directly affect, such as procedural and emergency response protection layers.

Major incident history. This training reviews past serious events, including the worst flammable and toxic releases, and fatalities that have occurred in the facility or in the technology. Delving into past incidents underlines the importance of protection systems and the credibility of the hazards. Photographs, if available, are provided to illustrate the consequence of the incident. Many trainees will relate more effectively to visual images.

Each facility must develop the appropriate training. New employees must receive initial training while other employees must get refresher training on a recurring schedule. A variety of delivery methods, from instructor-led training to computer-based self-paced learning, can be used.

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GET THE MOST **PILOT PLANT** FOR YOUR MONEY

Profit from a dozen pointers for cutting costs and schedule | By Richard Palluzi, pilot plant and laboratory consultant

PILOT PLANTS are inherently expensive and time consuming. So, organizations always are looking for ways to save money on pilot plant projects and speed them up. Here are some of the best ways to make your next pilot plant the most efficient, effective, fastest and least costly.

1. *Define your program goals in adequate detail before starting.* Spell out your objectives for the unit and prioritize them. Document the objectives clearly and review the document with all interested parties to ensure everyone is aligned. Determine the priorities among the goals because tradeoffs often will be necessary. Is lowering costs at the expense of a longer schedule acceptable, or is speed worth extra spending? Is higher accuracy of data worth the greater costs and effort versus accepting a slightly lower accuracy? When everyone isn't aligned, people tend to push the designer in competing directions — needlessly complicating the design and increasing the potential for rework later in the design process. Documenting the goals also ensures none are missed and that a relatively minor one doesn't receive undue emphasis. It also sends a clear message to all parties, including management, about what they can — and cannot — expect from the pilot plant, thereby eliminating the potential for unwarranted expectations. This process won't be fast or easy. However, it's an often-overlooked but critical step.

2. *Look carefully at all alternatives to new construction.* New construction always is costliest and takes the most time. Options commonly available include repurposing an existing unit, modifying an existing unit, relocating a unit from another location, or contracting out elements of the program to universities or outside research organizations. For example, a local college or testing laboratory readily might provide data on physical properties and kinetics. Also recognize the objectives may result in conflicting demands (e.g., high accuracy but fast turnarounds). Hence trying to achieve these conflicting goals by other methods or even in two units might be a better choice. Realize, too, that such options, even if available, may not actually save money or time or be the right answer. Nevertheless, it's always sensible to put some effort into ensuring that nothing potentially advantageous is overlooked. Recognize, however, that new construction maximizes your ability to customize the pilot plant to do exactly what you want. Almost any other alternative will require some compromises.

3. *Identify all key issues and requirements needed to meet the program objectives.* Make sure the pilot plant design addresses all these critical requirements. Separating needs from wants never is easy but is critical for reducing cost and schedule. Review the final design for elements that don't contribute to meeting these key requirements and consider eliminating them to simplify the design and operation and thus reduce costs and schedule. Consider a cold eyes review to help in the identification. People differ in their own views of the most critical requirements. This step forces a discussion that hopefully should lead to a consensus on what are the most critical items. Most pilot plants accumulate a large number of "requirements"

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that analysis shows really aren't essential. Their elimination or at least reduction saves considerable costs and schedule time as well as simplifies the design.

4. *Make a preliminary or scoping estimate and schedule early.* This should identify if there's a gross mismatch between expectations and resources. If so, then secure additional resources (budget, schedule, people, etc.) or cancel the unit. Don't waste limited resources on a program that can't be funded. Ensure the estimate and schedule are realistic and don't just reflect an inspired guess or wishful thinking. Developing a realistic scoping estimate is difficult and requires significant pilot-plant and cost-estimating experience; verify the person making the estimate is qualified to do this demanding work.

This step often is bypassed if there appears to be a mismatch in the hope the detailed design will result in a much-less-expensive unit (and a manageable mismatch). My experience is that this hope rarely is fulfilled. So, needless effort usually goes into redesigning the unit once the "official" cost estimate is made to force a match between budgets and desires. This effort often results in rushed designs, failure to understand the consequences of changes, and a poorly performing pilot plant.

5. *Develop a detailed design basis for the proposed unit and circulate it to all interested parties.* This step serves as a valuable check that the design basis addresses all the key requirements and all the parties' concerns — but also risks reopening previous discussions as to goals and requirements. Cutting off such exchanges early is crucial to avoid senseless rework. However, different views and concerns that do need addressing before the design starts likely will surface. This step also forces everyone to reach agreement on numerous small points early, avoiding rework later. In addition, it's useful in identifying any needs that have been missed and any noncritical desires that have crept into the design.

The detailed design basis will take time and effort to develop and, again, to review. Make sure everyone does review it or unnecessary problems will

arise later. Establish a formal review and approval process for prospective changes that subsequently come up.

6. *Strive to get the most experienced pilot-plant designer available.* That person usually will be faster and produce a better design, and also will be better able to identify and address potential problem areas. In addition, a seasoned designer more likely will challenge preconceived ideas and suggest cheaper or faster alternatives. Experienced pilot-plant engineers are rare and often difficult to engage due to cost or other commitments — but it's still worth putting in the extra effort to try to find one.

7. *Arrange for a cold eyes review of the proposed design by an experienced pilot-plant designer.* The less experienced the primary designer is, the more important this becomes. A cold eyes review allows a broader view of the final proposed design before too much is committed. It also can identify weak areas in the design, riskier approaches or blind spots. If not identified and corrected, these always will create problems later. Make sure this review occurs late enough in the design so all details can be checked. However, leave enough time for properly conducting it and addressing any uncovered issues before work starts.

8. *Evaluate the design for potential problems and develop fallback positions.* You should include elements or develop plans for what to do if the primary design doesn't work as expected. For example, adding a sight glass can enable confirming proper operation of a level instrument; providing extra space and power can allow installation of a larger pump if required. These fallback positions often make the difference between a good design and a poor one. The decision to pre-invest in any of these fallbacks always is difficult. However, having a plan lets you more critically evaluate if the extra expenditures now are worth the potential savings later if something goes wrong. Many will turn out to be relatively inexpensive and worth doing.

9. *Perform a detailed review of the design for startup problems.* This simple step often can identify many potential issues, so you can modify the design to avoid them and thus save significant time and effort later. The list of overlooked startup problems is extensive but some typical examples include:

- How can the instrument be calibrated? Does it demand special training or tools? A pilot plant usually has loads of instrumentation (Figure 1), so, ignoring such issues may severely slow startup.
- How can the new level probe be set? Does it need a sight glass or an added port at the high and low levels?
- How do you fill the micro-flow feed line the first time?

Develop a detailed startup plan that lists all the necessary steps in adequate detail to enable identifying the resources required and estimated duration. This avoids the common practice of guessing what will be needed and how long a job will take — both are recipes for disaster. Such a plan always helps both to manage expectations and allow the commissioning process to go faster and more efficiently.

10. *Perform a detailed hazard analysis and risk assessment of the final design before locking it down.* This helps ensure no outstanding safety issues will arise to increase costs and slow construction. Don't wait until after approval to do the review because such a delay may add costly or more-time-consuming requirements. Often, failure to perform this review results in significant cost overruns or lifelong safety issues.

Figure 1. Because pilot plants usually are well instrumented, inadequate attention to calibration needs can markedly hamper startup. *Photo courtesy of EPIC Process Systems.*

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11. *Consider all possible options for the most efficient way to construct the unit.* Should you do it in-house or use a contractor? Should you seek vendor help for some custom components that it can fabricate faster or better? Can you construct the unit in a shop and then move it to its final location for installation? Shop construction almost always is faster and less expensive then field construction. Building the unit in a shop as a group of modules and shipping them to the final location for installation (Figure 2) and assembly in nearly all cases is a lower cost option. Be careful to evaluate all the hidden costs for working in the field: e.g., the time to get to and from the job site, the time waiting for permits, the time lost walking to stockrooms, lunch and rest rooms, etc.

12. *Develop a realistic final cost estimate and schedule for the unit.* This often will differ from the preliminary estimate, particularly if the original estimator is inexperienced in pilot plants or the design has been forced to evolve in directions different from those envisioned at the time of the first estimate. It allows a final review as to whether or not the unit should progress or if the program, design or schedule needs modification to accommodate more limited funding. Realizing you have a budget gap at this point certainly isn't ideal but is far better than recognizing the issue at a later stage.

Figure 2. Fabrication in a shop instead of in the field usually provides equipment faster and at lower cost. *Photo courtesy of EPIC Process Systems.*

Following these pointers will help you succeed with your next pilot plant. You can find more guidance in the listed references. ●

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Cyber Security Gets a Local Look

Efforts increase to thwart threats posed by people on sites

By Seán Ottewell, Editor at Large

WHEN SURVEYED at the Black Hat USA 2017 information security event in July in Las Vegas, 60% of attendees said they believe a successful cyber attack on U.S. critical infrastructure will occur in the next two years. More than two-thirds reckon their own organizations will have to respond to a major security breach in the next 12 months.

Chemical companies, understandably, don't want to reveal the cyber-security steps they are taking. For instance, Dow Chemical, Midland, Mich., and Eli Lilly, Indianapolis, Ind., wouldn't comment for this story. Lubrizol, Wickliffe, Ohio, did say that it totally prohibits the use of USB flash drives on its control systems. Lanxess, Pittsburgh, Pa., ensures the safety of employees, customers and local communities with a wide array of site security measures, in compliance with Department of Homeland Security requirements, notes president and CEO Antonis Papadourakis.

Cyber-security breaches often result not from remote attacks but instead from local actions such as staff or contractors using infected USB flash drives and laptops or from physical incursions, experts note. Fortunately, rapid advances in technology — from malware detection and remediation to perimeter protection — are giving plants better tools to address these threats.

The infected USB flash drive remains an ongoing threat for introducing malware, mostly as a result of activities by unknowing, untrained or unconcerned employees or contractors, stresses Galina Antova, co-founder and chief business development officer of Claroty, New York City. So, ongoing training and awareness campaigns still are important, bolstered by technology controlling the use of USB ports on the plant floor.

"While the USB threat remains an issue, it is diminished, in relative terms, to the risk of the extended attack surface that has resulted from the rapid convergence between business and industrial networks. Third parties such as contractors and industrial control system (ICS) equipment vendors — together with employees not located at the plant or working from home remotely — connect to the plant network via a VPN [virtual private network] that typically terminates to a 'jump box.' From there, the employees or contractors have unfettered access to any of the equipment in the environment," she explains.

Following extensive consultations with customers, including chemical companies, Claroty has developed Secure Remote Access (SRA) to tackle this. It works by dictating which assets employees or third parties can access or see. It also enforces company authentication policies.

The remote access session is recorded for auditability. Also, importantly, an administrator, such as a security team member, network manager or plant engineer, can watch exactly what is being done — getting a virtual "over the shoulder" view of the session.

"In addition to auditability for security and compliance purposes, the session view and recording helps prevent a big issue that asset owners have with third parties saying they will be doing certain changes and then making other changes that were not previously authorized and possibly endangering process reliability, safety and security," adds Antova.

This approach boasts two key differentiators, she says. First, it leverages the company's background in and deep understanding of ICS protocols and the hazards posed to chemical companies by poorly designed information technology (IT) centric technologies. Second, SRA is integrated into Claroty's Continuous Threat Detection product — giving security and plant floor teams a consolidated picture of potential risks.

"With Continuous Threat Detection, chemical customers have often identified multiple network configuration (network security hygiene) issues and were able to fix them before they served as an attack vector. The chemical teams also commented that the ability to control and monitor third parties has helped improve security and resolved the issue with third parties going 'off script' when making remote changes to the environment without being monitored or reviewed," she notes.

RATCHETING UP RESPONSE

Achieving a cohesive security strategy requires investing in threat detection, remediation and response, counsels Moreno Carullo, CTO of Nozomi Networks, San Francisco.

"As threats evolve, and as OT [operational technology] converges with IT environments, we see a greater emphasis being placed on identifying and reacting to cyber threats, rather than simply trying to prevent cyber threats altogether. Preventative solutions and technologies need only to fail once, while reactive and remediation solutions are able to mitigate cyber threats, learn from and advance against them," he says.

The company's SCADAguardian tool uses artificial intelligence (AI) and machine learning to develop a comprehensive model of a network, its devices, connections and operational baselines. It uses this same technology to continuously advance its anomaly detection capabilities and analytics engine.

Carullo cites the case of the Industroyer virus, which is considered to be the biggest threat to ICSs since Stuxnet.

Here, SCADAguardian identifies process anomalies during phase one and phase two of an attack. Phase one, the infection phase, is when the malware establishes itself on a network and uses backdoors such as USB flash drives or contractor laptops to reach an external command and control (C&C) server. Phase two is when the C&C server directly pings nodes within the network to develop detailed understanding of devices and network operations in a chemical processing facility.

"In real time, SCADAguardian uncovers anomalous process behavior, a change in network traffic and any changes in process control such as irregular switch or PLC [programmable logic controller] demands. So any anomalies are isolated and remediation actions taken before system interruption. In addition, proactive threat-hunting capabilities include rules-based analysis and the use of signature assertions," explains Carullo.

Nozomi intends to further improve the accuracy and speed of its threat identification and remediation capabilities. Carullo also envisions advances in SCADAguardian's integration platform to more easily scale with enterprise environments, applications and operating systems.

UNCOVERING USB THREATS

Secure Media Exchange (SMX) from Honeywell Process Solutions (HPS), Houston, is aimed at USB-borne threats and was designed based on feedback from chemical and other process customers and cyber-security experts.

"The bottom line was the need for a product that provides maximum security but doesn't interfere with the normal business and operations of a process control facility," says Phoenix, Ariz.-based Seth Carpenter, lead cyber-security technologist, strategic innovation group.

As a result, a plug-and-play cellular option was introduced that doesn't connect to the plant's network at all but rather to HPS's secure cloud service ATIX.

"Through ATIX, we monitor and manage the SMX gateways as well, so the customer never has to spend any time maintaining SMX," notes Carpenter.

ATIX is one of the three key components of the SMX product. Second are the SMX intelligence gateways, the physical units installed at a customer site (Figure 1). Anyone wanting to use a USB removable storage device in a protected personal computer (PC) must connect it to one of these gateways before it's allowed on to a protected system. The final component is SMX Endpoint Protection Software installed on each PC protected by SMX. It ensures that any USB removable storage device has gone through an SMX Intelligence Gateway before use on the PC. If someone forgets to use the gateway first or the protection on the drive is tampered with between the gateway and the protected computer, the protection software will block the use of that drive.

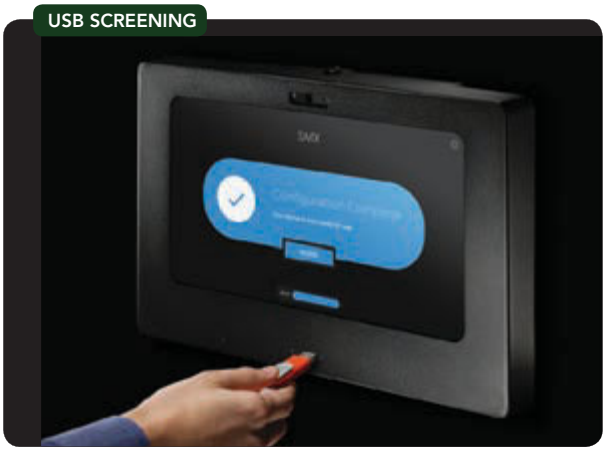

Figure 1. To be usable, USB flash drives must undergo checking by device at site. *Source: Honeywell Process Solutions.*

"So, there is a central gateway (or set of gateways) that performs the analysis and verification of all USB drives. All drives must be brought to one of these gateways before

use on a protected PC. There is also software which runs on each protected PC to ensure that users cannot skip the analysis and verification steps. It also gives us the granular control to quarantine and disallow individual malicious files but still allow other approved files to be used as needed," he stresses.

Also, by leveraging ATIX, SMX analysis in most circumstances is faster than a local anti-virus scan. HPS in the coming months expects to introduce further tools to streamline this process, he adds.

As part of its constant evaluation of new threats, the company is very interested in running potentially malicious software in a sandbox specifically tailored to a control system environment.

"Some advanced malware may try to avoid detection by remaining dormant until it detects that it has spread to its target environment. These tailored sandboxes may allow us to catch malicious behavior that would go undetected by traditional mechanisms," Carpenter explains.

POLICING THE PERIMETER

Because intruders can engage in cyber as well as physical attacks at facilities, operating companies are hardening their perimeter defenses, too. PureTech Systems, Phoenix, which specializes in developing video analytics surveillance software, counts a raft of chemical companies including ExxonMobil, BP Global, Honeywell Performance Materials and Chemicals, Occidental Chemical and Shell as customers. It also provides physical security for the protection of chemicals and fuels during shipping and storage.

"Chemical plants primarily have three main security concerns: protection of property, protection of lives and how

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to achieve this on a limited budget," notes vice president of marketing Eric Olson.

They also face the extra concern that inadequate protection of their assets can cause detrimental effects well beyond their fence lines, impacting people and property nearby, he adds.

Olson's major challenge concerning perimeter security at chemical plants is getting companies to accept a true return on investment (ROI): "Security spending is a very tough value proposition. Yes, you can consider its ability to reduce vandalism and theft, but it's difficult to leverage its value against lives saved, either at the facility or the neighboring population. It's unlikely the CEO is lying awake at night worried about the security of the facility, and the odds of a terrorist-type event occurring to any particular location is statistically very low."

Hence, companies usually set a low budget for perimeter protection and don't update systems in place in a timely manner, leaving chemical plants an easy target for intrusion, laments Olson.

A catastrophic event and government/industry mandates are the only mechanisms that seem to tip the ROI scale in these situations, he adds.

PureTech's involvement with the chemical industry focuses mainly on safeguarding the storage or transfer of harmful and potentially harmful substances. This may involve monitoring for a direct intrusion (Figure 2) or for a series of indirect activities such as loitering around perimeters or critical assets.

"Plants typically have fairly large perimeters and video analytics can utilize commercial off-the-shelf security cameras to provide intelligent surveillance over long distances, up to several kilometers. That protection is more than just surveillance: it includes intelligence, meaning knowing the difference between a passerby and a person loitering; the ability to track a suspicious target automatically with a camera; and assessing a target's level of threat based on attributes such as speed, location, intruder type, etc.," explains Olson.

Because intelligent video technology underpins a broad range of emerging applications including driverless cars, it will become more affordable, use ever more powerful algorithms and get combined with deep learning technology, he forecasts. "It will recognize more involved issues and patterns that may suggest foul play. It will also bring more automation to the process, meaning more surveillance and increased security response without the need for an increased security force to manage it."

The company itself is advancing

Figure 2. Monitoring picks up person that has gotten by fence at site. *Source: PureTech Systems.*

the technology. PureTech in June received a patent on a video-based detection and tracking system that uses the company's geospatial video analytics technology to track aerial targets such as drones and aircraft. (For more on efforts to reduce risks posed by drones, see: "Washington Targets Drones," http://goo.gl/o2ytiu.)

Its current PureActiv system can use drones positively — as a means of adding airborne surveillance and response to a facility's surveillance arsenal. Features such as drone-dispatch-to-event integrate drones into existing video surveillance systems to provide extended video protection.

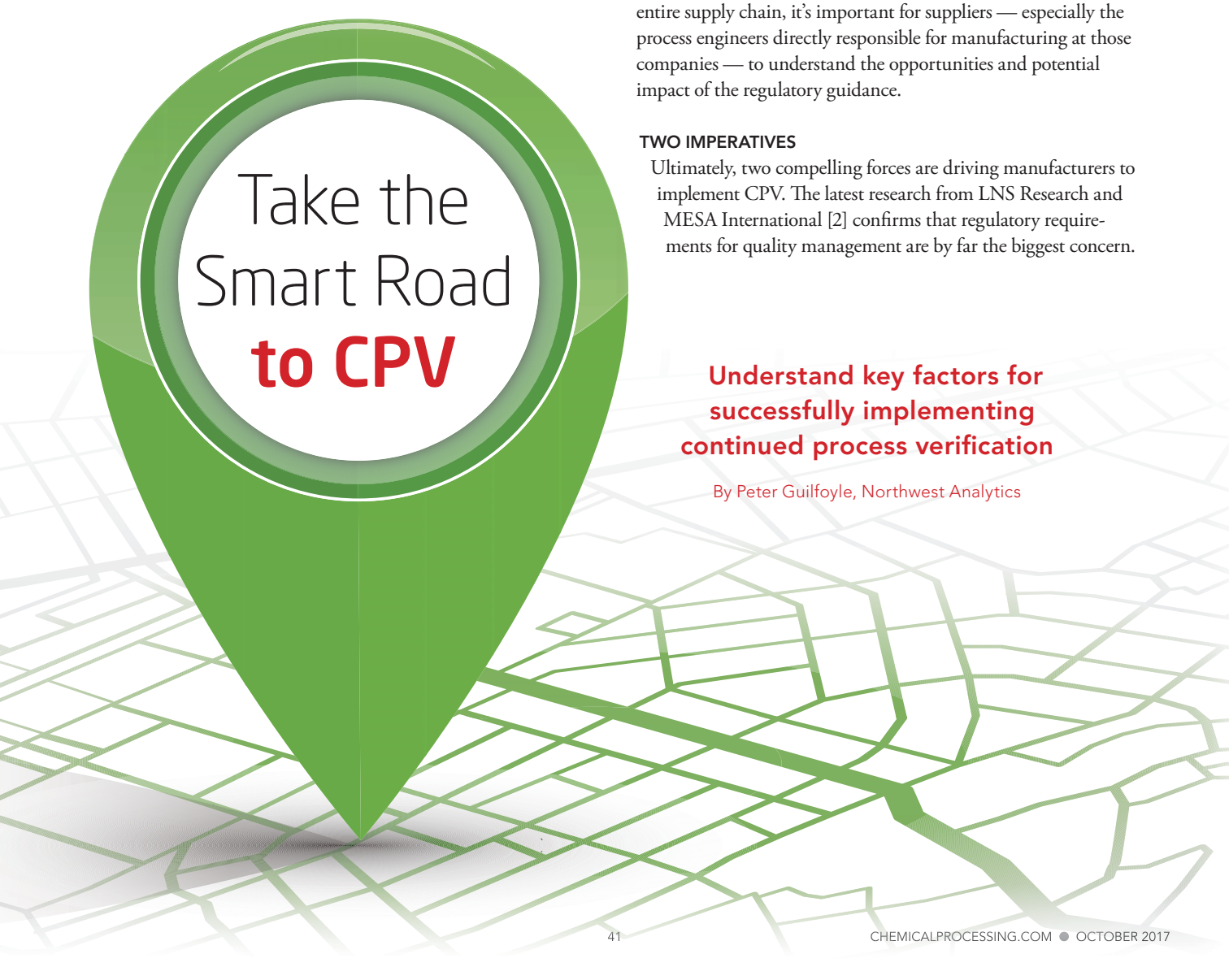
FULLY AUTOMATED DRONES

The need for a pilot on the ground to control a drone imposes some limitations, such as in range. However, changes are more than in the wings. Indeed, Airobotics, Peta Tikva, Israel, has just gotten the world's first approval to fly fully automated commercial drones without a pilot. In essence, the company's software and AI replace the pilot.

The Civil Aviation Authority of Israel (CAAI) granted certification following two years and over 10,000 flight hours of extensive testing and trials, largely at Israel Chemicals and Intel sites in the country.

Airobotics sees the security potential of such drones for perimeter patrol routine surveillance, risk tracking and monitoring, threat assessment and defense against intruders.

The company has started its first commercial operation in Australia — for a mining company — and now is looking to the U.S. for further expansion.



Take the Smart Road to CPV

Understand key factors for successfully implementing continued process verification

By Peter Guilfoyle, Northwest Analytics

THE QUEST by leading pharmaceutical companies to achieve continued process verification (CPV) — or continuous process verification as it's called in the European Union — has begun in earnest. Originally a guidance issued by the U.S. Food and Drug Administration (FDA) in 2011 [1], and subsequently by the European Medicines Agency (EMA) in 2014, CPV is intended to demonstrate that every step in a validated manufacturing process remains in the validated state.

This guidance not only impacts pharmaceutical manufacturers themselves but also likely will ripple through their supply chain, including chemical and specialty chemical companies.

Stage 3 of the guidance specifies statistical process control (SPC) and process capability analysis (PCA) as its foundation. This means that CPV goes beyond simply monitoring production processes to actually improving them. The ultimate goal is active process understanding and, if needed, proactive intervention and control. It is intended to provide information about process health — ideally in as close to real time as possible/practical — so a manufacturer can make changes to keep a process in the "sweet spot" and avoid producing off-specification and, therefore, potentially ineffective or, worse, dangerous poor-quality product. This includes extending that control to the inbound active ingredients and excipients from suppliers.

As a result, process engineers at chemical and specialty chemical manufacturers supplying pharmaceutical companies will need to satisfy increasing customer (and regulatory) demands to deliver "product to control" not just to specification. This will offer them opportunities to drive cost reductions and yield increases in their own processes using the same real-time analytics, visibility and control approach employed by their customers.

The good news is that many top chemical and pharmaceutical manufacturers — and their suppliers — for years have used an older sibling of CPV called enterprise manufacturing intelligence (EMI). These companies, by actively promoting their capabilities, stand to improve their position in the market.

Given the prominence and critical nature of CPV along the entire supply chain, it's important for suppliers — especially the process engineers directly responsible for manufacturing at those companies — to understand the opportunities and potential impact of the regulatory guidance.

TWO IMPERATIVES

Ultimately, two compelling forces are driving manufacturers to implement CPV. The latest research from LNS Research and MESA International [2] confirms that regulatory requirements for quality management are by far the biggest concern.

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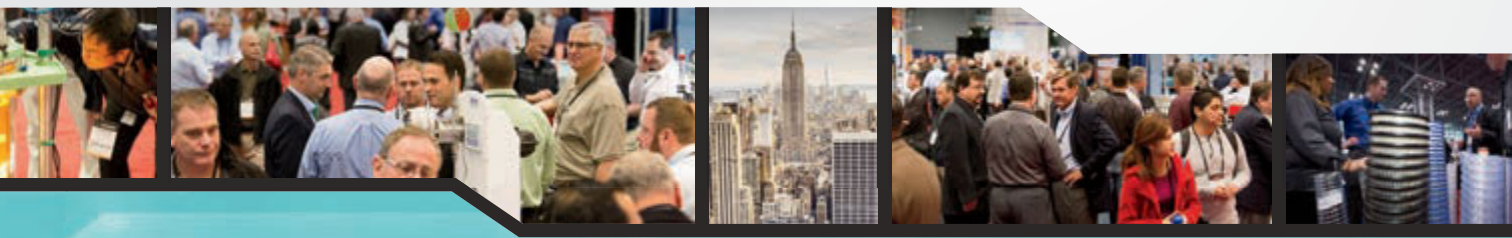

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A recent article [3] notes: "Regulatory agencies will come to expect robust CPV programs rooted in sound process understanding… Inspection frequency may be influenced by the quality of a company's CPV system and reported metrics for process health."

The FDA's guidance stresses the need to use data and acquired knowledge to continually improve processes by changing them based on the analytics-based root-cause analysis of problems. CPV, in turn, plugs directly into the quality-by-design framework as an ideal means to systematically identify and mitigate risks associated with product manufacture by continually monitoring, verifying and enabling immediate action for optimal process performance. CPV serves to provide ongoing verification of the process design and aids in enhancing process understanding [4].

The other key driver compelling manufacturers to implement CPV is competitive economic pressure. A recent article [5] predicts that companies — both brand manufacturers and contract service providers — that can adopt new technologies into their operations that result in better understanding, improved control and lower cost will come out winners during the turbulent times ahead.

The same process changes made to meet the regulatory guidance also enable manufacturers to identify and proactively address sources of process variation. That translates directly into ongoing process improvement, greater yields and more reliable delivery to the downstream supply chain. In turn, this leads to lower costs and higher margins, which is particularly important to companies with slim margins such as active materials and excipient suppliers, contract manufacturers and makers of generics and products that have lost patent protection.

These driving forces not only make delivering on CPV a strategic imperative for manufacturers but also increase the pressures to select technology that provides results quickly and reliably. To do so requires leveraging a manufac-

turer's existing technology infrastructure while also enabling fast implementation (weeks not months or years), quick assimilation and understanding at all levels of the organization (operators to executives), easy scale-up to cover the enterprise, and delivery of quantifiable results immediately.

Fortunately, the FDA leaves the details of how CPV gets implemented to each individual manufacturer, as long as it's done within the parameters of the original guidance. This allows companies the latitude to explore how leading manufacturers have achieved the equivalent of CPV.

As already noted, some of the top chemical and specialty chemical companies for years have used EMI. Its requirements [6] mirror those of CPV outlined by the FDA — namely, the ability to:

- aggregate/access data from many sources, including from other production sites;
- provide structure for the data that helps users find what they need;
- analyze these data;
- visualize the analyzed data to call attention to the most important information of the moment; and
- automatically transfer the analyzed data to the proper decision-maker to enable action.

EQUIPMENT VIEW

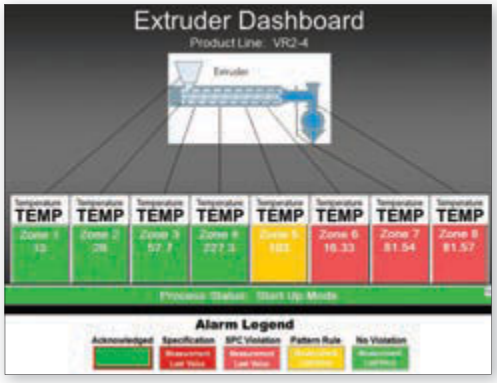

Figure 1. Staff at plant require data on particular unit to refresh fairly frequently, perhaps as often as once every half hour.

These requirements deliver the key elements of CPV — improving process visibility, monitoring processes in real time, and applying analytics through the manufacturing process.

THE WAY FORWARD

With EMI providing the blueprint to achieve CPV, the challenge pivots to finding the smartest way to do it. Here, manufacturers can benefit from the experiences of those who have successfully deployed EMI.

Most of the functional aspects of CPV currently are met by more mature applications with established best practices including:

- flexibility — easy connection to multiple data sources, and delivery of role-specific dashboards from the same underlying data;
- timeliness — deployment in a matter of weeks instead of years; and
- scalability — from line or unit levels to enterprise level to cover multiple plants.

Now, let's look at some points that deserve particular attention.

Data aggregation through direct connectivity. A company's current validated systems, such as those for laboratory information management, enterprise resource planning, manufacturing execution, quality, historical data, etc., should not complicate the ability to deliver CPV.

The CPV system is an integral part of overall risk management and receives inputs from several other systems that support process design, development, qualification, nonconformance investigations, complaints, change controls, process data monitoring and raw material testing [3].

The usual approach for aggregating data across disparate systems has been to put all the data into a warehouse or data lake. However, that approach imposes the need to revalidate the system as well as the duplicated data (a significant issue by itself). That comes at a steep price in terms of time, personnel

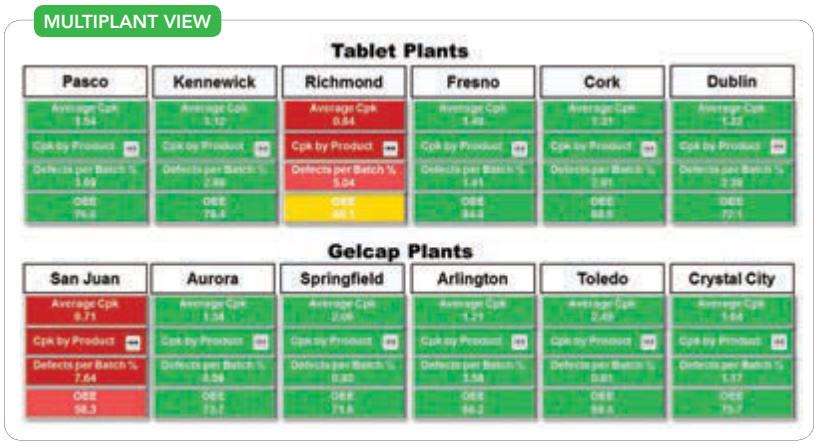

Figure 2. Dashboard allows corporate staff to compare the performance of different plants making the same product.

resources and financial commitment.

Instead, it's better to leave the data where they were originally captured — in multiple existing validated data stores — and connect to them through industry-standard methodologies (e.g., OPC, ODBC, OleDB) or well-established application program interfaces to access the data directly for use by a global analytics layer. This leaves the data fully intact (and validated) with the original systems-of-record.

Just as critical is a system that lets you deal with all the different types of data (e.g., transactional, historized, sampled) — stored in multiple database technologies — required by CPV; these data likely will come from process development, clinical, process qualification and other full-scale production lots [3].

Data aggregation through direct data-source connectivity greatly simplifies the first critical step on the path to CPV/EMI, increasing the pace of implementation, deployment and value.

Data analysis. Manufacturing analytics and intelligence rank as the No. 2 and 3 software implementation priorities, according to a recent industry study. The top application of analytics is continuing manufacturing process improvement — a key attribute of CPV.

Analysis of data and reporting for CPV also may involve examination of existing process measurements and improved methods for data tracking and analysis beyond what typically is done for process validation [4].

When it comes to choosing which data to track and analyze, pharmaceutical manufacturers are ahead of their counterparts in other batch and process industries. They already have figured out what's important for keeping processes on track and have been doing it for years — long relying upon critical quality attributes, critical process parameters and key performance indicators.

As already noted, the FDA's guidance on analytics refers specifically to SPC and PCA, identifying them as the most appropriate for the widest range of data and users. SPC analytics engenders user confidence because it provides a low rate of false-positives, clarity of presentation, the ability to take action related to the signals and, thus, overall usefulness in increasing process understanding while decreasing operation risk.

The analytics techniques spelled out in the guidance primarily analyze variation, both short term and over time. Such analyses require data that are sampled properly for the statistical techniques, have adequate precision and can be readily queried from data sources that may include inappropriate data (such as historian data collected during startup, shutdown and process upsets).

Fortunately, SPC and PCA techniques are among the most robust and adaptable methods available. Recommending relatively proven and well-understood approaches avoids the difficulties and time typically required to implement esoteric statistical techniques and the creation and maintenance of complex models.

Dashboards. CPV involves not just monitoring and alarming processes with analytics but also visualizing and communicating what's important at any given time to enable immediate intervention and action to maintain a steady production state. The key aspects of this are understanding what real time means for different roles and providing appropriate context.

• Real time. The results of an ongoing monitoring effort may be most impactful if they are reported to interested parties as close to real time as possible [3]. Experience with EMI shows that "real time" takes on different meanings depending on the role of the person interacting with a dashboard and how quickly that person needs to see a warning signal and respond to correct alarm-generating conditions. Sampling rates for process data are measured in minutes, not seconds, while update rates necessary for quality control stations and laboratory tests are much lower. This simplifies data integration and reduces hardware and network performance requirements.

For a process engineer, real-time dashboards refresh anywhere from every 30 minutes to once per shift, at the start of the day or on-demand for meetings and to assist problem resolution teams (Figure 1). This tactical view and alarming enables course corrections, optimizing across multiple variables and phenomena.

Corporate's real-time view is usually strategic with daily or even weekly refreshes sufficing for product-related purposes and for comparing the economics of global production factors like product quality and yield across multiple plants making same product (Figure 2). However, alarm conditions for selected parameters critical to process health or safety will trigger notifications for imme-

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diate awareness and action as required.

• Context. Delivering analyzed data to the right people at the right time is only part of the equation. It is also essential to include as much context as possible with the data and to strive to increase the richness of the available information as the systems evolve to effect the right process and operational changes.

A manufacturer should establish a business process that addresses how often the results of the CPV program are reported, in what way the reporting is accomplished, and who the target audience is. The company should regard the CPV plan as a living document, updating it accordingly as process changes occur. Finally, a practice not specifically called out in the EMI definition — but a key and proven element of longer-term success and a best-practice across the process industries — is establishing an assignable cause/corrective action (ACCA) program; this corresponds to corrective and preventive action (CAPA), a mandated activity that most pharmaceutical companies have in place. It is essential that the CPV/EMI technology selected contribute to and integrate easily with existing CAPA activities.

TAKE THE RIGHT STEPS

Because regulations do not dictate a particular way to deliver CPV, industry leaders face a challenge but also an opportunity to define how best to achieve it at their companies. EMI not only offers a clear established option to do so but also strengthens a manufacturer's position in an increasingly competitive market.

Proven EMI implementation and execution blueprints provided by recognized leaders in the chemical industry greatly reduce the overall risk by codifying the technology requirements necessary for success that conveniently fit seamlessly in an existing validated environment. ●

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CONDUCTIVITY MEASUREMENT OPTIMIZES NAPHTHA TANK DRAINING

More precise removal of water phase provides substantial benefits

By Lee Ju Young, Emerson Automation Solutions

THE VALUABLE role that conductivity measurement can play often is under-appreciated. For instance, conductivity is an excellent way to detect the interface between a non-conductive liquid such as a hydrocarbon and a conductive aqueous solution. Such measurements can enable significant saving of time and money, as Hanwha Total Petrochemical, Seoul, South Korea, found out.

Hanwha Total operates a large petrochemical complex consisting of 13 separate plants at Daesan, in South Korea's Chungnam Province. There, the company manufactures building-block chemicals used for making of a host of other chemicals needed for various consumer products. Processing at Daesan starts with a naphtha cracker, yielding propylene and ethylene, which are the raw materials for producing many polymers.

AUTOMATED DRAINING

Figure 1. Loop-powered analyzer and conductivity sensor enable efficient removal of water from tank with minimal loss of naphtha.

The naphtha feed for the cracker is kept in storage tanks. During storage, water accumulates and sinks to the bottom of the tank because it has a greater specific gravity than naphtha. This water would interfere with the cracking process and so requires periodic draining to prevent it from flowing into the cracker. During tank draining, it is necessary to monitor for any hydrocarbon leakage into the drain sump located at the tank area. Such leakage may mandate additional treatment of the drained water so it complies with environmental regulations for discharge and also represents a loss of naphtha.

Traditionally, Hanwha Total assigned an operator to manually perform tank draining on a quarterly basis. In the draining mode, the water passes through a special pipe assembly with a glass section. The operator, upon seeing the oil start to flow through that glass section, informs the control room to close the drain valve.

This is a very tedious task for the operator because tank draining is a lengthy process (taking approximately 2–3 hours) that requires the operator's presence during the entire operation. Also, visually determining the point at which oil, not water, begins to drain is not easy. Hence, there is a danger the drain valve will be closed too late, resulting in hydrocarbons flowing into the sump. This increases the load on the downstream water-treatment facility and, thus, water treatment costs and also wastes costly hydrocarbon raw material.

Conductivity is ideal for monitoring the drain. The water has a conductivity between 650 and 1,000 µS/cm while the naphtha has essentially no conductivity. As the water drains the conductivity is high, but when the naphtha interface is reached the conductivity falls. Thus, using an interlock system to close the valve at the first sign of a conductivity drop can ensure that draining incurs a minimum loss of naphtha.

In May 2016, Hanwha Total installed a Rosemount 1066 loop-powered liquid analyzer and

402 conductivity sensor (Figure 1) in 12 tanks. If the conductivity level passes a set threshold, the sensor alerts an operator in the control room and the system automatically closes the drain valve. The simple addition of the analyzer and sensors has substantially reduced time demands on the plant's staff and, even more significantly, has dramatically decreased leakage of costly naphtha from the tanks.

Using conductivity measurements coupled to an online interlock system has provided Hanwha Total with several key benefits:

- Draining now takes considerably less time.
- Control is real-time and better while affording significant savings over the prior labor-intensive approach.
- Eliminating additional water-treatment work allows operators to focus on other equipment.
- Minimizing naphtha contamination of the water eases compliance with environmental regulations, avoiding potential fines while giving plant management peace of mind in knowing that wastewater meets regulatory requirements.

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In addition, the retractable mounting assembly of the 402 conductivity sensor yields further savings because it enables doing maintenance work on the sensor without interrupting the process.

Conductivity analysis is one of the most commonly used liquid measurements — for good reason. As this installation exemplifies, adding conductivity instrumentation can significantly improve process efficiency, quality and reliability.

LEE JU YOUNG is a senior account manager for Emerson Automation Solutions in Seoul, South Korea. Email him at juyoung.lee@emerson.com.

Pumps Present a Pretty Pickle

Readers reflect upon the change of pump type and cause of the failures

INSPECT THE PUMP

Consider the following:

1. If elastomers are used in the stator/rotor, they would fail due to high temperature or dry run, among other reasons. Ensure you have continuous flow. You may monitor temperature (suction/ discharge) or flow rate to the PC pumps.
2. Inspecting the internals of your failed pumps could point to some possible causes of the premature failures: abrasive wear may indicate rubbing of metallic parts, which in turn could have been caused by high temperatures or vibration; chemical attack may indicate presence of corrosive chemicals.
3. Is your lube compatible? CP lube may not be compatible with PC requirements.
4. Cavitation could have damaged the pump. Because (I assume) you didn't have cavitation with the CPs, the feed to the pumps might have become lighter, thus increasing the chance of cavitation. One early indication is erratic flow and discharge pressure. Check to make sure you have sufficient net positive suction head (NPSH). For your wellhead application, this is not easy to do. You may look at the speed of the PC pumps and CP pumps. If the PC pump speed is excessive, it could contribute to cavitation problems.

For extreme variations in temperatures, some vendors recommend metal rotor/stator combinations.

GC Shah, senior HSE consultant
Wood Group, Houston

WHY THE CHANGE?

"If it's not broke, then don't fix it" still rings true today. The CPs "performed well for over 20 years" and operations and maintenance had accepted them. This is a good run for centrifugal pumps in sour, dirty service. I generally am in favor of trying new products, but how much more effort and money are you willing to spend on the PC pumps instead of replacing them with the tried and proven CPs?

The vapors contain 2% (20,000 ppm) H_2S (which is lethal) and indicates that the oil and water phases are also sour. Add the CO_2 and water vapor, and the mixtures are very corrosive. Corroding through 3-in. standard pipe (0.218-in. wall thickness) in 20 years gives a corrosion rate of 0.011 in. per year, which is acceptable for sour service. In this service, liquid velocities should be kept below 5 ft/sec. Cut open some of the pipe and inspect for a solid layer of FeS that helps reduce/ prevent further corrosion/erosion. Is the problem corrosion, erosion or sulfide stress cracking? Although changing pipe material may give you a longer life, it probably is not worth the added cost.

The PC pumps failed after only two months. Did the alternative pump vendor meet all of the engineering specs? Were the manufacturer's installation, operations and maintenance recommendations available and followed? Is there adequate NPSH for all operating

THIS MONTH'S PUZZLER

The pipeline company I work for replaced some centrifugal pumps (CPs) that performed well for over 20 years with progressive cavity (PC) pumps at an old oilfield gathering station. (See online figure at http://goo.gl/fW7MGc.) After two months' operation, the PC pumps suddenly failed. Because the station is down, the company decided to do some much needed maintenance. While sniffing for leaks before construction could begin, we discovered several, in particular around the new pumps. In addition, it looks like regulators will ding us for over-using our flare and for complaints about hydrogen sulfide emissions because the flare failed to ignite properly.

My first problem is finding out why the PC pumps failed and what to do about the flare. We had relied on a world-renowned engineering company for the previous work; it had highly recommended a particular make of PC pumps. However, my company opted for a different pump vendor because maintenance insisted on the brand for "consistency" in the equipment inventory. The engineering company also installed a new flare ignition system about the time of the pump replacement.

Why do you think the CPs ran so well for so long and the PC pumps failed? Is the flare problem somehow connected with the pump failure? What other thoughts do you have?

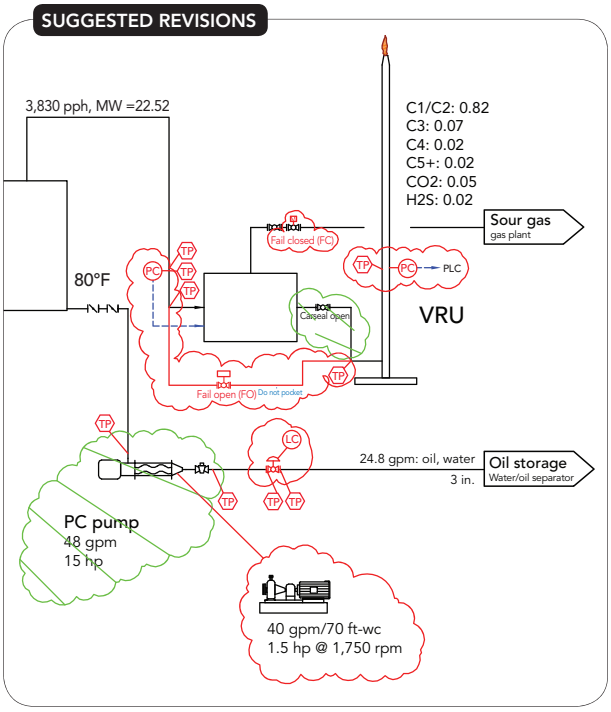

Figure 1. One reader recommends a variety of significant changes, as shown in red.

conditions? Send the pump(s), with history and operating conditions, to the manufacturer for inspection. That vendor can tell you a lot. In many cases, it will bear or share the repair cost under warranty. Consider sending the second pump to an independent pump repair shop.

The PC pump will move 48 gpm but you only need 25 gpm. Consider the changes in red in Figure 1. Because the PC pump essentially is a positive displacement pump, either speed control or recycle is required for a steady 25 gpm. Alternatively, the pump can be an on/off operation, but initially pumping only water may flush the lubricant on the seals and lead to early seal failure.

Based on the 15-hp motor, the pump discharge is about 180–250 psid. Unless the oil storage is a long way off, you only need about 10–30 psig pump discharge to flow to an atmospheric storage tank. A small centrifugal pump, operating at 1,200–1,800 RPM to minimize NPSH-required, should work well. The CP should be able to handle solids up to about ¼–½ in., so use a suction strainer without the screen to minimize suction pressure drop.

The block labeled "VRU" looks more like a separator and the box next to "Carseal Open" would be the VRU. The separator should operate at lowest possible pressure so as to minimize vapors at the oil separation/storage area. A VRU package normally tries to maintain a suction pressure

between 1–8 oz. (2–14 in. H_2O). The piping and components between the separator and the VRU will cause pressure drop and surges, especially if the piping has pockets. If the VRU is not very close to the separator, then locate the suction pressure transmitter on the separator. Take precautions that the VRU does not create a vacuum and pull oxygen into the system.

Larry Tarkington, consultant
San Antonio, Texas

GIVE MORE DETAILS

The text said: "After two months' operation, the PC pumps suddenly failed." Is it possible to know why the pump failed?

Ernesto Calderon, consultant
Techint Engineering and Constructors,
Quito, Ecuador

WHY WAS THE SWITCH MADE?

PC pumps excel where different liquids can be expected and where the viscosity and density change. They can easily handle slurries that would destroy a CP. In such cases, PCs are the pump of choice. However, keep in mind that changing the pump type may not be the most effective solution if a problem exists and, indeed, may create other problems.

Don't blindly choose CPs above a viscosity of 100 cP or where the density changes significantly. In fact, carefully review the use CPs when the viscosity is much above 50 cP. Operating a CP pump with a medium viscosity fluid increases the horsepower draw and decreases the throughput.

A CP performed well for 20 years. So, the first question to ask is why was the low-cost CP replaced by an expensive, apparently unreliable PC pump? Is someone at corporate expecting a denser, falling API crude oil? There must be more to it than a maintenance engineer's wish to cut down on inventory.

Another concern is seals. PC pumps aren't designed to prevent leaks like CPs. Small wonder the leak detection pegged the meter. Another concern may be that the PC pump bearings aren't protected against corrosion like those on the CPs. Without data on pump performance before it failed, it's difficult to find the failure root cause — that's one problem with remote locations.

Dirk Willard, consultant
Burley, Idaho

DECEMBER'S PUZZLER

My company is trying to decide whether to sell or expand a facility it purchased. Unfortunately, we inherited a mess from the previous owners. There are no equipment files, and many equipment nameplates are missing or are only partially legible. Some pumps and blowers were made by vendors that have been taken over by other manufacturers; they can't find the files for such legacy products. Much of the equipment was purchased used. Some equipment was imported from Korea, Japan and Germany. No drawings exist at all. We brought in an engineering firm for the first two months but it over-ran its budget; we fired the firm for lack of progress.

What can we do? How can we determine equipment capacities and create data sheets for equipment like pumps, blowers and instruments? I don't even have an equipment list.

Send us your comments, suggestions or solutions for this question by November 10, 2017. We'll include as many of them as possible in the December 2017 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.

You Get What You Measure

Consider how this can impact advanced process control

You should immediately check three things.

THE TRUISM given in the headline may seem trite but still bears repeating and reinforcing. It certainly applies in troubleshooting and in plant operations. If you want your measurements to mean something, they must meet two criteria. First, the measurements must relate to something important. Second, the person responsible for the measurements must find it easier to make correct measurements than incorrect ones, and must consider them so important that any temptation to take shortcuts is unthinkable.

My earliest memory of the importance of that dates from high school. I was reading a book on the steamer wars in New York in the late 1800s and early 1900s. A full chapter was dedicated to the shameful disaster of the steamer "General Slocum."

Steamers had to carry cork life vests. Regulations in 1904 called for checking these life vests by weighing them. Assuming they were filled with cork, enough weight would ensure a minimum buoyancy. On June 15, 1904, the steamer General Slocum caught fire. Before the day finished 1,021 people had died and others were never found. The official report into the disaster [1] starts with a letter from President Theodore Roosevelt that bluntly states: "The Department of Justice has secured the indictment of the manager and three employees of the Nonpareil Cork Works of Camden, N.J., for putting upon the market compressed cork blocks for use in making life-preservers, each of which blocks contained in its center a piece of bar-iron weighing several ounces. This last offense was of so heinous a character that it is difficult to comment upon it with proper self-restraint." While the iron bars in the cork weren't the cause of most deaths, they certainly compromised the buoyancy of the life vests.

DESTROYED STEAMER

Figure 1. A fire on June 15, 1904, on the "General Slocum" cost over 1,000 lives. *Source: Government Printing Office.*

What was measured was the weight of the life vest. It weighed the correct amount despite containing some iron instead of cork.

Advanced process control (APC) systems can add large benefits for modern plants. They continuously optimize against plant constraints. They even may directly calculate factors such as $/h of enhanced profitability or $/h of loss due to non-optimum operation. Yet, in spite of their potential benefits, some plant operators resist them — often for good reason. The automation industry has a history of over-promising and under-delivering with advanced controllers. Operators may turn off an advanced controller if they see few benefits or if the controller creates problems for them. Nevertheless, even imperfect APC may provide some value.

One way to foster the continuing use of APC is to measure the fraction of the time the software is controlling the process. More than one operating company measures the amount of time advanced controllers run and then pays bonuses to the plant staff based on the hours running.

Of course, if you measure hours, what you get is hours. If the advanced controller had problems that made the operators turn it off, these problems don't just go away but the time-in-service measurement provides no insight about them. (In their quest to get the bonus, the operators invariably mount ongoing pressure to get the problems solved another way.)

When trying to troubleshoot a process with an advanced controller, you can't do much without some critical basic information. You should immediately check three things:

- Is the process operating within the correlation range of the controller?
- How much is the controller allowed to vary the controlling variables?
- What are the interaction parameters in the controller?

If the process is operating outside the correlation range or calibrated conditions of the controller, there's not much you can do until the controller gets updated. This is its own huge topic outside the scope here. A *CP* article "Overcome Fear of Advanced Process Control" [2] describes some issues and warns: "The benefits of APC can degrade over a short period of time if the application isn't properly monitored and maintained."

The other two tie back to you get what you measure.

If all the control valves have extremely limited ranges of allowable variation, the plant doesn't have an advanced controller. If the controller can't move anything, it isn't optimizing.

One of the most common uses of APC is to handle systems with a large amount of interaction between parts of the process. Most advanced controllers explicitly deal with this via some type of interaction matrix. Review the matrix when the controller is acting oddly. If the matrix shows extremes in interaction parameters, the controller has lost much of its purpose.

At one extreme, highly correlated parameters are essentially the same as ratio control between variables. At the other extreme, highly non-interacting parameters are like splitting the advanced controller into smaller parts. In some cases, the advanced controller is nothing more than a conventional collection of single-input/single-output control loops hidden inside a mysterious box.

The operators have responded to their problem (APC that doesn't work) and their incentives (more money if it stays turned on). They continually harangue and press the person setting the tuning until the system doesn't create problems for them. The right answer is to fix the control system so it makes the operators' job easier, not harder.

When troubleshooting, always keep in mind incentives and measurements can determine how the plant is run.

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ANDREW SLOLEY, Contributing Editor
ASloley@putman.net

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The Masterflex L/S Cytoflow pump head was developed specifically for pumping live cells and shear-sensitive fluids. The pump head has a large-diameter rotor resulting in high flow rates at low motor speeds. The pump head is available in 2- and 3-roller configurations — two-roller heads offer higher flow rates while three deliver less pulsation. The pump head is compatible with all Masterflex L/S drives that accept two or more pump heads. In addition to the high flow rates at low motor speeds, the Cytoflow pump head has a convex roller design, furthering its cell viability advantages. This combination is designed for pump operators looking to minimize the impact on live cells and to maintain the consistency of shear-sensitive fluids.

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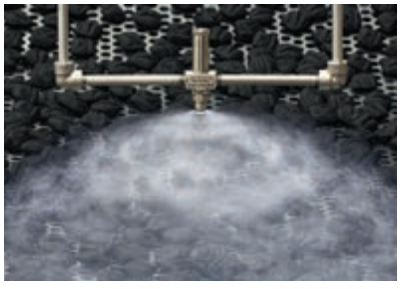

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ADVERTISER INDEX

Team Probes Solubility Prediction Problem

Model now has the potential to handle small molecule solutes

These tools are available open access and free of charge.

UNDERSTANDING THE solubility of molecules in solvents is crucial to product development. The application of a diverse range of chemicals, from paints and inks to pesticides, relies on this knowledge.

Since the late 1960s, Hansen Solubility Parameters (HSPs) have been the main tool for predicting if one material will dissolve in another and form a solution, especially when solvents for polymer solutions are needed.

The three parameters used are dispersion, polar interactions and hydrogen bonding. The coatings and polymers industry in particular has obtained excellent results when using these parameters to predict the solubility of polymers.

In principle, the same parameters can be used to find solvents for smaller molecules such as drugs and cosmetics. However, here HSP runs into twin prediction problems. First, drugs and cosmetics typically have more-varied functional groups than coatings and polymers. Second, the parameters exclude thermodynamic considerations regarding mixing, melting and dissolution — factors that can't be ignored for small molecules.

To tackle these problems, scientists Manuel Louwerse and Gadi Rothenberg of the sustainable chemistry team — one of 20 research priority areas at the University of Amsterdam (UvA), the Netherlands — have teamed up with Bernard Roux and his team at Solvay's Laboratory of the Future, Bordeaux, France. Since its foundation in 2004, the scientists in Bordeaux have had a particular focus on physical chemistry — with solubility and solvent behavior at the heart of their endeavors.

Together, the joint team has developed what it describes as a practical toolbox for predicting the solubility of small molecules in different solvents. These tools are available open access and free of charge, and can enhance solvent selection and formulations of many industrial products, they say.

The team says it has improved Hansen's model, adapting it to handle small molecule solutes by including the thermodynamics of mixing, melting and dissolution.

They have done this by studying the details of entropy and enthalpy and making several corrections that make the Hansen methodology thermodynamically sound without losing its traditional ease of use.

When a compound dissolves, molecules leave the crystal and mix into the solvent. This increases the entropy but usually costs some enthalpy. The key issue here is that the amount of entropy gained by mixing determines how much enthalpy is lost while keeping a negative change in energy. Because the entropy effect depends on the concentration, the temperature and the size of the molecules, these should all be included, notes the team.

Splitting the contributions of electron donors and acceptors among the solvent and solute is another improvement made to the Hansen parameters.

The team notes that this is especially important in hydrogen bonding, which is relevant to many solvents and solutes. The mantra "like dissolves like" is too simplistic here. Hydrogen bonds form between donors and acceptors, so one needs donors to dissolve acceptors, and vice versa. By splitting the donor and acceptor contributions of each solvent and solute, the UvA team obtained more accurate models.

These new models are much better at predicting the solubility of small molecules in solvents and solvent blends. Tests on a large industrial dataset of 15 different solutes and 48 solvents and their blends showed that fit qualities improved from 0.89 to 0.97. The percentage of correct predictions rose from 54% to 78%. Another important advantage, notes the team, is that the new model enables predictions at extrapolated temperatures.

The results and the models are published as an open-access paper in the international journal *ChemPhysChem* (http://goo.gl/dtnLgQ). According to the authors, the paper already has raised many comments and the improvements suggested are currently being incorporated into a newer version of the widely used Hansen Solubility Parameters in Practice software.

Most of the industrial formulation data are confidential. However, the team has published open access the full description of the theory and the models. Also included are the full and annotated Matlab routines in the supporting information, enabling everyone to use these new tools for designing new solvent mixtures and formulations.

"Industrial partners need to keep their data confidential, but most of them realize that open-access publishing of the methods and tools creates good will and enables further developments by both collaborators and competitors. By sharing methods and tools, companies can benefit from each other's knowledge without sacrificing data," notes Rothenberg.

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