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Building a world that works

How to Minimize Risk and Realize ROI with a Lubrication Management System

Scott Smith, Motion

Too often, we view lubrication fluid storage and handling as "out of sight, out of mind" and let the lubrication maintenance team address the details. It would take more pages to thoroughly detail everything associated with proper fluid management, but for now, let's look at some basics.

Facilities commonly receive bulk lubrication oils in what we deem as clean and proper storage devices, such as jugs, drums and totes. The long-accepted practice has been to store these items in some type of storage room or shed, and pump out what is needed—when it is needed—into a transfer container.

In today's world of reduced maintenance staff and higher employee turnover rates, coupled with increased safety risks, we should consider the following when analyzing plant site lubrication storage and management:

- What does one slip and fall from a dirty, oily floor really cost, not to mention the employee's harrowing experience?
- How do new employees understand and remember the lubrication fluids required for each piece of equipment?
- Do your lubrication fluids meet any ISO cleanliness codes you might have in place directly out of the storage device?
- What is the effect on employee morale and retention with a dirty, disorganized and chaotic fluid storage room?
- What does one cross-contaminated premature pump, gearbox or other major component failure cost?

Figure 1. Built by one of Motion's Service Centers, this oil storage system was designed for plant maintenance, featuring highly organized placement and color-coding. The unit type shown is universal and applicable in all kinds of industries, including chemical processing—and can be customized to handle the proper fluid types for the application.

It is important for management to understand what can be done to minimize company risk. All of the above can be greatly improved or diminished if one considers investing in lubrication fluids management storage and dispensing systems for the plant site.

What does this investment look like? Here are some proven methods to improve your lubrication fluids storage and management systems:

- Consider a stacking system for bulk storage to replace all the typical unorganized drum storage and the confusion that can come with it. This will also reduce oil spills on the floor and create a safer, highly organized and cohesive environment.
- Develop a color-coded storage and dispensing system for each type of fluid, matching each machine to the lubrication type (Figure 1). This will allow any person to visually understand what fluid is required in each piece of equipment.
- Minimize storage and the transfer containers' exposure to external contamination.
- Use pump and filtration systems to move fluids from bulk storage to dispensing containers.
- For large fluid transfers to equipment, consider a cart system to minimize contamination risks and reduce physical fatigue in lubrication staff. This can include removing spent fluids while installing the new fluid.

This type of investment does not have to happen overnight; it can be accomplished in stages—often making capital expenditure approvals easier. The most important thing to understand is the cost versus benefits. From there, develop a plan or strategy that will result in a more efficient, safe and user-friendly lubrication fluids management system.

Scott Smith is West Group Fluid Power Manager at Motion. A certified fluid power specialist, he has over 35 years of experience in the fluid power and industrial distribution business, including more than 12 years with Motion. Scott holds a degree in manufacturing engineering from the Oregon Institute of Technology.

For more information, visit Motion.com/chemicalprocessing or Mi Fluid Power Solutions at Motionind.biz/3RFm2G1.

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BPA WORLDWIDE

Please Recycle This Magazine

Folio Editorial Excellence Award Winner

It's Time To Say Goodbye

I've had a long and enjoyable career as an editor

I am leaving you in good hands.

I LIKE palindromic numbers. So, after reaching the age of 77 in September and having worked for 55 years, it seems a suitable time to retire. This is my last issue as editor-in-chief of *Chemical Processing*.

When I was studying chemical engineering at The Cooper Union in New York City, I worked on the school paper. I really enjoyed that, which spurred me to look for a way to combine engineering and editing. Fortunately, the then-leading magazine in the field, *Chemical Engineering*, was located nearby in midtown Manhattan. So, in 1967, I applied for an editorial position. Cal Cronan, its editor-in-chief, decided to take a chance on me; I started on the magazine even before I had formally graduated.

A major step for me was becoming its European editor. Based in London and traveling throughout Europe, I quickly lost the America-centric orientation I had of the chemical industry. Most importantly, it's when I met my wife, Elizabeth, who is from the North West of England.

After four years abroad, I returned to New York to take on the role of managing editor of the magazine.

In early 1990, the American Institute of Chemical Engineers (AIChE) sought an editor-in-chief for its flagship publication, *Chemical Engineering Progress*. Dick Emmert, AIChE's executive director, believed the magazine needed to better serve a key element of the institute's membership — engineers in industry — and hired me to boost its relevance to this core constituency. However, AIChE's publication committee largely consisted of academics, many of whom scoffed at the value of content with a practical orientation. Fortunately, Emmert rode shotgun for me.

Then, in 2003, Putman Media offered me the opportunity to return to a trade magazine — as editor-in-chief of *Chemical Processing*. As I noted recently ("Work From Home Wisely," https://bit.ly/3s90sj5), allowing an editor-in-chief to work remotely was unheard of back then. However, John Cappelletti, head of the family-owned company, was open-minded — and it has worked out well over these last 19 years.

CP has been blessed with a supportive environment and real teamwork, which has led to remarkable staff stability. Brian Marz has been publisher since 2007. That's also the year Seán Ottewell, our editor at large based in Ireland, started. Amanda Joshi, managing editor, came onboard in 2010. They share my dedication to providing you with the highest quality and most useful content.

So, too, does our new Editor-in-Chief Traci Purdum, who joined the magazine in 2008 and most recently has been executive digital editor. She long has overseen our website and written the Chemical Processing Online column in the magazine. She also hosts the popular podcast Process Safety with Trish & Traci. With her promotion, *CP* is hiring a new executive editor.

I retire knowing I am leaving you in good hands.

In addition, let me reassure you that you'll continue to get real-world pointers from columnists who have written for *CP* for ages: veteran engineers — Tom Blackwood (Solid Advice), Andrew Sloley (Plant In-Sites), and Dirk Willard (Field Notes) — and a seasoned lawyer specializing in the chemical industry — Lynn Bergeson (Compliance Advisor).

I'll close with an old journalistic palindrome: ### [which means nothing more to come]. ●

MARK ROSENZWEIG, Editor in Chief
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Mind Materials-Handling Mischief Makers

Don't let attrition or agglomeration ruin your day

How the customer samples and handles the product can create avoidable issues.

MY PREVIOUS columns on major solids-processing technologies focused on separations. Crystallization gives us a purer product from a mixture of solids and fluids. Solid/liquid separation allows us to extract the high-purity material while drying removes the last traces of solvent. Each operation improves the quality of our product but at the expense of some of the product (i.e., due to attrition or agglomeration). This same issue continues when moving and delivering the product.

In my July 2017 column, "Run a Pneumatic Conveyor Test," https://bit.ly/3sZ0nyR, I listed seven items to check when running a pneumatic conveyor test at a manufacturer's facility. While I emphasized attrition as a watch-out, I only suggested looking at something similar to your intended layout. Before deciding on that layout, you should evaluate the number of elbows, transitions and straight-run lengths. (Most manufactures have computer programs that can help in that evaluation.) We had an existing pneumatic conveyor line with too many elbows. I suggested using a new line with fewer elbows to cover about the same distance and also spacing the elbows farther apart and eliminating a section where the line dropped down in elevation. In addition, because of the length of this dilute-phase conveyor, we expanded the line about two-thirds of the run length. This significantly reduced attrition, prompting the plant to modify the existing line.

The other side of attrition is agglomeration. In some cases, you must have a little attrition to create efficient agglomeration (see my January 2022 column: "Solidify Your Solids Processing," https://bit.ly/3IV206K). However, agglomerated particles may not be strong enough to withstand intense handling. To avoid this issue, postpone particle separation until just before the product is put into bags. This allows the fine particles to protect the agglomerates during transport across the plant.

Screens often handle particle separation — but elutriation or even a fluid bed can do a better job. The fluid bed usually is less efficient but can serve as an agglomerator by adding a fine spray of solvent. While the emphasis in my October 2009 article, "Clamp Down on Clumping," http://bit.ly/2OD2seS, was on preventing agglomeration, you can use the techniques to improve the particle size distribution.

How the customer samples and handles the product can create avoidable issues about meeting its specifications. So, it is important to agree on these items before sending out product. My favorite example of how not to sample is thief sampling; dipping the sampler into one compartment is not a good technique. The better way to deal with this problem is by providing a composite sample taken at the time of product loading.

EXPLORE ISSUES POSED BY SOLIDS

Check out previous Solid Advice columns online at www.ChemicalProcessing.com/voices/solid-advice/.

We often forget that dust collection is an integral part of delivering a product. In bagging operations, we must maintain a clean working environment, with any dust going into the bag rather than on the bag or around the work area. Usually a bagging operation includes a built-in dust collection system. It could be a hood, push-pull or other local ventilation. Remember that a dust collection system also is a pneumatic conveyor: the gas velocity is all that is carrying the particles to the dust collector. In tightly fitted collection points, maintaining dust suspension requires adding extra air. What often is overlooked is balancing air flows, especially when using multiple bagging operations. Proper balancing is needed to ensure the dust is carried away from the work area. If it isn't and the local velocity is too low, the system will plug up.

In addition, pay attention to the handling and storage of slurries and wet cakes, as mentioned in my November 2018 column, "Deftly Deal with Wet Cakes and Pastes," https://bit.ly/3zJTDbP. These materials are troublesome to begin with but can suffer from attrition as well as phase changes and even color changes. For instance, we were surprised when a dryer product started showing a slight reddish color — but only on Monday's production. It turned out that wet cake left from Friday's production often was stored until Monday. To disperse the stored cake, a ribbon blender was used to feed the dryer. Unfortunately, an amine in the solids broke down over the weekend and caused the color change. We had to modify the union contract to finish all material on Friday.

Remember, the job is not done until your product is out the door. ●

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Avoid Hazards in Dust Remediation

Safeguards should cover more than electrical components

Does your plant floor look like the inside of a U-boat?

A POORLY designed dust-collection system led to the severe burning of seven workers at a U.S. Ink plant in New Jersey in 2012, https://bit.ly/3eCTLTh. It's a situation I've seen several times during my career: low "pickup" velocity, low duct velocity and a poor understanding of the dust being collected prompted an accident. The New Jersey installation also suffered from poor commissioning practice — the engineer never fully tested it. It exemplifies remediation gone bad.

Here's another example you won't find on the website of the U.S. Chemical Safety and Hazard Investigation Board. Astaxanthin caught fire in a dryer at a bioproducts manufacturer. A half-dozen resistance temperature detectors (RTDs) were strategically located in the duct following at least two previous fires but no effort was made to fix the duct work, which likely caused the dust accumulation. The site added more RTDs after I left but never corrected the duct work.

To address dust fire hazards, you must reduce two risks: 1) static ignition; and 2) fire risk from heating. Typical countermeasures are: 1) dust collection; 2) housekeeping; 3) inspections; 4) hazard and operability studies (HAZOPs); and 5) layout changes.

Grounding and bonding are critical to breaking the fire triangle: fuel-oxidizer-ignition source. However, such efforts alone won't save you: dusts often provide their own fuel *and* oxidizer. Inspections and constant vigilance are the answer — as is good design. Consider an outside consultant to train and retrain your people; training gaps are a constant source of problems. Inspections should include top-down and bottom-up. Have a third-party review design changes and do a post-mortem on construction and commissioning work. Integrate all consultant work between corporate and plant.

Understanding heating risk involves both combustion chemistry and environment. Remember, a combustible liquid's flash point can be much lower than reported, by 100°F perhaps, depending on the situation. Dust hazard tests are even less precise.

Some dusts, like Astaxanthin, can self-heat, resulting in an explosion. Others are great insulators and can cause a fire as insulation burns off a motor.

Now, let's consider some solutions.

Dust collectors are your last line of defense; good design is your first. You can justify collectors based on recovery of valuable product. However, they might not work right if you don't consider these factors: 1) poor pickup; 2) tramp air leaks into ducts; 3) an inaccurate pressure drop estimate; 4) high pressure drop because of wetted bags or cartridges; and 5) holes in filter media. These are the main causes of failure. Items 1, 3, and 4 reflect poor design; items 1, 2, 4 and 5 also can stem from poor maintenance.

Unless you make housekeeping as easy as possible, your people will cut corners. Edward Deming created the red bead experiment (see: https://bit.ly/3TfgMe6) to show executives how impossible they made their workers' jobs; don't do that! Streamline the process floor and equipment to reduce hands-on work as much as possible. Erase the clutter. Did you ever see the 1981 film "Das Boot?" Does your plant floor look like the inside of a U-boat?

Inspections won't work if everyone knows they're coming. Keep an element of surprise. Encourage workers to take the initiative to identify issues during interviews. One reason dust is ignored is because management won't spend money to fix problems; so, incentivize improvements and publicize changes and failures as they occur.

HAZOPs should reveal problems with your operation but often fall short of this lofty goal. If they aren't deep enough, simply rely on checklists, and allow teams to sleepwalk through them, HAZOPs will be nearly useless.

One reason people often seem disinterested during the process is because they believe a site won't spend the money to fix problems. I once sat in on a HAZOP on the same day the plant manager gave us a vigorous lecture on not spending money. I can't tell what happened the rest of the week as I think I was asleep.

Let me offer another important tip on HAZOPs: They're only as good as the people involved. Too often, turnover, takeovers, and excluding line workers in the belief they don't understand the process undermine the value of HAZOPs.

Sometimes, you just have to start over. Equipment parts aren't available. Breakdowns can't be made up by a second shift. Dust is everywhere. Weigh the cost of production disruptions and improve the layout. ●

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Upcycling Process Eliminates Sorting

Novel method converts mixed plastic wastes into high-value products

A COALITION of researchers led by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), Golden, Colo., has developed a proof of concept for combining chemical and biological processes into a method that could expand the range of recyclable plastics by avoiding the need to sort plastics by type. Scientists from Oregon State University (OSU), Massachusetts Institute of Technology, the University of Wisconsin-Madison and Oak Ridge National Laboratory also took part in the study.

"Our work has resulted in a process that can convert mixed plastics to a single chemical product," says Lucas Ellis, an assistant professor of chemical engineering at OSU in Corvallis, Ore.

A recent article in *Science* explains how the researchers applied the method to a mix of three common plastics: polystyrene, polyethylene terephthalate, and high-density polyethylene.

First, an oxidation process broke down the plastics into a mixture of compounds including benzoic acid, terephthalic acid and dicarboxylic acids. The researchers then engineered a soil microbe, *Pseudomonas putida*, to biologically transform the mixture into one of two products — polyhydroxyalkanoates, which are biodegradable plastics, and beta-ketoadipate, a component in performance-advantaged nylon.

The researchers next plan to try the process with other types of plastics including polypropylene and polyvinyl chloride.

"The chemical catalysis process we have used is just a way of accelerating a process that occurs naturally, so instead of degrading over several hundred years, you can break down these plastics in hours or minutes," notes Kevin Sullivan, a postdoctoral researcher at NREL.

The robustness of the catalyst will require more investigation. Ellis explains: "The system of catalysts we used included a free-radical initiator, called *N*-hydroxyphthalimide (NHPI), along with several metal cations known to help guide reaction selectivity in oxidation chemistry. This combination is used commercially in the production of terephthalic acid from xylenes, thus is a proven industrial chemistry and quite robust. However, the commercial system uses a bromine-based free-radical initiator. Bromine (Br), in these reaction conditions, is extremely corrosive and, depending on the final form, can be a germicide. We opted for a less-corrosive catalyst system, using NHPI. It is less robust but much more biologically friendly (less toxic) than Br. It is very possible there could be a process developed around using a Br-based free-radical initiator."

Contaminants found in mixed plastic wastes often plague other catalytic systems, but Ellis doesn't suspect this is an issue.

Figure 1. Combined catalyst system uses chemical and biological processes to break down several types of plastics. *Source: Oregon State University.*

"Most plastics have additives like free-radical scavengers or dyes, which can be a problem for some catalytic systems. … Depending on the quantity and identity of free-radical scavengers found in mixed-plastic waste, there would be some change in activity of our catalyst system. However, these additives would likely reduce the efficacy of oxidation reactions with plastics stoichiometrically; in other words, if we provided more NHPI the chemistry would proceed. (Again, we could explore other free-radical initiators as well.)"

The team acknowledges opportunities exist to further improve integration of the catalytic and biological steps.

"One unique aspect of our proposed concept is the need to synergize the chemical processing system and the biological system. For example, the chemical process cannot produce (or must minimize) chemicals toxic to biology, this includes solvents, catalysts, and reaction byproducts. Thus, the bridge between the chemical and biological process will be extremely important for overall process economics and final product yields. One could imagine two different extremes for unit operations between chemistry and biology (with a wide array of options in between): 1) have minimal separations (likely cheaper) and feed the non-purified effluent from the chemical reactor to the biological system or 2) highly purify the products from reaction to feed the perfect feedstock to biology. … We believe there are opportunities to incorporate low-operating-cost separations in-between these unit operations, to not only maximize product value, but also minimize cost," explains Ellis. For example, he adds, incorporating specialized separation unit operations to extract potentially high-value reaction products from the chemical process before feeding to biology.

Captured Carbon Dioxide Produces Ethylene

RESEARCHERS AT University of Illinois Chicago (UIC) have developed an electrolysis-based system that converts nearly 100% of captured carbon dioxide (CO_2) into ethylene (C_2H_4). Their approach involves passing an electric current through a 3D-printed aqueous flow-through electrochemical cell, half of which is filled with a water-based solution, separated by a membrane from the other half that contains captured CO_2. An electrified catalyst made of copper mesh draws charged hydrogen atoms from the water molecules into the other half of the unit where they combine with charged carbon atoms from the CO_2 molecules to form C_2H_4.

The cell achieved a Faradaic efficiency of nearly 58%, producing gaseous C_2H_4 with a purity of 52 wt. % and no CO_2 in the product stream, report the researchers.

Two Spectrolab XTJ triple-junction solar cells used in tandem with the electrochemical cell converted 10% of the energy from the solar panels directly to the carbon product output. This is well above the state-of-the-art standard of 2%, the researchers write in a recent article in *Cell Reports Physical Science*.

In addition to C_2H_4, the UIC researchers were able to make other carbon-rich products useful to industry with their electrolysis approach.

The process can convert up to six metric tons of CO_2 into one metric ton of C_2H_4, recycling almost all the CO_2 captured, says research lead and UIC assistant professor of chemical engineering Meenesh Singh. Because the system runs on electricity, the use of renewable energy can make the process carbon negative, he adds.

This approach surpasses the net-zero carbon goal of other carbon capture and conversion technologies by actually reducing the total CO_2 output from industry, emphasizes Singh.

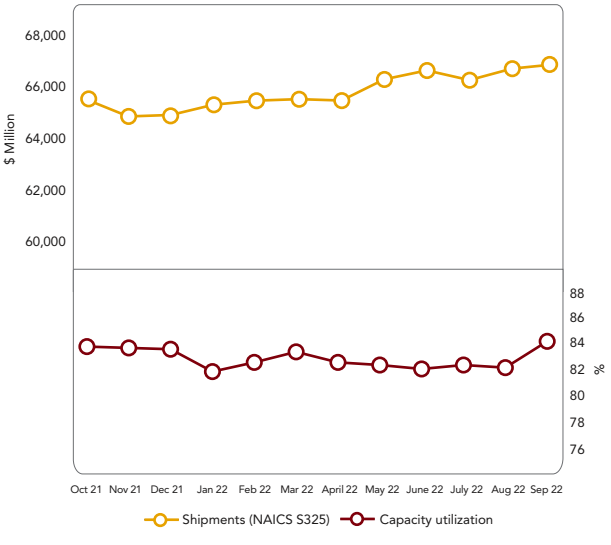
"It's a net negative. For every one ton of ethylene produced, you're taking six tons of carbon dioxide from point sources that otherwise would be released to the atmosphere," he explains.

Scaling-up the process poses engineering challenges, including increasing the energy efficiency of the process beyond 60% while improving both product separation and collection efficiencies, Singh admits.

For now, the team is focused on scaling-up integrated reactors that can capture CO_2 directly from flue gas and covert it to produce 1–10 kg/d of C_2H_4.

The work is garnering industrial support, with Braskem America, Philadelphia, which operates five polypropylene plants in the United States, the principal sponsor. The company's level of investment remains confidential.

ECONOMIC SNAPSHOT



Both shipments and capacity utilization increased. *Source: American Chemistry Council.*

How Much Energy Can You Save?

Pinch analysis and benchmarking offer reliable methods for determining energy savings

Underlying methodologies and assumptions are inherently different.

I CAME into the energy efficiency arena through pinch analysis. The pinch methodology enables us to calculate a rigorous target for energy consumption, based on a simplified physical model of heat transfer in an industrial process, together with simplified economic assumptions ("Take the Heat Off Pinch Analysis," July 2019, https://bit.ly/3ES2A3I). In its basic form, pinch analysis only considers savings through heat recovery, assuming a pre-determined plant configuration, in which only the heat exchangers can be changed. The genius of the pinch approach is that it allows us to calculate the energy target without knowing the design of the optimized heat exchanger network.

In practice, there is no guarantee an economical design will achieve the pinch target; the target is even more difficult to attain in revamp situations than in new plant designs, as the existing equipment and plot space restrictions often limit possible improvements. Over the years, many clever techniques have been developed to mitigate these challenges; advances in computing have helped, but, to some extent, challenges remain.

Other types of target-setting also are used, most notably, benchmarking. These often act as a basis for estimating potential energy savings, thus justifying energy management programs ("Quantify Your Energy Efficiency Program," October 2022, https://bit.ly/3h06H6j). Several for-profit providers offer benchmarking services, including energy benchmarking, for different industries around the world.

Pinch targets and benchmarks are similar; both provide a quantitative measure of the potential for saving energy in a process and are useful in driving improvements in energy efficiency. However, the underlying methodologies and assumptions are inherently different. While pinch targets represent the amount of heat the process would consume with an optimized heat exchanger network, benchmarking, on the other hand, is based on performance comparison of different types of assets or practices to find the most effective or economical. Rigorous benchmarking of existing processes is based on the statistical comparison of actual operating data. In other words, pinch targets represent what might be achievable, whereas benchmarks represent what already has been achieved.

Due to anti-trust requirements, benchmarks are commonly developed by confidential side-by-side comparisons of validated operating data from at least four similar company plants. This practice avoids revealing any one company's data points. Results usually are reported back to individual producers as a set of averages and statistical measures, which can be compared to that producer's own data. These comparisons can show a producer's overall standing versus competitors and indicate areas where further efforts will pay off. The benchmark results, together with monetary gap calculations, provide an economic justification for improvement efforts. This, in turn, can drive key business decisions, including the development of multi-year strategic improvement plans.

In some parts of the world, government mandates necessitate energy benchmarking to drive conservation and energy consumption improvement efforts, as well as decarbonization. The mandates typically set aggressive energy-reduction goals, which may go beyond those dictated by normal economic returns, to achieve national or regional energy objectives.

Energy benchmarking is well-established in the process industries. Global refineries have practiced it for many years, thus a large body of experience and a great deal of data exist. Nearly every refinery is unique, with different processes and facilities, so a factor-based approach, based on the fundamental crude distillation process, has become well-accepted.

More widely produced petrochemicals and plastics also have used benchmarking, and over the years have compiled reliable databases for the more-common products and processes. Products made in fewer locations or using widely varied technologies require more specialized analysis.

Many large-volume industrial chemicals and fertilizers also have access to dependable benchmarking databases. Like the situation with petrochemicals, some lower-volume materials require more specialized analysis.

(For more information, see: Mark Eggleston, "Energy Benchmarking" in Alan P. Rossiter & Beth P. Jones, *Energy Management and Efficiency for the Process Industries*, Wiley-AIChE, 2015, pp. 56–65.)

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European Commission Spurs Confusion

Government body calls for adding new hazard classes to label regulations

This could be a very big deal in the United States.

ON SEPTEMBER 20, 2022, the European Commission (EC) began a public consultation on an initiative that would introduce new hazard classes to Regulation (EC) No 1272/2008 on the Classification, Labeling, and Packaging of Substances and Mixtures (CLP). It would add hazard classes and criteria for endocrine disruptors and substances that are persistent, bioaccumulative, and toxic (PBT); very persistent and very bioaccumulative (vPvB); persistent, mobile, and toxic (PMT); or very persistent and very mobile (vPvM). This column explains why this could be a very big deal in the United States.

WHY IS THE EC PROPOSING THIS?

The inclusion of the new hazard classes addresses commitments under the Chemicals Strategy for Sustainability (CSS). This is a key building block for the European Green Deal and is intended to protect human health and the environment. Public consultations on the revisions to the CLP regulation were held in 2021, eliciting a variety of responses. Some supported the introduction of new hazard classes, while others pointed out that the introduction of new hazard classes, which are not currently part of the United Nations (UN) Globally Harmonized System of Classification and Labeling of Chemicals (GHS), would "lead to potential information overload in hazard communication, distort the level playing field of international trade, and lead to cost increases for various activities."

The proposed changes include amendments to Part 3 of Annex I of CLP to incorporate new hazard classes for endocrine-disrupting properties for human health with definitions, classification criteria for both substances and mixtures, and new label elements. The definitions proposed do not align with World Health Organization (WHO) definitions and criteria for endocrine disruptors. A separate inclusion in Part 4 of Annex I of CLP would include endocrine-disrupting properties for the environment. This would add definitions, classification criteria for both substances and mixtures, and new label elements.

Part 4 will also include the introduction of PBT or vPvB properties, the criteria of which align with the concepts introduced in Annex XIII to Regulation (EC) No 1907/2006 on the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), except it includes, as part of toxicity criteria, consideration for endocrine disruption for humans and the environment. Classification as a PBT or vPvB will include new criteria for classification of substances and mixtures, and new label elements.

Further proposed amendments to Part 4 include the additions of PMT or vPvM properties, and will contain definitions, classification criteria for substances and mixtures, and new label elements. Note that "persistent" and "very persistent" here are defined identically to P and vP from PBT and vPvB. "Toxicity" definitions also are identical to T from the amended PBT. The introduction of "mobility, (M)" and "very mobile, (vM)" centers around organic carbon partition coefficients (Koc) and Koc with pH values for ionizable substances. A log Koc of less than 3 meets the criteria for M, and a log Koc of less than 2 is considered vM.

DISCUSSION

The UN GHS adaptation into its CLP regulation is one of the most complex aspects of GHS implementation. CLP contains many variations to UN GHS that result in a hazard communication process consistently misaligned with other countries' approaches. The proposed revisions lack clarity and add layers of confusion to an already complex approach to hazard classification. Previous responses to comments agreed the criteria are important, but introducing PBT, vPvB, PMT, and vPvM was not necessary.

Adding endocrine disruption to the toxicity category also invites confusion with respect to alignment with REACH Annex XIII. Changes to the safety data sheet (SDS) format as part of the amendments to Annex II to REACH, which take effect later this year, also incorporate endocrine disruption. By including these endpoints as required elements for classification, the EC appears to be pushing its agenda in advance of any consideration of the UN GHS subcommittee and the process of harmonization. Comments from responders noted these measures should only be introduced in response to implementation at the UN GHS level.

Stakeholders should consider the implications of these criteria and the impact of the hazard communication tools utilized within the European Union. These endpoints are not part of the United Kingdom approach, and the addition of new hazard classes will create further separation from the post-Brexit operations for companies within the region.

LYNN L. BERGESON, Regulatory Editor
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IF HIRING is any indication, chemical engineering professionals are having a good year. During the early days of the pandemic, respondents to our annual job satisfaction and salary survey reported some hiring and pay freezes took effect, but now a switch has flipped. Nearly 30% of respondents to this year's survey — 12% more than last year — shared staffing levels at their sites are somewhat or significantly larger than the previous year (Figure 1). For some context, from year-to-year, it's unusual to see more than a 2–3% variation in any particular response to our salary survey questions, so any 10%+ increase certainly deserves noting. One respondent even shared, "Our department has doubled in the past 6 months. The new hires are receiving an extremely high starting salary."

"[My] salary adjustment (increase) to better match current market was appreciated. Recent hiring difficulties, largely due to salary, seem to be making a difference in wanting to retain existing expertise," added another.

Indeed, salaries are quite competitive in the frenzied job market. This year, chemical engineering professionals reported an average salary of $121,513 (Figure 2), a significant jump from the pandemic-induced $106,000 reported last year and the highest average salary we've ever recorded in the 17 years we've been conducting this survey.

"The survey stops at $150K+, but the industry is paying upwards of $200K to $250K plus bonuses, this artificially lowers the average compensation," advised one commenter. In fact, the highest percentage of respondents (nearly 30%) report making more than $150,000 per year.

HOW WE GOT RESPONSES

A total of 784 people participated in this year's online survey hosted on alchemer.com. From March through August of 2022, respondents accessed the survey questionnaire via ChemicalProcessing.com, e-newsletters, social media, and e-mail blasts sent to *Chemical Processing* subscribers.

WHAT IS THE PROFESSIONAL STAFFING LEVEL AT YOUR SITE NOW VERSUS 12 MONTHS AGO?

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
The same	44.0%	45.3%	45.5%	43%	44.8%	45.6%	50.4%	52%	45%	40%
Somewhat smaller	18.8%	16.9%	16.4%	23.9%	20.7%	18.9%	14%	23%	27%	24%
Significantly smaller	5.0%	4.7%	4.1%	6.7%	6.7%	5.6%	4.8%	7%	11%	7%
Somewhat larger	28.2%	29.9%	29.9%	23.7%	24.1%	27%	27.8%	17%	13%	24%
Significantly larger	4.0%	3.2%	4.1%	2.8%	3.7%	2.9%	2.9%	1%	4%	5%

Figure 1. Respondents report strong hiring as staff levels rose more than 10% compared to last year.

AVERAGE SALARY OVER THE YEARS

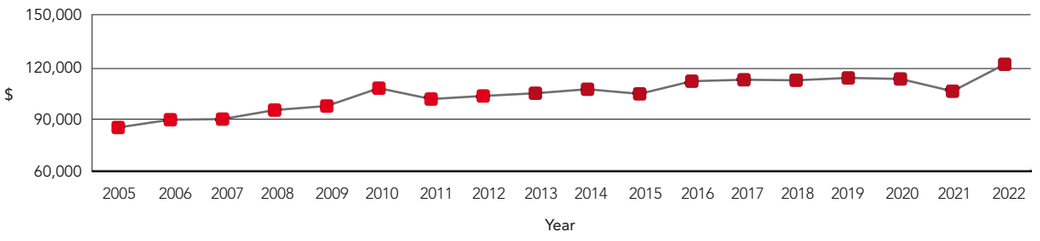

Figure 2. The average salary shot up in 2022.

"[My salary is] probably above market, but for 20+ years of experience and a ChemE BS and an MBA, it does feel good to be compensated this well," mused another.

Many respondents echoed such satisfaction:

"I'm quite satisfied with the company's compensation package."

"I am very happy with the current benefits and compensation in the context of unemployment in recent years."

"The company I work for is very generous with salary and bonuses."

"The company I work for provides GREAT compensation and benefits."

"Salary compensation is a little below what I would prefer, but the benefits from the company are good."

BONUS BONANZA

Another financial perk with positive numbers is bonuses and raises, both of which fell slightly in 2021 only to recoup in 2022. For example, in 2021, 46% reported receiving a salary increase within the last year. In 2022, that number rose to

HOW LONG HAS IT BEEN SINCE YOUR LAST SALARY INCREASE?

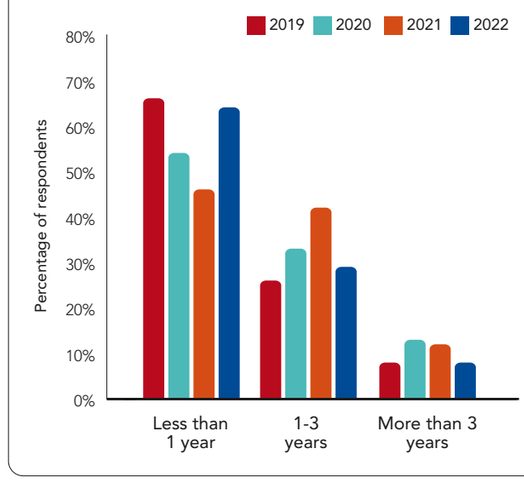

Figure 3. More companies gave out yearly raises compared to last year.

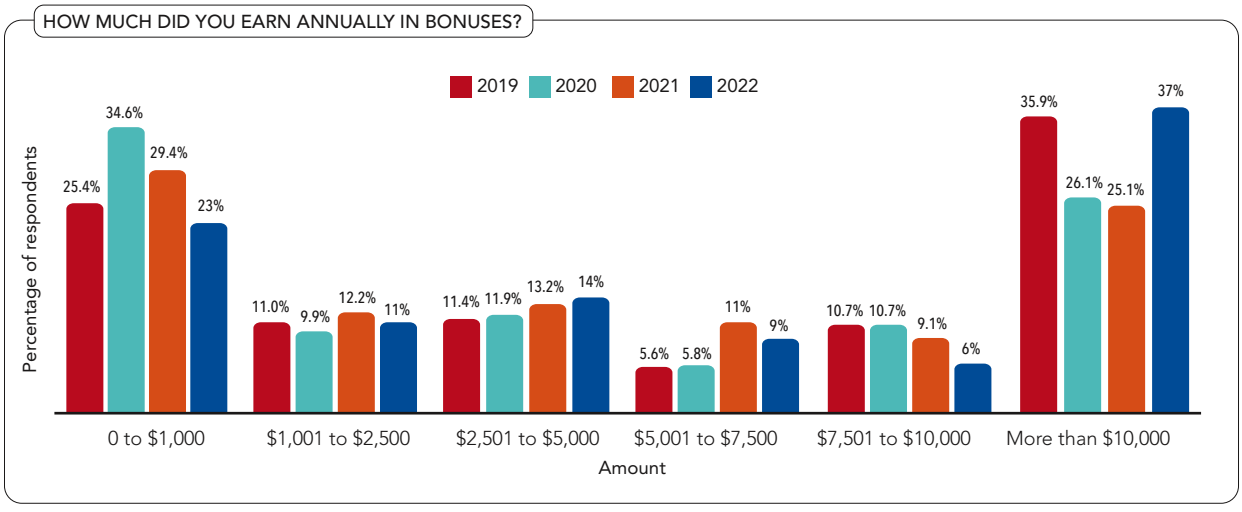

Figure 4. More reported larger bonuses of more than $10,000 this year.

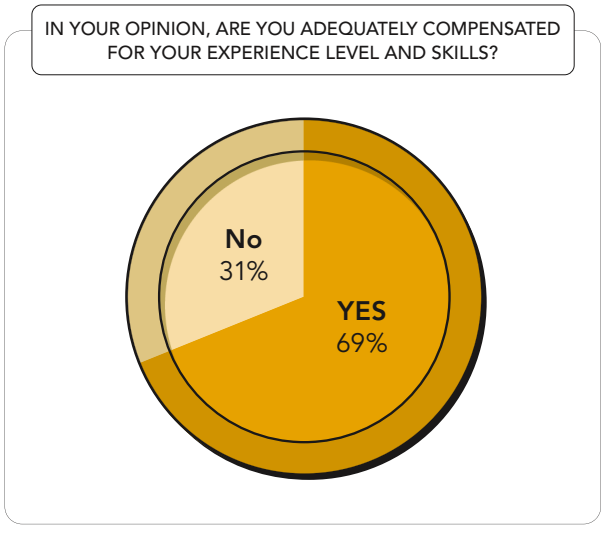

Figure 5. More than half of respondents feel their experience matches their compensation.

64% (Figure 3). In addition, of those that received a salary adjusment, only 2% took a pay cut, compared to 6% in the middle of the pandemic.

"I recently received a large raise. Before this, I was undercompensated," revealed one commenter.

"I am not unhappy with the compensation, but it could be better. My last raise was unusually high. They are typically much less and not merit-based," mentioned another.

For 2022, salary survey participants revealed an average raise of 4.16%, which falls more in line with 2020's 4.12% and certainly better than last year's 3.7%. The average bonus for the last several years has hovered around $6,000, but for 2022, respondents reported hefty bonuses with the average increasing to $7,480, another record number. Many, nearly 38%, received bonuses exceeding $10,000, the highest amount we tally (Figure 4).

"I am well compensated, and the bonus program when maxed out allows me to double my salary," shared one participant.

Another claimed the compensation and benefits are "well worth it. Good base salary. Excellent 401k and contributions, great perks, and a bonus equal to over 30% of annual salary."

Most respondents had similar positive remarks: "I am pleased with my salary, bonuses, benefits package and grateful for a good pension."

"I am satisfied with my compensation and the opportunity to receive a bonus which is directly impacted on how I perform with all the divisions in our company."

"Have been very happy with compensation and benefits and feel that job performance is taken into consideration."

In fact, nearly 70% (Figure 5) of respondents said they feel they're adequately compensated for the work they perform (compared to 66% in 2021).

CHALLENGES AND CONCERNS

While results are favorable regarding overall job satisfaction, comments voicing displeasure — mostly attributed it to being underpaid — had some respondents revealing they left jobs to get their salary up to par.

"[I'm] seriously underpaid vs. market; management is learning that via inability to hire new engineers at the salary they are offering. No clue if this will be addressed before all experienced staff retires," grumbled one participant.

"I don't feel my compensation and benefits [are] high enough and am looking to negotiate a raise before the end of the year; otherwise, will look elsewhere," warned another.

When it comes to employment, having one foot out the door seems to be the trend. Of those with jobs, more than

one-third of respondents (36%) say they've been with their employer anywhere from 0–5 years, further highlighting the slew of both employment opportunities and opportunistic job hopping.

AVERAGE AGE OF RESPONDENTS IS 48

The recent hiring uptick also adds to the task of retaining and finding skilled workers. In a January 2022 poll, we asked readers "How tough is it for your site to hire enough skilled craftspeople," and more than half (56%) of respondents categorized such hiring as moderately difficult.

"I was the guy who you published in last year's salary review who was bellyaching about not getting an increase because my company was overly conservative about the pandemic. Because the company did well and the fact that our competitors were poaching our people, they gave our engineers an across-the-board 15% raise to stop the bleeding. So, it ended up working well for me, but our company lost a lot of people before that."

As employees leave, those that stay often are stuck managing those jobs on top of their own — leaving personnel stretched thin with more work and longer hours. On average, 50% note they work 41–50 hours a week, followed by another 20% clocking anywhere from 51 hours to more than 70 hours a week. The pandemic also reportedly increased workloads by as much as 22%.

Even before this labor crisis, our survey consistently tracked the long days as one of the least appealing aspects of working in the chemical engineering field (31%), only topped by lack of recognition (36%) when we asked participants what they dislike about their jobs (Figure 6).

"Be prepared to work long hours, weekends and holidays. You will be away from home a lot," warned one respondent.

"Compensation and benefits are quite good, but the workload is not manageable and little recognition of extra effort put in to meet the demands," voiced one participant.

Many respondents also shared another concern — that recent cost-of-living (COL) salary adjustments don't keep

WHAT DO YOU DISLIKE ABOUT YOUR JOB? (MULTIPLE RESPONSES ALLOWED)

	2016	2017	2018	2019	2020	2021	2022
Lack of recognition	38%	37%	38.5%	37.6%	39%	32%	36%
My company's work environment	29%	30%	32%	29%	22%	23%	24%
Hours and workload	29%	24%	30%	26%	25%	32%	31%
Salary and benefits	26%	27%	25%	23%	27%	24%	20%
The commute and traveling	25%	28%	24%	27%	25%	22%	25%
Lack of challenge	12%	11%	14%	10%	14%	17%	15%

Percentage of respondents

Figure 6. Lack of recognition and the hours and workload continue to be top detriments.

TAKE A LOOK BACK

Chemical Processing has been conducting an annual salary/job satisfaction survey for more than 15 years! For a look back at past surveys, visit any one of these conveniently listed links:

2021 — https://bit.ly/3sHDv6B
2020 — https://bit.ly/39iASOq
2019 — https://bit.ly/3f8HTD3
2018 — http://bit.ly/2S6sEQD
2017 — http://bit.ly/2mnxZEo
2016 — http://goo.gl/NOaC4R
2015 — http://goo.gl/YtU0xd
2014 — http://goo.gl/IroA1C
2013 — http://goo.gl/NckQ5c
2012 — http://goo.gl/x00kEt
2011 — https://bit.ly/3DgbgB3
2010 — https://bit.ly/3DgooWJ
2009 — https://bit.ly/3fcEedd
2008 — https://bit.ly/3TL40Er
2007 — https://bit.ly/3fjORuH
2006 — https://bit.ly/3zlABbF
2005 — https://bit.ly/3UbeCMB

pace with the current levels of inflation and insurance premiums, making them barely adequate.

"Compensation is generally good; however, COL increases have not kept up with recent inflation increases," said one commenter.

"Compensation is not keeping up with inflation, real buying power results in 5% pay cut currently," relayed another.

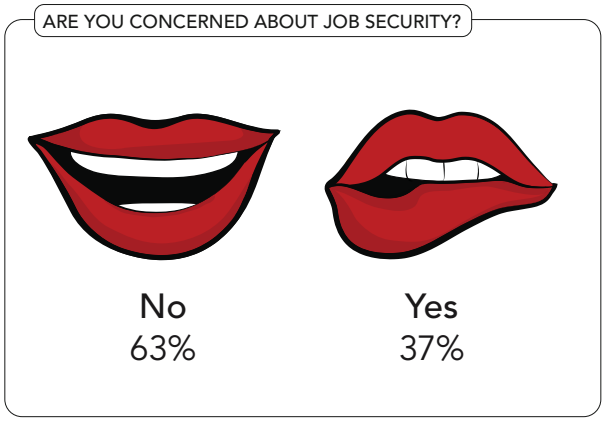

Figure 7. More than half of respondents aren't concerned about potential job loss.

"After not having any salary raise for the past four years, and with inflation going sky high, my compensation is lower than I expected," added another commenter.

"At the moment, there seems to be no movement on adjusting salaries to keep up with inflation," shared another.

THUMBS UP

"Working for the chemical industry is a pretty good gig," said Martha Gilchrist Moore, chief economist and managing director, Economics and Statistics at the American Chemistry Council in her 2022 Mid-Year Situation & Outlook webinar hosted by *Chemical Processing* (https://bit.ly/3DHGXED). In her presentation, she had good news to share: even with inflation, labor market and supply chain issues, chemical output and employment will continue to grow.

This might explain why job security concerns are at their lowest levels with 63% stating they're unconcerned about job loss, a 10% jump from 2021 (Figure 7). In fact, when we asked, "what are the chances you'll be laid off or fired in the next two years," 75% say "none" or "just a very slight chance" (Figure 8).

Adding to this, 92% of our respondents report their

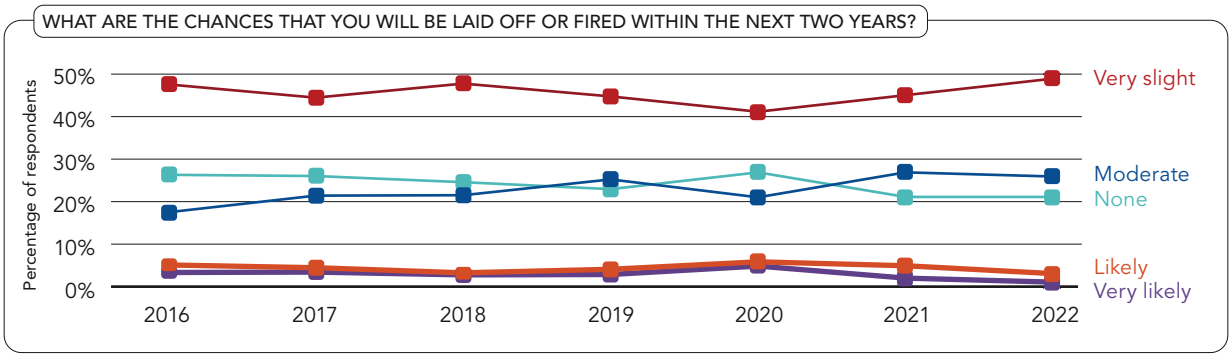

Figure 8. Respondents reporting the likelihood of losing their job edged down compared to last year.

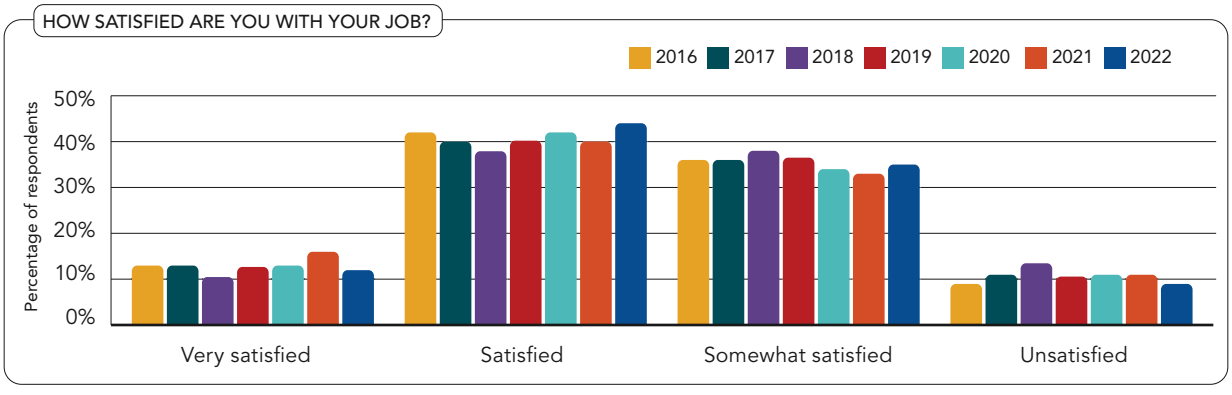

Figure 9. Job dissatisfaction fell 2% from last year.

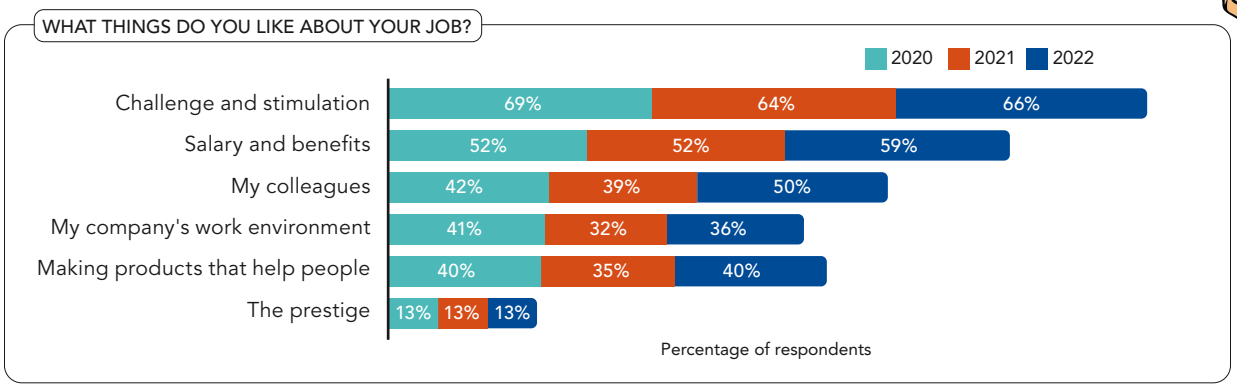

Figure 10. Challenge and stimulation rank highest in job satisfaction, followed by salary and benefits.

employment status as "working full time," compared to just 79% last year and 88% in 2020.

With that, job satisfaction also is at an all-time high. Last year, 89% were at least somewhat satisfied with their jobs. It's now ticked up to 91% (Figure 9).

The top three factors contributing to job satisfaction (Figure 10) continue to be the high level of challenging work (66%), the salary and benefits (59%) and rapport with colleagues (50%).

"Find a job that you get satisfaction and work-life balance from rather than basing it on salary only," advised a respondent.

One even gave a shout out to its employer: "Dow Chemical is top tier in compensation and benefits. I'm very lucky to work for them." ●

AVOID PROJECT CONTRACTING PITFALLS

Following ten best practices can avert adverse impacts

By Stephen Liccini, Pathfinder LLC

PROJECT CONTRACTING covers the spectrum of pre-award and post-award activities — from developing and awarding contracts through their administration. An owner's good contracting practices throughout these stages can avoid costly time-consuming mistakes and adverse impacts, and help ensure project success. Such practices facilitate good project management for both the owner and contractor, regardless of project scope.

Contracting is highly successful for some projects but much less so for others. The latter usually suffer from mistakes and adverse impacts that can result in poorer-than-expected performance, disputes or claims.

Mistakes made in contracting are not attributable to a particular type of project or contract type or to geographic location. They occur both before and after contract award (see Figure 1), and affect project outcome. It's important to understand that contracting mistakes are project management mistakes.

So, here, we'll look at common mistakes and how to avoid them. While this article is written from an owner's perspective, its concepts and recommendations also should prove useful to contractors.

COMMON MISTAKES

One or more reasons may contribute to an organization's contracting method/process "missing the target." Common mistakes include:

- Inappropriate strategy, e.g., a lump-sum basis applied to a poorly defined new or revamp project, resulting in a proliferation of changes.
- Misfocused bid review balance, e.g., one too centered on a contractor's commercial offerings with

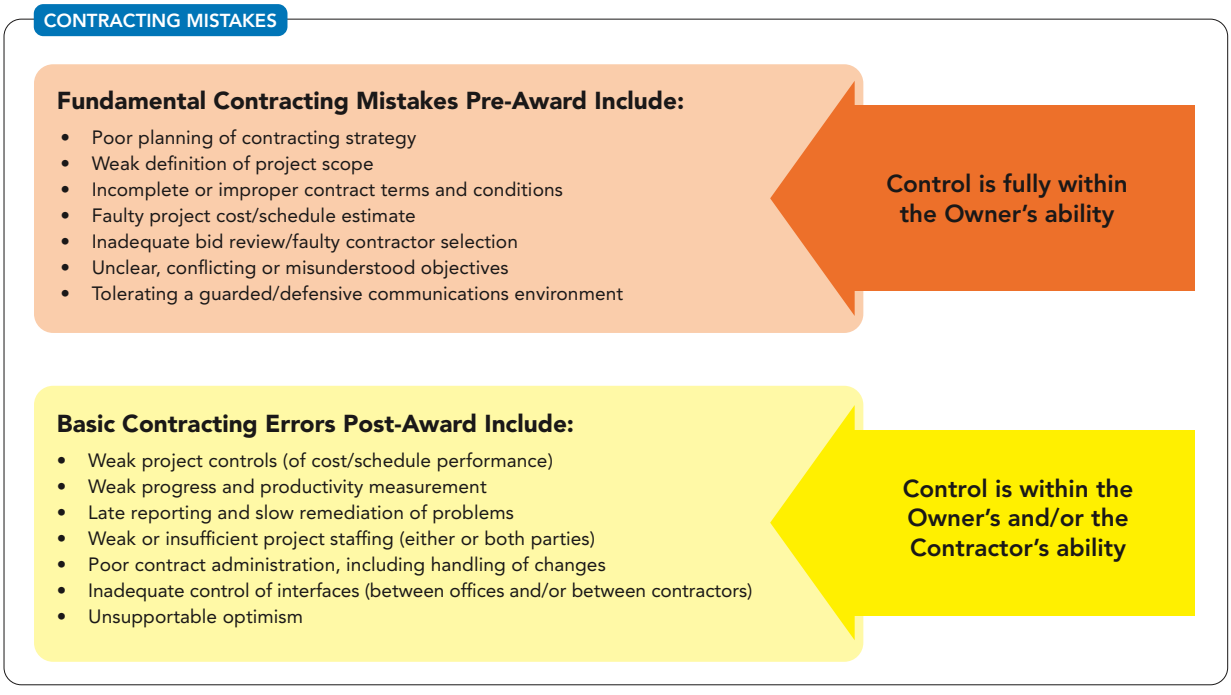

Figure 1. Errors can arise both pre- and post-contract award.

not enough attention devoted to the contractor's capabilities/execution plans/people and necessary upgrades of these.
- Faulty contractual terms, i.e., incomplete or ambiguous definition of scope, obligations, deliverables or completion requirements, or imposing onerous/inequitable risk conditions.
- Flawed project targets, e.g., poor quality/unrealistic cost and schedule estimates.
- Inadequate team composition due to underestimating the number or qualifications of resources needed for the project.
- Wrong management procedures, i.e., weak tools/practices used to steward project performance.

Contracting mistakes directly correlate with adverse business impacts. These errors often can increase project costs as a result of a higher-than-normal level of change orders. Adverse business impacts also include longer project schedules, which occur just as frequently as cost increases. Longer schedules, which can extend for several additional months, can be change-order driven as well as caused by lower productivity. Other negative business impacts of contracting errors include quality, startup and operability problems, often due to higher-than-normal defects/deficiencies during project execution as well as disputes and claims, along with the damaged business relationships they generate.

Many contracting mistakes stem from issues that received insufficient attention, such as not starting the contracting process early and, thereby, foreclosing options that may be optimum for the project. Other issues that sometimes get inadequate consideration are examination of the balance of contract risks (execution, commercial and legal) between the owner and contractor as well as a good definition of project objectives, which can be unclear and not prioritized. Project schedules that don't have at least a 50% probability of achievement and cost estimates with inappropriate contingency levels also can set a project up for failure at the outset of contract award.

TEN BEST PRACTICES

By adhering to these, an owner can avoid contracting pitfalls and promote project success. Figure 2 shows these key practices. Let's look at what they involve:

1. *Project Definition.* Regardless of project or contract type, ensure the project is well defined. Confirm its objectives, scope, site conditions, schedule and execution strategy are clear, complete and suitable for obtaining good bids.

2. *Contracting Strategy.* At the earliest possible point, analyze all viable compensation options and select the optimum approach for the project. Outline project risks and mitigation measures (both pre- and post-award). "Select the right horse for the course."

3. *Contract Documents.* Use sound, proven and comprehensive contract templates and then tailor them for the project; confirm the contract satisfies the "4 Cs" — clear, complete, concise and consistent.

4. *Project Estimate.* Verify the cost/schedule estimate and its development basis are sound and consider factors such as site specifics, market conditions, execution strategy, labor availability/productivity, good benchmarks, an appropriate contingency, etc. Use peer reviews to test the estimate's quality and its confidence level.

5. *Bid Review.* Carefully plan and document the bid review (e.g., methodology, selection criteria, review team, schedule) before receipt of proposals. Never allow a bidder to "buy" the

Figure 2. These can head off common contracting errors.

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contract with unusually low commercial terms. Ensure the bid review focuses on the contractor's execution experience with similar projects and that plans are sound and tailored for the specific project, and evaluate the quality of key people to be assigned to the work. Remember during negotiations: "Your business relationship starts during bid review."

6. *Contract Award.* Select a reputable/capable contractor. Confirm both parties fully understand the contract requirements as well as any special risks or unusual commitments. Use team workshops after the award to promote joint understanding and foster alignment.

7. *Project Staffing.* Before award, make sure both contractor and owner resources are qualified, sufficient in number, and deployed on time to manage the project, including its interfaces. Clarify roles/responsibilities within the team and, when more than one office or entity will provide services, verify roles/interfaces/plans are well understood.

8. *Contract Administration.* Ensure timely/fair administration to maintain the sanctity of the contract terms. Use appropriate/effective change-management forms/procedures to steward potential and agreed changes. Keep communications open and frequent (a "no surprises" approach).

9. *Project Execution.* Require weekly assessment and reporting of key performance indicators such as cost (expended, incurred, forecast), progress versus schedule, productivity, safety and other critical issues. Thoroughly capture the status of all vendors' and subcontractors' work.

10. *Project Management Behavior.* Strive to function as a single team working together toward a common goal:

- promote open communications at all levels and foster a "we" versus "me" behavior;
- recognize accomplishments;
- promptly process information requests and scope variations;
- don't allow disputes to fester — analyze and escalate disagreements until resolved;
- regularly monitor performance, closely steward against plan and ensure that corrective actions are effective; and
- set an example of honesty, integrity and consistency.

EMULATE INDUSTRY PACESETTERS

A pacesetter generally is defined as an individual/company that is more successful than its competitors by developing new products, methods, standards, etc., before anyone else. In our industry, a pacesetter is an organization whose

capital projects are consistently completed on-time and within budget to established quality and safety standards and without claims.

Along with the ten best practices outlined above, industry pacesetters use other techniques to ensure effective contracting practices and successful project completion:

- *Documented Contracting Procedures.* These cover the full contracting process with checklists for key contracting steps.
- *Proven Well-Constructed Contract Templates.* These are designed for various compensation and types of project contracts, and come with accompanying guidance on how to tailor the templates for projects.
- *Good-Quality Resources Dedicated To Project-Contracting Activities*. This often is a centralized group of strong performers — very knowledgeable of contracts, the contracting process and the market. These people are project experienced, well-trained and selected for their skills/capabilities (and do not handle routine purchasing activities).
- *High-Quality Training Programs*. These cover all major aspects of contracting.
- *Superior/Up-To-Date Database*. This provides accurate information on past strategies, bid reviews, contracts, project outcomes, contractor's performance, market trends and lessons learned.
- *Efficient And Effective Communications/Cooperation*. Open and supportive dialogue occurs between members of each project team and the contracting personnel.
- *Single Points-Of-Contact For Functional Support*. This involves selecting a suitable person in law, tax, finance, etc., i.e., someone well-versed in project contracts.

CONQUER CONTRACTING CHALLENGES

Contracting covers a wide spectrum of activities from early project planning through project execution and close-out — activities that are integral to good project management. You can promote project success by consistently applying contracting best practices and the drivers used by industry pacesetters. Good contracting practices minimize adverse business impacts and facilitate contract administration. ●

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OPERATIONAL EXCELLENCE PROGRAMS PAY OFF

Chemical makers benefit from diverse initiatives

By Seán Ottewell, Editor at Large

EFFECTIVE DESIGN and implementation underpin the success of any operational excellence program. To achieve such success, however, the chemical industry also must contend with other challenges, says Ana Khanlari, Houston-based industry marketing director, chemicals for Aspen Technology.

First is the lack of qualified personnel. Employees with longstanding expertise are retiring and the industry is finding it hard to recruit new talent with the skills to develop or successfully implement digital technologies. In response, she notes, chemical companies are leveraging tools such as artificial intelligence (AI) to drive innovation in developing new products.

The second challenge is the investment required to upgrade or create digital infrastructures. "This is an especially big hurdle for smaller chemical companies trying to determine priorities around where to gain the maximum return on their digital investments. Supply chain management and waste reduction can be two key areas of interest to invest in digital solutions here," notes Khanlari.

Finally, the industry's moves toward cloud-based applications and digitalization generally pose data protection and systems security challenges. Data integrity and intellectual property protection are crucial.

Even so, Khanlari finds that initiatives that improve efficiency, reliability, productivity, safety and, ultimately, profitability of operations are leading drivers in the design of operational excellence programs.

"Digital solutions play a pivotal role here by providing tools that can forecast demand and manage production planning, model and optimize the process, define key performance indicators, and troubleshoot and predict future behavior of the equipment," she explains.

Further, the assimilation of AI and machine learning (ML) with first-principles engineering models has led to powerful tools to simulate and optimize processes with gaps in available data or unsteady and transient conditions. Such digital technologies, including the company's own Aspen Hybrid Models, can play an especially important role in the design of new processes, she stresses (Figure 1).

"Whether to process a new bio-based feedstock or to recycle waste plastic, digital solutions can provide a realistic view while experimental data are scarce, difficult to gain, and scale is limited," adds Khanlari.

Sustainability increasingly factors into operational excellence programs and associated digital technologies, too, with metrics such as emissions reduction and waste generation under the spotlight.

As an example, Khanlari cites a SABIC plant that wanted to speed up progress toward its 2025 goal of cutting greenhouse gas emissions, energy consumption and fresh water use by 25% compared to 2010.

A digital twin of the plant's utility system, made using Aspen Utilities Planner, led to a 130-GJ/hr decrease in energy use from the plant — equivalent to a reduction in carbon dioxide (CO_2) emissions of nearly 60,000 tons/yr, assuming natural gas usage.

SABIC now is following up on that 2021 project by planning to deploy an online energy optimizer as a real-time decision-making tool to further improve the plant's processes.

KEY IMPETUS

Sustainability is a critical driver in operational excellence programs, right across the value chain, finds Aveva, Cambridge, U.K. "According to a PwC research, today's existing technology can help companies reach more than 70% of the targets that underpin the United Nations Sustainable Development Goals over the next decade," notes Stephen Reynolds, industry principal — chemicals.

Aveva is working alongside its customers to create operational excellence programs to leverage the power of the industrial ecosystem and deliver technologies to optimize engineering, operations and performance while also helping companies reach their environmental, safety and governance targets.

"We take maximum advantage of our data management and modeling solutions to quickly convert raw data into insightful information to inform the fastest, most accurate decisions," says Reynolds.

So, once a program gets the go-ahead, Aveva can deliver a scalable and maintainable evergreen digital twin that supports the entire plant lifecycle — while AI and cloud computing speed up engineering projects from concept to full production.

"Once the plant is live, our digital engineering blueprint is connected with real time data to become a live digital twin. As the project workflow progresses, other technology layers can be added to ensure quality and yields that are aligned to the customer´s vision and strategy," he adds (Figure 2).

The idea is to make chemical companies as agile as possible in their responses to changing market demands while at the same time maintain product quality with minimum wastage, maximum safety and optimum sustainability, he stresses.

As an example, he cites a project at Covestro, Leverkusen, Germany, where the Aveva PI System operations data management platform gathers data from more than 4,000 energy-specific tags across its plants, regional sites and business units.

This wider view of energy use enabled Aveva's team to uncover trends, reveal insights and make adjustments as necessary, allowing Covestro to cut energy consumption by 30% per ton of product and CO_2 emissions by 39% per ton — even as production capacity has increased.

"The program earned an energy management certification from the German government, securing major tax rebates," adds Reynolds.

China National Bluestar turned to the same technology when it wanted to increase production while reducing energy and material costs. However, managers at the company's headquarters in Beijing lacked real-time access to onsite data for corporate-wide reporting and planning, which hampered efforts to quickly identify problems and deploy best practices across sites.

Using the Aveva PI system, the company could better understand what was happening across 12 plants spread across nine provinces. The system's combination of improved performance monitoring and computing power provided much-needed visibility into plant operations while increased automation has made reporting faster and more accurate. More than 30 production units have been optimized. At one of its newly refreshed sites, Bluestar is saving $200,000/yr in steam costs alone.

To create a successful operational excellence program and leverage digital transformation to the full, chemical companies must have a clear view of their current challenges as well as their short- and long-term goals, counsels Reynolds.

"A digital transformation strategy and roadmap should then be tailored to the specific needs and objectives of each company. In our experience, digitally scalable and maintainable technology aligned with industry expertise is critical to achieving desired returns on digital investments. A proven record is also vital as is the possibility to run applications in the cloud. Even if they are not ready for cloud, they should make sure the digital investment will last as long as possible," he emphasizes.

Another aspect is the user interface. Applications that are easy to deploy, use and maintain will maximize return on investment and also attract the incoming

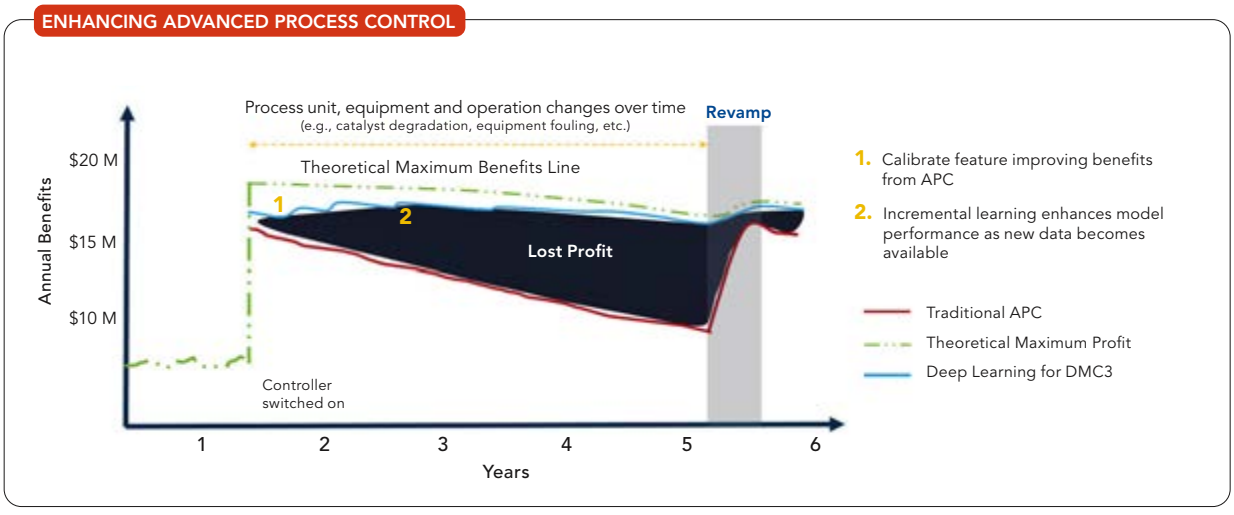

Figure 1. AI-enabled adaptive technology is especially valuable in the design of new processes. *Source: Aspen Technology.*

ENSURING ONGOING ALIGNMENT

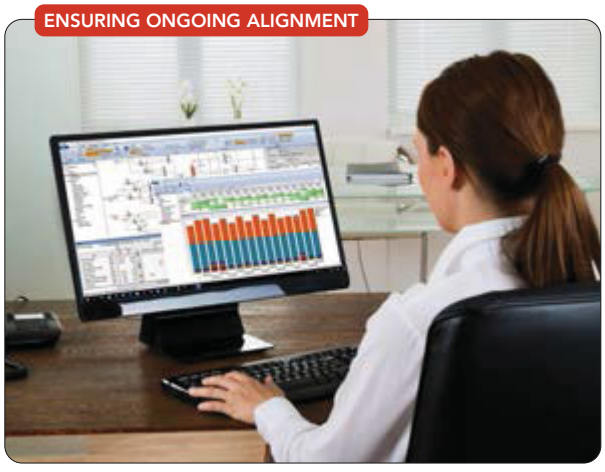

Figure 2. Addition of other technology layers as a project workflow progresses enables quality and yields to adhere to a customer's vision and strategy. *Source: Aveva.*

generation of workers, who generally steer clear of out-of-date, conservative companies.

Today's available digital tools enable easy access to information, collaboration and overall agility, so organizations can reach their profitability goals aligned with their sustainability targets.

"Operational excellence is critical for enabling business continuity, sustainability and profitability. Digital technology supports and drives operations by helping chemicals companies to operate efficiently and safely, increase competitiveness, and retain talent," Reynolds concludes.

FOREMOST FACTOR

A survey of over 100 senior operations staff at refining and petrochemical companies identified operational excellence as the top factor for remaining competitive and efficient, according to KBC, Walton-on-Thames, England, which carried out the survey.

"While still key, it is somewhat outdated. Most companies have already gone down the path and have established effective business processes that work best for their environment. There are still a few companies that need to focus more on integration and develop a road map," notes Shane Fitzsimmons, principal consultant, business development consulting/sales.

Secondly, the survey found that operational excellence is a means to drive operational discipline to improve business

performance. Importantly, before moving towards a digital transformation, all organizations must demonstrate repeatable results through the execution of safe operations.

Finally, digitalization itself is a means to codify operational excellence and drive to the next level of performance with predictable results. "The use of AI/ML on big data sets increases production efficiency and lowers cost per operating unit with higher overall equipment effectiveness (OEE)," stresses Fitzsimmons.

However while many chemical companies have expertise in certain areas, this varies enormously depending on their scale and end products. KBC's response to this variation is to take a holistic approach to the design of operational excellence programs. This involves pursuing a top-down operating model to maximize value creation while providing technical expertise across a particular plant or site's functions. At the same time, KBC's management change strategy focuses on the frontline to drive sustainable behavioral change. "Hand-in-hand with these two is the delivery of digitalization, automation and IT/OT [information technology/operational technology] integration options to control systems to automate plant and systems and embed the use of technology in the way of working," adds Fitzsimmons.

To illustrate, he cites a two-year-long project at an integrated refinery and petrochemical complex in Southeast Asia. The operator, feeling it was lagging behind industry peers, wanted to pursue a strategy of operational, commercial and human performance excellence.

KBC's strategy involved more than 50 of its consultants focusing on four work streams: value chain optimization,

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process and energy improvement, utility system optimization, and reliability and availability.

Using the holistic methodology, the consultants were able to make and implement many recommendations.

For example, they evaluated and implemented value, reliability and stability improvement opportunities across the entire complex to improve OEE. The application of leading-edge digital technology supported the development and deployment of these initiatives. Such optimized work processes also supported the creation of high-performing work teams who benefitted from coaching and mentoring on their use. Models and tools left behind after the project helped the company sustain continuous investment.

In the two years since the project was completed, the company has shaved $1/barrel off the cost of refining oil, improved OEE by 6% and reduced working capital tied up in the intermediate inventory by 13%. The customer also reports an improved workforce competency level and a much higher performing work team culture.

Another example involves a U.S. refinery in the final stages of a modernization and expansion project. It identified a need to restructure to improve performance in advance of commissioning new units.

Here, KBC applied an operational excellence methodology to identify performance improvement initiatives to implement before and after expansion. These plans included quick win opportunities. The consultants also developed an organization structure to effectively start up and run the newly configured refinery post expansion; these include team charters and job profiles to ensure clear, aligned accountabilities throughout the organization.

To incorporate key strategies into regular planning and optimization processes, KBC updated the linear programming sub-model. Organizational effectiveness was improved by doubling the mean time between failures for rotating equipment, which increased production throughput and reduced alarm frequency.

KBC identified more than $100 million/yr of potential yield and energy opportunities for the operator. In addition, it pinpointed about $50 million/yr of opportunities available for immediate implementation that required no capital investment. The decrease in environmental reportable incidents — from 16 to four year-over-year — resulted in savings of $5 million in fines.

Tailoring the design of operational excellence programs to each asset's starting point and aligning the programs to the targeted outcomes is crucial, believes KBC. An operational excellence program should focus on specific tangible goals and evolve over time. A program should place at its core three factors: build in results assurance and sustainability from the start; understand the balance between tools and capabilities; and focus on governance. ●

Choose the Correct Air Compressor

Consider five crucial factors before deciding

By Paul Humphreys, Atlas Copco Compressors US

CHEMICAL MAKERS demand the highest quality possible when it comes to compressed air. Efficiency also is very important to the competitiveness of chemical processors. A recent study by Atlas Copco pointed to the potential of saving 13 billion kWh in the United States through efficiency improvements.

"If it's not broken, then don't fix it" is a foolish strategy for compressed air. On the contrary, waiting for the compressor to schedule its own replacement time could cause you to suffer lost production and force you to make quick decisions, both of which can cost a lot of money. The challenge of trying to be efficient with compressed air is that you most likely will just baseline and benchmark using your energy bill. However, what if the energy bill always has inefficiency built into it? A 10% saving might look like a great job — but what's the real potential? Understanding that requires considering five factors when selecting a compressor.

1. WHAT DOES AN AUDIT REVEAL?

Never replace like for like — focus on an audit first. One of the key things an audit examines is inappropriate uses of compressed air and artificial demand, both of which could have boosted your compressed air usage and energy bill for many years.

Audits come in two primary types (as well as many sub-types) but the two basic elements to audit are system efficiency and quality, and air quality. Detailed supply- and demand-side audits always must be conducted on-site.

The term audit also often is used for more-straightforward studies that involve data-logging machines and monitoring performance over a defined period; we refer to these as surveys rather than audits. Its simple installation means the equipment necessary for a survey can be sent to the customer without the need for somebody to go on-site to set it up. Then, the hardware is returned, and the data are put into a modeling system to produce graphs that show where savings can be made. This all can be done remotely if the customer desires.

Air quality testing is something that quite understandably continues to gain significance; it even is mandated inside critical industries like food and beverage. This always involves gathering an air sample on-site while making sure not to contaminate the sample before it is sent away for testing.

The two most-common examples of artificial demand are leaks and air consumers left on when not required. Leaks can cause problems within your system that result in more energy consumption and costly resources needed to combat the issue. It's important to identify and repair all leaks, starting with the leak that consumes the most compressed air. After fixes are made, you should implement a continuous leak detection and elimination program to prevent future leaks.

It's also important to stop the supply of compressed air to applications that are not in operation. This can be accomplished by various methods, from manually closing a discharge valve to adding a solenoid valve and a control system in the air supply to each application. Closing the valve at night or on the weekend and preventing the compressor from turning on to fill leaks when production is not running can provide a huge source of energy savings.

2. MULTIPLE MACHINES CAN SAVE YOU MONEY

Compressor (or blower) applications fall into three general categories:

- low-pressure air — output pressure of 150 psi (10 bar);
- medium-pressure air — output pressure between 150 and 1,000 psi (10.4 to 68.9 bar); and
- high-pressure air — outlet pressure above 1,000 psi (69 bar).

Determining what equipment works best for you can depend on the applications you are running.

Using higher-than-needed pressures and extended cycle times will result in excessive air usage. Open-blowing applications also waste compressed air that easily can add unnecessary costs to your energy bill.

Typical applications for medium-pressure air within chemical processing include pneumatic controls and valves, general plant air for rotating equipment and tooling and even for product drying. Using high-quality low-pressure air really can offer a large cost-saving opportunity in the following applications:

Refining. This includes petroleum refining and the variety of processes employed in converting crude oil into useful products, including gasoline, kerosene, jet fuel and diesel oil.

Pneumatic Conveying. Chemical processors use pneumatic conveyancing to transport dry bulk materials, including powders and granular forms as well as chips and pellets. Because manufacturing plants that use pneumatic conveying have employees working nearby, worker safety requires using blowers with low-noise and low-vibration technologies.

*Wastewater Treatmen*t. Plants treat wastewater using aerobic biological processes to digest waste byproducts. The millions of bacteria feeding on organic waste to break it into carbon dioxide, nitrogen gas and water need oxygen; so, large amounts of air are blown into aeration tanks.

Processors often rely on high-pressure air (or other high-pressure gases) if they are making their own packaging or perhaps even running their own fleets on renewable natural gas.

Every plant manager knows the cost of downtime. Fortunately, it's possible to build a system that can eliminate or reduce downtime. One way is by adding a second compressor or running two smaller ones instead of one large one; doing this has never been easier. Another option involves treating compressed air, which often is called the "fourth utility" inside a plant, like the other utilities — gas, electricity and water — in essence, buying air and not the actual compressors. For the right customer, this has several advantages, including avoiding a significant capital expenditure at the start of the project as well as maintenance responsibility for the equipment — which the manufacturer instead handles.

3. FOCUS ON QUALITY

This relates to both clean and dry air. First, when it comes to clean air, the highest quality of compressed air is essential; it must be guaranteed ISO 8573-1 oil-free — also known as Class Zero. Contamination by even the smallest quantities of oil can result in costly production downtime and product spoilage.

Removing moisture for corrosion protection also is important for the equipment using the air and the air system itself. Particulate created from rust and scale can foul lines and damage components of the air system. In the worst case, corrosion could lead to failure in the pipe work, creating leaks and preventing air from reaching the process where it is needed.

Most manufacturers use compressed air dryers as one of the methods for removing moisture. Air exiting a compressor is heated and 100% saturated with water. As the air cools, water begins to condense. Because the air typically gets cooler the further it gets into the system (air systems also often pass through cold areas like the outdoors before reaching the process), it is much more effective to dry the air prior to distributing it.

Filters and separators can remove liquid moisture droplets from a system. However, they can't remove water vapor — that requires a dryer.

4. CAN YOU ADD ON-SITE NITROGEN INTO THE MIX?

Taking control of your industrial gas supply is a growing trend across multiple industries. Did you know that running a compressed air system means you are already 50% of the way toward making your own nitrogen?

Chemical blanketing, also called tank padding or inerting, is a very simple process

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of applying nitrogen to the empty vapor space inside a container or vessel to control the composition of a specific chemical. The gas is used during production, storage, transportation and final packaging, and can be employed in a variety of container sizes, ranging from a small bottle to a million-gallon tank. But why use nitrogen specifically? Simple: it's an inert gas, meaning it's non-combustible and will help prevent fires and explosions. Additionally, nitrogen helps to displace oxygen, thus preserving the integrity of products that otherwise would degrade in oxygen's presence and preventing unwanted chemical reactions. For these reasons, it is considered as the security blanket of the chemical industry!

So, when sizing a compressor, it's sensible to consider whether you would also like to include the capacity for current or future on-site nitrogen production.

5. WHAT TO LOOK FOR IN A SUPPLIER

We at Atlas Copco aren't fans of the term "total-solutions provider" when it comes to our business. However, we can provide most of what is needed in your compressor room — compressors, blowers, vacuum pumps, dryers, chillers, and nitrogen and oxygen generators. All these pieces of equipment have the same controllers and are specifically designed to work together. This offers enormous benefits when it comes to central connectivity, remote monitoring, service contacts, and operator use.

The old way to deal with a service issue was to call the manufacturer. Its service representative would ask, "What message do you see on the controller?" You would answer. Then, the person would ask you to do something — but, if you didn't happen to be next to your compressor, you might have to call back. If you were lucky, you'd reconnect with the same service representative so you didn't have to explain everything over again. Today, compressor users and the manufacturer can access system data at the same time in real time. Everyone can see the system's history and the sequence of events that might have led to the issue. Technicians can connect into the compressor ahead of time, shortlist what they believe to be the issue, and be more proactive. Their visits can be shorter, reducing any downtime (Figure 1).

In terms of service operations, leading manufacturers use systems to optimize their fleet of technicians on the road. Global positioning system (GPS) technology keeps

FIELD TROUBLESHOOTING

Figure 1. GPS enables field specialists to know where to go next, saving time and ensuring issues get handled by priority.

office specialists in constant contact with field-based teams and pinpoints their whereabouts. Direct relaying of address details for the next job to the service vehicle's GPS system ensures accurate communication. All of this makes scheduling more efficient and allows the company to respond in line with the urgent needs of the current day.

The last and perhaps most important element, relates to that time-tested maxim: an ounce of prevention is worth a pound of cure. The latest monitoring equipment for compressors can detect heat changes, altered vibration and other issues, enabling taking corrective action, such as shutting down a compressor to forestall overheating, before a problem becomes more serious. Remote 24/7 monitoring now is widely available for compressed air systems. This development has spurred manufacturers to set up remote monitoring centers. A simple analogy here is this: we entrust alarm companies to monitor our homes in exchange for peace of mind — why not have the same peace of mind for your compressor? We can assure you that your plant cannot operate without compressed air! ●

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Use HAZOPs Properly

Don't treat them as design development reviews

It is not the purpose of a HAZOP to do engineering.

A HAZARD and operability study (HAZOP) checks designs for safety risks. Unfortunately, companies too often broaden its role. As a fairly recent letter to the editor [1] pointed out: "An important rule for HAZOPs is that it is not a design activity, but rather a design check (for hazards and operability)." The letter writer was emphasizing that a HAZOP isn't intended to solve the issue identified. Instead, later work, outside the HAZOP, should straighten out the problem. This makes sense. Trying to solve the problem in the HAZOP keeps the meeting going, tying up all participants for more time. Additionally, the participants in the HAZOP may not be the right people to resolve the issue. Of course, any changes proposed should be verified as well.

While the sentiment expressed by the letter writer is valid, my thinking is even broader. I strongly believe a HAZOP mostly is a safety design check, not a design development review. Making and finalizing major design choices should occur long before a HAZOP. Let's look at some examples to see the difference.

In the first example, a client was well into the design process to build a new biosynthetic plant. Its output was to be a bio-based material that could serve as a drop-in replacement for an existing industrial product. Multiple parts of the process took place under vacuum. The vacuum systems selected used liquid-ring pumps. The HAZOP review identified the issue that maintenance on the pumps created personnel exposure to the seal fluid. One recommended action was to consider switching to steam-jet ejectors for the vacuum systems. This is the equivalent of having a HAZOP-recommended action of replacing distillation with freeze crystallization for purifying a product because the freeze crystallization runs at a lower (safer) temperature for personnel exposure.

The issue here is not whether you think liquid-ring pumps have better or worse safety than ejectors. Experience shows that both systems have well-understood reliability and safety characteristics. Rather, the issue is that revisiting a major technology choice is not the purpose of a HAZOP. Its aim is to deal with the safety and operability within the system you have.

HAZOPs occur relatively late in the design process. The place to make major technology choices is during preliminary engineering — or process hazard analysis (PHA), at the latest. Making fundamental changes in work scope late in the work flow has major consequences to cost and schedule.

In the second example, a set of HAZOPs was scheduled to review an entire new biofuels plant. By the time it was finished, this set of HAZOP meetings stretched over 18 weeks. About six weeks in, a new controls-and-instrumentation engineer showed up from the client company. In the very first session afterward, the engineer looked at the drawings and said "These interlocks don't meet our company's standards. You'll have to redo them all." Silence descended.

This started a month-long debate on what the standards really said and what actually was needed; it mostly involved arguments between various groups within the client company. I personally didn't have an agenda on which approach to take; both looked acceptable to me. I just wanted a decision, any decision, but a decision — and to know which approach to use and whether everything needs to be redone. Again, this is a type of question that should be decided before a HAZOP.

If you ever hear "We'll review that in the HAZOP" or "We'll decide that in the HAZOP," stop immediately. Work already is headed off the rails. The purpose of the HAZOP is to identify things to check, not to do engineering. That's the point of the letter that started this discussion. And it's certainly not to make conceptual changes, which is the focus of this column.

How you avoid late engineering is to get the right skills involved early. Well before any HAZOP there should be a PHA, a piping-and-instrumentation-diagram review, a construction review — or whatever else you think is needed. Too often, plants will not assign senior operating personnel to these early meetings. As a result, many operating issues get raised at the last minute. This is a project management error. Get the plant people involved earlier rather than later. ●

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1. Staible, F.E., "HAZOPs Are Not a Design Activity," *Chem. Eng. Prog.*, Vol. 117, No. 5, pp. 4–5 (May 2021).

ANDREW SLOLEY, Contributing Editor
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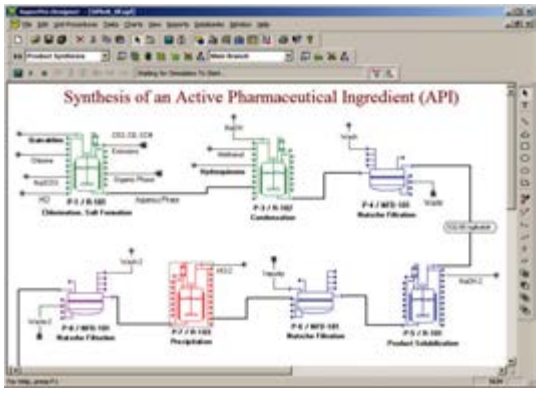

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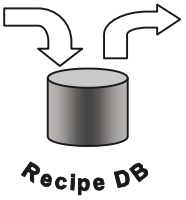

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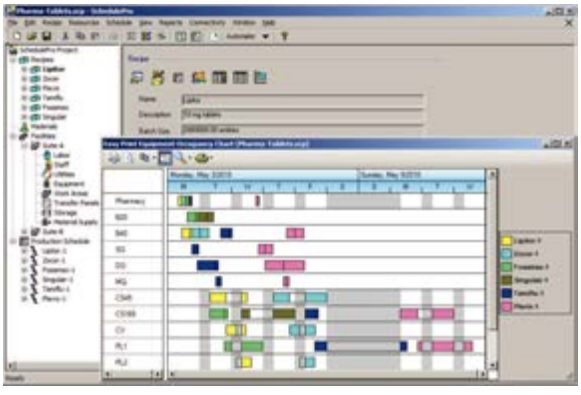

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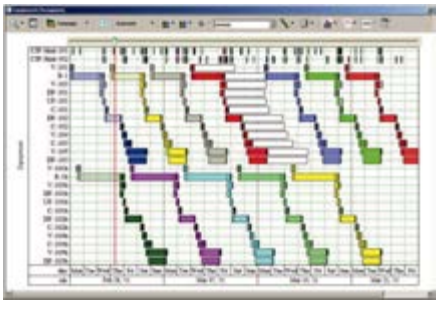

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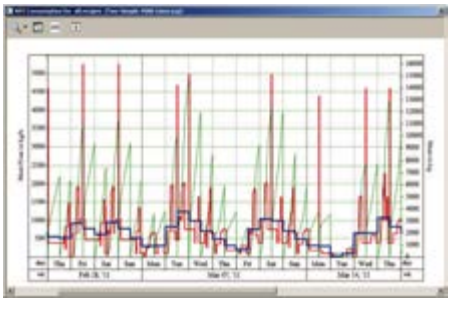
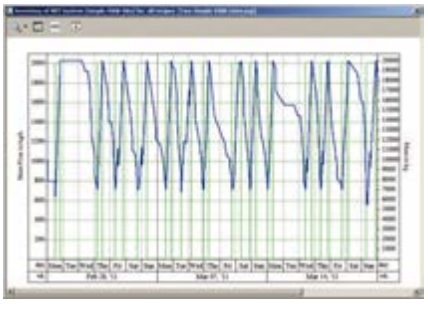


Tracking demand for resources (e.g., labor, materials, utilities, etc.)



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SchedulePro is a versatile production planning, scheduling, and resource management tool. It generates feasible production schedules for multi-product facilities that do not violate constraints related to the limited availability of equipment, labor, utilities, and inventories of materials. It can be used in conjunction with SuperPro (by importing its recipes) or independently (by creating recipes directly in SchedulePro). Any industry that manufactures multiple products by sharing production lines and resources can benefit from the use of SchedulePro. Engineering companies use it as a modeling tool to size shared utilities, determine equipment requirements, reduce cycle times, and debottleneck facilities.

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Blasts Cause Chemical Weapons Concerns

Pipeline explosions occurred near Baltic Sea World-War-II-era munitions dumpsite

The Baltic Sea is basically one of the most heavily polluted seas on the planet.

THE SEPTEMBER 26 blasts that ruptured the Nord Stream gas pipelines in the Baltic Sea have prompted fears about release of contaminants from long-discarded chemical weapons and other munitions from disrupted sediments and under the seabed.

The €7.5-billion ($7.3-billion), 1,200-km-long pipelines were built to transport natural gas from Russia to Germany and are designed to last at least 50 years. They are operated by Nord Stream, Zug, Switzerland, a consortium of five shareholders.

At full capacity, the pipelines could transport more than 55 billion m^3/yr of gas. According to Nord Steam, that's enough to satisfy the energy demand of more than 26 million European households.

However, the pipelines pass over an area known as the Bornholm basin, where, in 1947, the allies dumped approximately 32,000 tons of Germany's estimated 65,000-ton chemical weapon stockpile. The primary dumpsite originally was to span no more than a radius of three nautical miles, but later widened to secondary and tertiary zones, spreading the chemicals over a significant area.

In addition, Soviet troops tasked with dumping chemical weapons from Nazi stockpiles in Poland and Germany dropped tons of wooden crates containing them overboard before reaching the agreed dumping ground — further widening the contamination zone.

As part of a 2019 environmental impact assessment for Nord Stream 2 construction work, scientists from the Danish Centre for Environment and Energy (DCE) at Aarhus University, Aarhus, Denmark, carried out investigations of the seabed on, around and under the proposed pipeline route.

Their report, "Nord Stream 2 chemical warfare agents (CWA) marine risk screening," used chemical analysis of sediment samples to look for CWA residues. Subsequent risk modeling of the tiny level of residues found led the DCE to conclude the selected route added negligible environmental risk.

However, a report in the October 21 issue of *Nature* quotes Aarhus University environmental scientist Hans Sanderson's concerns that the violent expulsion of methane from the ruptured pipeline might have sent contaminants into the water column, where they could harm marine wildlife. These contaminants include the radioactive isotope cesium-137, toxic flame-retardant polybrominated diphenyl ethers, and heavy metals including mercury, cadmium and lead.

"The Baltic Sea is basically one of the most heavily polluted seas on the planet. So this sediment here is full of junk. These explosions [also] took place as close to the dump site of these chemical weapons as possible," he said.

Sanderson is one of two co-authors of the original 2019 environmental impact assessment.

Meanwhile on October 14, the Swedish Coast Guard reported the gas leak — originally 950-m wide — was no longer visible following an overflight of the Swedish economic zone in the Baltic sea and considered the area no longer closed.

Following this announcement, Nord Stream sent in a specially equipped survey vessel to gather data at the pipeline damage on Line 1 in the Swedish economic zone.

On November 2, Nord Stream issued a statement on this work: "According to preliminary results of the damage site inspection, technogenic craters with a depth of 3–5 m were found on the seabed at a distance of about 248 m from each other. The section of the pipe between the craters is destroyed, the radius of pipe fragments dispersion is at least 250 m. Experts continue to analyze the survey data."

While that survey progresses, the pipe repair and subsea intervention (PRSI) emergency pool managed by Equinor, Stavanger, Norway, is preparing to offer its expertise in any future repair activities.

The PRSI, formed in 1987, has over 20 members together responsible for more than 20,000 km of energy pipelines. Their activities range from supply of basic equipment to specialists in hyperbaric welding such as the Trondheim-based Norwegian Science Institute (Sintef).

"It is by no means impossible to repair major pipeline damage. Damage is rare, but it has happened, as a result of material fatigue, impact, wear, adverse chemical processes, pipeline twisting and other unexpected physical incidents," explains Sintef welding expert and senior research consultant Ragnhild Aune.

"Fortunately, the Nord Stream pipelines are in shallow waters and the damage is located at depths of no more than 100 m. This means that it is possible to carry out repairs using a diver-assisted system, for which emergency procedures for hyperbaric welding — welding under water at great depth — already exist," she adds.

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