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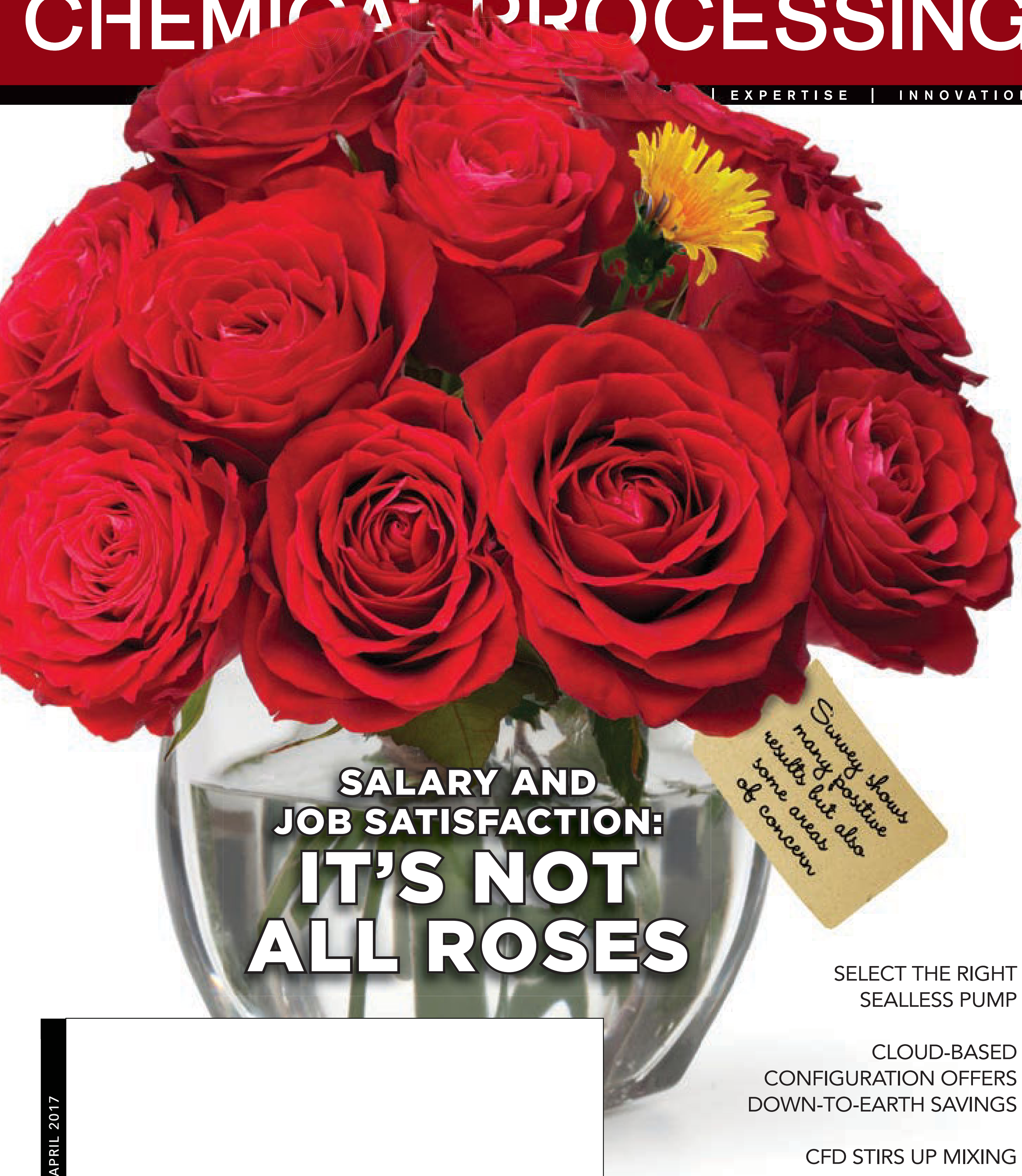

SALARY AND JOB SATISFACTION: IT'S NOT ALL ROSES

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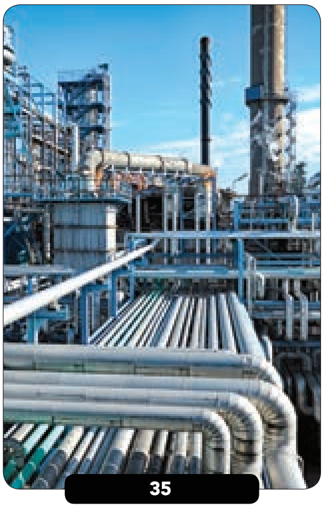

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Carbon Contest Chooses Winners

Four technologies win funding for further development

In 2019, one project may receive an additional C$10 million.

IN MARCH, Emissions Reduction Alberta (ERA), Edmonton, Alberta, announced the winners of the second round of the ERA Grand Challenge: Innovative Carbon Uses. The four projects selected each will receive up to C$3 million (≈$2.25 million) over the next two years to spur development of their technology.

The Grand Challenge focuses on technologies that promise to significantly reduce greenhouse gas (GHG) emissions by productively using carbon dioxide. The 24 first-round winners announced in 2014 got C$500,000 (≈$325,000) in funding ("Carbon Competition Names First Round Winners," http://goo.gl/2nDJvo).

The second round was open to all comers worldwide. Nineteen round-one winners entered along with 69 new applicants. The projects chosen include three from round one as well as one new entry:

• *A process to use CO_2 and saline wastewater to produce re-usable water and oil-field chemicals.* Aimed for use on-site at oil and gas operations, the technology is being developed by Mangrove Water Technologies, Vancouver, B.C., a spinoff from the chemical engineering department at the University of British Columbia. The method relies on a reactor that uses electricity to desalinate wastewater while also producing chemicals such as carbonate salts and hydrochloric acid. It promises to cut operational costs, water consumption, wastewater generation and carbon footprint. Round two funding will support a field pilot at a site in Alberta.

• *A route to make high quality fuels and feedstocks from CO_2 and wastewater using sunlight.* The process from McGill University, Montreal, and Lumenfab Nanotechnologies, Montreal, produces materials such as methanol that can serve as fuels or "green" feedstocks for making petrochemicals. It gets energy from low-cost silicon-wafer solar cells. Funding will enable building a high-efficiency scalable system and field-testing it in Alberta.

• *A sustainable method for producing cement while using CO_2.* The process from Solidia Technologies, Piscataway, N.J., reduces the carbon footprint of cement and concrete by as much as 70%. It results in lower GHG emissions during cement production and then permanently sequesters CO_2 emissions during curing. The method also cuts water consumption during manufacturing by 60–80%. In addition, the concrete boasts better workability and durability than traditional concrete and cures much faster.

• *A technique to inject CO_2 into concrete to sequester the carbon and improve the concrete's performance.* This new entrant — from CarbonCure Technologies, Dartmouth, Nova Scotia — is designed for retrofitting onto existing concrete plants. It not only sequesters the CO_2 but also makes the concrete stronger and less expensive. The technology already is being deployed commercially; the ERA funding will go toward maximizing overall GHG benefits and improving the economics so it suits smaller concrete plants.

For more details on these technologies, check: http://goo.gl/uSgGLM.

The Grand Challenge will wrap up in 2019. At that time, one round-two project may receive up to an additional C$10 million (≈$7.5 million) to help commercialize the technology in Alberta.

ERA (originally called the Climate Change and Emissions Management Corp.) receives funding from the government of Alberta. This money comes from a fund that large emitters in the province pay into as a compliance option if they can't meet emissions reduction targets.

The Grand Challenge is a grand idea that merits emulating.

MARK ROSENZWEIG, Editor in Chief
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2017 Webinars Promise Best Practices

The lineup covers myriad topics including safety, energy efficiency and water/wastewater.

"This year's roster includes a series on process safety and special webinars on explosion protection and prevention."

ONCE AGAIN we've put together a roster of webinars aimed at helping you make your plant as efficient, safe, environmentally friendly and economically competitive as possible.

This year's lineup also features a four-part process-safety series hosted by Dr. M. Sam Mannan, Regents Professor in the Artie McFerrin Department of Chemical Engineering at Texas A&M University and Director of the Mary Kay O'Connor Process Safety Center.

According to Mannan, "Safe operation of industry involves two broad issues: the technical knowledge and understanding of hazard and risk associated with the operation; and the implementation of that knowledge into practice. As we address these issues, we are faced with the inevitable question, 'Why do incidents keep happening?'"

To help answer that question, Mannan is delving into four key aspects of process safety. The first installment of the series, Leadership in Process Safety, is now available on-demand and brought home the point that when leaders personally commit to safety and plainly communicate its importance to all members of the organization, safety thrives. Mannan also discussed how leaders must ensure they aren't giving mixed messages and must lead by example.

Part two of the series, Enforcement and Operational Discipline, tackles regulations. It will address the need for regulations to be science-based and take into account all the data available as well as practical factors. Additionally, once a regulation is developed, clear and systematic methods must be developed for comprehensive enforcement. This live event is on April 18 at 2 p.m. ET. Like all the installments of the series, an audience-driven Q&A session will take place at the end; take advantage of this opportunity to get an expert's insights. You can learn more about this webinar and the rest of the series here: http://goo.gl/60rH3A.

In addition to our process-safety series, this year we have two special webinars aimed at explosion protection and prevention. The first event is on May 24 at 2 p.m. ET and will discuss, among other things, the dangers of electrostatic discharge and the importance of grounding. Sponsored by IEP Technologies, a specialist in explosion protection, the discussion will be led by Burke Desautels, IEP's vice president of aftermarket engineering, and Michael O'Brien, head of marketing and product management for Newson Gale. Newson Gale, which provides electrostatic grounding for hazardous areas, was recently acquired by IEP's parent company.

The second special event is a Combustible Dust Control Roundtable. On Sept. 21 at 2 p.m. ET, we are bringing together industry leaders in hazard identification, evaluation and control of combustible dust hazards for an exclusive discussion. Our moderator, Guy Colonna, division director of the National Fire Protection Association, will challenge panelists with tough questions to increase awareness of the hazards and the available safeguards against fires and explosions during combustible solids processing and handling. You can learn more about the roundtable and the IEP Technologies webinar here: http://goo.gl/RKsv7L

In addition to safety, we also are featuring other best-practice-based topics. On May 11 at 2 p.m. ET, we will host a webinar dedicated to energy efficiency. Minimizing energy consumption is critical for optimizing a plant's economic performance. This webinar will provide insights on how to achieve energy savings. You can sign up for this event here: http://goo.gl/iDywVN

Water no longer is a resource that most plants can take for granted. The cost, quality and even availability of feedwater can pose challenges. Meanwhile, wastewater faces tightening discharge requirements that impact its treatment. This webinar, presented on July 20 at 2 p.m. ET, will offer ideas for optimizing water use and stewardship.

I serve as moderator for all of these events. I look forward to your participation. Be sure to say hello to me via chat during the presentations!

TRACI PURDUM, Senior Digital Editor
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HEARD ANY GOOD JOKES?

We are creating more ways for you to have fun when visiting our website. In addition to all the award-winning content that serves engineers designing and operating plants in the chemical industry, we have a lot of light-hearted material. Very soon we will be rolling out a Jokes page. We are on the lookout for clean knock-knock jokes, corny jokes, hilarious one-liners and clever riddles with an engineering or chemical industry flavor. Send them to our Chief Fun Engineer, Traci Purdum, at tpurdum@putman.net.

Watch Out for Phony Interviews

Some companies use those and other ruses to get free consulting

A real interview shouldn't focus only on your unique expertise.

THEY REALLY must like me, she thought. Even the recruiter who sent her to the company was impressed: the interview lasted over two hours. She had answered all the questions the firm had about her expertise in a particular area of pharmaceuticals. Yet, a week went by and nobody got back to her or the recruiter. Finally, the company called to say it wasn't hiring.

Sadly, this isn't the only story I know of using an interview for a nonexistent job to pick the brain of a "candidate." It's a common experience in information technology (IT) and research. I've heard of PhDs giving dissertations they thought were interviews only to be left on a string.

Unfortunately, unethical companies feel they can exploit the job market to get insights for free instead of paying for consulting.

To avoid being a victim, you might start by identifying the company's business pain, i.e., why a recruiter contacted you. Perhaps, the firm can't figure out what's wrong with its fluid bed reactors or the performance of a key distillation column isn't consistent. Maybe it doesn't have a specialist in freeze-drying. Once upon a time, companies hired knowledgeable contractors to solve their problems. Now, in desperation or because they're cheap, some unscrupulous firms instead opt to bring in one expert after another in fake interviews to glean insights so they can train their engineers.

A better approach than waiting for the company to get to its business pain is to identify other areas in your background that address items it should value. If the firm isn't the least bit interested, that's a red flag. Talk this through with the recruiter. If the recruiter sends more people back to that company, don't deal with that recruiter again.

Try this as a tactic: ask why the company is interested in you. Inquire about which of your personal traits drew the firm to you. A real interview should delve into who you are and how you fit in an organization, not just your unique expertise. Be wary if you only get unconvincing or canned responses.

Multiple interviews provide another warning sign that you're being played. IT companies like this trick. I read of one candidate finally refusing a fourth face-to-face interview after he remembered being in a room with several people who scribbled vigorously while never asking him any questions. Think of how much time this consumes — three interviews and probably two to three months.

Sometimes, a company actually does have an opening but deliberately draws out the hiring process. This often benefits human resources (HR) managers and sometimes even company executives. HR managers gain because they can rewrite and improve the job description: the more candidates they meet, the better they understand the job and the better candidate they ultimately can recruit. Company executives win because they can eliminate a position if left open for an extended period, say, more than four months, because somebody is filling in. Recruiters and engineers both suffer from this practice. However, the recruiter at least can continue to send other candidates; the job hunter is completely out of luck.

A more familiar form of exploitation doesn't target you directly. Instead, it involves posting a question in a LinkedIn group or other sites that have engineers as members. You're probably familiar with such queries. Someone asks how to properly purge a line with nitrogen for a hot tap or something like that. Engineers love a challenging question where they can show off their expertise. Bingo! Free advice.

Now, let me emphasize that I'm certainly not against helping others by sharing technical expertise this way. That's why I regularly contribute to *CP*'s Process Puzzler, www.ChemicalProcessing.com/voices/process-puzzler, and why the many experts in *CP*'s online "Ask the Experts Forum," www.ChemicalProcessing.com/experts, offer valuable advice.

If answering a query doesn't require a lot work and time, do it. On the other hand, some people posting questions request detailed calculations or follow up repeatedly with additional questions. Don't waste your time and become their unpaid consultant. Either ignore these requests or simply tell the people that you get paid for your experience and knowledge.

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Copper Catalyst Cracks C-H Bonds

Method mimics nature for more efficient, environmentally friendly oxidation process

RESEARCHERS AT Southern Methodist University (SMU), Dallas, and The Johns Hopkins University, Baltimore, have discovered a way to break the tough carbon-hydrogen molecular (C-H) bond. The method, the researches say, constitutes a first step in developing cheap, environmentally sustainable, and efficient approaches that could replace traditional oxidation processes.

Isaac Garcia-Bosch, assistant professor in the Department of Chemistry at SMU, and chemist Maxime A. Siegler, director of the X-ray Crystallography Facility at Johns Hopkins, used copper catalysts in combination with a nitrogen-based ligand and hydrogen peroxide to convert C-H bonds to C-O bonds.

"We take inspiration of the metalloenzymes found in nature that are able to carry out the oxidation of very challenging substrates (such as methane) under very mild conditions (room temperatures, 1 atmosphere). These enzymes have environmentally benign metals in their active center (like Mn, Fe and Cu). What we do …. is try to emulate the active center of these enzymes by designing simple low-weight metal catalysts that can carry out similar organic transformations outside the biological environment. Our goal is to develop synthetic methods to functionalize organic molecules based on cheap and clean reagents like Cu and O_2 or H_2O_2," explains Garcia-Bosch.

OXIDATION

Figure 1. Upon mixing the reactants (copper, ligand, hydrogen peroxide, and carbon-hydrogen substrate), the colorless solution turns green-blue, indicating that an oxidative process is occurring. *Source: SMU.*

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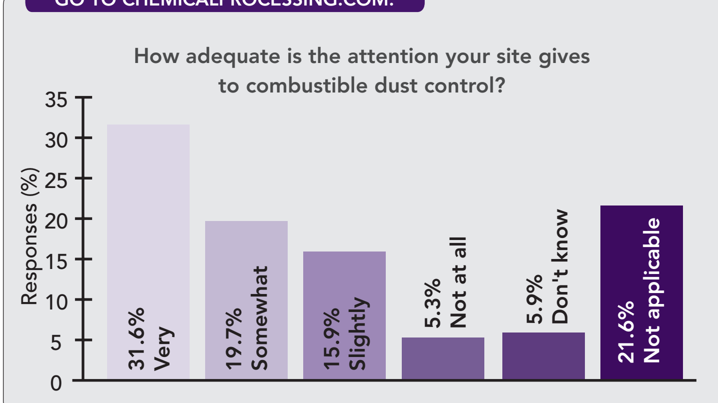


Over 40% of those respondents with combustible dusts feel attention is very adequate.

"This is a very important discovery because it's the first time it's been proven that Cu can carry out this kind of oxidation outside of nature in an efficient way," Garcia-Bosch adds. "…Cu is relatively cheap compared to other metals such as palladium, gold or silver, and hydrogen peroxide is readily available, relatively cheap and very clean. One of the byproducts of oxidations with hydrogen peroxide is water, which is the cleanest waste product you could have."

An article in *Angewandte Chemie International* provides more details on the project.

"We tested this catalytic system for different substrates and we saw that it's not very selective. That's a problem," admits Garcia-Bosch. "If we have molecules that have many different C-H bonds, then it's going to oxidize all of them in a non-selective manner."

"We are now developing a system … to selectively oxidize C-H bonds using Cu and green oxidants (like O_2 and H_2O_2) under very mild conditions (room temperature). We found that the system is not catalytic (stoichiometric amounts of Cu are required) but we are able to hydroxylate C-H positions that are very difficult to functionalize using other oxidative methods. We hope that soon, we will be able to develop Cu complexes able to carry out similar selective oxidations under catalytic amounts of Cu."

"We would also like to carry these oxidative transformations under smaller amounts of oxidant (close to 1 equiv.) and lower catalyst loadings (lower than our current 1%)," he adds.

"The fact that our best copper catalysts don't generate over-oxidation products (like carboxylic acids) helps to explain their excellent catalytic performance, in combination with their robustness," believes Garcia-Bosch.

Producing the catalyst on a larger scale is fairly straightforward, says Garcia-Bosch. "However, I should point out that Fenton oxidations at large scale might be dangerous and should be carried out with caution," he warns.

CO_2-to-Methane Process Shines

RHODIUM NANOPARTICLES exposed to ultraviolet (UV) light catalyze the conversion of carbon dioxide almost exclusively to methane, report researchers at Duke University, Durham, N.C. Such plasmonic photocatalysis may offer high selectivity in other important reactions, they add.

"Effectively, plasmonic metal nanoparticles act like little antennas that absorb visible or ultraviolet light very efficiently," explains Henry Everitt, an adjunct professor of physics at Duke. "We discovered that when we shine light on rhodium nanostructures, we can force the chemical reaction to go in one direction more than another. So we get to choose how the reaction goes with light in a way that we can't do with heat."

"The fact that you can use light to influence a specific reaction pathway is very exciting," comments Jie Liu, a professor of chemistry at Duke. "This discovery will really advance the understanding of catalysis."

The UV-light-driven catalysis boasts 98% selectivity to methane, unlike conventional catalytic processes that yield methane with about equal amounts of carbon monoxide and other side products, the researchers note.

More details appear in a recent article in *Nature Communications*.

The researchers also hope to use sunlight for that conversion, says Everitt. "We can use simulated sunlight soon, but using actual sunlight is a longer-term goal. We would be happy to partner with anyone interested in pursuing this." They also are investigating other rhodium-catalyzed reactions driven by heat. "We are looking at other reactions and other catalysts, too, since different reactions require different catalysts," Everitt adds.

"Our greatest remaining challenge is to ascertain how best to exploit the advantages of illuminated rhodium catalysts. We've shown that light highly selects methane over carbon monoxide, but we don't yet know how much faster the reaction can go and how this advantage can be adapted for large-scale production. Designing the right reactor that can incorporate light is another challenge," he explains. "We need help to design a reactor that can incorporate light sources and can also be used at high temperature."

"...Photocatalysis has always been challenging to implement on industrial scales because of the limited penetration depth of light within the catalyst. Our approach has the same limitations, but we believe the selectivity and superlinear dependence on light intensity provided by the rhodium plasmonic photocatalyst will be quite compelling to industry," he concludes.

ILLUMINATING RESULTS

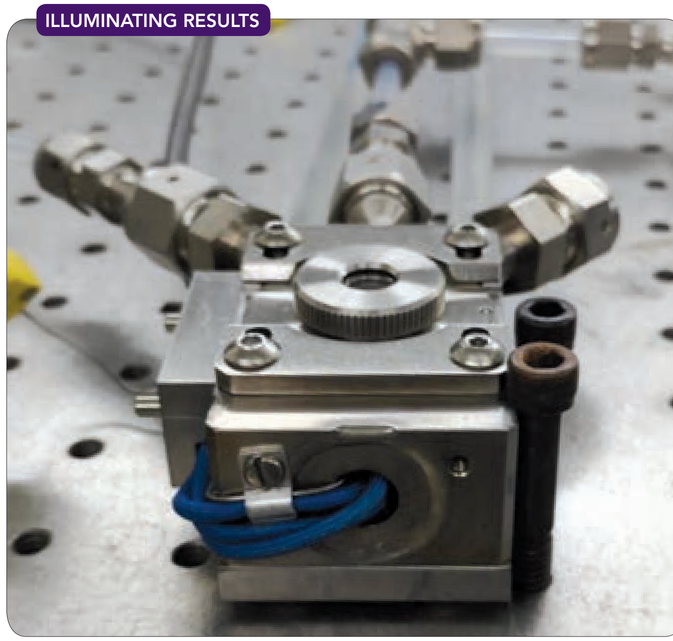
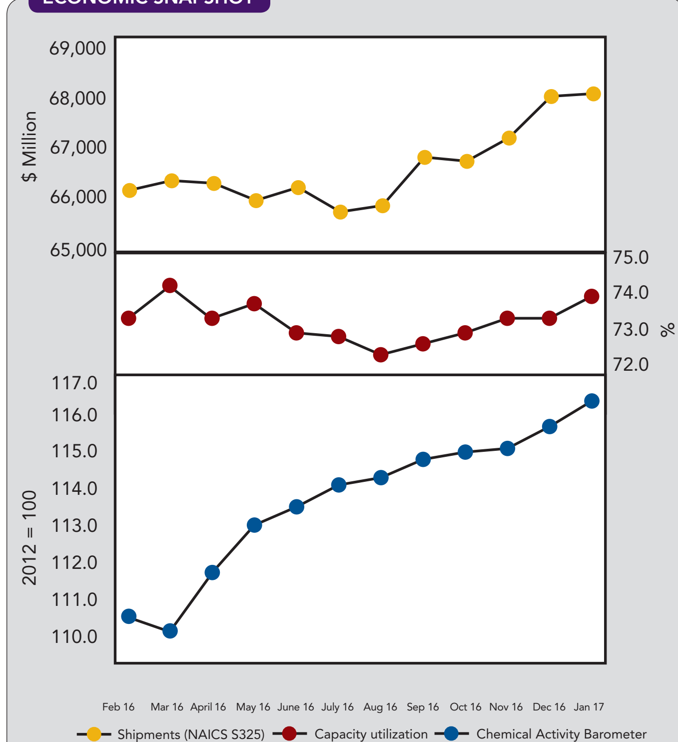


Figure 2. Laboratory reactor uses UV light to make methane with very high selectivity. *Source: Duke University.*

ECONOMIC SNAPSHOT



All three metrics continue to climb. *Source: American Chemistry Council.*

Keep Your Cool This Summer!

Address any issues with cooling tower fill before hot weather arrives

A walk-around followed by a quick performance test can avoid summer headaches.

THE APPROACH of summer is a good time to check the performance and, more importantly, the physical condition of your cooling towers. After all, it's easier to repair a tower when weather conditions don't put a strain on its cooling capacity.

A cooling tower passes air over tiny droplets or the exposed surface of a water film. In both cases, a small amount of water is vaporized, drawing the latent heat from the remaining liquid water, reducing its temperature. Splash fill continuously breaks up droplets of water dropping down the tower; the fill is arranged so the droplets fall from one splash bar to the next, avoiding agglomeration. Film fill spreads the liquid out on highly wetted plastic, exposing the maximum surface area to the air stream. The amount of water vaporized depends on the airflow over the droplets or film and the ambient wet bulb temperature. As the wet bulb temperature approaches the sensible temperature, the capacity of the air to absorb vapor reduces. This, in turn, increases the temperature of water leaving the tower.

You often can observe the condition of the fill from the face of the tower. Concentrations of flow can indicate water maldistribution, which can stem from either blockage or missing distribution devices. Sagging or missing fill may be visible as well.

Along the Gulf Coast, ambient weather conditions may strain a cooling tower even in the winter; a poorly functioning tower could pose significant issues in the summer. A walk-around followed by a quick performance test can avoid summer headaches.

LEARN FROM JAKE

It was a very hot August in Texas. Jake had been called in to help diagnose a condenser problem. The plant made a component used in a downstream facility and a drop in its output was curtailing production there of a product that was in a sold-out condition. So, the company was forced to resort to a much-higher-priced alternative source to supply the downstream unit.

Jake took a quick look at the condenser operator screen. The unit condensed the exhaust steam from the process compressor's steam turbine drive. The compressor was experiencing reduced flow, decreasing plant production. Jake immediately recognized that the inlet cooling tower water temperature significantly exceeded design. Ambient conditions were high but the temperature was much greater than the design approach temperature. A quick check at the local weather bureau confirmed his expectation.

Jake had brought temperature loggers, which he had calibrated the night before. As he set up the equipment, he also surveyed the condition of the fill. The plant engineer assigned to help him indicated that upgrading the splash fill to a new design was in process. That design, suggested in a recent research paper, promised to drop the approach temperature. The splash fill bars would be installed parallel instead of perpendicular to the flow. The tower was a cross-flow design, meaning the air flowed perpendicular to the down flow of the water droplets. Jake thought the idea made sense.

As they made their survey, Jake noted that he was puzzled by the lack of fill in the front face of the tower. The plant engineer responded that the installer had said the more-efficient design required less fill. That seemed questionable to Jake; a performance test of the three cells verified the tower was the problem. One unconverted cell was at design performance. Fortunately, available performance records confirmed the tower had performed to design in the past.

Jake then contacted the author of the research paper, who indicated the same amount of fill was needed to achieve the desired approach.

The threat of a lawsuit persuaded the installer to complete the installation with the right amount of fill. Temporary cooling towers were brought in to get the plant through the August/September hot spell. Production was increased and no downstream sales were lost.

So, check the performance and condition of your towers right now. If you've upgraded or even replaced the fill, ensure you got what's required. Also, it's a good idea to spend time with the installer's team to verify they understand the job and to ensure quality. Contact reputable sources for information if you don't understand what they are doing or proposing.

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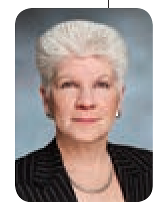
TSCA Implementation Remains On Target

The EPA is issuing framework rules on a timely basis



The EPA staff is to be commended.

IMPLEMENTATION OF the newly amended Toxic Substances Control Act (TSCA), signed into law last June, is in full swing. The U.S. Environmental Protection Agency (EPA) has been working hard to meet statutorily imposed deadlines for promulgating three "framework" rules by June 2017. To date, the EPA is on target. This column discusses the three framework rules.

TSCA INVENTORY NOTIFICATION

The recent TSCA amendments require the EPA to designate TSCA Inventory substances as active or inactive in U.S. commerce. On January 13, 2017, the EPA published a proposed rule that would require an electronic notification for chemical substances listed on the TSCA Inventory that were manufactured (including imported) for non-exempt commercial purposes during the 10-year time period ending on June 21, 2016. The EPA also would accept such notices for chemical substances that were processed. The agency would then use these notifications to distinguish between active and inactive substances for prioritization reviews and include the active and inactive designations on the TSCA Inventory.

The EPA also proposes to establish procedures for forward-looking electronic notification of chemical substances on the TSCA Inventory that are designated inactive, if and when the manufacturing or processing of such chemical substances for non-exempt commercial purposes is expected to resume. Upon receipt of a valid notice, the designation of the pertinent chemical substance would be changed on the TSCA Inventory from inactive to active. The proposed rule includes procedures to submit Notices of Activity (NOA) both for the retrospective (Inventory reset) and forward-looking (activation) activity notifications, the details of the notification requirements, exemptions from such requirements, and procedures for handling claims of confidentiality. Comments were due March 14, 2017.

PRIORITIZATION PROCEDURES

The EPA proposed on January 17 procedures to establish the risk-based screening process and criteria it will use to identify chemical substances under TSCA as either high-priority substances for risk evaluation, or low-priority substances for which risk evaluations are not warranted at the time. The proposed rule describes the processes for identifying potential candidates for prioritization, selecting a candidate, screening that candidate against certain criteria, formally initiating the prioritization process, providing opportunities for public comment, and proposing and preparing final priority designations.

The EPA notes that prioritization is the initial step in a new process of existing chemical substance review and risk management activity established under recent TSCA amendments. The agency incorporated all of the elements required by the new TSCA, but also supplemented those requirements with additional criteria it expects to consider, some clarifications intended to provide greater transparency, and additional procedural steps to ensure effective implementation. Comments on the proposed rule were due March 20, 2017.

RISK EVALUATION PROCESS

On January 19, the EPA proposed a process for conducting risk evaluations to determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, including a potentially exposed or susceptible subpopulation, under the conditions of use. The process doesn't consider costs or other non-risk factors. Risk evaluation is the second step, after prioritization, in a new process of existing chemical substance review and management established under the new TSCA. The proposed rule identifies the steps of a risk evaluation process including scope; hazard and exposure assessment; risk characterization; and a risk determination. The EPA proposes this be used for the first ten chemical substances to be evaluated from the 2014 update of the TSCA Work Plan for Chemical Assessments, chemical substances designated as high-priority substances during the prioritization process, and those chemical substances for which the EPA has initiated a risk evaluation in response to manufacturer requests. The proposed rule also includes the required "form and criteria" applicable to such manufacturer requests. Comments were due March 20, 2017.

CONCLUSION

The EPA staff is to be commended for proposing these regulations on a timely basis, and working hard to implement the new law. Many stakeholders are expected to comment on the proposals, as they truly are foundational to the entire domestic chemical management program and their promulgation will have lasting implications for years to come.

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SALARY AND JOB SATISFACTION: IT'S NOT ALL ROSES

Survey shows many positive results but also some areas of concern

By Amanda Joshi, Managing Editor

GET READY for good news. The chemical industry should see steady growth this year and well into 2018, according to several reports. For instance, Thomas Kevin Swift, chief economist of the American Chemistry Council, a group whose members include leading chemical manufacturers, offers an upbeat assessment. In his annual economic outlook, "American Chemical Makers Fly Higher," http://goo.gl/QBGtXT, he reported that output of chemicals will expand over the next two years, and as a result, employment in the chemical industry will rise, growing from 803,000 in 2014 to 833,000 in 2018. The industry should post a net gain of about 35,000 high-paying jobs by the end of the decade. Furthermore, retiring of baby boomers will make the need to attract and retain talent paramount.

Another upbeat prediction comes from a recent survey of more than 10,000 people at chemical and other process manufacturers, equipment suppliers, and design/engineering firms by the organizers of the biennial Chem Show. In that survey, 82% of respondents expect their sales to increase this year, with 69% additionally rating the 2017 business climate as either good or excellent.

Such positive sentiments extend beyond the prospects of companies. Chemical engineers who participated in our latest annual Salary and Job Satisfaction survey indicated that salaries, raises and bonuses all edged up, and staffing levels also swung upward.

LET'S TALK NUMBERS

To start, respondents reported an average salary of $112,637, a small rise from the $111,809 we found last year (Figure 1). In addition, raises inched up to 4.13% from 4.09% and the average bonus came out at $6,569 compared with $6,433 in 2016.

Following this trend, hiring also showed a slight increase, with almost 30% of respondents reporting staffing levels at their sites are now significantly or somewhat larger than 12 months ago — a 1% uptick from 2016 (Figure 2). Nearly 45% said staffing has remained the same, and those reporting layoffs dropped 2% from last year.

Survey participants also expressed confidence in their job security, with 56% unconcerned — the same number reported last year (Figure 3). When asked, "What are the chances that you will be laid off or fired within the next two years?" 21% of respondents conveyed there was no chance of that happening — up 4% from 2016 (Figure 4). Furthermore, 60% said they feel adequately compensated for their experience and skills (Figure 5).

One engineer stated, "I feel like I am adequately compensated for the hours that I work and the freedom that I receive."

"I believe my total compensation package, including salary, bonus and benefits, is above average and helps motivate my performance," added another.

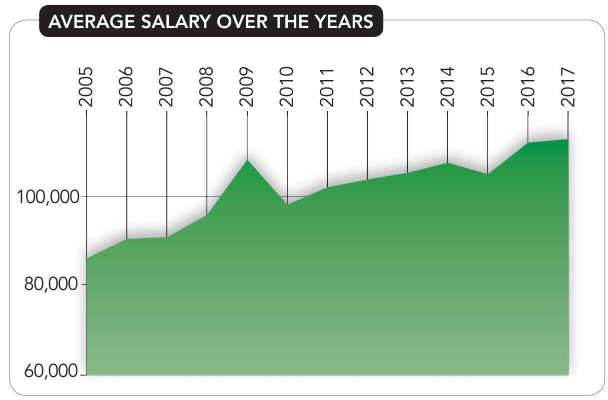


Figure 1. The average salary edged up slightly.

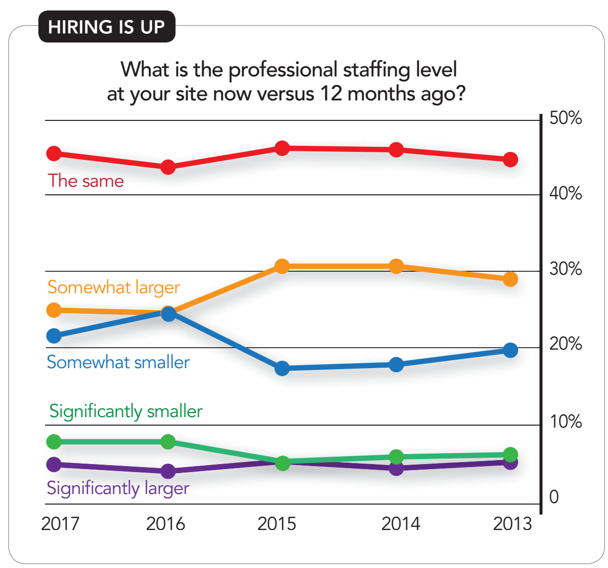


Figure 2. Hiring appears to have increased, with more than a third of respondents reporting a somewhat or significantly larger staff.

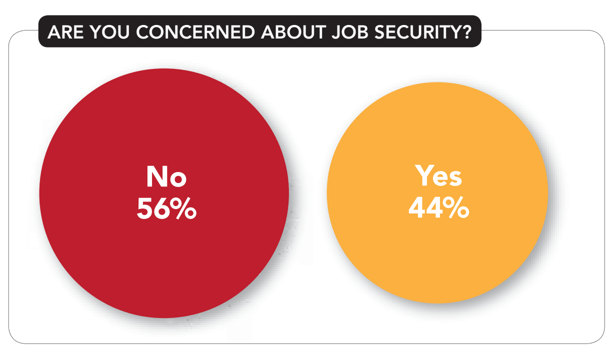


Figure 3. More than half of respondents say they are unconcerned.

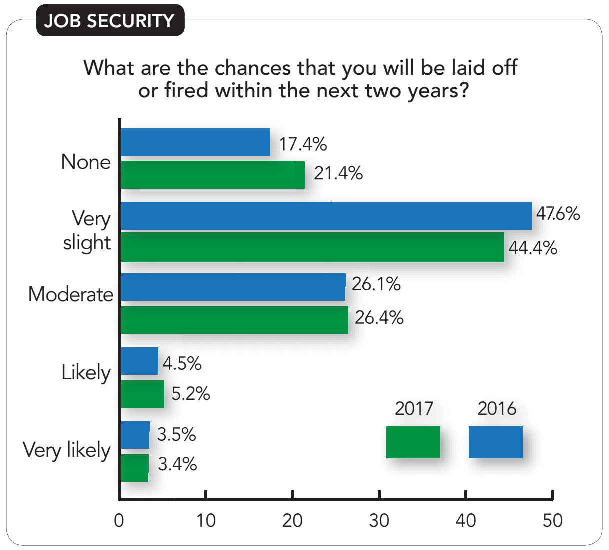


Figure 4. Compared to 2016, more respondents were confident they would not lose their job.

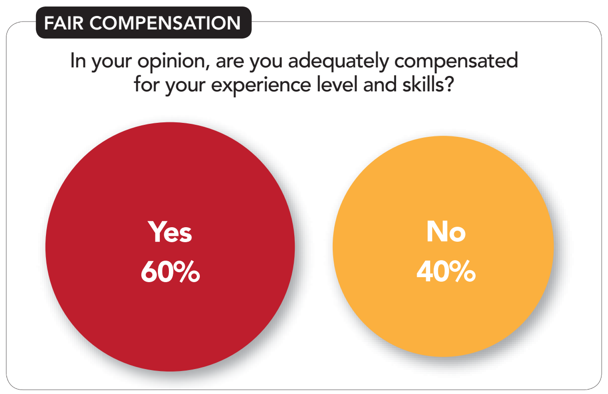


Figure 5. More than half of respondents feel their experience matches their compensation.

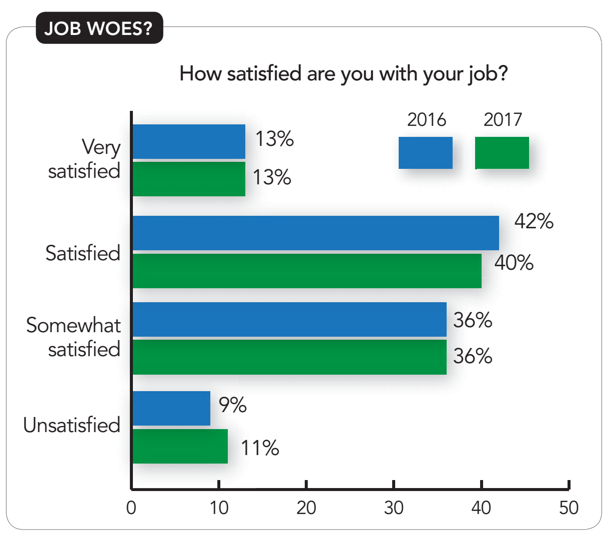


Figure 6. Compared to last year, the number of those not happy with their work increased 2%.

WHAT'S THAT SAYING?

As the old adage goes, "You can't please everyone," and this is certainly true in the chemical industry. Despite all the positive news, 2% more respondents than last year expressed dissatisfaction with the job (Figure 6). Most (37%) attributed this to a lack of recognition (Figure 7).

"[My job is] adequate for role description but additional work outside defined role not adequately recognized or rewarded," noted one respondent.

"Good bonus program but raises are few and low. Good performance is not necessarily rewarded," echoed another.

"No recognition, no pay increases, yet the company claims profits in the $250-million-plus range each year. No advancement, and extremely arrogant company executives. 60%, 5-year turnover rate. Wish age discrimination laws in this country had some meat to them, if so, many of us older workers would be far better off," griped one unhappy employee.

The work environment (30%) took second on the list of dislikes about their jobs. Ranked third: the commute and traveling, a jump from fifth place last year. "[It's] hard work, long hours, lots of travel," noted one respondent.

Salary and benefits took fourth. The hours and workload, which in years past has been one of the top three grievances, ranked fifth on the list.

"Severely underpaid for the multiple duties far beyond and outside of my job position that I constantly deal with. Multi-billion-dollar corporation refuses to give any sort of bonuses or profit sharing, no company match on 401(k), insurance rates are a joke; I can go on and on, yet the head honchos ... all make six-figure salaries while every other employee makes far below the industry average. It's a sham and there should be federal regulations in place to not allow corporations to be so unjust in the allocation of their funds in regards to what they pay their employees," lamented one contributor.

"Compensation and benefits would be good if I only worked 40–45 hrs per week, but I don't due to work load," groused another.

"We put in lots of hours and work is still in your head after you leave," observed one respondent.

Lack of challenge doesn't seem to be a problem, with only 11% saying they disliked this about their job.

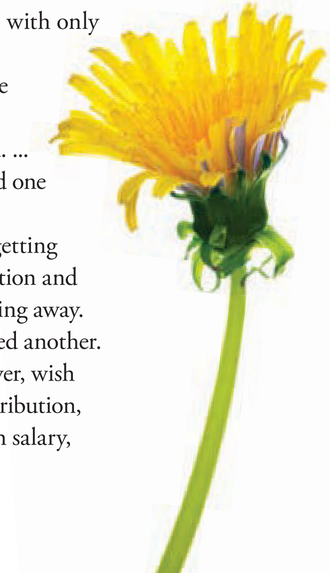
Even those who are happy with their salary were quick to add that benefits were lacking.

"The benefits can be better than currently offered. ... Health insurance co-pays are killing me," complained one contributor.

"Compensation is good, but benefits have been getting worse, year after year. I work for a very large corporation and since they took over, benefits have been gradually going away. Recently, [they] took away further pension," grumbled another.

"I am paid very well for my position. I do, however, wish benefits (health care, 401(k) contribution, HSA contribution, etc.) were better. That is the tradeoff, obviously. High salary, bad benefits. I like that more than the other way around."

"Salary is at par with the industry standards but benefits are not satisfactory.... may be due to company financial position and market challenges," noted another participant.



SHOULD YOU STAY PUT?

If economic forecasts are on target, jobs should be in ample supply and nearly 40% of our respondents say they plan to look for new work within 1–5 years (Figure 8). But one contributor warned, "The grass isn't always greener somewhere else. Keep working and you will be recognized."

"Don't make a knee-jerk reaction about leaving a company," added another.

"[My compensation is] comfortable, but could be better if I shopped myself around. I'm not willing to leave my home location to see if the grass is greener. I'll deal with a lawn with brown spots," said one content engineer.

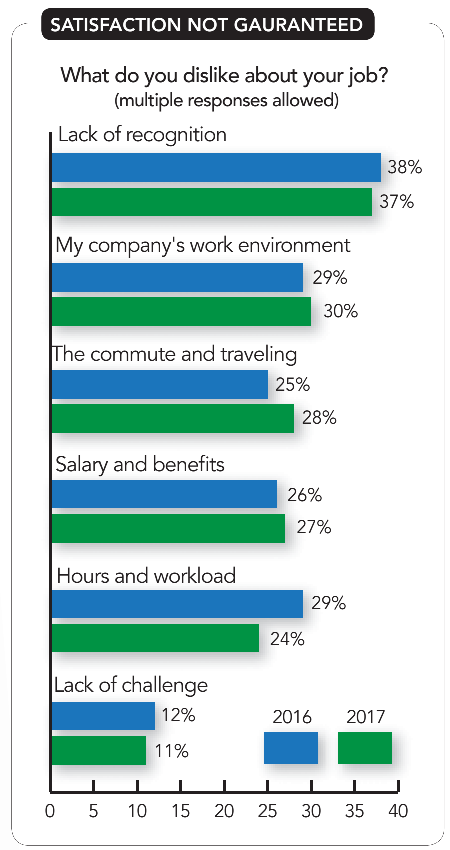
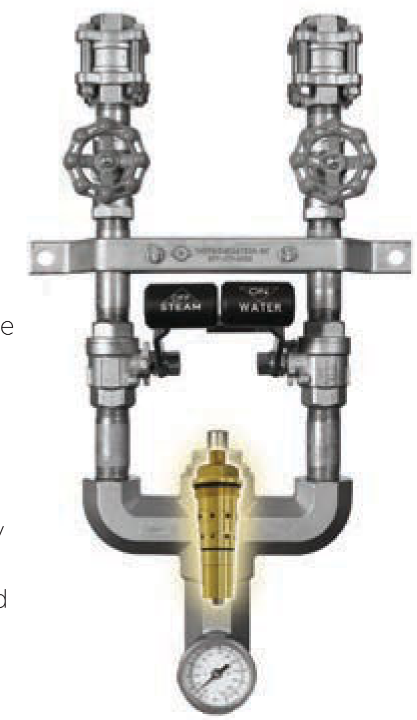


Figure 7. Lack of recognition continues to be the most dissatisfying aspect of the job.

WANT TO SEE MORE?

Survey respondents have a lot to say — more than what we can cover here. We have created an eBook that includes more data, charts and comments from engineers about the industry's outlook as well as advice for aspiring chemical engineers. To download the ebook, visit http://goo.gl/FafGQX.



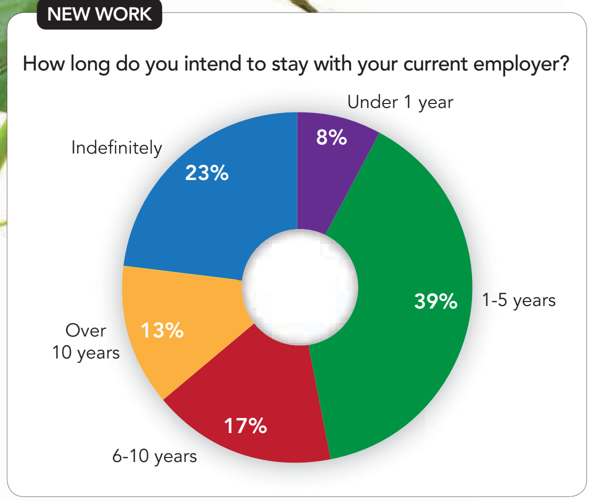


Figure 8. Nearly 40% said they plan to stay with their company only 1–5 years.

"My employer is very fair and pays amongst the best. I also live in the Midwest where the cost of living is relatively low. It would be very difficult for me to look elsewhere to a higher cost of living; knowing that other companies wouldn't match the pay, I would have to reduce my standard of living," explained one survey participant.

Some recognized their good relationships with their employers as reasons to stick around. "I am well compensated and have had an excellent relationship with my present employer for 16 years," expressed one happy staff member.

In fact, fostering those relationships is what keeps some in their jobs. "I am well compensated..., but it takes a ton of time to do what I do. Creating relationships doesn't happen over night," explained one contributor.

Building such relationships was a key piece of advice many dished out to students considering a career in the field. "Work environment and culture is extremely important; ask questions about it during an interview," advised one participant. (Note, for more on finding the right company, see "Watch Out for Phony Interviews," http://goo.gl/b4bBke; "Are Good Bosses Nearing Extinction?" http://goo.gl/QFZjaJ; and, "Should You Work as a Contractor? http://goo.gl/M1RijX.)

"Be prepared for change and recognize the importance of

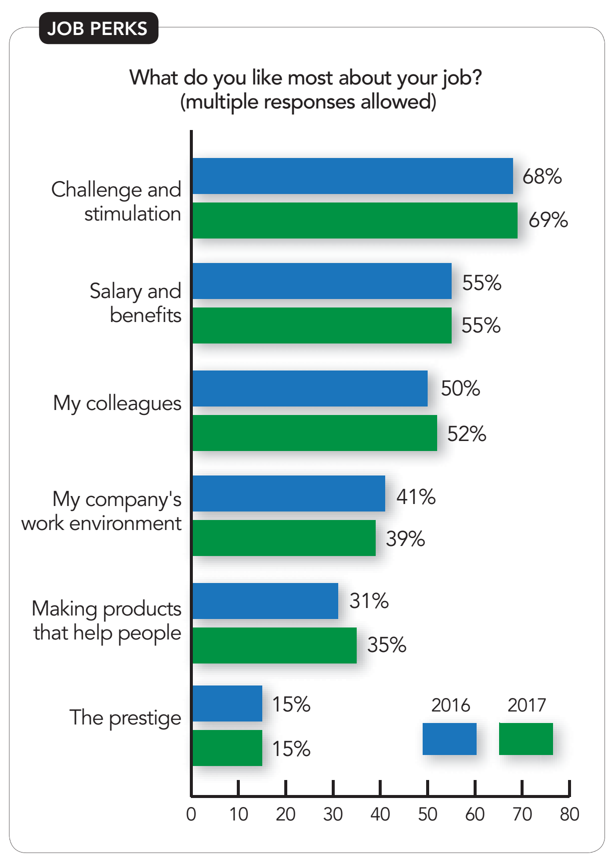


Figure 9. As in previous years, the challenge and stimulation rank highest in job satisfaction, followed by salary and benefits.

working well with your peers," recommended one worker.

Another advised newcomers, "Be loyal to your employer, but not too loyal."

"Compensation is great.....leaving jobs unfortunately is the only way to advance salary ... despite loyalty and performance," counseled one.

However, "To improve your compensation," said one respondent, "be willing to travel, relocate, and accept temporary assignments that might take you away from home for a time."

"This job requires family flexibility to travel,' noted another.

Travel is a big proponent (or detractor) to those looking for jobs. Said one reader: "I am disproportionately well-compensated because I am an American expat living in China. 20% of my pay is hardship allowance for living overseas. I enjoy the challenges of working here, but it's not for everyone."

JOB SATISFACTION

What makes a job satisfying? Our survey participants always have said the challenge and stimulation of the job makes them happy workers (Figure 9).

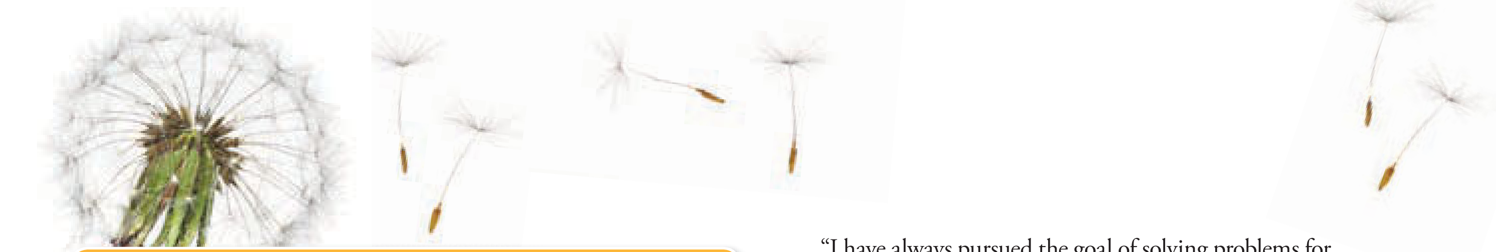
CHECK OUT PAST SURVEYS

Chemical Processing has been conducting an annual salary/job satisfaction survey for more than 10 years. If you'd like a more detailed look at our past surveys, go to www.ChemicalProcessing.com or use one of these conveniently listed links:

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 — http://goo.gl/2ZkSVR
2010 — http://goo.gl/lnxZ2N
2009 — http://goo.gl/WYDx0Y
2008 — http://goo.gl/MbYYcP
2007 — http://goo.gl/VmESyE
2006 — http://goo.gl/mZFlCx
2005 — http://goo.gl/OZEPN7

HOW WE GOT THE DATA

A total of 875 people participated in this year's survey. From January through March, respondents accessed the survey questionnaire via a link listed on www.ChemicalProcessing.com, in e-newsletters and in e-mail blasts sent to subscribers. Additionally, those who follow *Chemical Processing* on Twitter (http://goo.gl/KgUHcA), Facebook (http://goo.gl/Oo18qz) and LinkedIn (http://goo.gl/7TaFNa) were encouraged to take part.



CONGRATULATIONS TO DRAWING WINNERS!

Ten lucky respondents received gift cards to vendors of their choice. The winners, randomly selected via www.random.org are:

- Ben Ablon, OpEx Director, Elektromekanex
- Nick Ashley, Corporate Process Safety Advisor, Albemarle Corporation
- David Donnick, Principal Process Engineer, AdvanSix, Inc.
- William Gusnard, Senior Engineer - Coatings and Insulation Subject Matter Expert, Southern Company
- John Hill, Vice President of Production Operations, Paraclete Energy
- Richard Kajander, Research Fellow, Neenah Paper Inc.
- Aaron Smalley, Technical Advisor, The Dow Chemical Company
- Nicole Sykes, Program Manager, EWIE
- Sayandro Versteylen, VP, Product Technology, Paper Pak Industries
- Paul Wilkins, Regional Compliance and Quality Manager, Linde Gas NA

We appreciate all the answers and comments we received from this year's survey participants.

"I have always pursued the goal of solving problems for people and obtained satisfaction; the compensation has always followed. I have enjoyed my work all my life," said one.

"It's an interesting job with many day-to-day challenges," added another.

Ranking second on the list of what they like about their job was salary and benefits; working with their colleagues was a close third.

"I am very satisfied with my compensation and benefits. I work for a great company," responded one content worker.

Rounding out the top four — the work environment.

"My management is as generous as business profitability will allow, so I'm sufficiently satisfied. The work environment more than makes up for any lack I may perceive," noted one engineer.

"Chemical process engineering is a lucrative field for highly skilled, experienced engineers. This is a field where people can make good money and do important, interesting work," said an enthusiastic participant.

"I sincerely encourage anyone who aspires to come into this field. It's a great profession that gives you a lot of challenges that make you stronger," conveyed another.

Understand the advantages and limitations of the two main options

By Amin Almasi, rotating equipment consultant

CENTRIFUGAL PUMPS comprise over 90% of all pump installations in the chemical industry. They have proven to be the most economical pumps in various services; they require much less maintenance and operational efforts than other pump types. A centrifugal pump usually includes a casing (housing) having a cavity, a suction and a discharge; a shaft located in the cavity has an impeller (or impellers) positioned to receive liquid from the suction and exhaust that liquid to the discharge. Unfortunately, problems with shaft seals often arise — indeed, seals cause more than half of all unscheduled shutdowns of centrifugal pumps.

Many plant operations can't tolerate any leakage of liquids for safety, environmental or economic reasons. Yet, some difficult services pose a nightmare for seal selection. This has spurred the development of sealless centrifugal pump technologies.

Sealless versions now are available for all common centrifugal pump designs: end-suction top-discharge used for single-stage pumps; top-suction top-discharge used for multi-impeller horizontal pumps; and multi-impeller vertical pumps (sometimes with 30 impellers or more) used for high-pressure applications.

Magnetic drive units are the most common sealless pumps at chemical plants but submerged motor pumps also find wide use. Both types of pumps have proven themselves over many years in a variety of different services.

MAGNETIC DRIVE PUMPS

These are close-coupled pumps that can be quickly and easily stripped and rebuilt in the field; most often they don't require traditional alignment. Such units usually handle corrosive or difficult liquids; materials of wetted parts must suit the particular liquid.

Magnetic drive pumps have some limitations and disadvantages. For instance, they don't come in large sizes and with high power ratings. Many internally circulate the liquid being pumped for bearing lubrication and cooling; so, those pumps aren't appropriate for some applications, such as ones involving liquids susceptible to forming scale.

Magnetic drive pumps also should not run dry. While that's more or less true for centrifugal pumps in general, a magnetic drive pump is more vulnerable to damage from dry running because the pump liquid provides bearing lubrication. Some manufacturers have developed bearing materials and coatings that are more forgiving of upset conditions and can run dry for a limited time; this also depends on the particular pump's details and service. Upset conditions often result in some liquid remaining in the pump; this aids in bearing lubrication and prevents the bearings from breaking during brief dry-run periods. Hopefully, advances in bearing technology eventually will allow dry running for extended periods.

The magnet system transmits all the pump power and so requires special attention. A straddle-mounted design with bearings on either side of the inner magnet provides excellent stability and operation; this modern design reduces radial loading and allows the pump to better tolerate off-peak operation — and is far superior to the old-fashioned overhung inner magnet design.

RECIRCULATION FLOW

Every magnetic drive pump has a recirculation flow system — usually either discharge to suction or discharge to discharge.

In the discharge-to-suction design, the fluid enters the magnetic coupling area at a high-pressure discharge point and returns to the bulk flow at the suction eye of the impeller. In the discharge-to-discharge design, the fluid enters the magnetic coupling area at a high-pressure discharge point and returns to the bulk flow at a point behind the rear shroud of the impeller. Each design has its advantages; so, make the choice between them on a case-by-case basis. Other recirculation flow paths and designs also are available in special magnetic drive pumps.

In the discharge-to-suction design, the flow is routed to the suction through either thrust balance holes in the impeller or through a hole along the axis of the pump shaft. The differential pressure between the recirculation inlet and return locations drives the recirculated liquid at high velocity. As the differential pressure rises, the internal flow rate increases but at a decreasing rate. The internal flow will reach a maximum beyond which any additional increase in differential pressure will have negligible impact. This occurs when friction losses begin to become the dominant factor affecting flow. The observed internal pumping effects primarily are caused by the action of the inner magnet ring and thrust washers.

The differential pressure between the recirculation inlet and return locations is lower for the discharge-to-discharge design, so it creates less recirculation velocity. However, discharge-to-discharge recirculation provides a larger flow path. Moreover, its flow pattern is characterized by high localized pressure and little interference with suction flow. Overall, the mass flows are comparable. Internal pressures in both systems prevent flashing of most liquids at the magnetic coupling interface or internal bearings.

Discharge-to-suction recirculation tends to have better impeller thrust balancing characteristics due to its routing of the flow through the impeller eye balance holes. However, this provides minimal advantage and, with the growing use of silicon carbide thrust bearings, isn't a significant factor.

MAGNETIC DRIVE PUMPS

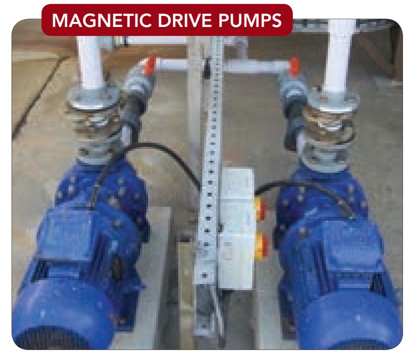


Figure 1. Such units are the most common sealless pumps used at chemical plants.

Discharge-to-suction recirculation also tends to flush solids better due to its higher velocities. In general, pumps with silicon carbide bearings can handle a higher level of solids because these bearings stand up well to most commonly encountered abrasive solids. A pump equipped with discharge-to-discharge recirculation typically has a lower required net positive suction head ($NPSH_R$) because the recirculation return flow doesn't interfere with fluid flow through the suction eye.

THRUST BALANCED PUMPS

The design of such units ensures virtually no thrust-bearing load; this leads to high reliability and long pump life. One type of thrust balancing system has a valve with a ring extending from the impeller hub; this is used to define a variable-sized vent between the ring and shaft. The pump usually includes wear rings with axially extended rings that permit the thrust balancing system to operate within a range of axial positions, with the particular one chosen based upon the operating point of the pump and specific gravity of the fluid.

Balancing axial hydraulic thrust on an impeller (or impeller assembly) reduces or eliminates maintenance of axial thrust bearings by generally maintaining spatial axial separation between members of any axial thrust bearing during normal pump operation. Moreover, the thrust balancing system increases mechanical efficiency and decreases torque-driving requirements of the pump by cutting friction associated with axial thrust bearings. In particular, the thrust balancing system may reduce the activity (for example, duty cycle) of axial thrust bearings or avoid the need for axial thrust bearing(s) altogether. However, a conservative engineering approach is to replace a conventional axial bearing with an auxiliary axial bearing intended for intermittent use in conjunction with the thrust balancing system. Nevertheless, in general, many sealless pumps (whether magnetic drive, submerged motor or another type) don't have axial (thrust) bearings.

This system also could include a radial bearing positioned in an impeller recess at or near the center of gravity of the pump upstream from the thrust balancing valve, i.e., further toward the discharge pressure or direction of fluid flow, to improve resistance against dry running and prevent flashing of the pumped liquid.

SUBMERGED MOTOR PUMPS

In these units, the motor and hydraulic sections are directly coupled with a common shaft and fully submerged in

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the pumped fluid. This isolates the unit from the atmosphere and thus completely eliminates the need for seals or couplings; pumped fluid fills motor gaps and voids. There's practically no leakage. Design of bearings and their compatibility with the pumped liquid is important.

The primary reason for submerged motor pumps' popularity is their inherent safety and reliability. Another benefit is the avoidance of alignment problems normally associated with pumps that use couplings. In addition, the liquid in which the assembly is submerged acts as effective sound insulation; these pumps operate very quietly.

Some of these pumps are long multistage vertical units — e.g., one plant uses a 15-stage pump to move liquid from a high-pressure storage tank. A usual design has three radial ball bearings along the pump shaft line. This construction yields a stiff rotor perfectly guided on multiple points. Bushings in all non-bearing carrying stages provide additional damping. The stiff and damped rotor dynamics enable safe pump operation in different steady state and transient situations.

Many submerged motor pumps can't or don't use thrust bearings because of the low load capacity of these bearings or previous failures. Instead, a specially designed balance drum assembly usually compensates for axial forces. Such an assembly should meet the requirement of the axial thrust balancing in all anticipated conditions, i.e., for whole operating range considering flow, head, etc.

Submerged motor pumps come in a wide variety of power ratings and sizes. As a very rough indication, motors range from 50 kW to as much as 3.5 MW and capacities extend to 4,000 m^3/h and over 4,000 m of head. The motors are a unique design. The starting current required is approximately 6 to 6.5 times the full load current because of the amount of torque required for starting the pump. Soft starters, auto-transformers and variable frequency drives have worked very well in many different applications to reduce the starting current. However, proper setup of starting parameters in any current-reduction-type starting system is important.

Most submerged motor pumps today are vertical types whose hydraulic design evolved from that of standard American Petroleum Institute (API) vertical in-line or other API vertical centrifugal pumps. Multi-vaned diffusers rather than a volute casing usually provide diffusion. The diffusers can be axial flow (to maintain smaller diameters) or radial flow (to maintain shorter stage lengths). Impellers are of radial- or mixed-flow (Francis) type, closed shrouded design and the hydraulic stages are radially split. The pumps can have up to 25 stages (or sometimes more) to satisfy service requirements. Typically, the first stage is a high-specific-speed axial flow inducer, used to improve $NPSH_R$ performance.

MAKING A CHOICE

Magnetic drive pumps usually suit small- and medium-sized services involving corrosive, toxic, dangerous and other troublesome liquids that should not contact the environment or the electric motor. On the other hand, submerged motor pumps can handle medium- and large-size applications with clean and usually non-corrosive liquids so long as the fluid doesn't cause difficulties if delivered to the electric motor.

AMIN ALMASI is a rotating equipment consultant based in Sydney, Australia. E-mail him at amin.almasi@ymail.com.

CFD STIRS UP MIXING

Progress in simulation provides improved mixer performance

By Seán Ottewell, Editor at Large

THE ERA of mixing simulations requiring experts in computational fluid dynamics (CFD) and sometimes taking weeks to run is long gone. Driven by huge leaps in computing and related technologies, companies such as Ansys, Comsol and Flow Science are bringing easy-to-use mixing simulation to the engineer's desktop.

"Advances in parallelization and high-performance computing, as well as templatization, have brought accurate CFD simulation into the reach of non-expert chemical engineers," says Bill Kulp, lead product marketing manager, fluids, Ansys Inc., Pittsburgh, Pa.

Exemplifying this, the company has just begun a project with Nalco Champion, Houston, that will give chemical engineers there — none of whom are experts in simulation — access to Ansys Fluent and a simulation app based on an analysis control technology (ACT) template to quickly and efficiently scale up processes for new chemicals.

"The company has been quite frustrated with failures, especially with new reaction designs that won't work with their library of tank models, and are looking to CFD simulation to reduce costs and increase the success rate of their scale-ups," explains Ansys senior account manager Erik Shank.

Up to now, Nalco Champion's workflow typically involved completing hundreds of new reactions, 10–15% of which wind up moving into production test phases. Of these, only a handful eventually go forward, based on reaction yield, availability/cost of feedstock chemicals and other relevant data.

With each scale-up costing around $250,000, Nalco intends to use simulation to improve process costs and efficiency by eliminating at a very early stage the ones that are less likely to succeed.

"Chemical engineers can now focus on reactions and not complex CFD. The overall goal is to automate the process with a user defined field (UDF)/ACT extension to allow them to submit reactions into the simulation for on the fly decision-making," adds Shank.

SUCCESS IN INDIA

Kulp points to a 2016 project carried out with Aditya Birla Science & Technology, Navi Mumbai, India, which resulted in an improved impeller for the mixing tank used in viscose staple fiber (VSF) manufacturing.

VSF is produced by dissolving a wood pulp slurry in caustic soda and then forcing the solution through tiny holes in a metal cap. Mixing the slurry and caustic soda solution is both time consuming and expensive in terms of electricity use.

The Ansys team started with a steady-state multiphase simulation of the existing mixer to better understand the turbulent nature of the VSF mixing process. They employed a number of models to do this, including the frozen rotor mixing model for impeller motion and the Euler-Euler inhomogeneous multiphase model to simulate the liquid/solid mixing in the system.

This led to an initial impeller design, which then went through six iterations to optimize the tradeoff between mixing performance and power consumption. The final design (Figure 1) uses a curved-blade impeller placed near the bottom of the tank and provides a fivefold improvement in mixing of the solid suspensions together with a 12% cut in electricity consumption.

FASTER DECISION-MAKING

CFD technology itself continues to advance, driven by improved computing resources and robust, accurate and scalable numerical methods. Important, too, is the ability to successfully perform multivariate analyses.

"These enable our customers to carry out hundreds of 'what if?' types of analyses early in the design phase and quickly assess product performance for strength, power, thermal, pressure, flow rate, electrical or a number of other performance requirements. Through this digital exploration, designers and product engineers can identify optimal combinations while eliminating outlying designs — saving time and money. This multivariate design-of-experiment approach helps them to identify the 'best' operating condition rather than one that is simply 'good enough,'" says Kulp.

This thinking is reflected in the launch of Ansys 18 at the end of January. The latest version of the company's simulation technology also integrates with Internet of things platforms to ease the use of "digital twins" of assets in operation.

Digital twins are virtual representations of individual operating assets that can be used to improve the performance and productivity of the actual equipment through simulation technology. Sensors on a mixer, for example, relay specific operating data such as temperature, vibration, impact and loading to the digital twin. This continuous feedback helps engineers optimize the operation of the mixer and can predict adverse conditions long before they happen — potentially unlocking massive production and maintenance savings for entire processes and plants.

"The use of digital twins is really exciting because it puts simulation at the heart of product and equipment development. You take simulations of individual components and processes and tie them together to form a complete digital prototype. This can be customized based on specific history of an individual device to predict performance over time — for example, reliability and likely failure modes," he adds.

IMPROVED IMPELLER

Figure 1. Velocity vectors for the final impeller design show improved mixing performance with a stronger downflow than achieved with the original. Mixer also uses 12% less electricity. *Source: Aditya Birla Science & Technology Co. Pvt. Ltd.*

As simulation is adopted across the entire product lifecycle, engineers are becoming more empowered to imagine more options, a trend Ansys calls pervasive engineering simulation.

This, Kulp believes, is a glimpse of the future: "In 5–10 years Ansys simulation may be embedded with your PID/control software for pervasive predictive control of your mixing processes."

SIMILAR STORY

Comsol, Stockholm, Sweden, is seeing the same thing. "Simulation is becoming much more widely used and understood by the chemical industry," notes chief technology officer Ed Fontes.

The company has developed a broad portfolio of software modules, including one for mixers that is particularly aimed at the batch, fine chemicals and pharmaceuticals end of the market, and the CFD and chemical reaction engineering modules that are targeted at bulk manufacturers.

As an example of the use of the mixer module, he cites an Argentinean laboratory that was working to take a fermentation process from pilot to commercial scale.

"It's quite easy to get a uniform mixture here, but if the shear rates are too high you will kill the yeast cells and you will not get any fermentation. So what we look for is an optimum of maximum mixing velocity with the minimum damage caused by shear rate — which is a kind of contradiction. So to achieve this we need to create eddies, a sort of chaotic flow, but with not too violent velocity gradients."

Once a pilot-scale process worked

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"Don't Get Mixed Up by Scale-up," http://goo.gl/qt7rhR

and a model had been validated for that scale, Comsol used the model to estimate the maximum shear rates; these data then served as the limit for the allowed shear rates in a model of a full-scale process (Figure 2).

"In other words, we can use the model to maximize the mixing for the full-scale process under the condition that the shear rates are below the values that would kill the yeast cells. This type of scale-up problem is very common in the pharma industry, too. Processes that are sensitive to operating conditions can be dealt with in a similar way for scale-up and design," he adds.

The savings for users come from getting a much better product, plus only needing one pilot plant before going full-scale instead of the 20 or more that are used in some cases.

Comsol stresses that it takes a unique approach for generating the mathematical equations used in CFD and chemical reaction engineering modules. "Everyone in this field produces numerical models that make approximations of the continuous mathematical models by using different types of discretization such as finite difference, finite volume, finite element, etc. We are different in that we generate a full mathematical model with no approximations as a first step. Users can even apply their own mathematical equations via the graphical user interface (GUI) and these are incorporated just as any other 'native' equation into the problem. That's unique to us and it makes the simulation even more efficient for users. It's also patented," says Fontes.

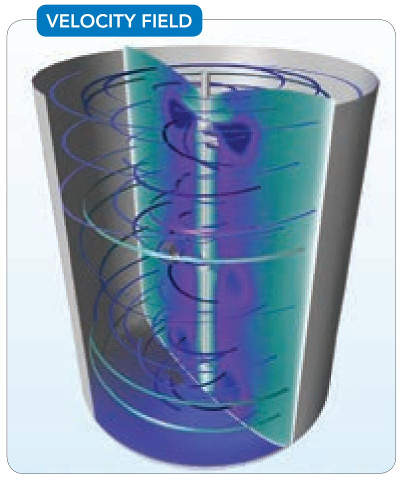


Figure 2. Simulation shows that mixing is not good but shear rates are moderate, which is crucial for fermentation application. *Source: Comsol.*

Users don't need programming skills, just the math, he emphasizes, noting that chemical engineers typically already have — or can look up — the mathematical expressions they require. There's no need for a dedicated software operator to incorporate a company's own expressions for transport properties, material properties and reaction kinetics into a model.

CONTINUING CHALLENGES

Simulating multiphase flow still poses challenges. Comsol has adopted a twin approach with its interface tracking and dispersed multiphase flow models.

The challenge with the first is to get an accurate description of the flow, droplet breakup and droplet coalescence (or bubble break up and coalescence) at a decent performance rate. Better performance allows for simulation of more droplets (or more bubbles), which also increases the fidelity of the description of the flow of the whole multiphase mixture.

The findings about interaction between droplets from detailed interface tracking models can be used in dispersed multiphase flow models, where the two phases are modeled as volume fractions rather than as individual droplets or bubbles. The dispersed models thus are approximations of the more-detailed interface tracking models.

"The challenge here is to accurately describe interactions between droplets, droplet breakup and droplet coalescence without having the detailed description of the interface. Dispersed flow models have to be adapted to the nature of the fluids and the conditions of the flow to a higher degree than do interface tracking models; these can be done *ab initio*, i.e., with a minimum of assumptions and approximations," notes Fontes.

Another initiative is Application Builder. This allows an R&D department to build an app specifically for use in its own processes or plants. It boasts an intuitive and user-specific interface, and allows process engineers access to a ready-to-use simulation app that is tailored for their needs.

"Some of our customers are using the Application Builder already and finding it a very efficient way of benefiting from simulation," he adds.

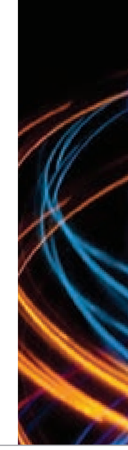
The company also hopes eventually to offer access to large eddy simulation (LES) technology which gives extremely detailed descriptions of turbulence.

GIVING MIXING ITS DUE

"The chemical industry stands to gain a lot from using computational tools such as CFD, but mixing processes are sometimes overlooked because of their assumed simplicity. However, there are many interesting ways to achieve excellent performance using modern numerical techniques," notes Ioannis Karampelas, CFD engineer with Flow Science Inc., Santa Fe, N.M.

Many such techniques are included in the company's Flow-3D Multiphysics modeling software package and its dedicated post-processor visualization tool FlowSight.

"All commercial CFD packages come bundled with some form of visualization tool but FlowSight is



designed to be very powerful, simple to use, and easy to understand. For example, an engineer trying to redesign a process needs a very intuitive visualization tool to evaluate the effectiveness of various design changes," he explains.

This approach works particularly well to better understand and optimize processes where experimental measurements are hard to obtain, i.e., for parameters that are not easily measured and for processes that are inherently dangerous because of the presence of toxic substances, for example.

The same approach also has helped suppliers of mixer-related equipment to more accurately develop and tailor their products to customer demands. "This avoids unnecessary prototyping costs or potential over-engineering. Both have been a problem for some suppliers," says Karampelas.

The CFD technology itself continues to evolve. In terms of numerical algorithms, for example, discrete element modeling now can be readily applied for a variety of problems where interactions of spherical particles are important for properly modeling heat transfer, while an LES turbulence model is ideal for accurately simulating turbulent flow patterns.

Despite its cost and demand on computational resources, Karampelas believes that it is important to be able to offer a full suite of turbulence models, not least as LES already is the method of choice for the majority of academics and some industries, for example power engineering.

"Nevertheless, there are certainly cases where the use of CFD may be limited or impractical. This includes problems where the scale of interest may vary by different orders of magnitude, for example, modeling bulk fluid evaporation from nanoparticles, and problems where important physical phenomena are still unknown, poorly understood or, perhaps, extremely complex, for example, modeling the Mpemba effect," cautions Karampelas.

On the other hand, the advent of even more powerful hardware and updated numerical algorithms will make using CFD software the optimum approach for solving a plethora of design and optimization problems, he believes.

"The ability to model more and more complex processes such as complicated heat exchange systems and novel mixing technologies represents only a glimpse of what may be possible in the near future. The main advantage of using numerical methods is that designers are now only limited by their imagination, opening avenues for optimizing a variety of chemical plant processes from small-scale mixers to large-scale reactors and distillation columns. Although the experimental or empirical approach will always remain relevant, I am confident that CFD will be the tool of choice for the engineers of the future," he concludes.

CLOUD-BASED CONFIGURATION OFFERS DOWN-TO-EARTH SAVINGS

Projects involving field instruments gain a variety of benefits

By Amol Chaubal, Honeywell Process Solutions

FIELD INSTRUMENTATION increasingly relies on digital communication. So today, project success greatly depends on the ease of configuring devices to exchange data across digital networks. Modern smart devices have highly sophisticated capabilities but configuration remains a mostly manual process. In addition, far too many field devices must be designed for a given application and are heavily customized. This makes them expensive, difficult to change and engineering intensive. It also requires a large amount of documentation and testing.

Fortunately, with the current growth of the Industrial Internet of Things, opportunities exist to deploy cloud-based applications and smart connected assets to reduce the time, money and mistakes associated with instrument design, ordering, configuration and setup. Cloud engineering with integrated tools and automated documentation offers a way to decrease project risk and schedule, lower implementation costs and effort, simplify operations and minimize lifecycle cost, improve efficiency due to less downtime, and enhance safety. Engineering/procurement/construction (EPC) firms frequently achieve upfront savings of 15–30% of engineering cost by putting cloud-based tools to work.

FASTER COMMISSIONING

Figure 1. Configuring loops via the cloud can cut commissioning time to minutes from hours.

CLOUD-BASED APPLICATIONS

A new breed of engineering application takes instrument configuration to the cloud, enabling error-free instrument ordering, pre-configuration to simplify installation, and online collaboration to increase project efficiencies. This translates to major reductions in device configuration and setup time. Cloud-based execution also eliminates duplicate engineering effort, minimizes errors and provides a simple "out of box" experience from specification start to installation while slashing testing requirements and commissioning effort.

With an automated device commissioning capability, engineers can configure control loops via the cloud and cut commissioning time to minutes from hours (Figure 1). Moreover, binding of the physical device in the field is automated with configuration done in the cloud.

Whereas project engineers once dealt with complicated and repetitive tasks in the initial project stages, automated device commissioning allows teams scattered about the globe to perform configuration development and testing. People can collaborate on work using the same tool and don't need to send information and emails back and forth. All the testing can be done one time — in the cloud — using smart capabilities to time-stamp completed tests and flag future changes to the database.

Cloud-based tools also ease selecting the right instrument and configuration based on the exact parameters of an application (Figure 2) — avoiding costly mistakes upfront in the project. Personnel can use laptops, tablets or cell phones to input technical data about their specific requirements, collaborate with other stakeholders via a cloud infrastructure to expedite engineering decisions, and then determine the optimal setup for the necessary devices on the project. Documentation of the inputted design parameters and instrument configuration preserves engineering work electronically and allows for automated building of a model number for the device that is unique to the configuration requirements. As such, instruments can be ordered and delivered preconfigured, ready to be installed in the field, saving installation time.

In addition, the new web-based tools feature a graphical interface familiar to the younger generation of workers now assuming an increasing role in automation projects.

PUTTING NEW TOOLS TO WORK

The latest cloud-based configuration and commissioning tools can address a number of persistent challenges. In particular, they can handle one of the most difficult jobs on any automation project: determining where to land a field instrument within the control system. In one sense, this serves as the lynchpin for the rest of the configuration. In another, more traditional view, the entire control strategy paradigm is based on what channel that field instrument is connected to. Make a mistake and the entire control strategy doesn't work.

THE RIGHT DEVICE

Figure 2. Cloud-based tools ease selecting the correct field device and configuration.

With the advent of an automated device-commissioning capability, the inherent intelligence of smart transmitters such as those employing the HART protocol helps do away with time-consuming steps that once were mandatory on every project. It also addresses conventional requirements for a large, centralized marshaling area and enables moving redundant input/output (I/O) into the field.

Modern online tools allow workers to perform initial device configuration, and later functional testing, in the cloud. Once devices are installed in the field and connected to I/O modules, automated device commissioning occurs for each cabinet. This process also documents device configuration and location for future reference.

When a technician connects a HART 6 or 7 device to, for example, a distributed control system (DCS), the system detects the connection and interrogates the device to see the tag name contained in the 32-character string that comes with the HART standard. After determining the device name, the system then configures the respective controller, I/O module and device. This feature obviates hardware changes late in the project because only software requires modification.

Automated device commissioning also eliminates the rigors of programming control systems whenever new instruments are connected. Traditionally, control room personnel had to create a measurement point and program it to work with each new device. An automated device-commissioning tool performs this programming automatically — saving time in creating new measurement points.

Project teams can take advantage of automated device commissioning to simplify and self-

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document late changes in an automation project. Controller, I/O and server performance can be fully simulated, allowing testing of a system configuration independent of the ultimate hardware platform.

In addition, an automated commissioning tool can serve to locate crucial wiring mistakes such as mismatched instrument channels and automatically update the configuration. Previously, this would have required technicians to spend hours verifying the power supply, checking connections to the I/O modules, etc.

New online configuration tools do have limitations. For example, taking full advantage of auto-detection and configuration capabilities requires use of HART 6 or later devices. For non-HART devices like discrete inputs or outputs, there often isn't much to configure.

STREAMLINED PROCESS

Cloud-based tools further improve effectiveness when specifying and deploying large numbers of new field instruments, as is common in a unit expansion. The traditional approach involves a multitude of steps — e.g., selecting an appropriate instrument, choosing suitable options and ensuring their compatibility with each other; then once the device is installed, setting the parameters necessary to optimize performance and enable communication of the right information, testing, troubleshooting, etc. Using a cloud-based tool can save time, reduce costs and minimize risk.

An online application and validation tool can significantly enhance the instrument selection process by providing step-by-step guidance in choosing the best level, pressure and temperature devices for a given project. A validation function helps determine the optimal setup for the instrument application. Then, a configuration function can build a complete device model number, obtain pricing information and place an order.

For example, in a typical tank-gauging application, the required inputs include:

- information about the tank and its measurements;
- details and measurements of any obstacles inside the tank;
- particulars about the product(s) housed in the vessel;
- the anticipated temperature range inside the tank over time;
- the expected pressure variation;
- specifics about any area safety certification necessary; and
- attributes of the connection type needed for the level instrument.

Tools featuring an interactive, graphical representation of the process installation enable the use of pre-defined shapes to illustrate a tank or pipeline, place an instrument in the desired location, and enter process parameters. The application works in the background to choose the right device and identify the appropriate options and configuration for the application. A warning occurs if the instrument is incompat-

ible with the specified service environment. If needed, the user and supplier representative can simultaneously view the application schematic in real-time while discussing changes on the telephone. The application helps eliminate the possibility of mismatched options and other common errors in the ordering process.

The use of a cloud-based application and validation tool also ensures that instruments arriving on site are pre-programmed by the factory based on the information provided during the online specification procedure — eliminating the need for manual data entry using a hand-held device or keypad. In this way, configuration work is done only once and instruments are ready for immediate installation upon arrival.

Should an instrument fail in the future, the factory or service representative can call up the original online schematic to view all the application and service parameters, and see where the instrument is installed. This simplifies troubleshooting of device malfunctions, saves time and improves efficiency.

SUBSTANTIAL BENEFITS

Overall, a cloud-based approach can provide:

- reduced project risk;
- decreased engineering cost and effort;
- improved project efficiency;
- less duplication of engineering effort; and
- fewer configuration errors.

Using automated device commissioning and online instrument application and validation tools becomes even more compelling on large mega-projects involving multiple EPC companies. Advantages here include:

- reduced specification time;
- faster commissioning;
- ease of operation; and
- lower implementation cost.

Thanks to cloud execution for instrumentation scope, project personnel can reconfigure field devices on the run and make changes as needed without significant impact on physical infrastructure. They also can reduce the potential for costly mistakes due to the ability to easily rework any stage of the process.

To sum up, new cloud-based technologies enable both EPCs and end users to realize dramatic improvement in project results. These tools can play a key role in ensuring controls and instrumentation pose the least risk to project schedule, cost and risk while at the same time fostering safe, efficient and reliable plant startup and operation.

AMOL CHAUBAL is senior product marketing manager for field instrumentation at Honeywell Process Solutions, Pune, India. E-mail him at Amol.Chaubal@Honeywell.com.

Rethink Operations Management

Tackle serious flaws that often undermine efforts

By Mike Neill, Petrotechnics, North America

OPERATIONAL EXCELLENCE (OE) is becoming the focus for large chemical, petrochemical and refining companies. Such initiatives are aimed at building and sustaining efficient, safe and effective operations. Many firms adopt these programs intending to improve their health, safety, environmental and quality performance. Most OE initiatives focus on defining and implementing best practices and standardizing these methods across a facility or an enterprise. The output is measured in terms of commercial success, productivity, safety, sustainability and more. Achieving consistent performance improvement is the goal. To do this, operators must identify and manage any and all risks that threaten success.

The success of any OE initiative depends upon three key elements:

- *People (beliefs, values, and capabilities)*. Personnel must know what they should do, understand why, and be capable of doing it.
- *Processes (how things should be done)*. Organizations need a defined and properly communicated approach that controls output and ensures consistency in practice.
- *Technology/tools*. People and organizations require underpinning support for delivering efficiency, consistency and process control.

One of the challenges to achieving OE in a facility can be the organization itself. Most companies understand the benefits of integrated teams but tend to behave as though they are composed of silos, e.g., maintenance, engineering, asset integrity, reliability, operations and health/safety/environmental. This is understandable because each functional discipline usually uses in its own distinct language and methodologies. Yet, these silos can create difficulties and may adversely affect the objective of optimal operations. For instance, they may rely on information systems specific to their discipline, resulting in data silos that the rest of the organization can't easily access.

This is a major challenge to OE where achieving efficient, safe and effective operations depends upon critical ad hoc decisions that impact a range of disciplines. When

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functional/discipline priorities conflict, cross-functional tension influences these decisions. Consider, for example, inspection, preventative maintenance and repair that drive the majority of daily activities. These efforts typically are carried out in a live plant with inherent hazards and ongoing operational activities such as starting up or shutting down equipment, isolating energy sources, changing out filters, pig receiving, operator rounds, etc. Other departments also might be active in the vicinity, e.g., working on adjacent units, small construction projects, temporary location of equipment, crane operations, etc. Constraints on these activities — such as safety considerations, budget, work clashes and resource limitations — are sure to arise. In other words, operators seldom can do all they want when they want. Priorities must be established and compromises made; sometimes a decision will mean deferred or canceled work. This is merely one example of how cross-functional conflict occurs in a plant and leaves frontline operations responsible for deciding priorities and agreeing to a plan of work.

Many other examples come to mind: The integrity group must check wall thicknesses on inlet piping but the pipe insulators who must remove the lagging material are tied up on another project. Process safety is pushing for repairs to an underperforming deluge system but the high cost of transporting spares by air means that, unless the budget is released, they would have to travel by sea and wouldn't arrive for three more weeks. Maintenance wants to carry out preventative maintenance work on a compressor but operations, which already is behind on meeting monthly production targets, doesn't want to take the unit offline.

Integrated planning should help minimize clashes but often the pertinent criteria aren't available when plans are set. For OE to be effective, operators must optimize their plans, ensuring they've identified the impact on risk of any activity scheduling. This is easier said than done because operators can't simplify and communicate the components of risk to an extent where people other than the process safety experts can easily assess them.

Even process safety lacks models that can effectively evaluate risk in a dynamic mode with multiple components. Instead, most risk-models based on process hazard assessments, bow ties and layer-of-protection analyses are scenario-based and are more suited to design than the reality of day-to-day operations.

THE REALITY

Multiple activities and barrier status together impact the risk of major accidents. While until now frontline operations may have "sensed" the risk, they haven't had the tools they need or easily accessible information to help them judge their real level of risk. As a result, many decisions are based on gut instinct rather than on data and a structured approach.

Plants today typically rely on multiple barriers to prevent a major event from occurring, with additional

MIDDLE EAST COMPLEX GAINS MAJOR BENEFITS

Planning and executing the first total complex shutdown (TCS) of one of the Middle East's largest petrochemicals and refining sites — a production facility in Saudi Arabia that processes 400,000 bbl/d of crude oil and 1.2 million t/y of ethane — posed a formidable challenge. It involved a peak of about 25,000 staff from contractors as well as 2,500 site employees.

Petrotechnics provided its software as well as a project manager and eight subject matter experts for about two months, from Oct. to Dec. 2015. With this support, risk-based activity and safety-critical tasks relating to the TCS and simultaneous operations were managed in a standardized manner, strict internal safety standards were adhered to, and a safe, standardized and consistent TCS approach was achieved. The OE software integrated with existing management and control systems to ensure uniform information for planning and execution across the enterprise.

To reduce the risk of injury to workers, 63 reusable templates were developed and approved by the operating company's safety engineer to identify hazards of specific tasks. This led to the creation of about 42,000 job safety analyses for more than 3,200 equipment job packs. The site's next turnaround will take advantage of this library of ready-to-use templates.

barriers to mitigate the consequences and limit escalation should it occur. To accurately judge the current overall level of risk, operators must understand the status of their fundamental barriers.

Operators have a lot of information on the status of their barriers across the plant. Unfortunately, these details are locked in data silos, typically only accessible to individual disciplines. For example, information on corrosion under insulation of a particular section of piping might appear in an inspection database operated by the asset integrity group. Another database, handled by the electrical group, covers the condition of gas seals on switch boxes. Meanwhile, the instrument department tracks whether or not the relief valves on the main vessels have had calibration checks. Such information may be critical to decisions being made by operations, for example, on hot work planned that requires the temporary defeat of gas detectors but isn't easily discovered without considerable effort.

The individual giving permission for potentially conflicting activities to proceed must know the status of the asset's fundamental barriers in the area where the work will take place. All too often, the default assumption is that the barrier status is good.

Investigations following major incidents often show multiple barrier failures progressively escalate risk to the point where an event occurs. However, this risk state is not identified otherwise intervention would occur. Many individual failures may not seem significant — but collectively, they can result in severe consequences.

A FULLER PICTURE

OE isn't just about safety; it's also about working efficiently and effectively. This means having excellent planning, scheduling and execution of maintenance and inspection work. The cost of maintenance and inspection is one of the highest components of the budget, so most operators are keen to ensure their workforce is highly utilized and performing the right tasks.

Historically, companies have invested heavily on improving planning and scheduling and adopting advanced techniques such as risk-based maintenance and condition monitoring to ensure the optimal use of maintenance staff time. They frequently rely on key performance indicators such as "schedule compliance" or effective "time on tools" to judge effectiveness. However, all too often these metrics indicate poor results despite sophisticated planning. One of the reasons is because the plan doesn't contain all the elements necessary to execute work.

For example, consider the replacement of an underperforming actuated valve on a fire water main. The

ZOOMABLE DISPLAY

Figure 1. Hazardous work activites underway and impaired process safety barriers are apparent.

TIME VIEW

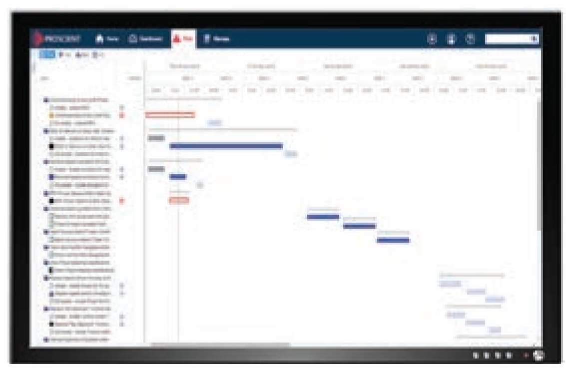


Figure 2. Display highlights if tasks planned to be done at the same time raise risk.

RISK DETAILS

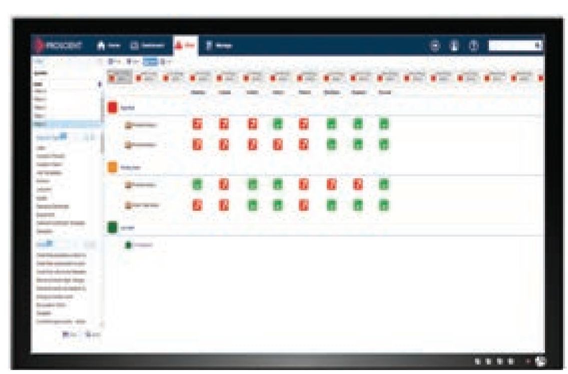
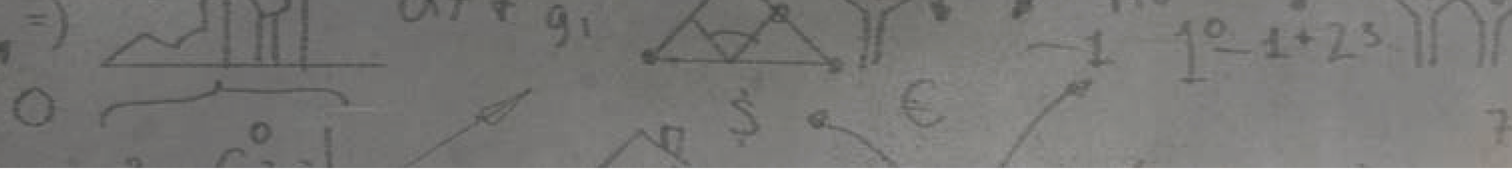


Figure 3. Screen shows cause of elevated risk level and vulnerabilities of barriers.



maintenance management system has scheduled this activity for a Thursday morning and allocated two instrument technicians for six hours. Unfortunately, this valve and actuator weigh 140 lb and are located 30-ft up on a rack. So, several sets of activities involving multiple crafts must occur in sequence. Scaffolders must erect a working platform to gain access. Instrument and electrical technicians must isolate the actuator. The fire water system must be isolated before the flange can be broken and the replacement installed. A crane is required to remove the old unit and lift in the replacement. Then the whole process must be reversed. What was originally scheduled to be a job easily completed in a shift may extend 2–3 days once all task components are taken into account. Moreover, before any work begins, a contingency plan must be initiated and agreed for the period when the fire water system isn't functional. During that time, operations must postpone any hot work in the area.

The result is the actual work schedule can differ greatly from what was planned — causing friction among departments whose performance measures are impacted. Many craftspeople end up with low "time on tools" because they are waiting for sequenced work to be completed. Planning will receive low plan attainment and will blame maintenance, which then will point the finger at operations for not releasing equipment on time!

As with safety risk, the resulting performance comes down to decisions made during planning and work execution. The data to improve those decisions exist in the organization but aren't easily accessible in real-time when shift-to-shift, hour-to-hour decisions must be made.

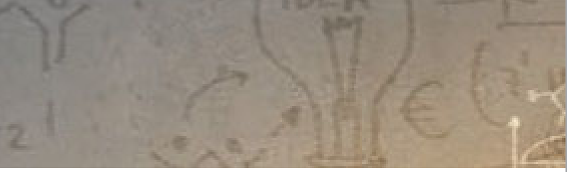
The industry has lacked systems to bring information together, including tools to manage activities and risks in an optimized way. This undoubtedly would provide organizations the visibility they need to work together more effectively.

A BETTER WAY

OE software platforms are emerging. These dedicated systems are designed to deliver integrated OE across an organization. They enable integrating data from multiple sources and visualizing all risk and activity in real-time. All activities, including permitted and non-permitted work, the defeat of safety systems, confined space work, operations activities and more can be connected with impaired barriers. The impact of risk and activities can be understood geographically and by time (current and historical).

Zoomable displays of the plant (Figure 1 on p. 41) show hazardous tasks such as hot or confined space work taking place as well as impaired process safety barriers. In addition, they incorporate operations activities such as the startup of a compressor or pump. Algorithms assess and display the risk impact. The cumulative risk measures predicted and real-time degradation of fundamental barriers are based on the work schedule and ongoing impairment of specific equipment.

Operations teams can import the planned work schedule and add other criteria to make the plan more comprehensive. A display of all activities in sequence enables better decisions to ensure accurate, safe and executable work plans.



"Time views" (Figure 2) incorporate rules to show work clashes that are unsafe such as hot work and breaking containment in the same space at the same time. The algorithm indicates overall cumulative risk for each shift projected against the work schedule.

Dedicated risk views (Figure 3) provide a drill-down to see what is causing elevated levels of risk against fundamental barriers and also display if sequential barriers have the potential to fail. Identifying this level of vulnerability is crucial to avoiding incidents and preventing their escalation. In addition, these views can be used to simulate the repair of impaired barriers and forecast future risk reduction. Now the leadership team has real data to prioritize repair work during its planning sessions.

The emergence of OE software platforms offers an opportunity to rethink operations management. The ability to easily visualize and share information in a single place enables siloed organizations to more effectively optimize their activity plans with a common purpose of improving safety, production and quality. These tools already are helping organizations to efficiently execute their plans (see sidebar on p. 40).

A lot of progress has been made in OE programs over the years to integrate and optimize processes that, in turn, energize and align people. These efforts have had success but have been limited by discrete and disconnected technologies. The emergence of a dedicated OE platform bridges that gap.

Now operators can use technology to integrate people and processes to collaborate and deliver excellent operations!

MIKE NEILL is president of Petrotechnics, North America, Houston. E-mail him at mike.neill@petrotechnics.com.

Relief System Requires Review

Performance raises serious concerns about current arrangement

THIS MONTH'S PUZZLER

I'm a new-hire production engineer at an ethylene oxide plant. I graduated last year and just finished my probation period, winning my white hat. I went over the production logs a few weeks after I got here and found a real problem: the pressure relief valves (PRVs) keep popping every few months. I wanted to say something right away but, being a new graduate, I didn't want to question a situation that others already have scrutinized. Recently, though, I talked to the operator on shift at the time of the last PRV release. He said the operators rely on an "automatic" manual vent (one with a lift ball) to prevent the PRVs from opening (figure online at http://goo.gl/DVTi6j).

I then spoke to a few more operators. They all told me they're so busy since a plant expansion that they have trouble controlling the reactor pressures; sometimes they just let the vent catch the upsets. The PRVs only pop every so often, one said. The foreman advised me drop the matter.

However, I looked more into it and found the manual vent opened every few days and the PRVs have popped about three times a year over the past two years. I can't get more data because the trends only go back that far. Interestingly, I talked to accounting and discovered we use twice as much sulfuric acid in the scrubber as we did two years ago.

I dug into our files and couldn't find the sizing calculations for the vent. I don't think this vent is even legal. What should I do?

CHECK THE RELIEF SCENARIOS

I certainly share your concern but in no way want to insinuate any wrongdoing by your company. Evidently, the scrubber is installed to vent each reactor on a manual basis and would probably be permitted based on the number of reactor batches in a year and the expected contents of these reactors — assuming very small quantities of reactants. The reaction is probably designed to go to completion with the least environmentally sensitive reactant in excess, protecting the scrubber vent from the most sensitive, such as ethylene oxide.

Such an arrangement of relief devices, including the manual ball vent (note the CSO [car seal open] valves on it in the same manner as the PSVs), in ever-increasing pressures is unusual. I would be more concerned over the relief scenarios of the PSVs. What would these scenarios be to be staged as they are? The goal of a reaction control would be to stay below the 245 psig of the manual vent (manual is a misnomer because it seems to open automatically). That should be done at the reactor inlet end. Pressures approaching the 245 psig should cause a pause of the reaction or lower the rate of the reactant addition. If these are manual additions, the vent ball may be needed for slight excursions but manual relief of the reactor with the worm manual vent should not be used.

Generally, releases in an unusual event going out of a relief device may not be a permit violation. However, the regularity of the reliefs you describe would seem excessive. A PSV should not blow that regularly and, if it has blown, it is usually scheduled for maintenance at the next available outage. It appears that operation of the ball vent is designed to be more frequent or even perhaps with no real deterioration of the device mechanics.

The concern here is that during these vents the rate of reaction will go faster than planned. Hence, the operating pressure will be higher than planned, exceeding the capacity of the scrubber. The net result is potential release of some amount of the constrained reactant, i.e., ethylene oxide.

Better control on the reactant additions is needed, with sufficient documentation of the controls and relief scenarios so the next new engineer will be able to fully understand the operation and safety features of the system.

Tom Brader,
staff instrument engineer
Valero, St. Charles, La.

TREAD SOFTLY

What was it that Collin Powell said about Iraq? "If you break it, you own it." Your first step is to determine if there is an upgrade project planned for the reactor vent; if calculation procedures aren't available from the corporate engineering files, then they should be part of that project. From the figure, it appears that the lifting ball is the first line of defense and was designed before the additional reactors were added. This suggests that it may be at capacity. Did anyone check the capacity prior to the expansion? Obviously, if you suggest something is a problem, then it becomes your burden to solve. There is an alternative scenario: your company or plant is ignoring the problem — and now you'll be seen as a troublemaker for raising the issue.

As to the question about the legality in the use of the lift ball vent, it's perfectly safe if there are relief valves protecting the maximum allowable operating pressure. A lift ball is no substitute for a relief valve because it isn't recognized by the API and OSHA as a safety device.

We ran into this problem on a reactor project I worked on. OSHA wouldn't budge. They got curious when we mentioned we had a lift ball.

I can tell you one thing that will get you in trouble with regulators: not having design calculations for a lift ball vent. Although it's not an official relief device, you must have calculations for it — that is what we were told. When I sized the lift ball for higher pressure and flow, I modified calculations for a variable-area flow meter tube, a rotameter: reference rotameters in Noel de Nevers' "Fluid Mechanics for Chemical Engineers," 2nd edition, and Richard Miller's "Flow Measurement Engineering Handbook," 3rd edition. I also

JUNE'S PUZZLER

We manufacture astaxanthin by fermentation and decided to switch from spray-drying to freeze-drying or lyophilization because freeze-dried astaxanthin is 41% more active than the spray-dried version and can be stored without refrigeration.

A block flow diagram developed by project engineering summarizes the proposed design (Figure 1); the process involves sterilization, low-temperature drying in a turbo tray dryer followed by freezing and drying in a series of tray dryers ending with a belt dryer.

The design has evoked a lot of criticism. Production complains it's too complicated and will make it hard to keep the product sterile. Corporate management says we can do away with the sterilization because the freezing process will eliminate bugs. The construction manager argues that maintaining a vacuum between the dryers and even in the dryers themselves will be tough: he suggests going with multiple batch dryers instead. Research counters that the continuous dryers will produce a more-consistent product, even more so than the spray dryers, which are batch. Our safety manager is concerned about dust in the belt dryer. What do you think of the design?

Send us your comments, suggestions or solutions for this question by May 12, 2017. We'll include as many of them as possible in the June 2017 issue and all on Chemical-Processing.com. Send visuals — a sketch is fine. E-mail us at ProcessPuzzler@putman.net or mail to Process Puzzler, *Chemical Processing*, 1501 E. Woodfield Rd., Suite 400N, Schaumburg, IL 60173. Fax: (630) 467-1120. Please include your name, title, location and company affiliation in the response.

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

FREEZE-DRYING PROCESS

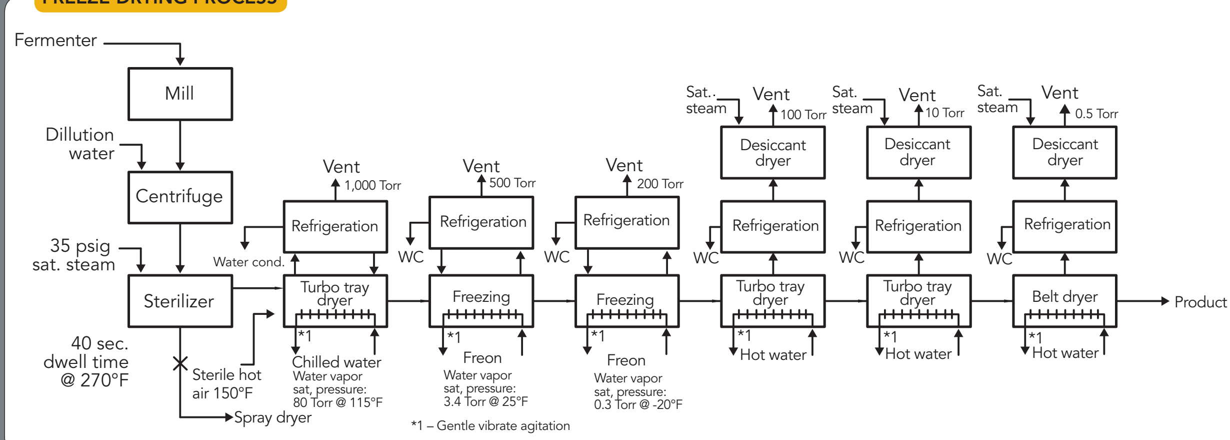


Figure 1. Proposed design has provoked negative comments from a variety of staff.

CHECK OUT PREVIOUS PUZZLERS

To see all the Puzzlers that have been published over the years, go to: www.Chemical-Processing.com/voices/process-puzzler/.

got some help from vendors in establishing flow coefficients. In my case, I additionally had several years of reliable data on lift pressure. Once I reviewed this information, I reverse-engineered the calculation for the existing ball. All of this was useful in designing a larger lift ball to operate at a higher pressure.

Now, let's consider some safety concerns I noticed when reviewing the figure. The trouble is with the material being handled: ethylene oxide. It polymerizes with itself and actually eats polytetrafluoroethylene — not the light-weight partially fluorinated version but the fully fluorinated polymer. When it polymerizes, ethylene oxide can cause a chain reaction that results in an explosion. Even when it doesn't cause an explosion, it can gum up valves. As a normal practice, relief devices are removed and replaced if they operate — this is especially important with a material like ethylene oxide. This probably explains why the acid scrubber is consuming large quantities of sulfuric acid. It is likely that the rupture disc is broken under the lift ball. It is even possible that the ethylene oxide reacted with the steel coating the ball to affect its performance by creating additional drag. It is even possible that the ball could eventually fail because it has become corroded to the wall of the vent chute. This could be the reason why the relief valves have been opening more often, or it could be that the relief valves added to the relief header aren't meeting capacity. In addition, if relief valves are being frequently replaced, there is the risk someday that someone will leave it in and it won't perform because it's gummed up. There are some serious questions about the current design of the relief system.

Normally, I advise against adding multiple relief valves. As with spray nozzles in scrubbers, you're always better with one rather than many. You should insist on a review of the relief requirements.

Dirk Willard, consultant
Wooster, Ohio

Deflate Random Errors

Take steps to minimize their impact on the accuracy of pressure readings

You must tackle random errors differently than bias ones.

LAST COLUMN, we looked at overcoming bias in pressure gauges ("Do Simple Things Right," http://goo.gl/ZivsMi). The gauges also may have random errors in readings. When purchased, pressure gauges should come with paperwork showing the expected error of the gauge. It should include both the bias and the random error.

What's a typical error? A good gauge well suited for most troubleshooting work has an expected error of 1 or 2%. This percentage may relate either to the entire range of the gauge or the particular reading. If given as a percent of reading, the error may apply only to a restricted range on the gauge.

To see what this means for us, let's go back to last column's example of using a 0–100-psig gauge to take readings from 81 to 49 psig. Table 1 lists some readings and the expected error for percent-of-range versus percent-of-reading. It shows that percent-of-range gauges really give a fixed error amount and that percent-of-reading gauges tend to be more accurate. However, the latter are more expensive. Unless you're careful, your purchasing department will get the lower accuracy gauges.

GAUGE WITH 1% ERROR

Reading, psig	Possible error, percent-of-range	Possible error, percent-of-reading
81	± 1	±0.81
74	± 1	±0.74
71	± 1	±0.71
64	± 1	±0.64
61	± 1	±0.61
49	± 1	±0.49

Table 1. Error as percent of range is fixed but varies as percent of reading.

TWO SETS OF GAUGES

Set	Reading	Range for values, high minus low, psi
1	A	0.3
1	B	0.6
1	C	0.5
1	D	0.2
2	E	0.5
2	F	0.6

Table 2. Using two sets of four gauges provided accuracy close to ±1%.

Some larger plants have internal instrument shops that repair out-of-specification or damaged gauges. If that's the case at your site, do you know the accuracy of the gauge you're getting back from the shop? Often, the answer is no. Lack of knowledge adds uncertainty. Unless the gauge is tested, assume it has an error of 2% of range or more.

At the start of any pressure survey, put all the gauges on a common point with steady pressure and take readings. Then, don't use any gauge that is more than the error range away from the average.

Reducing the effect of random errors requires different techniques than those for addressing bias. Using multiple gauges at the same location and at the same time can cut the consequences of random errors. Whether or not you must resort to this depends upon the accuracy and precision necessary to justify a conclusion.

Consider a situation I faced a while ago. It required measuring four points to create a pressure profile. The pressure ranges were from 5 psig to 22 psig. The most important range was 12 psig to 22 psig; that range demanded an accuracy of ±0.25 psi to enable a valid decision.

We had 0–30-psig and 0–60-psig gauges available. At the start, we assumed all gauges had an accuracy of ±2%. This created a problem. Relying on single gauges would cast real doubts on the certainty of our conclusions.

So, we used eight gauges split into two sets. One set contained two 0–30-psig and two 0–60-psig gauges. The second set consisted of four 0–30-psig gauges. During use, we identified one gauge as being damaged and removed it from service. Table 2 shows the variation found among the gauges at common points. Assuming random errors, the accuracy was closer to ±1%.

The eight gauges allowed us to deploy four gauges at each location to average out random errors. Taking two pressure surveys with the sets switched enabled us to remove biases from the readings. Both techniques together generated a usable pressure profile and helped identify the process problem.

Even simple jobs such as taking pressure readings have a right way. Performed correctly, pressure profiles can be an invaluable troubleshooting tool.

ANDREW SLOLEY, Contributing Editor
ASloley@putman.net

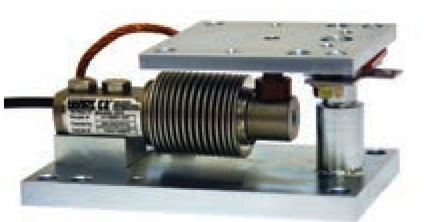
WirelessHART Adaptor Withstands Hazardous Areas

The Bullet loop-powered WirelessHART adapter communicates data regarding measurements, diagnostics and parameterization from 4 mA to 20 mA and HART field devices. The adapter comes in a flameproof Ex-d enclosure for use in explosion-hazardous areas up to Zone 1. It can be connected to an Ex-d field device either directly or via a conduit, or mounted to a terminal box via a cable gland. In Ex-d-to-Ex-d configurations, devices and all components on the adapter side that can cause ignition are installed in housings equipped with corresponding cable ducts. These housings can withstand the internal explosion pressure that could occur.

Pepperl+Fuchs
330-425-3555
www.pepperl-fuchs.us

Weighing System Suits Low-Capacity Applications

The OneMount line now includes a model designed for small hoppers, tank weighing systems and bagging machines, and other low-capacity applications such as checkweighing and conveyor scales. Its Advantage beam sensors allow a vessel or hopper to be installed, bolted and welded using the mount itself without additional installation accessories. The system's integral spacers carry the full-rated capacity without the load cells installed. The 360° checking mechanism allows load points to be installed in any direction, and C2 electronic calibration further speeds installation. Load cells can be replaced with minimal tank jacking (⅛-in.), and matched mV/V/ohm load cells can be replaced without recalibration, minimizing maintenance.



Hardy Process Solutions
858-278-2900
www.hardysolutions.com

Flame and Gas Controller Offers Direct Link

The Eagle Quantum Premier (EQP) flame and gas safety controller with device level ring (DLR) outputs is a SIL-2 capable, fault-tolerant, addressable system that integrates into the process control system. It is globally certified to the latest standards for fire and gas safety system performance and hazardous locations, including NFPA 72, to provide notification for both flame and gas detection and releasing circuits for mitigation of fire hazards. It's designed to operate in hazardous locations from -40°C to +85°C. Its DLR interface provides a direct communication link to programmable logic controllers. Its design allows for distributed releasing circuits and lower wiring and installation costs than point-to-point systems.

Det-Tronics
800-765- 3473
www.det-tronics.com

Smart Sensor Checks Motor Health

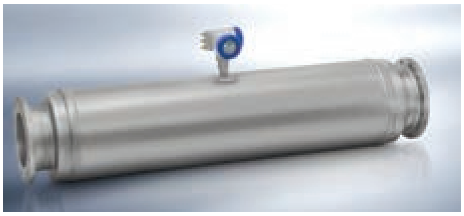
ABB Ability Smart Sensor for motors uses compact sensors to pick up multiple data from low-voltage (LV) motors and provides information about motor health and performance via a smartphone or a dedicated web portal. The remote condition monitoring device enables uptime optimization, predictive maintenance regimens and efficiency improvements for LV motors. By converting regular LV motors into intelligent, connected machines, the sensor allows advanced maintenance planning that will help businesses to cut costs and boost productivity. Predictive analytics based on data from the solution can reduce downtime by up to 70%, extend motor lifetime by as much as 30% and cut energy consumption by up to 10%, claims the company.

ABB
800-435-7365
www.abb.com

Electromotive Seat Valves Offer Precise Control

Type 3360/3361 electromotive seat valves are designed to help improve performance, reliability and cost-effectiveness, the company says. Potential uses for the process control valves include applications with stringent requirements for control accuracy and process stability. They also are intended for applications in which the use of compressed air is undesirable or impossible. Examples of such applications include large-area storage systems with long distances to the single valves, as well as systems for mobile, decentralized water treatment. The valves' electrical solution maximizes efficiency. They provide stable processes with optimal operating parameters and are easy to clean due to a compact, hygienic design.

Burkert Fluid Control Systems
800-325-1405
www.burkert-usa.com



Mass Flow Meter Handles Bulk Measurements

The Optimass 2000 S400 16-in. Coriolis mass flowmeter reportedly is ideal for bulk measurement of petroleum and oil, as well as raw chemicals, syrup and molasses. The large-diameter mass flow meter also has been approved for custody transfer. With its four straight-tube design, the meter offers significant energy savings with a lower pressure drop, the company says. Its small footprint also suits applications where space is limited. Able to handle flow rates as high as 4,600 t/h, the meter features an accuracy of 0.1% with a turndown of 20:1, and an optional 0.05% "flat" accuracy with a turndown of 10:1.

Krohne
800-356-9464
www.us.krohne.com

Pressure Transducers Meet Compliance Standards

The Cerabar PMP11, 21 and 23 pressure transducers measure up to 6,000 psi and are expandable to specific application requirements. The transducers come with threaded or welded hygienic process connections, meet a variety of industry standards including FDA, FM, IEC and Ex, and provide 4–20-mA or 0–10-Vdc output signals. The PMP11 and PMP21 pressure transducers measure pressures from -15 to 6,000 psi at temperatures from -40°F to 212°F with accuracy of 0.5% and 0.3%, respectively. The IP69 housing and process isolating diaphragm are 316L stainless steel. The PMP23 can be used in CIP and SIP applications at temperatures up to 275°F for a maximum of one hour.

Endress+Hauser
888-363-7377
www.us.endress.com

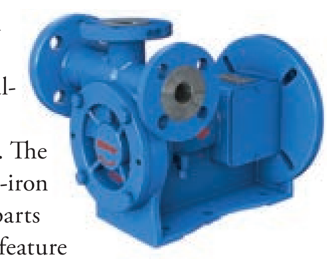
Controller Easily Connects to Weighing System

The EVA HE controller is the processing unit, electronic device or measuring amplifier for the C-Lever flow metering system. The weighing system controller includes all the required connections to easily connect to existing installations. The controller can be updated and adjusted remotely. In addition, a range of settings can be saved via data logging. The start-up, updates and bug fixes all are carried out online. The system has a 5.7-in. color display with touchscreen and an intuitive interface for simple operation. Different material densities, irregular material flows or extreme friction don't affect the accuracy of the measuring process, the company notes.

Rembe
704-716-7022
www.rembe.us

Turbine Pump Minimizes Installation Costs

Ebsray RC40 series redesigned regenerative turbine pump has increased flow rates, and its single-stage impeller reportedly provides high performance with low maintenance requirements. C-Face motor brackets fit NEMA, and IEC B5 and B14 motors, while a three-ported design with two discharge ports provides installation flexibility for lower installed cost. The pumps have ductile-iron pressure retaining parts (body/cover). They feature a maximum differential pressure to 200 psi (14 bar) and maximum flow rates are 52.8 gpm (200 L/min) with motor speeds up to 3,500 rpm. Multiple port options are available in one body design: ANSI, DIN and NPT. The pumps comply with ATEX, AS1596 and UL51 codes.

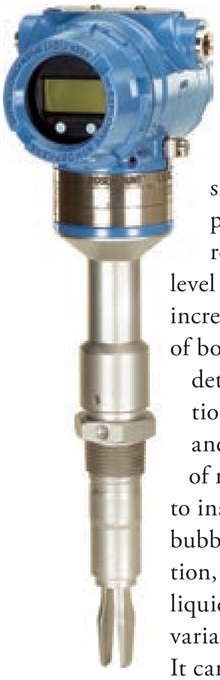


Blackmer
616-241-1611
www.blackmer.com

Compressors Reduce Energy Costs

With flows from 595 to 882 cfm at 125 psig, the redesigned DSD 125–175 rotary screw compressors are up to 25% more efficient, says the company. The models deliver lower lifecycle costs with their simple maintenance and built-in heat recovery options for reduced energy. The compact units include an enhanced cooling design, eco-friendly filter element, integral moisture separator with drain, and an electronic thermal management system. Units also come standard with Sigma Control 2. This intelligent controller provides compressor control and monitoring with enhanced communications capabilities for seamless integration into plant control/monitoring systems and the Industrial Internet of Things (IIoT).

Kaeser
877-586-2691
www.kaesernews.com/DSD



Level Detector Helps Improve Safety

The Rosemount 2140 wired HART vibrating-fork level detector with smart diagnostics and remote proof-testing capability reportedly provides reliable level detection while helping increase safety and efficiency of both plant and workers. The detector performs in applications with high temperatures and harsh conditions. Its lack of moving parts makes it easy to install and maintain. Flow, bubbles, turbulence, foam, vibration, sediments content, coating, liquid properties and product variations don't affect the device. It can be used to monitor not only liquids but also liquid-to-sand interface, which enables the build-up of sand or sludge deposits in a tank to be detected.

Emerson
314-553-2000
www.emerson.com/en-us

Device Extends IT Security to the Plant Floor

The Allen-Bradley Stratix 5950 security appliance incorporates new security technologies to help protect plant-floor systems. The device uses adaptive security appliance (ASA) firewall and FirePower technology to create a security boundary between cell/area zones or to help protect a single machine, line or skid. This supports compliance with IEC 62443. The device also uses deep-packet-inspection (DPI) technology. Developed in collaboration with Cisco, the DPI technology enables inspection of the Common Industrial Protocol and other industrial protocols. It includes four 1-gigabit Ethernet ports, and is available with copper-and-fiber or copper-only, small form-factor pluggable (SFP) slot options.

Rockwell Automation
414-382-2000
www.rockwellautomation.com

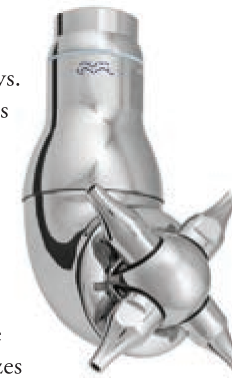
Refrigerated Air Dryer Saves Energy

The Flex Series refrigerated air dryer uses heat transfer technology and phase change material (PCM) to efficiently remove liquid from compressed air. Designed with a 3-in-1 heat exchanger, the PCM encapsulates the refrigeration and compressed air circuits. This allows the phase change material to stay colder for longer periods of time, cycling the refrigerant compressor less often than conventional energy-saving designs. Its flexible design and increased multi-flow bandwidth allow for deployment into a range of flows, without compromising initial costs or energy consumption. The PCM itself is an eco-friendly refrigerant that melts and solidifies above 0°C and doesn't require the use of glycol, pump, tank or hot gas bypass.

SPX Flow, Inc.
704-752-4400
www.spxflow.com

Tank Cleaning Machine Saves Time

The TJ40G rotary machine uses a high-impact jet stream to effectively clean tough tank residues and minimize risk of product contamination. This four-nozzle rotary jet head cleans tanks 60% faster than static spray ball technology, which increases production uptime, the company says. In addition, its use of less water and less cleaning agents reportedly reduces operating costs by up to 70%. The machine handles tough tank residues as well as solids up to 1 mm in the cleaning fluid in tank sizes 50–1,000 m³. Its hygienic self-cleaning construction ensures cleaning fluid reaches the exterior surfaces of the rotary jet head, and critical interior components such as bushings, bearings and inner surfaces.



Alfa Laval
804-236-3276
www.alfalaval.com

Valve Positioner Simplifies Adjustments

The EP500 electropneumatic valve positioner has a cast aluminum enclosure suitable for outdoor installations. It uses simple force-balance control technology and can be mounted onto pneumatic actuators with strokes between 10 and 70 mm. Two gauges to indicate the supply air pressure and the output pressure to the pneumatic actuator, enable easily making zero and span adjustments. The positioner also includes improved calibration capabilities, an IP65-rated weatherproof enclosure, NAMUR mounting, and a readily accessible electrical access cap with compression-style wiring connectors. A mounting kit is included.

Spirax Sarco
800-883-4411
www.spiraxsarco.com/global/us

PUMP LOAD CONTROL

The PMP-25 pump load control guards against dry running, cavitation and overload. It monitors true pump power for maximum sensitivity. The display shows pump load, trip points and delays. Its NEMA 4X enclosure is small enough to fit on Size 1 starters and can be door-, panel- or wall-mounted.
Load Controls Inc., (800) 600-3247, www.loadcontrols.com

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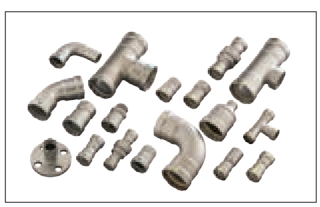

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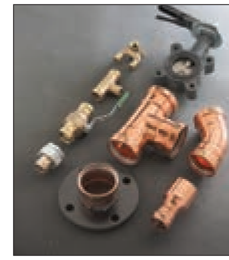

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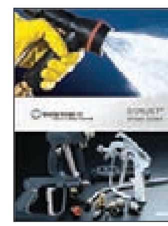

A publication featuring spray guns and a detailed technical reference section on spray technology is available from Spraying Systems Co. GunJet® Catalog 75 provides specific information on hundreds of low-, medium- and high-pressure GunJet spray guns that are widely used for cleaning and rinsing applications. The catalog includes helpful cross-reference tables to simplify matching extensions, adapters and spray tips to spray guns.
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Projects Target Carbon Dioxide Emissions

In one project, computer simulations tackle the amine chemical scrubber conundrum

"This is a game changer for designing and prioritizing new compounds."

RESEARCHERS AT North Carolina State University (NCSU), Raleigh, N.C., have used computer simulations to develop new molecular models that could be used to design cheaper and more efficient versions of the amine chemicals currently used in scrubbers to reduce carbon dioxide emissions.

In 2014, coal-fired power plants produced more than 14 billion mt of CO_2, representing 40% of the total amount generated by human activity worldwide, according to the International Energy Agency (IEA), Paris. At the same time, new environmental regulations and public incentives are progressively being put in place to limit the amount of CO_2 emissions from industry and to encourage new research for its storage and recycling.

However, as the IEA points out, with the average cost of capturing and storing CO_2 ranging between \$50 and \$100/mt, current scrubbing technology is too expensive to become a sustainable solution.

Part of the problem here is the inefficient amine-based solutions still used in industrial scrubbing applications require very costly absorbent regeneration. Even those that are considered good candidates, such as tertiary amines, can have CO_2 properties that differ drastically from one analogue to another despite apparently high structural similarity.

To tackle this issue, NCSU researchers are looking for new amine chemicals with better qualities such as faster absorption rates, higher CO_2 capacity and lower heats of reaction. Denis Fourches, assistant professor of chemistry at NCSU, and postdoctoral researcher Melaine Kuenemann worked to create computer models that could predict an amine's absorption properties based on its chemical structure.

They collected and curated experimental data from the literature and built a modeling set based on 41 publicly available amine solutions together with all their chemical and absorption properties.

Then they analyzed the chemical and structural characteristics of each amine and grouped them into families of chemicals with similar structural properties. Next, they looked at how well and how quickly these amines could absorb carbon. Using these data, the researchers created a series of models known as quantitative structure-property relationships models that can predict the amines' CO_2 absorption properties solely based on their structural characteristics.

These models utilize machine-learning techniques to predict which chemical structures are likely to have the best overall absorption properties. The researchers found the models to be reliably discriminating between amines with high absorption properties versus those that were less efficient.

"This work is the first attempt to develop computer models for fully evaluating and predicting carbon dioxide absorption properties of amine solutions," Fourches says. "The next step for us is to utilize these computer models to screen a virtual library of hundreds of thousands of new amines, and identify some new amine candidates predicted to have way better carbon absorption properties."

He adds, "If you had to test all of these thousands of compounds experimentally, it would take decades of work. With the powerful computers we have access to, this virtual screening can be done in a matter of days and is very inexpensive. This is a game changer for designing and prioritizing new compounds."

Meanwhile, the U.S. Department of Energy's Office of Fossil Energy (FE) has selected seven projects to receive \$5.9 million in funds to focus on novel ways to use CO_2. The seven will directly support FE's carbon use and reuse R&D portfolio, which in turn will develop and test novel approaches to convert captured CO_2 into usable products.

The projects fall into three technical areas: biological-based concepts for beneficial use of CO_2; mineralization concepts utilizing CO_2 with industrial wastes; and novel physical and chemical processes for beneficial use of the gas.

Five of the projects fall in the third category, with each getting nearly \$800,000 in FE funding. Among them, the University of Delaware, Newark, is to develop and test a two-stage electrolyzer process for converting flue-gas-derived CO_2 into C_2 and C_3 alcohols such as ethanol and propanol. The Gas Technology Institute, Des Plaines, Ill., is working on a direct, high-energy electron-beam synthesis process to produce chemicals such as acetic acid, methanol and carbon monoxide from CO_2. Development of a sorbent-based, thermo-catalytic process to convert captured CO_2 into syngas is the focus for TDA Research, Wheat Ridge, Colo.

In another development, Emissions Reduction Alberta has announced the Round Two winners of its competition for technology to productively use CO_2. For details, see "Carbon Contest Chooses Winners," p. 7, http://goo.gl/pQgCE4.

SEÁN OTTEWELL, Editor at Large
sottewell@putman.net


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