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DAY THREE | #AFPMAM
Wednesday | March 20, 2019

Pulitzer Prize-winning author touts past presidential leadership

ADRIENNE BLUME, Executive Editor, *Hydrocarbon Processing*

Doris Kearns Goodwin, Pulitzer Prize-winning author and presidential historian who worked in the White House under President Lyndon Johnson, spoke at the General Session on Monday about the leadership qualities of past presidents. She is the author of seven New York Times-bestselling books, including her most recent, *Leadership in Turbulent Times.*

Author and presidential historian
DORIS KEARNS GOODWIN

When she began her five-decade career, Goodwin "never imagined I'd be spending every day with dead presidents." She spoke about helping former President Johnson write his memoirs and how his presidential legacy, which was tainted by the Vietnam War, is being reconsidered in current times.

In her recently released book, Goodwin addresses leadership by former US presidents, including Abraham Lincoln, Franklin Roosevelt, Theodore Roosevelt and Lyndon Johnson. Although the presidents had very different temperaments and opinions, "each of these leaders had a particular skill to be the right person in the right place at the right time," Goodwin said.

Lincoln, for example, was not afraid to fail. He was the "dark horse" candidate in the 1861 presidential election, "and the rest, as they say, is history," Goodwin said.

Franklin Roosevelt employed humility to soften what some saw as an overly high sense of confidence. "He developed what he called a 'genuine fellow feeling' that made him want to improve the others' lives," Goodwin said. He persevered throughout the polio illness that left him paralyzed in his late 30s.

Many first ladies also had positive effects on the leadership of US presidents, Goodwin added. Ladybird Johnson provided "a welcome thorn in [President Johnson's] side" and was "a trusted voice willing and able to speak truth to power." Likewise, Eleanor Roosevelt championed for women working in US industry and provided a strong role model for succeeding first ladies.

"These presidents were approachable and accessible, able to reach out to make connections with people," Goodwin said. Lincoln shook a thousand hands on the day he signed the Emancipation Proclamation in 1862, Goodwin explained, which left his own hand shaking. Lincoln waited until his hand had steadied again before signing the document, so that it would not appear to future generations that he had hesitated.

In closing, Goodwin noted that "an unheralded leadership trait, and something that we need more today than ever before, is the ability to find time and space to think and to relax." •

Executives tout workforce diversity, sustainability and corporate stewardship

ADRIENNE BLUME, Executive Editor, *Hydrocarbon Processing*

An executive panel discussion on Monday afternoon, moderated by AFPM President Chet Thompson, addressed the issues of workforce, operational and environmental sustainability in the refining and petrochemical industries.

Panelists included Mike Coyle, President of Manufacturing for Chevron USA; Joe Gorder, Chairman, President and CEO of Valero Energy Corp.; Todd Fredin, Executive Vice President of Motiva Enterprises; Mark Lashier, President and CEO of Chevron Phillips Chemical Co.; Loic Vivier, Senior Vice President of Fuels for ExxonMobil Fuels and Lubricants Co.; and David Lamp, President and CEO of CVR Energy Inc.

Workforce diversity and inclusion are top priorities. Coyle talked about the definition of sustainability and how the industry can develop a workforce for the future. More diversity is needed, Coyle said. "Look at this panel, for example—we all look alike," Coyle said. "Well, we have one French guy," he quipped, eliciting a smile from Vivier.

Taking a more serious tone, Coyle next discussed the challenges facing the industry going forward, including how to interest young people in working in the energy sector and how to craft the workforce with diversity and inclusion as guidelines.

"How do we get our workforces to look more like the communities where we operate?" Coyle asked. "White men in leadership positions can affect the change. We need to change what we do today to change the future of our workforce."

Gorder noted, "We are a largely male workforce. This is changing as we go forward, but this is just the way it is right now. Approximately 20% of engineering graduates are women, and we work very hard to recruit them. To have the best organizations, we need to have really good people."

"The easiest thing for us to do as leaders in the industry is to continue to do what we have always done in the past, just because it works," Gorder said. "We can't do that anymore." He noted that views on diversity from younger generations entering the workforce are becoming more evident to older generations in management positions.

He gave an example of addressing Valero Energy's summer interns, not all of whom appreciated his view that gender and ethnicity are not as important as "everyone rowing in the same direction and working their hardest to succeed." The mixed feedback from interns made Gorder realize that younger generations may want to be appreciated for their differences, rather than being lumped into a single group, which has since made him change his views on diversity in the workplace.

Addressing knowledge gaps during the Great Crew Change. Thompson then noted that the US oil and gas workforce is aging, and asked, "How much of a concern is it that we have proper knowledge transfer to younger workers?"

Coyle explained how Chevron is doing more mentoring of new and young employees than ever before. The company is also striving for longer transition periods between jobs so that critical skills can be fully developed by younger workers.

Gorder noted that subject matter experts do a great job of sharing their knowledge with younger people in organizations. At the plant level, management can forecast what retirement schedules will look like, so that upcoming vacancies may be filled by well-trained individuals.

Thompson also remarked that younger workers tend to consider a company's social commitments before deciding where they want to work. In a recent survey, 87% of younger workers said they considered company social commitments to be a major factor in their decision on where to work—a trend that the industry must address.

Lashier asserted that sustainability is, and should be, a significant part of corporate culture. "How we can help the world be a better place resonates with our employees," he said. Corporate sustainability and responsibility must be articulated to employees so that they can feel good about themselves and the work they do for their industries and their communities.

Fredin explained how Motiva Enterprises has donated $6 MM, since Hurricane Harvey, toward infrastructure improvement and repair projects, as well as toward workforce development through hands-on, innovative platforms for teaching process technology.

"We understand that we have a role in community development," he said. "We need to partner with communities to have a sustainable future for both the companies and the communities in which they operate."

Changing the narrative on US fossil fuels. Lamp took a different tack on the subject of corporate responsibility. He spoke about how the industry has transitioned to cleaner fuels and transportation methods while reducing its environmental footprint over the past 20 years. "And we've only been demonized for it," he said.

"We've made so many improvements, but now they're talking about doing away with our industry completely [with the Green New Deal]," he said. Lamp noted that the industry, however responsible it may already be, must change its narrative and public education to maintain its relevance going forward.

Coyle noted that the US education system helps foster some of this demonization. "We need to get more facts out there to change the thought process and the view of our industry," he asserted.

"It starts with our individual companies," Gorder said. "We must educate our own employees. We're bringing millennials in, and a lot of them think differently than we do. We need to help them develop the understanding about what we're doing, and how what we're doing makes people's lives better … We have [sustainability] data coming out of our ears. We know that what we do is good, and we know why it's good, but we're pretty miserable at communicating it to others. We need to change that."

Environmental stewardship is key. Vivier spoke about how ExxonMobil has been practicing environmental stewardship for decades. The company has an operations integrity management system in place to monitor the total health of operations from top to bottom.

ExxonMobil has also invested $9 B in energy efficiency and environmental improvements, as well as carbon capture and other environmental initiatives. "But we're not done yet," Vivier said. "We will continue to improve our performance."

Gorder noted that business processes related to plant operations have changed to help avoid major emissions releases during plant upsets, while Coyle remarked that reclaimed water usage at refineries has become cleaner and more environmentally conscious.

Lashier then explained how 30 petrochemical and product manufacturing companies have come together in a recycling effort. The target is to raise $1.5 B to change infrastructure processes, especially in third-world countries where waste management is a significant problem that leads to pollution in waterways and, eventually, pollution in the oceans. He also told attendees about a startup company that is recycling polystyrene back into styrene monomer, which is then used to make new polystyrene.

"We are looking at innovation, infrastructure and education," Lashier said. "Unless we step up to make the beaches cleaner and clean up the oceans, no one will take us seriously, and our industry will face extinction." ●

Monday afternoon's executive panel discussion addressed the issues of workforce, operational and environmental sustainability.

AFPM

117TH ANNUAL MEETING CONFERENCE NEWS

Published by *Hydrocarbon Processing* as three daily editions, March 17/18, 19 and as an electronic edition on March 20. If you wish to advertise in this newspaper or submit a press release, please contact the editor at Mike.Rhodes@HydrocarbonProcessing.com.

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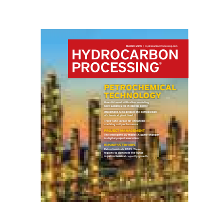

Asset performance management: Into a new era of organizational memory

JIM STUART, Lloyd's Register

It has often been said that knowledge is power, but in high-risk sectors such as the marine and oil and gas industries, knowledge is fundamental to something much more important: safety and reliability. Hard-won through long experience, knowledge is the difference between profitable operations and unreliable equipment at risk of failure from factors such as corrosion, human error and fluctuating operating conditions.

With an aging workforce and increased merger and acquisition (M&A) activity, it is becoming more difficult than ever for companies to retain that critical knowledge and experience within their organizational memory. Additionally, new technologies promise to change the working practices, skills and knowledge that tomorrow's operators will need. This leaves asset operators with a delicate balancing act: retaining/capturing invaluable knowledge of the past and making it usable/useful so that future works can build on this knowledge to more rapidly improve productivity.

Technology—specifically asset performance management (APM) solutions and those with a focus on risk, reliability and optimization tools and mitigation strategies—will be vital to owner-operators as they enter a new era of organizational memory.

Retain and maintain. In the refining and petrochemical sectors, the looming "great crew change" is a considerable source of anxiety. An aging workforce, coupled with a spate of early retirements during the downturn, leave the industry reliant on fewer and fewer seasoned experts. Even with an immediate, significant influx of young workers, comprehensive knowledge-transfer before it is lost to retirement is challenging.

At the same time, the gradual upturn in the oil and gas sector has led to an uptick in M&A activity. While renewed activity levels and investment in the sector are heartening, individual companies face a similar threat to the aging workforce: the loss of knowledge capital. M&A deals often lead to workforce changes, and experienced workers may view the event as a good time to retire or seek opportunity elsewhere.

As such, owner-operators are faced with two seemingly opposite trends—one born of the downturn, the other of the upturn—both of which put pressure on organizational memory. With APM, these skills, experience and know-how can keep assets running optimally. If too much of that knowledge is lost, an increased risk exists of major equipment failure that can impact human, safety and environmental factors, as well as the reliability and profitability of high-value equipment.

APM solutions can help mitigate this, as these solutions have traditionally excelled with quantitative, easily digitized data that can be used to aid asset owner-operators with their decision-making processes. However, the new generation of APM solutions have been designed with the aging workforce in mind and have been developed to better capture the more qualitative, more human element of knowledge, experience and best practices that might otherwise be lost. This knowledge can be rapidly deployed to augment newly developed insights or expertise.

Capturing this knowledge complements the need to deliver assurance and confidence to plant managers and operators. Digitizing expert knowledge and best practices is a key component of what Lloyd's Register (LR) terms "asset performance assurance," and it lies at the heart of the company's AllAssets platform. It enables engineers to map their understanding of failure mechanisms and causes and then sense-check their model against a rich library of information. This can then be codified and added to the solution, enabling a systematic approach to capturing human knowledge and best practices, all in one place and accessible across the organization.

In most organizations, the executive team relies on operations and maintenance staff to assure them with high confidence that the risk of an unplanned shutdown is minimized: production forecasts are met, plant performance is continually improved, and preventative maintenance work is scheduled at the least disruptive/most economically beneficial time. Modern APM systems that embody this concept of asset performance assurance enable teams to deliver exceptional knowledge-based asset performance strategies with a high level of confidence and assurance.

Building the knowledge base. By capturing and codifying workers' knowledge and experience, APM systems not only retain critical knowledge capital, they can also make it more useful to the company.

A seasoned engineer intimately acquainted with a particular asset and the operating conditions and maintenance/inspection activities to keep it running optimally is well-placed to pass on that knowledge to a handful of colleagues. What if the operator runs similar assets elsewhere around the world? A forward-thinking company might look to send the subject matter expert to other sites to provide training and broaden the knowledge base. However, this is still a fundamentally limited method of knowledge transfer.

By effectively capturing that experience digitally, workers around the world can gain access to pertinent knowledge through the APM system, as well as augment the pre-programmed risk models with their own knowledge and experience. In doing so, organizational memory is not just preserved, but enhanced and made more useful.

These benefits are not limited to individual companies. At the asset owner-operator's discretion, the APM provider can capture and anonymize the knowledge to provide benchmarks for similar assets to other owner-operators in the industry. This democratized, collaborative approach can improve best practices across maintenance, inspection engineering and operations. The results are reduced equipment failure, improved productivity and longevity, and better business performance across industry.

Preparing for the future. While maintaining critical, existing organizational knowledge, operators are also faced with the need for new knowledge and skills as technology advances.

Across all sectors, economic activity is becoming increasingly automated and digitized. Buzzwords such as the Industrial Internet of Things (IIoT), Industry 4.0 and "smart" components and systems all point to a fundamental shift in how assets are designed, built, installed, maintained and operated. Though industry veterans' knowledge will undoubtedly be needed to maintain legacy equipment with decades left of useful life, tomorrow's assets will require a different set of skills to run and optimize. Programming, cybersecurity, data science and analytical skills will become far more prominent.

As assets become increasingly sensor-enabled, and fine-grained data becomes the norm, machine learning and artificial intelligence (AI) will allow operators to fine-tune their APM systems in real time, better protecting and more profitably running assets.

Tomorrow's best-in-class APM systems will be those capable of combining these promising new technologies with the benefits wrought from hard-earned human experience and skill (i.e., marrying mature and new knowledge to upgrade not just organizational memory, but how it is applied). Those operators that, aided by APM technology, succeed in doing so can confidently step into a new era of asset performance assurance. Those that do not may find that the aging workforce outlives their company. ●

THREE LEGACIES ONE FUTURE

For years, the energy and petrochemical industries have counted on the catalysts, technology licensing, and services provided by the companies that comprise Criterion, CRI, and Shell Global Solutions. Today, these companies have come together under the Shell Catalysts & Technologies brand, working together as a more integrated partner to solve the industry's most complex challenges. As Shell Catalysts & Technologies, we channel years of experience providing value-adding solutions, technologies, and services that drive the industry — and the world — forward.

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Antifoulant technology improves refinery operating costs

XIOMARA PRICE and **JEFFREY A. ZURLO,** SUEZ—Water Technologies & Solutions

Significant fouling in the hot section of the crude unit preheat train can be problematic for refiners, causing increased energy consumption and requiring frequent heat exchanger cleanings to maintain throughput. Ultimately, fouling increases operating costs and reduces profitability. SUEZ—Water Technologies & Solutions develops fouling reduction programs through analyzing the operating performance and mechanical configuration of the system, root cause analysis, and antifoulant product testing on blended crude oil samples provided by the refiner.

Two crude unit programs are highlighted where severe fouling increased furnace firing demands and frequent heat exchanger cleanings to maintain distillation tower yields within target. Despite different operating conditions, both systems ultimately benefited from applying SUEZ's novel antifoulant program.

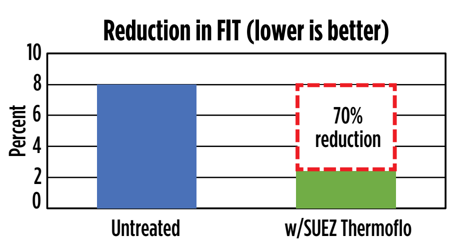

FIG. 1. Case 1 Thermoflo results.

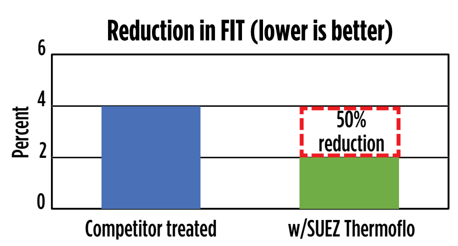

FIG. 2. Case 2 Thermoflo results.

SUEZ was invited to provide a cold-eyes review of the units and recommend an effective course of action. The goal for both units was to reduce loss of furnace inlet temperature (FIT) by 50% or greater. In both cases, bench testing determined SUEZ's novel coke-precursor suppressant antifoulant as the most effective treatment program. Additionally, heat transfer monitoring practices were improved to provide a solid baseline and enable adjustments to the program to ensure performance gains are realized. This technology is the latest development as part of SUEZ's Thermoflo™ antifoulant product family and was developed specifically to combat fouling from tight oils and other unstable crude oil blends.

In both cases, the refiner performed their own bench testing of SUEZ's proposed program alongside competitive programs to confirm that the best program available in the industry would be applied.

Case 1. This crude unit processes a variable crude slate, with blends throughout the run changing from low- to high-sulfur content based on market conditions. The variations impact the level of asphaltene instability and solids content with the ultimate result of high fouling rates. Despite cleaning heat exchangers starting three months into a production run and repeated at three- to six-month intervals, loss of FIT within the first year repeatedly exceeded 8% of the starting temperature, requiring a significant increase in fuel gas demand in the crude atmospheric furnace.

Antifoulant injection was initiated upon startup from a maintenance shutdown. On this unit, SUEZ's patent pending chemistry has been delivering significant results in the field. At the time of this article, the fouling rate has been reduced by more than 70% as compared to the untreated baseline—or only a 2.4% loss in FIT (**FIG. 1**)—while processing multiple blends of crudes, including some tight oil. Since the rate of FIT drop of the treated condition is significantly improved over the base case, the reduction in fuel gas required to maintain furnace outlet target temperature is also much lower.

Case 2. Similarly, this crude unit processes a variable crude slate and experiences significant fouling in the hot preheat exchangers. In this system, exchanger cleaning was performed every six months, and an existing competitive antifoulant treatment program was being injected to help reduce fouling. Despite these actions, FIT loss over the first year averaged 4% of the starting temperature. This second crude unit was also being monitored using a statistical model of the FIT to determine change in performance. As of this writing, the performance of the SUEZ Thermoflo program has shown to be approximately 50% better than the previously treated base case (**FIG. 2**), with loss in FIT limited to about 2%. This achievement includes a period of significant desalter upsets that temporarily reduced performance shortly after starting the program. During this period, treatment program performance dropped to the trended with the base case. Since the increased monitoring quickly showed the performance drop, the chemical dosage was increased for a few days to restore system performance and was then returned to target once the desalter performance was restored.

Takeaway. In both cases, significant improvements were made to the operational performance and flexibility through application and monitoring of the SUEZ Thermoflo programs. Combined, the net profit improvement for these systems is estimated at more than $1 MM/year in energy savings, after offsetting the cost of the treatment programs. Furthermore, no exchanger cleanings have been needed, simplifying operations and eliminating cleaning costs. The fouling reduction will also enable the customer to maintain its operational flexibility with reliability, while minimizing cleanings and potential personnel exposure. •

MCDERMOTT'S LUMMUS TECHNOLOGY OFFERS PATHWAYS TO PROPYLENE

The strong investment in gas crackers has made ethylene stream viable feedstock for propylene production via an integrated dimerization and metathesis technology. Both processes are characterized by successful commercial operation, low OPEX and CAPEX, and can readily be integrated into grassroots cracker designs or added to existing facilities.

McDermott's Lummus Olefins Conversion Technology (OCT) is a flexible and viable pathway to on-purpose polymer-grade propylene production. The required reaction components for this metathesis technology are ethylene and some combination of normal butenes and/or normal/iso pentenes.

While OCT can be utilized in a variety of C_4 streams, including the mixed C_4s produced in steam cracking, raffinate C_4s from MTBE or butadiene extraction and C_4s produced in fluid catalytic cracking units (FCCUs), McDermott's Dimer technology can also be employed to convert cracker ethylene to the required butylene. The dimerization technology is unique in that it selectively produces primarily 2-butenes, which is an ideal feedstock to OCT in combination with ethylene to produce polymer-grade propylene.

The dimerization and OCT main reactions interact with reactants ethylene, butylene and pentene components to produce propylene.

OCT can accommodate a wide range of feedstock streams, including those from cracker-based raw-mixed C_4s, butadiene extraction units, alkylation units and refinery mixed C_4s. This flexibility allows the operator to utilize lower-value feedstocks advantageously. The source of ethylene feed can be from a cracker or ethylene recovered from refinery off-gases. For C_5s, raw pyrolysis gasoline from an ethylene plant or C_5s from a refinery (after pretreatment) are acceptable feeds to the olefins conversion unit.

The characteristic feed flexibility, low investment costs, easy turn-up and turn-down, and low maintenance operations of the dimerization and OCT combine to make ethylene and lower value cracker and refinery byproduct streams viable pathways to production of highly valuable propylene. •

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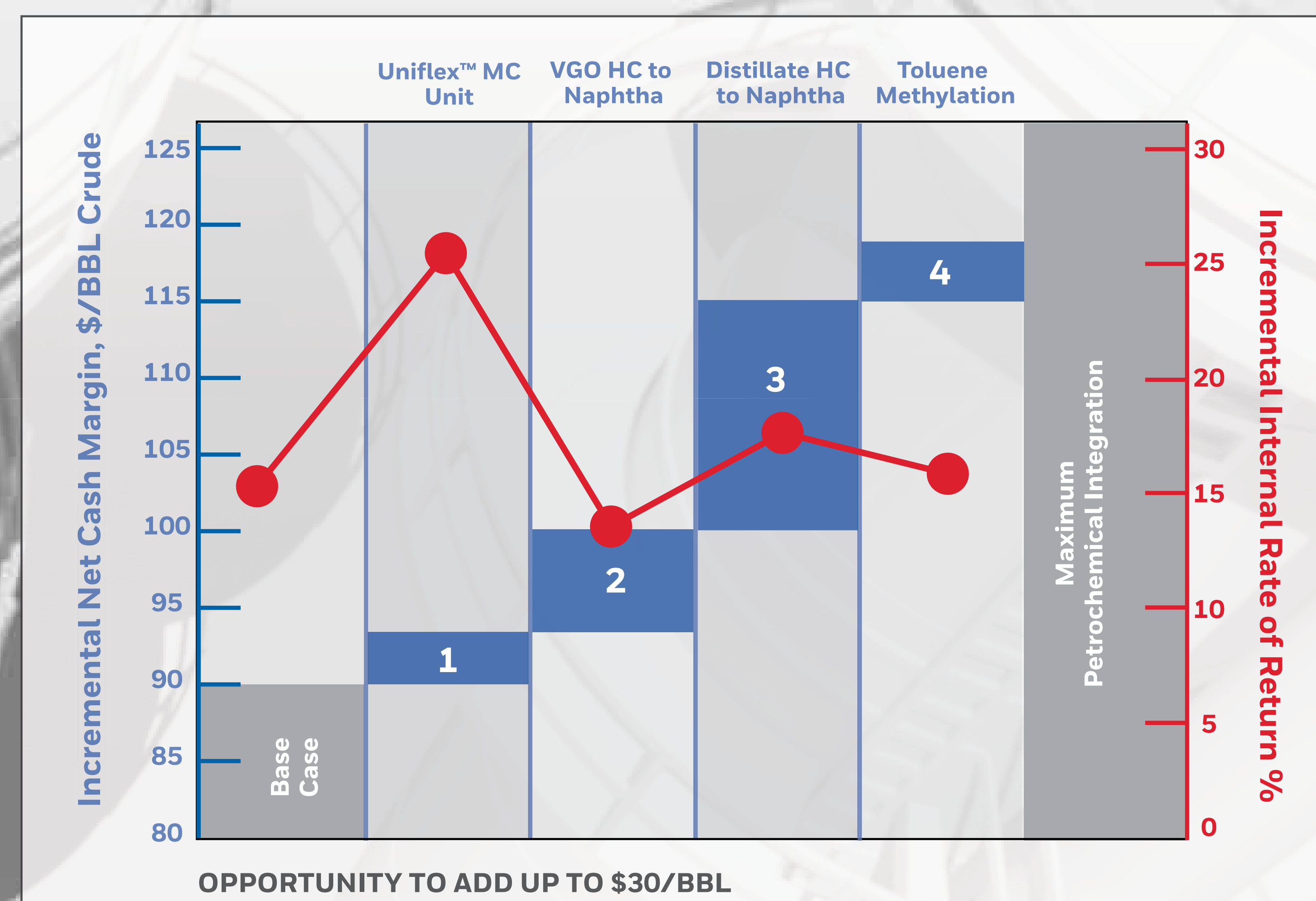
Figure 1: In a recent conversion study, Honeywell UOP outlined a step-wise, comprehensive configuration for diversification into petrochemicals generating an incremental IRR of up to 16%.



Honeywell UOP

THE TIME FOR DIGITALIZATION OPPORTUNITIES IS NOW

ADRIENNE BLUME, Executive Editor, *Hydrocarbon Processing*

A Tuesday morning panel discussion examined how to add value and efficiencies to operations through digitalization. Panelists included Mark Schmalfeld, Global Marketing Manager for BASF; Oscar Santollani, Supply Chain Manager for KBC Advanced Technologies; and Katherine Jones, Product Line Manager for Honeywell UOP.

Digital technology rollout. Schmalfeld talked about big data as a major digital trend. "First you need to look at: What data do you acquire and where? How do you connect the data points, and who do you share it with?" Digital transformation is expanding in waves across industries and value chains and is a major focus for the process industry, explained Schmalfeld.

Value can be added in digitalization through several technologies and programs, some of which are in the rollout phase and some in the pilot phase. Predictive maintenance and augmented reality are being rolled out at plants, while process optimization, vertical integration and digital plant technologies are in the pilot phase. Process optimization combines process knowledge with big data statistics, while digital plant transformation targets the implementation of a digital plant in an existing asset structure.

"Leadership as a whole needs to be supportive [of implementing digital technologies] and be willing to back the projects that add value," Schmalfeld said. "We'll also need to see industry cross-collaboration to make it work."

Santollani discussed how digital technologies can help make a step change in operating profits. Digitalization has several advantages for businesses, including helping manage day-to-day performance and reliability, enabling rapid responses to market swings, enabling operation at true optimum, squeezing the gap between potential and realized margins, creating more utility for the end customer, extending the problem-solving ecosphere beyond the plant, and outmaneuvering the competition.

"We believe that digitalization is a journey, and there is a roadmap for that journey," Santollani said.

The panel for Tuesday morning's "Adding value and efficiencies to operations through digitalization" session.

Optimizing asset utilization. Lastly, Jones discussed how to increase asset utilization with the use of the Industrial Internet of Things (IIoT). In a recent case example, a process reliability advisor was used for a CCR Platforming unit. The customer wanted to improve its aromatics yields by optimizing the feed into the aromatics unit. Honeywell UOP examined what operation in the process could be done differently to optimize aromatics yields. The solution was to leverage the underlying process model configuration and simulate "as-operating" conditions. Optimum reaction conditions to maximize aromatics yields were also identified.

In another example, the H_2S constraint in a unit overhead was limiting throughput. The solution included leveraging constraint analysis through the underlying process model. Identification of operating and capital improvements through a debottlenecking review led to a unit throughput increase of 10% for four consecutive months.

API PROCESS SAFETY SITE ASSESSMENT PROGRAM

ADRIENNE BLUME, Executive Editor, *Hydrocarbon Processing*

In a Tuesday morning breakout session, Andrew Broadbent of the American Petroleum Institute (API) talked about the API's process safety site assessment program, which was implemented in 2012, as well as promoting a culture of process safety.

The keys to the safety program, Broadbent explained, include the expertise of safety assessors (more than 40 years of experience per assessor), protocol feedback (such as interviews, lunchtime information exchanges, daily debriefs and closing

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Refining and shipping industries brace for new fuel regulations

MELISSA MANNING, IHS Markit

The refining and shipping industries are ill-prepared for the massive change in fuel regulation first announced by the International Maritime Organization (IMO) in 2008. The resulting market impacts will be major, costly and far-reaching, says a new report from IHS Markit, "Navigating choppy waters: Marine bunker fuel in a low-sulfur, low-carbon world."

The impending regulation by the IMO, which goes into effect January 1, 2020, aims to significantly reduce the amount of sulfur in bunker fuels that are relied on for commercial shipping. Collectively, these ships burn more than 3 MMbpd of residual fuel oil, which has a sulfur content that exceeds levels found in automotive gasoline by more than 1,000 times.

Burning fuels with a higher sulfur content leads to a greater level of toxic air emissions, including sulfur oxides, which are considered a threat to the environment and human health. IHS Markit expects most of the demand for high-sulfur residual fuel oil will switch to demand for the new lower-sulfur fuel in 2020.

The cost of compliance. The IMO confirmed in 2016 that global refiners and shippers must comply with these new environmental regulations by 2020, five years earlier than many anticipated. This sent tidal waves through industries that typically take many years to adapt to such a significant change that will require tens of billions of dollars in investment.

The new report says that compliance remains the greatest uncertainty with the new regulation, concern remains whether enough supplies of compliant fuels will be available in the world's many ports. The result will be higher freight costs for most cargoes, including petrochemicals, electronics and autos. Ultimately, those costs will be passed to consumers.

"Shippers will face significant compliance costs to either upgrade equipment or switch to more expensive, cleaner fuels," said Spencer Welch, Executive Director of oil, midstream and downstream for Europe, CIS and Africa at IHS Markit, and Manager of the study. "Refiners and fuel buyers will experience significant price impacts as they shift production to deliver greater volumes of very low-sulfur fuel oil (VLSFO) and find a market for their less-valuable fuels."

"The IMO is taking positive action to address shipping pollution, but the rapid pace of the implementation of this new regulation is making it very challenging for the refining and shipping industries to respond," said Sandeep Sayal, VP of downstream research at IHS Markit. "The global scope, the significant uncertainty in

▶ See REGULATIONS, page 16

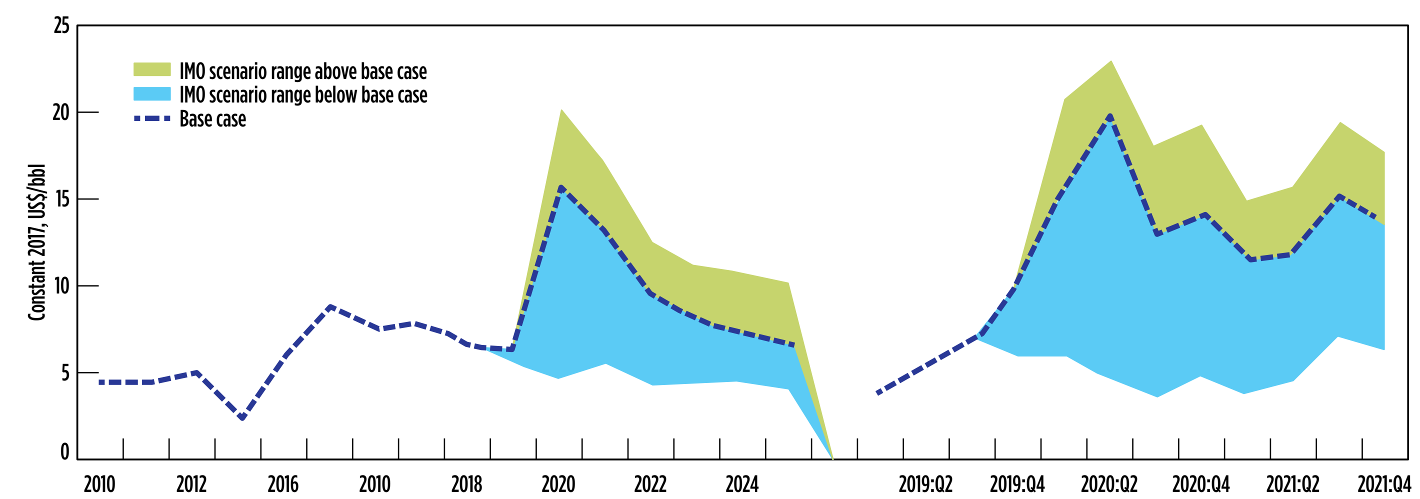

FIG. 1. The IMO 2020 low-sulfur bunker fuel requirement will likely drive significant margin increases for sophisticated refineries on the US Gulf Coast that have the flexibility to produce VLSFO compliant fuels. Source: IHS Markit.

Cybersecurity lessons from the Columbia gas disaster

MILLE GANDELSMAN, Indegy

In September 2018, a series of natural gas explosions in Andover and Lawrence, two Boston suburbs, resulted in more than 70 fires, one fatality, dozens of injuries, and destruction or damage to more than 100 structures. In the aftermath, approximately 9,000 customers were without power.

On October 12, the *New York Times* reported that an upgrade in the system caused gauges that monitored pressure levels to be taken offline, and that unchecked over-pressurization caused the blasts.

Initially, numerous sources speculated that the incident was an act of terrorism. While this was not the case, it illustrates how we look at critical infrastructure security. As oil and gas industry professionals, we are now acutely aware that once-isolated OT networks charged with the refining, mixing and distribution of petroleum are increasingly connected to the "outside world" via Industrial Internet of Things (IIoT) technology.

FIG. 1. Performing a risk assessment to identify and address vulnerabilities is key to protecting refining, petrochemical and distribution networks from insider and outsider threats.

While this digital transformation has yielded many benefits and cost savings, these systems are more vulnerable to security threats than ever before. Attacks like Wannacry, VPNFilter, Blackenergy and Industroyer are just a few of the recent malware campaigns that have directly impacted critical infrastructure. The actors in these instances were rogue factions, including nation-states that hacked into industrial networks and caused havoc.

While the over-pressurization of gas mains in Massachusetts was due to human error rather than a nefarious external actor, the outcome was the same. In fact, studies show that insider threats account for more than half of all industrial cybersecurity incidents.

Defining the insider. Three major types of insider threats must be addressed in OT (and IT) environments:

1. Malicious intent—This is typically a disgruntled employee or insider who is paid to exfiltrate information and/or cause damage to the organization.
2. Human error—As the most plausible explanation of why the gas mains were over-pressurized, human error occurs when an employee unintentionally causes damage and/or downtime by making incorrect changes to industrial processes/equipment.
3. Account compromise—Similar to the previous scenario, an employee unintentionally creates a security incident. Typically, an outsider tricks an employee through social engineering into divulging confidential information used to carry out an attack. Social engineering techniques include phishing emails, a "call from IT" requesting the user's ID and password, etc.

Protecting OT against the insider threat. Taking a cue from the lessons learned in the Massachusetts natural gas incident, protecting refining, petrochemical and distribution networks from insider and outsider threats involves several key best practices:

- Perform a risk assessment (FIG. 1) to identify and address vulnerabilities, such as over-privileged accounts, insiders with access to resources that are not required by their jobs, orphaned accounts from terminated employees, contractors, etc.
- Two primary vectors enable insider attacks: using the network and targeting devices directly via serial ports. The latter occurs when a user plugs a device into an industrial controller to distribute malware, upload new code, etc. Serial attacks can quickly propagate and evade network-based passive detection mechanisms. Monitoring both network activity and device integrity are

▶ See CYBERSECURITY, page 18

What is Rate-Predictive Control (RPC)?

ALLAN KERN, APC Performance LLC

Most people in the process control sector accept that it is unlikely that the proportional-integral-derivative (PID) algorithm will ever be replaced as the industry standard for single-loop control. However, a recent patented invention called Rate-Predictive Control (RPC) compels both academic and practical interest from several standpoints:

- RPC is a new and novel control algorithm (not a variation of PID) with several notable advantages and breakthroughs
- RPC is *inherently adaptive* to changes in process gain, which is a landmark development given industry's long and difficult history of loop tuning, auto tuning, model maintenance, etc.
- RPC is particularly well-suited as a *model-less feedback multivariable control algorithm* (XMC), something that remains (otherwise) sorely lacking in industry.

How does RPC work? RPC is simpler and more intuitive than PID. The key to understanding RPC is to perceive its simple mechanism and not necessarily to plumb its math (although its math is much simpler than PID or model-based control).

FIG. 1 illustrates how RPC works. When the setpoint is increased, RPC begins increasing the output at a preset rate (1%/sec, in this example). During each controller execution, RPC calculates the ongoing process variable (PV) rate-of-change and predicted future value. As the the predicted value reaches the setpoint, the moves are tapered and halted, so that the PV ultimately settles exactly on target, based on first-order process dynamics.

RPC prediction time is a tuning parameter that is set in a manner similar to PID integral time—i.e. usually equal to or somewhat longer than the actual 63% process time constant—to provide a smooth and reliable approach to setpoint with little or no overshoot or oscillation.

The pre-set move rate is selected based on experience and safe operating practice. It can also be thought of as a process speed limit. However,

▶ See RPC, page 16

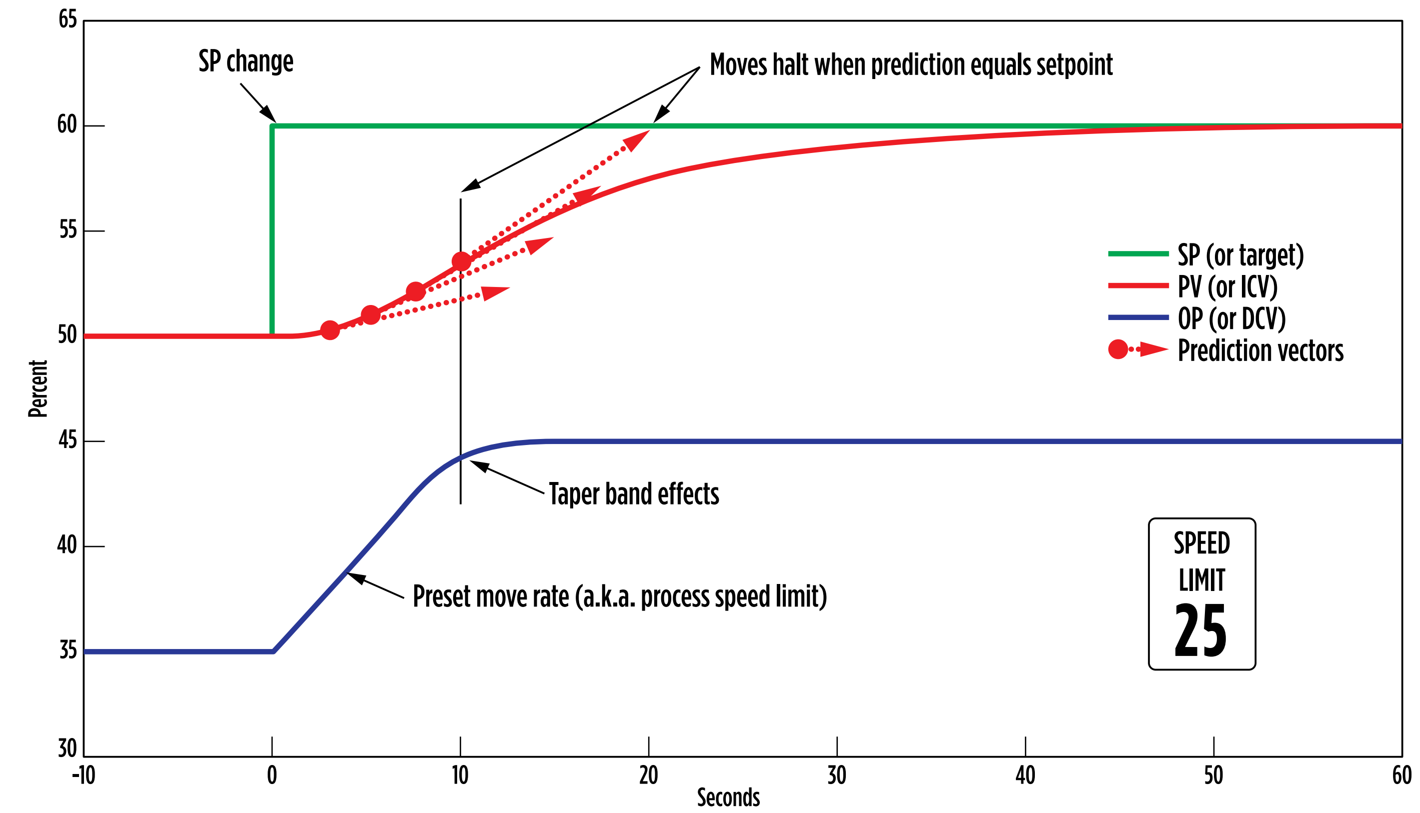

FIG. 1. Rate-Predictive Control (RPC) uses a pre-set move rate, and tapers the move based on the PV's predicted (apparent or already manifest) value.

Growing earnings in times of change with Celestia hydrotreating catalyst

KEITH WILSON, LOUIS BURNS, DEAN PARKER and PADMINI LINGARAJU, ExxonMobil; and RINUS CERFONTAIN, BOB LELIVELD and BARBARA SLETTENHAAR, Albemarle

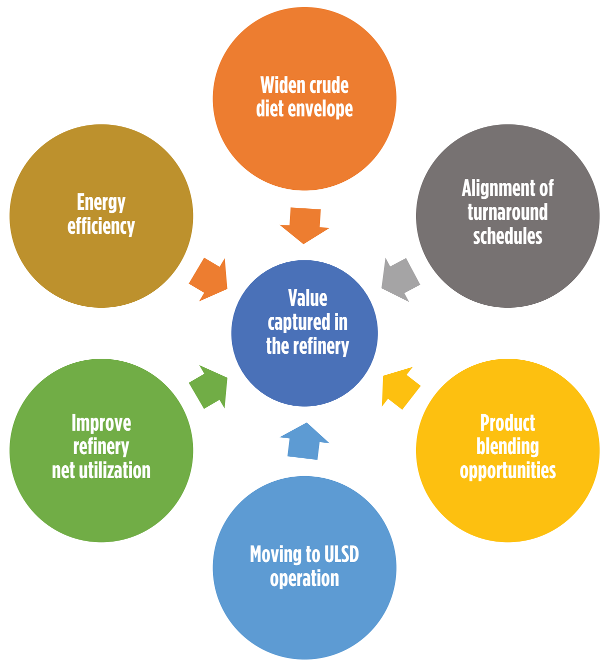

FIG. 1. Value captured in the refinery.

Refiners face numerous internal and external challenges to maintain profitable operation. Key focus areas for refiners to remain competitive include reducing feed costs, maximizing high-value products, optimizing capacity and meeting more stringent regulations. Optimizing supply and operation around these key factors is critical to achieving maximum profitability. Catalyst technology improvements help refineries deal with the challenges. If a typical activity improvement of 10% vs. a previous generation of catalyst from the same vendor is considered, the value is limited to only one of the following benefits:

- Feed rate increase or upgrading challenging feeds, assuming the refiner operates to a fixed run length, and processes higher feed rate or more difficult feed quality to produce constant product quality.
- Cycle length improvement, assuming the refiner operates fixed feed rate and quality, initiates the cycle with lower weighted average bed temperature (WABT) and allows the unit to run to longer cycle length.
- Product quality improvement, assuming constant feed rate and quality, fixed cycle length, but the refiner benefits from processing to an improved product quality.

ExxonMobil and Albemarle launched the first commercial bulk metal catalyst in 2001. The commercialization of Nebula® catalyst represented a whole new class of hydroprocessing catalysis innovation, and one that reset industry expectations for activity advantage. For more than 15 years, the higher activity advantage has led to Nebula catalyst being a proven commercial success, adding value across the refining industry.

Increased margin potential. ExxonMobil and Albemarle have partnered to develop and commercialize the Celestia™ catalyst, a second-generation bulk

▶ See CATALYST, page 22

REGULATIONS, continued from page 13

fuel-formulations and the volume of new lower-sulfur fuel demand are causing a scramble."

The IMO has signaled that it plans to enforce the new regulation seriously. Non-compliant vessels could suffer loss of charter to sail, and major insurance companies have also indicated compliance assurance will be essential to vessel insurability.

Options. Shippers have several options for compliance, including low-sulfur bunker fuels and liquefied natural gas (LNG). However, IHS Markit researchers expect onboard ship scrubbers, devices that clear harmful pollutants from exhaust gas, to be the primary compliance path for larger ships to continue to burn cheaper, higher-sulfur fuels. However, until those scrubbers can be installed (which for numerous ships will not happen before the IMO January 2020 deadline), many ships will have to burn the more-expensive, IMO-compliant VLSFO fuels.

"We estimate between 5,000 and 10,000 ships will undergo scrubber installation at a cost of $2 MM–$7 MM each, plus increased operations costs," said Krispen Atkinson, Senior Consultant, IHS Markit maritime and trade research. "To date, the industry has spent or committed more than $6.6 B to fit more than 2,000 ships with scrubbers."

Other ships will convert to compliant fuels with sulfur levels below 0.5%. However, those shipowners will see fuel costs escalate significantly due to the higher-quality fuel required and may face fuel compatibility issues. Each refinery complex could produce different (but compliant) regional formulations to meet the new fuel standard based on available crude oils, product slates, costs and supply chain logistics, presenting operational and continuity challenges for shippers.

Refiners will produce more distillates (higher-value components derived from crude) as new demand arises, with about half of the new compliant fuel coming from non-distillate sources within the refinery, but the remaining 50% will need to be sourced from refinery distillates. However, these same distillates are also needed for other growing diesel markets. As a result, refiners will likely have to make significant operational changes and ultimately invest billions to shift their existing product slates, increasing costs and distillate prices (relative to crude oil prices).

"Highly complex refineries (FIG. 1) that have the flexibility to convert various grades of crude oil into a wide range of refined products to meet market demand will benefit most from the IMO-specification change," Welch said. "Highly complex refiners produce the least amount of residual fuel oil and the highest amount of distillate and gasoline compared to less complex refiners. Less integrated and less complex refiners will likely experience the greatest market risk," Welch said. •

RPC, continued from page 15

RPC is not limited to a single speed. The move rate can be dynamically adjusted to meet various control performance criteria. For example, the move rate can be increased if constraint limits are exceeded.

The rounding in the output trend as the prediction approaches setpoint is a function of the RPC taper band, which serves to reduce the move rate as the predicted value approaches the setpoint, so that the move rate goes to zero as the error goes to zero. The taper band results in reliable control behavior in the face of real-life nonidealities, such as variance in process response, deadtime, inverse response, noise, etc.

It can be seen intuitively that RPC is inherently adaptive to changes in process gain. For example, if process gain becomes larger, the process response will be larger, the prediction vectors will extend farther, and moves will be tapered and halted correspondingly sooner, so that again the PV settles right on target. By the same reasoning, RPC is inherently adaptive to changes in the pre-set move rate, so that it can be manually tuned at will or dynamically adjusted to meet various high-performance criteria.

Advantages. Within RPC's humble mechanism are several notable process control advantages and breakthroughs.

RPC is inherently adaptive to changes in process gain. This is a landmark claim in an industry where the terms *tuning, retuning* and *detuning* have found roughly equal usage, and where auto tuning has come up far short of industry's hopes and expectations. These experiences stem from the same root cause: frequently and dynamically changing process gains. An inherently adaptive method is what these have been striving for all along.

RPC is more responsive to incipient error and more stable as the PV returns to setpoint, because it utilizes the predicted future value of the PV, not just the current value. Where a conventional PID controller might see only a small incipient error, RPC might see an effectively much larger error, and make a much larger move sooner by taking the predicted value into account. For the same reason, RPC is more stable as the PV returns to setpoint, with little or no unwanted overshoot or oscillation.

RPC looks like an old friend (it has PV, setpoint, output and mode), so it can be adopted seamlessly in an operations and control system environment. To control engineers, RPC is easier and more intuitive to learn and tune.

Despite its simplicity and trademark first-order performance, RPC is versatile and can easily be tuned for other types of performance. Classic quarter-amplitude-damping can be provided by a high move rate and short prediction time. RPC (like PID) works "as is" for both integrating and non-integrating variables. For loops with a very high "speed limit" (not uncommon in single-loop control, but rare in multivariable control), a large move rate can be combined with a wide taper band to provide a large response when far from setpoint, tapering to a safe speed as the setpoint is approached.

RPC is "model-less," which is another way of saying it is inherently adaptive. It does not use a process model (nor does it attempt to "roll its own" as with auto tuning or adaptive modeling). RPC relies on gain direction only, which is equivalent to PID control action (direct or reverse). Gain direction is the most fundamental and immutable aspect of any model.

Gain direction and approximate speed of response are the minimum information necessary for effective control of any loop. More detailed model information can theoretically be put to further advantage, but can also introduce more cost, risk and maintenance. From this standpoint, RPC provides a prudent and robust compromise between simplicity, performance and reliability. •

What's hiding in your critical controls?

SAM GALPIN, Bedrock Automation

According to a recent *Scientific American* article, the US military estimates that up to 15% of all spare and replacement parts for its weapons, vehicles and other equipment are counterfeit, making them vulnerable to dangerous malfunctions and malware. This is an example of the myriad ways that system components can be cyber-compromised even before they are deployed.

Protecting the component supply chain against such infiltration requires authentication and traceability of every element of system hardware, and software through assembly and test. Bedrock Automation took on this challenge and built a US-based cyber secure supply chain from the ground up, in parallel with the design of its Bedrock® Open Secure Automation platform (FIG. 1).

Intrinsic cybersecurity begins at the silicon level. Secure computing requires a tamperproof startup process. The first code the processor executes cannot be encrypted. Protecting this code with signatures or checksums does not help because if it can be tampered with, the checks come too late. This initial code must be built into the microprocessor chip. Later phases can use code that is signed and encrypted, but this again requires special silicon features to protect the secret keys. Intrinsic security rests on a foundation laid at the silicon level.

At the silicon level, Bedrock has unique visibility and control over its silicon supply chain that comes from designing and sourcing custom manufactured chips. Their circuit boards are made and assembled in the US, and all components are carefully sourced. The origin and lot number of every part from microprocessors to resistors on every circuit board is tracked in Bedrock's manufacturing database. Each board has a unique serial number. All boards are tested using custom test fixtures and software.

Final assembly of modules is done at a secure facility. This is where each module is loaded with real production software and its unique package of cryptographic certificates and keys is bound to immutable features of its silicon. These key packages are generated by a special high-security computing system and automatically loaded directly into the modules. Each module now has its full cryptographic identity and cannot be cloned or counterfeited. The module next goes through a first heat soak test. If all goes well, it is sealed into its tamper-resistant case and put through a final heat soak test.

As you modernize your automation systems, be sure that secure component supply chain is on the list of must-have requirements. •

FIG. 1. Each module of this Bedrock Open Secure Automation system has its full cryptographic identity, which prevents it from being cloned or counterfeited.

Enabling edge-to-enterprise visualization using hybrid cloud

RASHESH MODY, AVEVA

Amid continuous market change, refining companies are looking for ways to drive performance and remain competitive. That means achieving superior performance by driving value, agility and sustainability throughout the asset lifecycle. Digital transformation is at the heart of many of these efforts. Leveraging advanced technologies, operators can extract valuable insights from the data created across asset and operations value chains. This data can translate into increased business agility and reliability, or enhanced enterprise intelligence that can drive business decisions.

To help its refining customers accelerate their digital transformation journeys, AVEVA recently announced several updates to its Monitoring, Control and Information Management portfolio, delivering edge-to-cloud integration and advanced visualization tools, along with seamless access to advanced applications and powerful analytics. These advanced capabilities are delivered in AVEVA's portfolio including InTouch HMI, InTouch Edge HMI, System Platform, Historian and AVEVA Insight products, which provide enterprise-wide visualization and insight into operations and a high degree of commercial flexibility with subscription, a foundational element of digital transformation.

With these capabilities available in a hybrid cloud model, OT and IT requirements can be quickly bridged. Customers can create reusable industrial applications with rapid time-to-value and drive operational efficiency with increased visibility across multiple levels of an organization, in the discrete, process, hybrid and infrastructure industries.

This enhanced cloud offering provides a seamless, integrated experience that enables customers to access information and functionality from across AVEVA's broad range of proven value chain applications: from engineering design data, to manufacturing execution management, to predictive maintenance, and much more. Companies can benefit from the insights and work process digitalization, e.g., using real-time and historical data with machine-learning capabilities to predict possible faults or failures and take pre-emptive action through automated workflows supported by augmented reality tools.

OMI visualization improves operations. This latest release offers efficiencies and flexibility from edge-to-enterprise through a powerful data-driven operations management interface (OMI) visualization engine, native cloud integration for analytics and insights, while extending customer value with new subscription add-on capabilities across engineering, operations and asset performance lifecycles.

This new OMI-based visualization enables proactive, integrated operations in real-time through richer application integration across IT and OT domains, enabling companies to realize increased productivity and operational agility while reducing engineering effort and time.

"AVEVA is committed to partnering with our customers to achieve maximum value from industrial digital transformation. We enable smarter decisions by creating innovative technology," said AVEVA CEO, Craig Hayman. "The latest enhancements in our Monitoring, Control and Information Management portfolio, exemplified by the benefits delivered through the ADNOC Panorama initiative, perfectly illustrate how we are empowering our customers with edge-to-enterprise visibility."

Enterprise visualization in hydrocarbon industries. A leading example of where AVEVA's enterprise visualization and integration solutions have been deployed—and are a key enabler to wholescale digital transformation—is the diverse and complex operations of the Abu Dhabi National Oil Company (ADNOC). The Panorama Digital Command Centre (FIG. 1) enables ADNOC to monitor and optimize the performance of its assets and operations across 16 operating companies from its Abu Dhabi headquarters. This includes oil and gas development and production, through to processing, petroleum and chemical products to transportation and distribution.

H.E. Dr Sultan Al Jaber, ADNOC Group CEO, said, "The Panorama Digital Command Centre demonstrates how ADNOC is utilizing cutting-edge technology to find new ways to optimize our assets, unlock value and drive efficiencies across the company. It provides a single access point to critical operational and performance information, facilitating smarter and faster decision-making and better enabling us to uncover new solutions."

Subscription to digital transformation success. Greater flexibility in licensing, configuration and deployment models through AVEVA's new subscription offer significantly reduces total cost of ownership and minimizes complexity for AVEVA's customers. From the initial release of individual subscription offers in our Monitoring, Control and Information Management portfolio in 2018, AVEVA has seen a doubling of subscription volume across this portfolio. The current release represents the next step in making a wider portfolio bundle available through subscription and is in support of AVEVA's move to subscription- and cloud-based capabilities across its portfolio to deliver greater customer value. ●

FIG. 1. The ADNOC Panorama Digital Command Centre.

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required to detect these threats.

- Unify IT and OT security. Since both environments are often interconnected, an attack that originates on the IT network can move laterally to the OT environment. Establishing visibility across IT and OT networks by integrating security tools and the data they generate can help detect lateral attack activity.

Implementing security best practices in OT environments, and unifying controls and visibility across both OT and IT infrastructures, represents the best recipe for defense against insider and outsider threats. ●

MILLE GANDELSMAN is the Chief Technology Officer of Indegy, where he leads the company's technology research and product development. Prior to Indegy, he led engineering efforts for Stratoscale and spent several years managing cybersecurity research for the elite 8200 intelligence unit of the Israel Defense Forces. Mr. Gandelsman has more than 15 years of experience in ICS and cybersecurity.

SWAATS: Unloading the SRU, reducing operating costs, avoiding plugging issues

MICHAEL F. RAY, ThioSolv LLC; and **RAHUL KHANDELWAL,** GTC Technology

Refineries are increasingly requiring additional sulfur capacity. This trend is primarily driven by:

- Increased use of higher sulfur and lower-priced crudes
- Hydrotreating of heavier and more refractory streams
- Increasing hydrotreating severity to meet tighter sulfur specifications for some products.

The increased hydrotreating severity has resulted in greater production of sour water stripper gas (SWSG) as compared to amine acid gas (AAG), due to the ratio of hydrodenitrogenation (HDN) to hydrodesulfurization (HDS) increasing as hydrotreating severity is increased.

The sulfur recovery unit (SRU) plant load from 1 t (ton) of hydrogen sulfide (H_2S) in SWSG is much greater than 1 t of H_2S in AAG. On a molar H_2S equivalent basis, 1 mole of ammonia (NH_3) has an H_2S equivalent factor of 1.7 when compared with H_2S. In an SRU, only the sulfur pumps and piping are sized for the sulfur rate; the rest of the equipment (heat exchangers, reactors, etc.) and piping are all sized for gas traveling through the unit. The increased SWSG traffic results in additional load on the SRU and new/revamped tail gas treating unit (TGTU) capacity, which are quite expensive, and even up to 85% of the cost of the upstream Claus unit.

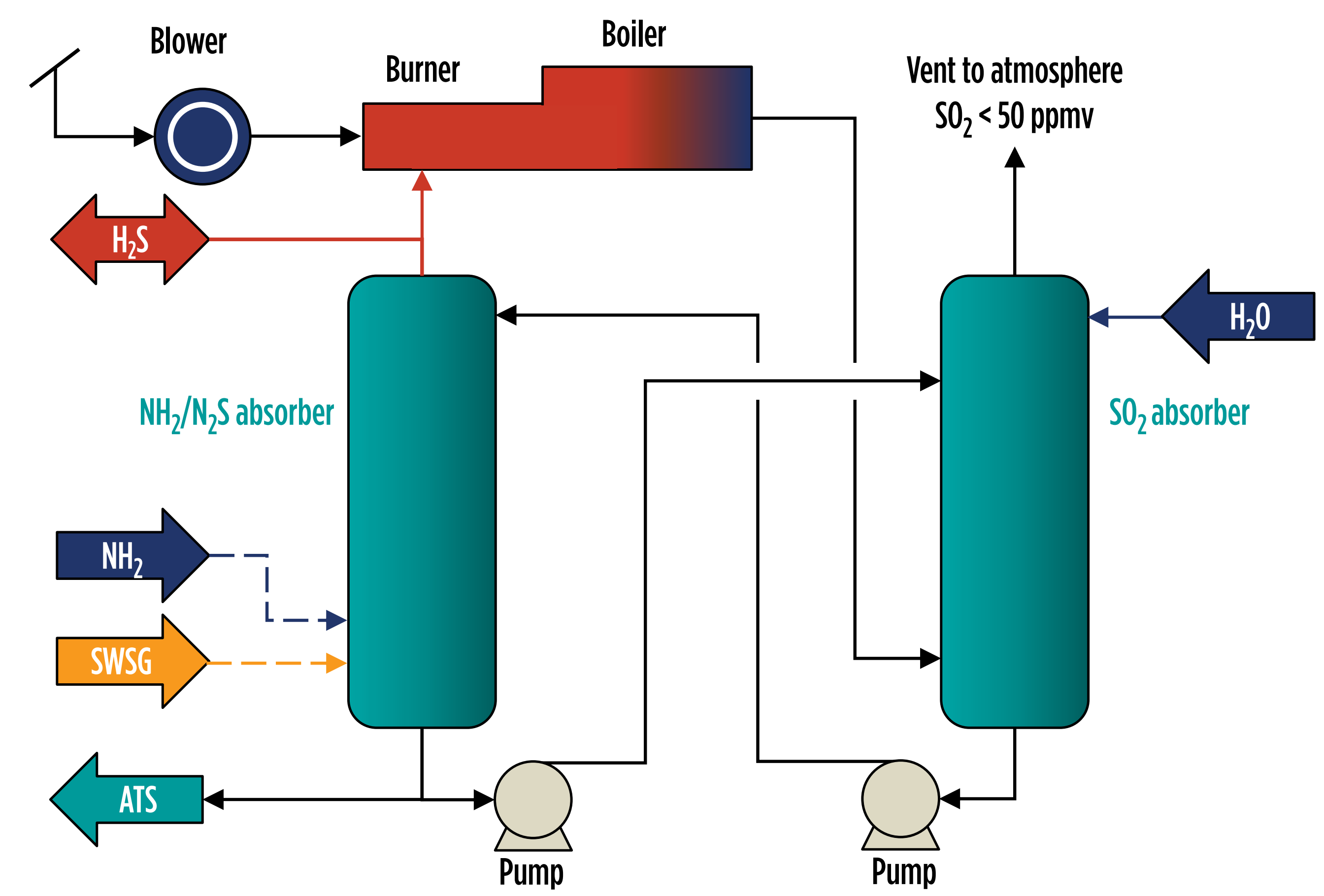

FIG. 1. Flow diagram of the SWAATS process, which converts NH_3 and H_2S from sour water to ammonium thiosulfate.

SWAATS technology (FIG. 1) offloads the SRU, but is also a much cheaper alternative as compared to a TGTU. Further, it converts the sulfur and nitrogen molecules into a higher priced benign fertilizer (ATS), which can be readily utilized by the fertilizer market.

The process consists of three sections:

1. The first section is the NH_3/H_2S absorber/reactor, which essentially absorbs all the NH_3 from the feed gas (typically SWSG) and converts part of the feed H_2S to ATS by reaction with sulfite in the solution circulated from the sulfur dioxide (SO_2) absorber. The ATS product is also drawn off from this section. NH_3-rich salt solution is circulated to the SO_2 absorber.
2. In the second section, H_2S not absorbed in the first section (as well as any contained hydrocarbons in the feed gas) is burned in a conventional acid gas burner with excess air. Heat removal is controlled to maintain the gas temperature above 550°F (288°C) to avoid condensing ammonium salts. The combustion gas then enters the SO_2 absorber.
3. The third section is the SO_2 absorber, where SO_2 made from the combustion step is absorbed in a multiple-stage contact with the NH_3-rich solution from the NH_3/H_2S absorber, followed by multiple countercurrent stages washing with water (introduced as make-up water) to the top of the vent gas scrubber. The make-up water rate is modulated to control the density of the product. The vent gas contains <50 ppmv SO_2 and no reduced sulfur or carbon monoxide (CO), so there is no need for additional incineration.

The conversion process can be operated under control and with emissions-meeting design limits, even while the feed rates to the conversion process are lowered to zero. The liquid rates in the various contactors remain constant, regardless of feed rate. The ATS product is a benign material used in fertilizer blends, safe for shipping, usually as a 60% aqueous solution. It is nearly odorless, with low toxicity and no H_2S emissions.

Presently, two commercial SWAATS units are in operation. All equipment employed in the SWAATS process are found in typical refinery service. Aside from freeing up capacity in the SRU by directing the SWSG entirely to the SWAATS unit, SWAATS also benefits the SRU operation with:

- Improved sulfur recovery: Removing the SWSG from the feed to the Claus unit results in better control of the H_2S/SO_2 ratio. It also eliminates much inert diluent gas and H_2O vapor that opposes the Claus reaction.
- Improved catalyst life: Despite the operational provisions in the thermal Claus reactor, some NH_3 still remains in the Claus furnace outlet gas. This NH_3 condenses as ammonium sulfate over the Claus catalysts leading to deactivation. Additionally, hydrocarbons present in the AAG split that is bypassed to downstream of the partition section face a reducing environment, inviting incomplete oxidation, particularly of the aromatics. Since SWSG is routed to the SWAATS unit and only AAG enters the Claus section, these potential problems pertaining to catalyst deactivation are avoided.
- Energy consumption reduction: The energy required to reheat the process gas to the SRU and tail gas treater reactors, regenerate the amine in the TGTU, and incinerate the treated gas to vent is proportional to the gas flowrate. Since SWSG contributes significantly to the SRU load, diverting the SWSG to the SWAATS unit reduces the energy demand of the SRU remarkably.
- The process recovers waste NH_3 and turns it into an advantaged fertilizer, which is a premium product in the fertilizer market. This results in value upgrading of the N and S molecules contained in SWSG, which are a nuisance when processed through an SRU. ●

US EXPECTED TO LEAD GLOBAL OIL SUPPLY GROWTH TO 2024

The US is expected to drive global oil supply growth over the next five years, adding another 4 MMbpd to the country's already booming output, according to the International Energy Agency (IEA).

US oil output will climb to 19.6 MMbpd by 2024 from 15.5 MMbpd last year. Gross crude exports will double, leading to greater competition, especially in the Asian market.

The outlook points to pressure on demand for crude from OPEC as the US and other rivals expand supplies. However, in a boost for the producers, the IEA does not see a peak in global demand yet. A boom in US oil supply due to shale oil has countered efforts by OPEC and its partners led by Russia to restrain supplies. The so-called OPEC+ group began a new round of oil supply cuts in 2019 to support prices.

By the end of the forecast (2024), oil exports from the US will overtake Russia and close in on Saudi Arabia, bringing greater diversity of supply, the IEA said. Global oil demand growth is set to ease as China slows but will still rise by an annual average of 1.2 MMbpd to 2024, when it will reach 106.4 MMbpd.

Even so, the IEA does not expect moves such as greater adoption of electric cars to put a cap on demand growth yet. The IEA continues to see no peak in oil demand, as petrochemicals and jet fuel remain the key drivers of growth, particularly in the US and Asia, more than offsetting a slowdown in gasoline due to efficiency gains and electric cars. ●

Solve refining, petrochemical industry challenges using multidisciplinary simulation

RAVINDRA AGLAVE, Siemens PLM Software; **AMY KNUTSON,** Mentor Graphics, a Siemens business; and **MATT STRAW,** Norton Straw Consultants

3D simulation for engineering is the mathematical, physics-based or other logical representation of a system, component or process that reproduces real-world behavior. This includes phenomenon such as fluid flow, structural analysis, heat transfer and chemical reactions all the way from electrical signals to hydraulic controls. Different physical length scales, or resolutions—whether system-wide (usually at lower resolution or detail) or at the detailed equipment level—can be done with 3D simulation. By combining multiple physics and multiple scales, simulation allows engineers to look holistically at multidisciplinary challenges.

Engineers can investigate many different design options and operating conditions to enable better decision-making. This leads to optimized efficiency and reduced risk. The most value from simulation can be realized when it is a core part of the engineering design and lifecycle management workflow of equipment, system or process, from initial concept through detailed design to operation and maintenance. This begins with the overall technology strategy for any company designing, constructing or operating process facilities and equipment.

Early simulation is just as important in initial designs as when considering and planning equipment and system upgrades and revamps. The insight gained from simulations can make a major difference in the time, cost and success of any system changes; problems and solutions can be analyzed in the virtual world before physical changes are made.

Siemens Simcenter STAR-CCM+ computational fluid dynamics (CFD) software enables engineers to explore their designs for processing plants, systems and machinery digitally through detailed, accurate 3D simulation and design space exploration. Designs can be explored virtually with a high degree of fidelity, improving confidence and performance while reducing uncertainty, risk, cost and time.

STAR-CCM+ has the capability of simulating all complex processes from flow distribution and mixing to combustion and scrubbing of exhaust gases and waste products. The exploration and optimization capability of Siemens HEEDS design-management software further enables engineers to increase their understanding and improve their system performance in less time at lower cost.

STAR-CCM+ offers a wide range of models to simulate reaction and combustion processes and enables technology and equipment developers to accurately simulate the full range of multiphase flows to identify optimum designs and demonstrate full-scale performance at real operating conditions.

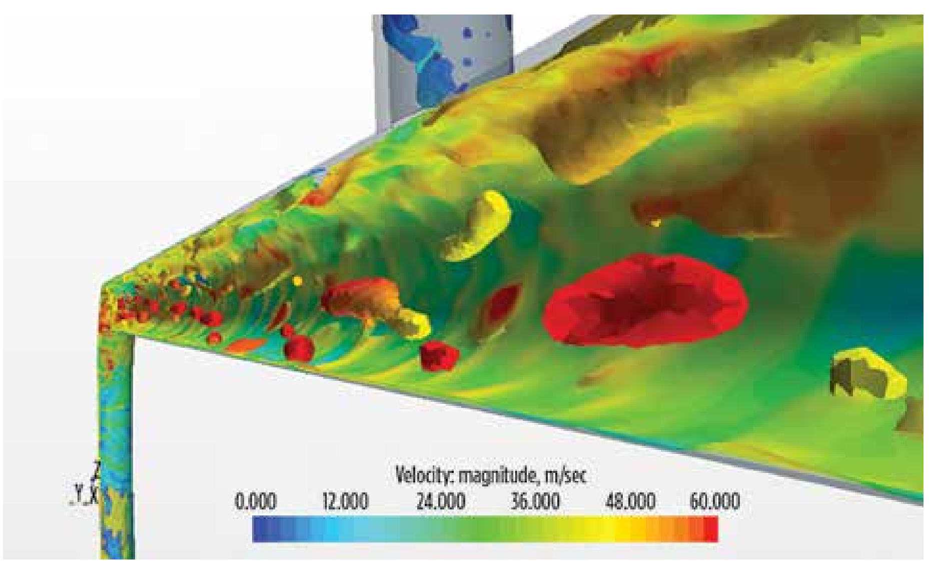

FIG. 1. The multiphase flow through a process system where simulation was used to demonstrate that process fluids passing dead-legs and intrusive elements would not generate vibrations.

Selecting best-fit material for construction. In a recent revamp project, process flowrates were to be increased, leading to extreme low temperatures in piping downstream of a new valve during the process repressurization. Using simulation early, it was demonstrated what material would be suitable in different areas of the pipework downstream of the valve. Not only did this simple simulation inform the engineering team of the extents of low temperatures, but also enabled them to save costs by avoiding the replacement of stainless pipes with higher-cost materials that would have been required if conservative estimates were used rather than using a simulation approach.

Time, costs savings for crude heating and naphtha cracking. Efficient transport and processing of natural resources is critical to a viable midstream or downstream business. Effective burner design in a fired heater requires efficient combustion and thermal management, while emissions must be minimized to reduce environmental impact. Empirical calculations cannot reproduce the complexities of such systems and testing can be time-consuming and expensive, and limit innovation.

Reducing structural risk in multiphase pipe flows. Making changes to support equipment or control vibration is often unviable for existing operations infrastructure both economically and from a design aspect. Whether the identified vibration risk really exists can be assessed by simulating the required operating conditions and the system response to changes. By combining structural simulations with fluid dynamics analysis, the fluctuating pressure field induced by the flow can be predicted and the system's dynamic response assessed before making any changes in the physical world.

FIG. 1 shows the multiphase flow through a process system where simulation was used to demonstrate that process fluids passing dead-legs and intrusive elements, such as thermowells, would not generate vibrations (from either slugging flows or general turbulence and pulsation) that were identified as a risk using an initial screening method. In this case, simulation enabled a successful upgrade and replacement of a larger control valve to be installed to facilitate increased process flow without an increase in the risk of pipe vibration. ●

EIA: USGC REFINERY DEMAND FOR HYDROGEN INCREASINGLY MET BY MERCHANT SUPPLIERS

US Gulf Coast (USGC) petroleum refiners increasingly rely on merchant suppliers, rather than their own production, to provide the hydrogen (H_2) used to reduce the sulfur content of fuel.

Between 2012 and 2017, consumption of H_2 sourced from merchant suppliers increased from approximately 1,750 MMft^{3}d to 2,200 MMft^{3}d, a 25% increase. Over the same period, onsite production of H_2 from natural gas fell from 475 MMft^{3}d to 415 MMft^{3}d, a 13% decrease. Merchant suppliers accounted for more than 85% of H_2 consumed by refineries in 2017.

Limitations exist on the amount of H_2 that can be produced onsite compared with that provided by merchant suppliers. A large share of H_2 used by USGC refineries is supplied by a 600-mi, 1-Bft^{3}d network of H_2 pipelines stretching from Lake Charles, Louisiana to Houston, Texas.

Between 2012 and 2017, USGC petroleum refineries (PADD 3) increased hydrocracking capacity by 50%, with a similar increase in distillate production. Over the same time, steam methane reforming (SMR) capacity decreased by 19%, leading refiners to purchase more H_2 from merchant suppliers.

Unlike USGC refiners, Midwest refiners historically have not been as reliant on merchant suppliers due to a lack of dedicated H_2 pipelines. Some Midwestern refiners use more Canadian sour crude oil, which requires more H_2 to process. Overall, the utilization of USGC refinery SMR units has been between 41% and 48%, while in the Midwest it has risen from 60% in 2012 to 66% in 2017.

HAZARDOUS INDUSTRY LEADERS BELIEVE DIGITAL TRANSFORMATION IS KEY TO OE

Sphera has released the annual *Operational Excellence Index* (OEI) survey report, which highlights trends in digital transformation and OE strategies across the hazardous industries.

Previously conducted by Petrotechnics, now a Sphera company, the index surveys oil and gas, chemical, energy and industry manufacturing professionals to gauge attitudes around OE and the measures taken towards its adoption.

Respondents (90%) agree that digital transformation will accelerate their ability to achieve OE, not just as a one-off target but as an ongoing business objective. This is a significant increase from last year's report, where 73% of leaders agreed that going digital was key to achieving OE. Implementing digital technologies is now aligned with overall business goals, with 55% leveraging technology to reduce operational risk and 55% to improve asset availability and uptime.

While industry leaders agree digital is essential to OE, more than half are still trying to figure out what "digital transformation" means for them, and 69% are just beginning their digital journey. The approach to digital matters, according to 83% of survey respondents, who admit they have relied on legacy systems to improve their business agility but had not embedded operational best practices cross-functionally.

The good news is the industry is on the brink of a major step forward when it comes to achieving OE through digitalization. Leaders (75%) recognize the need to create new, insight-driven business processes across enterprise functions. ●

Is fixed-bed hydrotreating a viable IMO compliance solution?

ED PALMER, Wood Group

The 2020 implementation date for the impending IMO ships bunker fuel regulations is coming soon and, unlike previous fuel regulations (e.g., US gasoline and diesel fuel sulfur), no consensus exists for the best technological/logistical solution to produce compliant fuel (**FIG. 1**). Approaches being considered include:

- Blending a variety of existing, low-sulfur refinery products to make compliant fuel
- Incremental coking capacity for processing high-sulfur feedstocks with subsequent hydrotreating of the coker gasoils to produce bunker fuel
- Installing scrubbers on ships for sulfur oxide (SO_x) removal
- Slurry bed hydrotreating
- Fixed-bed hydrotreating of high-sulfur bunker fuel
- Residua from light (shale) crude.

FIG. 1. No consensus exists for the best technological/logistical solution to produce compliant fuel for the impending IMO ships bunker fuel regulations.

Fixed-bed hydrotreating technology was commercialized more than 40 years ago with the primary objective of producing low-sulfur fuels for power plants. Many units were built in Japan and other countries in Asia using technology supplied by several licensors. This approach however is very capital intensive. Further, due to the low space velocity, short cycle lengths and high hydrogen (H_2) consumption, operating costs are also relatively high.

Fixed-bed hydrotreating. The reactor concept is one of the main design considerations for a fixed-bed hydrotreater designed to produce compliant bunker fuel.

- Reactor space velocities are approximately 0.25, so multiple reactors in series are required.
- A guard reactor is employed to remove foulants/scale and metals, such as nickel, vanadium, silica, iron and arsenic. Other contaminants in the feed, such as diolefins, are also removed from the feed prior to processing in the desulfurization reactors. The guard bed catalyst has moderate desulfurization (HDS)/denitrogenation (HDN) activity. The cycle length is typically set at 6 months–12 months. Due to the potential difference in the reactor cycle lengths, the guard reactor system can be designed for isolation and catalyst replacement independent of the desulfurization reactors. Key considerations are appropriate valving, reasonably rapid cool down time to allow catalyst replacement, and startup/catalyst conditioning considerations following catalyst replacement.
- The desulfurization reactors have a transition catalyst with balanced activity followed by a higher-activity treating catalyst to ensure meeting the ultimate HDS objective.
- For shop fabricated reactors [14 ft–16 ft-internal diameter (ID)], the maximum single train throughput is 30,000 bpd–40,000 bpd.

The expectation is, at least initially, that the gross margin for compliant IMO bunker fuel starting in 2020 will significantly exceed the estimated values.

Effective feed filtration is another key design consideration. A financial analysis for a fixed-bed hydrotreater complex designed to process 40,000 bpd of high-sulfur bunker fuel and yield compliant IMO 2020 product is summarized below. The design utilizes hot/cold high-pressure and low-pressure separators to optimize heat recovery. A simple stripper is provided for product fractionation. The total installed cost for this facility is estimated to be $845 MM, based on a US Gulf Coast location at an existing refinery and mid-2022 startup. The following facilities are included in the hydrotreating complex:

- 40,000-bpd fixed-bed hydrotreater with 2,000 psig reactor pressure and 0.25 space velocity
- 50-MMft^{3}d hydrogen supply via steam methane reforming
- 300-gal/min sour water stripper
- 1,000-gal/min amine regeneration unit
- 175-tpd Claus SRU with tail gas treating
- Allowance for incremental utilities, feed/products storage/waste treatment, fire water, flare, offsite piping.

TABLE 1. Estimate of the gross margins needed based on 15% IRR and 20% IRR

	US$/bbl of feed	
	15% IRR	20% IRR
Net earnings[1]	7.73	11.73
Fixed operating costs[2]	3	3
Variable operating costs[3]	2.95	2.95
Wild distillate yield credit[4]	–1.35	–1.35
Required bunker fuel margin	12.33	16.33

[1] 20-year project life, straight line depreciation, 330 d/yr onstream
[2] Maintenance, insurance, and operating labor and supervision
[3] Utilities, catalyst and chemicals
[4] 2 vol% yield on feed; $50/bbl fuel gas credit included in variable operating costs

TABLE 1 shows an estimate of the gross margins needed based on 15% internal rate of return (IRR) and 20% IRR for the project.

The estimated breakeven gross margins indicate that an investment for a grassroots bunker fuel hydrotreating complex will likely have attractive economics. Obviously, other issues must be addressed, including environmental permitting, financing for private developers, feed/product contracts, project warrantees, etc. However, the expectation is that at least initially the gross margin for compliant IMO bunker fuel starting in 2020 will significantly exceed the values estimated in this analysis. ●

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Silo busting with the digital twin

Information silos within oil and gas companies harbor significant inefficiencies and hinder the achievement of operational excellence. The desire for a single source of truth for all data types that can be consumed in decision-making and execution has been driving the pursuit of IT/OT convergence, which has largely remained elusive. The key to change is a digital twin that works.

The ideal. The digital twin should be an accurate virtual representation of an asset's full lifecycle and range of operation. It is ideally created during the initial study to evaluate asset feasibility and is used and further developed during asset design, construction and commissioning. It facilitates the optimum design of the asset and the training of asset operators. It works in the present, mirroring the actual plant in simulated mode, but with full knowledge of the plant's historical performance and an accurate understanding of its future potential.

Is a process simulator the same as a digital twin (FIG. 1)? Not really. A process simulator should be able to transition from a rigorous design tool into a digital twin driving operations, including production management and supply chain optimization.

Most well-run plants will have a process simulation model of the plant, possibly created during plant design or since that stage. The use of process simulators for operations support is, however, limited to ad-hoc use by unit engineers for troubleshooting and investigating improvements. Process simulation requires the engineer to determine what is likely to happen and then configure and use it for what-if scenarios to attempt a calculation of where the best value lies.

This approach presents challenges: improvements are only identified when engineers are focused on the right areas, if at all. Often, operators lack confidence in the results of the ad-hoc model, so unit engineers want to review the model again when making changes or an unexpected outcome occurs. The rate of change slows or results in no improvement, and unit engineers often stop using the model or build and test the model excessively, thereby losing focus on other more valuable improvements. This leads to increased time and cost, delayed optimizations, missed improvements for the business and lost profits.

For more than a decade, Petro-SIM has been a rigorous design tool that applies in-depth physics and chemistry to real-time production data to drive business decisions for production management and supply chain optimization activities.

Traditional simulator	VS.	Digital twin
An accurate representation of a particular operating case	➔	An accurate representation of the asset over its full range of operation, all the time
Static provision of a snapshot in time	➔	Captures the full history and future of the asset
Built on an ad-hoc basis to answer a question	➔	Automated, regular model runs; built-in to business work flows
Owned and used by isolated groups on an ad-hoc basis	➔	Centralized single version of the truth, used by everyone; outputs delivered directly to the business; strong governance systems

FIG. 1. Comparison of process simulator and digital twin, which is always aligned with and drives business data model.

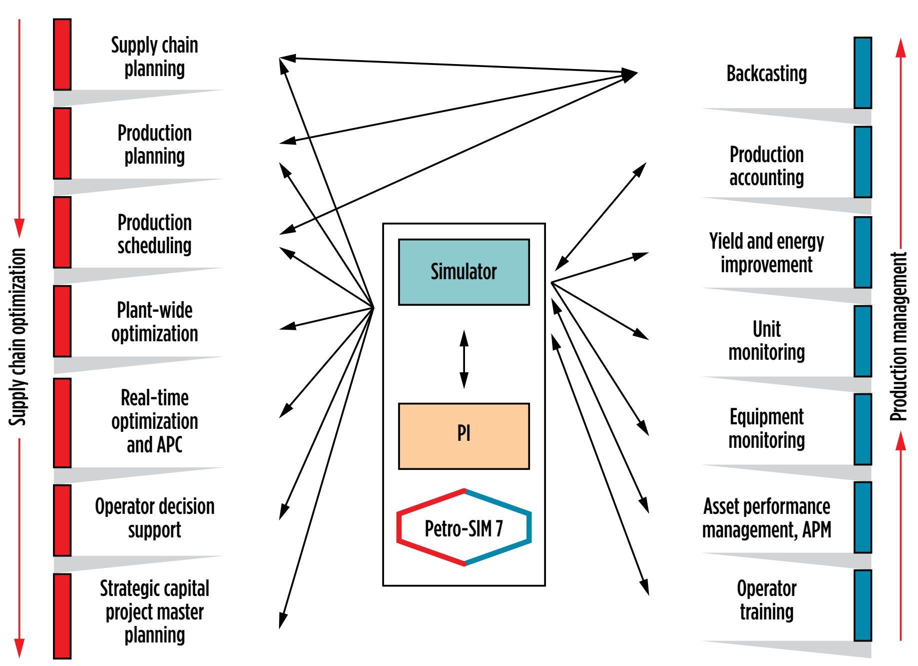

FIG. 2. All Petro-SIM model outputs are automatically written back into the PI system, in real-time, including the comparison of measured vs. simulation model vs. LP model outputs.

Collaboration. In February 2019, KBC announced a collaboration with OSIsoft to accelerate digitalization across the energy and chemical industries and eliminate the disappointment of big data analytics.

Through this collaboration, Petro-SIM has been configured to enable everyone to see inside and perceive things that are not being directly measured. High-quality and accurate predictions are instantly available and run in a consistent way that can be understood and agreed on. It enables automated creation of PI Asset Framework (PI AF) templates from Petro-SIM and automated updating of PI AF templates if the Petro-SIM model changes. It enables automated population of the Petro-SIM model with current PI data and automated population of the PI database with Petro-SIM outputs. Any PI tag changes trigger automatic notification to Petro-SIM.

Automated calculation of unit performance analytics allow "What if?" and "What's best?" scenarios to be run automatically to determine available strategies that maximize profitability.

All Petro-SIM model outputs are automatically written back into the PI system, in real-time, significantly enhancing the quality and richness of data in the PI system. This includes comparison of measured vs. simulation model vs. LP model outputs to help track when models and actual plant performance diverge. Other parameters include (but are not limited to) temperatures, pressures, flows, densities, viscosities, stream characterization of feeds and products, catalyst activity and run length projections, catalyst circulation rates and heat exchanger/fired heater fouling. In turn, a higher fidelity record of operations in the PI system will help drive smarter decisions across the enterprise by bringing Petro-SIM insights to PI Vision dashboards and other systems integrated with the PI system. This also enables drill-down into Petro-SIM models from PI Vision (FIG. 2).

The necessary first step is provided toward making Petro-SIM not just a rigorous design tool, but also the asset's digital twin that can perform monitoring, surveillance, supply chain optimization and other advanced applications and services.

The significant value offered by Petro-SIM-based digital twin addresses:

- Making the right decisions on bad data
- False positives arising out of analytics initiatives
- Needing measurement in parts of the system where it is risky and difficult
- Decision-making on a plant-wide and individual unit level between siloed groups
- Reliability and maintenance being optimized in isolation of process/yield/energy considerations
- Planning errors or inaccuracies having to be "mopped up" by storage/system flexibility, and proliferating errors from one plan to the next
- Operator training on actual situations experienced in the plant
- Distrust of and lack of understanding of plant-wide and individual unit operations/economics in real-time
- Sub-optimal decisions made because of non-utilization of available non-measured/inferred indicators
- Engineering time wasted by doing repetitive tasks
- Non-compliances with corporate engineering/design standards
- Inability to "plug in" proprietary IP, knowledge and know-how into routine activities.

Used in these ways, Petro-SIM boosts the value derived from production management and supply chain optimization activities, as well as reduces total cost of asset lifecycle simulation. •

CATALYST, continued from page 16

metal catalyst offering greater hydroprocessing margin potential. The new ultra-high activity catalyst is commercialized by ExxonMobil in distillate and hydrocracking pretreat units and has demonstrated step-out activity and performance over Nebula catalyst. The Celestia catalyst has taken hydroprocessing activity and margin potential to new levels, showing more than three time's higher activity vs. leading NiMo conventional catalysts. With the Celestia catalyst, ExxonMobil set about benefiting from all three margin opportunities, simultaneously achieving increased feed rate, cycle length and improved product quality. In addition, the company achieved significant energy savings and improved yields. The benefit was substantial rather than incremental.

ExxonMobil has loaded the Celestia catalyst in stack loads with Nebula catalyst and conventional NiMo catalysts, benefitting from careful planning and intelligent loading schemes designed to maximize value potential. An illustration of the Celestia catalyst's impact can be seen from a heavy feed VGO hydrocracking unit. By incorporating a partial fill of Celestia and Nebula catalysts pretreat reactor, co-loaded with a leading NiMo catalyst, the unit gained a transformative activity boost, providing a platform for ambitious high-margin process planning.

The Celestia catalyst produced significant value to the VGO hydrocracker operation: maximized the feed rate of a challenging coker VGO; significantly reduced nitrogen slip; increased aromatic saturation and unit conversion with higher diesel and jet yields; improved product quality, including diesel cetane and jet smoke point; improved hydrocrackate export quality, leading to higher profitability in an affiliate steam cracker; and increased heat recovery, leading to a reduction in furnace firing and significant energy savings.

The hydroprocessing Celestia bulk metal catalyst offers refiners substantial opportunities for increased activity and value, enabling a fast and effective payback within a few months as well as continued and enhanced profit contribution. •

Digital transformation through seven integrated power and process strategies

CONSTANTINE LAU, Schneider Electric

Digital transformation should be an enabler to achieve business objectives. While industrial companies are embracing digital transformation, many lack roadmaps for how to proceed. For oil and gas and petrochemical enterprises, this should extend throughout the lifecycle of the plant by integrating power and process management systems to derive real value for the business. Enabled by the Industrial Internet of Things (IIoT) and big data, oil and gas enterprises can reap rewards in seven key areas to provide value across the enterprise, from front-end engineering design (FEED) to operations and into the supply chain.

The confluence of digital transformation and the constant pressure to reduce CAPEX and OPEX are driving the industry to rethink the separation between process automation and power management. The integration of power management and process automation commences in plant design, extends through engineering and commissioning, and is applied throughout the operating life of an asset.

The seven integrated power and process strategies are depicted in FIG. 1.

1. **Integrated asset data intelligence** is a single data intelligence infrastructure for both manufacturing processes and electrical distribution and equipment. This value driver provides customizable, multidiscipline 3D design tools to aid in the construction of process plants, creating a digital twin of the plant: a 3D model of the physical plant equipment and associated process that can be utilized throughout the business lifecycle of a plant asset for design, training, maintenance, expansion, etc. The digital twin matures through stages of FEED studies, detailed design, construction and optimization.
2. **Power system optimization** enables the design of power supply and distribution equipment that matches expected plant power demands, ensuring that the power system is not overdesigned. This can be accomplished through early engagement with energy management experts and through the aid of process and electrical simulation modeling tools.
3. **Unified simulation** of the plant is used for engineering and commissioning, operator training and real-time optimization. The model becomes a vital digital asset. The "living" digital twin possesses reliable predictive capabilities over a wide range of design and operating parameters. Once developed, unified simulation is applied and upgraded as necessary, without having to recreate the models.
4. **Single project execution** enables the power system and automation supplier to work closely with the engineering, procurement and construction (EPC) firm during the design phase around a broader scope for a project. This new role consolidates scope under a single power system and automation supplier, enabling better coordination and integration of systems and reducing project risk, especially during plant commissioning.
5. **Power and process systems integration** of process control systems and electrical power management systems includes a unification and rationalization of distributed control systems (DCS), energy management control system (EMCS), networks, controllers, alarms, historians and intelligent electronic devices (IEDs).
6. **Integrated asset management** is about diagnostic monitoring and maintenance of plant assets, including electrical supply/distribution, process equipment, turbomachinery and the automation infrastructure that monitors and controls these assets. Asset performance management collects data about how equipment is performing and provides the tools and applications that predict the best use of assets to achieve operational goals at minimum cost.
7. **Process energy optimization** is about managing the tradeoffs between energy types— the fundamental physics and chemistry of the process mean that relationships exist between electrical, gas, steam and chilled water—throughout the processes to minimize cost and the plant's carbon footprint.

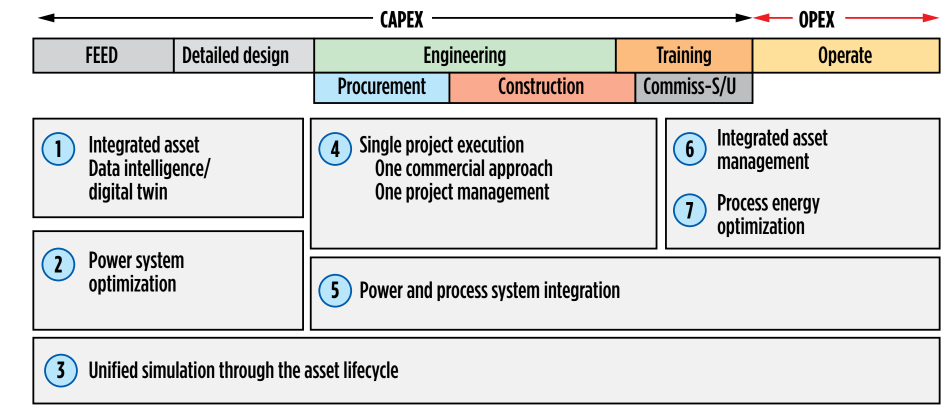

FIG. 1. Digital transformation across the lifecycle through integrated power and process strategies.

A value-focused digital transformation, which leverages connected devices and IIoT, can bring all seven strategies together to extend the life of the operation and reduce both CAPEX and OPEX significantly. A single view of asset management, energy management, automation (both power and process) and safety monitoring systems is enabled through IIoT. Knowledge from various plant teams is no longer siloed or inaccessible, and the monitoring and analysis of process information can be done remotely or through a centralized process, enhancing insights and the decision-making process.

Digital transformation links connected products, such as field devices, and edge control systems to apps and analytics, which must be robust and secure. Interoperability and data analytics can deliver value across the entire enterprise supply chain, but security and reliability are foundational to connected products and edge controls.

One of the strategies with the highest priority for digital transformation is prescriptive analytics for asset management, which is model-based and often uses machine-learning algorithms that recognize patterns and can enable detection of anomalous conditions in equipment or processes and recommend next steps. Machine-learning or artificial intelligence monitors plant behavior from both the process and electrical systems, supporting continuous operation, locally and remotely.

The value of integration is not limited to commissioning or plant operations. Value is generated in the initial FEED studies, where an integrated approach can have its most profound, long-term financial effect on the asset. Value is therefore realized throughout the lifecycle of the asset when all seven strategies are applied and used together, increasing savings in both CAPEX and OPEX throughout the plant lifecycle.

All seven strategies are achieved through a combination of different technologies and engineering disciplines.

The technologies comprising the seven strategies are expected to catalyze organizational and process changes that bring together historically separate disciplines of process automation, power management and others in ways that will realize this vision. Business leadership will direct the journey toward digital transformation and the requisite organizational and cultural changes needed to achieve this vision, based on measured, sustainable value for shareholders, employees and communities. •

SESSIONS, continued from page 12

conferences), ongoing benchmarking methods (e.g., the site can compare its performance vs. the rest of the industry, and the industry can then measure performance over time and identify areas for improvement), and sharing best practices.

As of March 15, 2019, the API has performed 66 general site assessments covering 28 of 39 US refining companies. Additional opportunities for process safety improvements are myriad and varied. One is the identification of new API standards, recommended practices or modifications. "Then we can go into a smaller petrochemical site for an assessment and not be overwhelming," Broadbent explained. "When you go into a small refinery, your team sometimes can be larger than the site's management staff."

"Based on the premise that the advanced process safety program has been around for seven years, we wanted to look at how are we doing," he said. "We expected to see site improvement seven years down the road." The API examined data between 2012 and 2015 and between 2016 and 2018. The sites assessed since 2016 scored higher, indicating that improvements are taking place. "It will be interesting to see what happens when we go back to those sites for a second time," Broadbent said.

Another key element of process safety is safe work, including ownership of the "stop work" program. "Most sites tell you they have a stop work program in place, and then you get to a site and you can tell that they're not so comfortable with it," Broadbent explained. "But when we get there, we help them see that they should shut down a job if hazards are present." •

API's ANDREW BROADBENT during Tuesday morning's "Process safety site assessment program—promoting a culture of process safety" session

SCENES FROM THE 2019 AFPM ANNUAL MEETING

1 **Sascha Vukojevic** from hte GmbH (left) and **Raul Adarme** from Motiva Enterprises spoke about the importance of best catalyst technologies identification and evaluation regarding the performance of high-value conversion units like hydrocracking, cat-feed hydrotreating, reforming and lubes.

2 Barclays' **Michael Cohen** provided an overview of global oil market fundamentals, including crude oil and refined product supply and demand, at Tuesday morning's session, "Global oil outlook: Balanced in the eye of the beholder."

3 In the session, "To change or not to change: Human operational performance theory," **Dr. Todd Conklin** of Conklin & Associates presented different ways of dealing with workplace safety that are applicable to administration, management and workers.

4 Audience Q&A following technical sessions is a great way to share techniques and best practices with the expert panels, presenters and fellow attendees.

5 Axens N.A.'s **Christian Vaute** joined his fellow super heroes at the company's hospitality suite on Monday night.

6 Collaboration and shared ideas are two of the key tenets of the AFPM Annual Meeting.

7 Monday evening's sports-themed KBR hospitality suite included trivia, generous prizes and some breakdancing refs.

8 Blasting virtual aliens was one of the activities at the Albemarle hospitality suite.

9 The opportunity to eat, drink and beat the house with some blackjack is always a welcome respite after a busy day at the Annual Meeting.

10 Athlon hosted an evening with the true sounds and flavors of Texas.