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# Supporting our industries through unprecedented times

**CHET THOMPSON,** President and CEO, American Fuel & Petrochemical Manufacturers

We are living through unprecedented times that are wreaking havoc on our industries, the markets and, most importantly, our lives. First and foremost, I hope you and your families are safe and doing well. Everything else pales in comparison.

Amid concerns about the spread of COVID-19, we made the difficult decision to cancel AFPM's Annual Meeting, which was slated to take place March 22–24, 2020, in Austin, Texas. Nothing is more important to our industries than safety, and in evaluating the rapidly evolving COVID-19 situation, it became clear to us that canceling this meeting was the only sensible course of action to protect the health and safety of our meeting registrants and vendors, our staff and the Austin community.

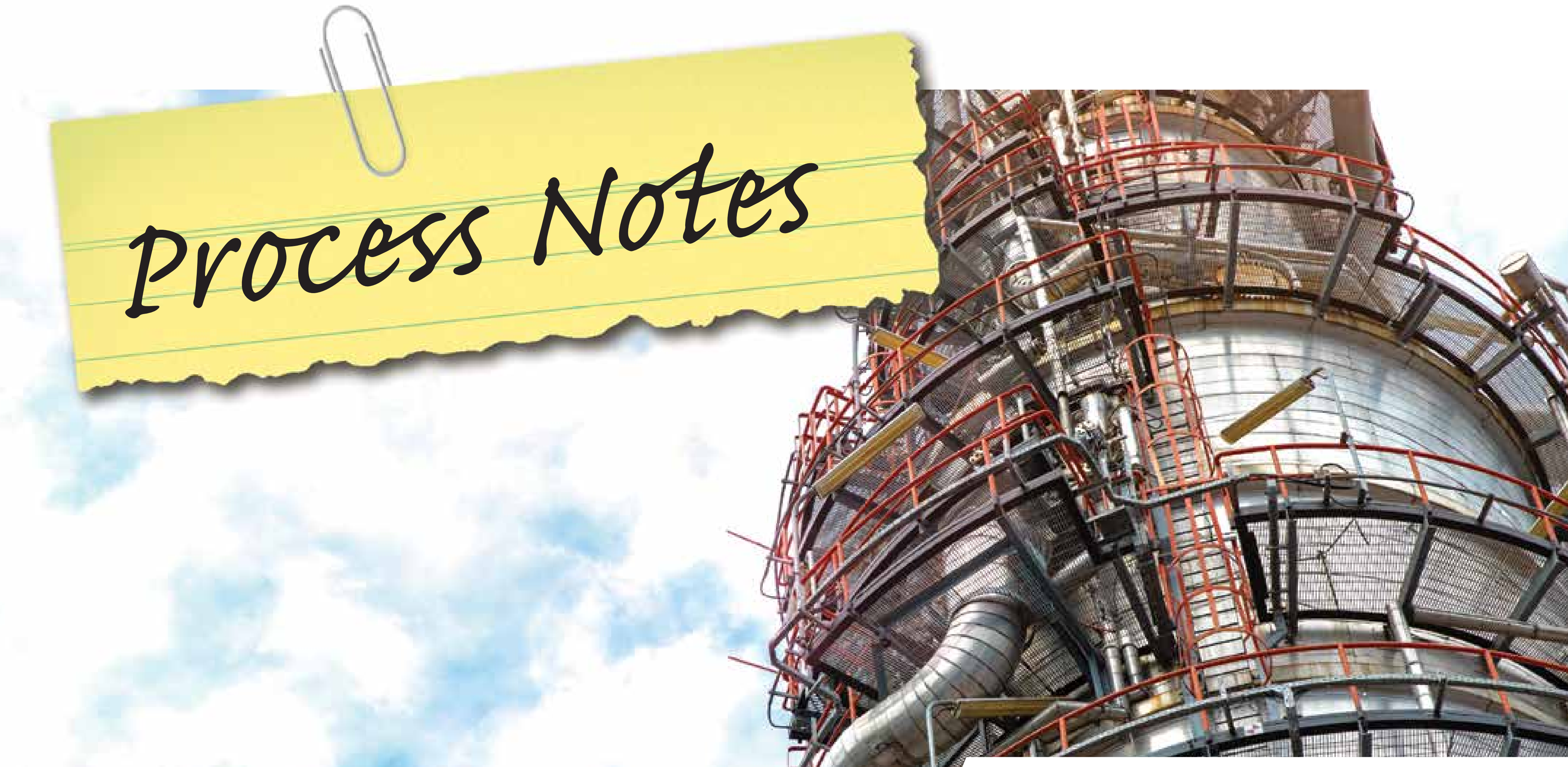
We were very much looking forward to this gathering and the industry knowledge-sharing it facilitates each year on topics like safety, sustainability and the global outlook for fuels, among other issues critical to our industries. We are now looking at ways to bring this important content to you in different formats and will update you as our plans are solidified.

AFPM is here to support our members and industries throughout this crisis. My team and I have been liaising with government officials, closely tracking the latest information from health experts, and communicating regularly with leaders within our industries to share important updates and resources. We are in touch daily with the Administration and other public officials about the impacts that the outbreak is having on our industries, our preparedness, how our companies are safeguarding employee health, and how we are helping our communities during these trying times.

While the full extent of how this virus will impact our workplaces, our communities and our own loved ones is not yet known, I have great confidence in the fuel and petrochemical industries. I know that we have the capacity to respond to this challenge with the same resiliency and spirit that we have shown in the face of other obstacles over the many decades that we have been in operation.

In this moment, we have a unique opportunity to ensure the continued availability of essential products—including those now relied upon by emergency responders, hospital workers and by Americans who need access to fresh food. Our industries claim some of the most intelligent, creative and hard-working people in the world. Together, we will once again rise to the occasion and successfully meet the challenges before us.

Thank you for your support of AFPM. Stay safe, and we will see you next year. ●




*Vacuum tower cutpoint delivers profits*

# Cutpoint Concerns

Crude unit vacuum tower performance is often critical to a refiner's bottom line. The vacuum tower bottoms stream is valued far below the gas oil cuts, so most refineries look to minimize it. Many vacuum columns are also designed or revamped to produce a diesel cut, recovering diesel slipped from the atmospheric column that would otherwise be downgraded to VGO product.

Good vacuum column performance can maximize the profitability of downstream units by removing distillate hydrotreater feed (diesel) from FCCU or hydrocracker feed (VGO) and removing VGO from coker feed (resid).

One important measure of vacuum column performance is VGO/resid cutpoint. The cutpoint is the temperature on the crude TBP curve that corresponds to the vacuum tower resid yield.

Vacuum column cutpoint depends on three variables:

1. Flash zone temperature
2. Flash zone pressure
3. Stripping section performance (if present)

Flash zone temperature is driven by vacuum heater coil outlet temperature (COT). Increasing COT increases cutpoint. Vacuum heater outlet temperature is typically maximized against firing or coking limits. When processing relatively stable crudes, vacuum heaters with better designs and optimized coil steam can avoid coking even at very high COT (800°F+, 425°C), but poorly designed heaters may experience coking with COT below 700°F (370°C).

Flash zone pressure is set by vacuum system performance and column pressure drop. Lower flash zone pressure increases cutpoint until the tower shell C-factor limit is reached, at which point the packed beds begin to flood. Vacuum producing systems are mysterious to many in the industry, so a large number of refiners unnecessarily accept poor vacuum system performance. With technical understanding and a good field survey, the root causes of high tower operating pressure can be identified and remedied.

In columns with stripping trays, stripping steam rate and tray performance are important. Stripping steam rate is limited by vacuum column diameter (C-factor) and vacuum system capacity. Any steam injected into the bottom of the tower will act as load to the vacuum system, so vacuum system size, tower operating pressure, and stripping steam rate must be optimized together. Depending on the design, a stripping section with 6 stripping trays can provide between zero and two theoretical stages of fractionation, which can drive a big improvement in VGO yield.

Although the variables for maximizing vacuum tower cutpoint are simple, manipulating them to maximize cutpoint without sacrificing unit reliability is not. Contact Process Consulting Services, Inc. to learn how to maximize the performance of your vacuum unit.

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# Industry innovations offer consumer-friendly approach to cleaner vehicles

American Fuel & Petrochemical Manufacturers

Often overlooked in the compendium of efforts toward a cleaner vehicle fleet are bold, industry-led innovations in efficient liquid fuels, vehicle designs and internal combustion engines that continue to dramatically reduce tailpipe emissions.

Building on decades of broader efforts alongside automakers to advance fuel-efficient technologies and vehicles, refiners are leading the effort to transition the U.S. to high-octane gasoline to boost efficiency and, in doing so, reduce carbon emissions by an amount equivalent to taking hundreds of thousands of vehicles off the road each year.

More fuel-efficient engines and vehicles have contributed to a more than 100% increase in vehicle miles traveled between 1990 and 2018, while carbon dioxide ($CO_2$) emissions from all sources rose by just 12% in roughly the same period, according to the U.S. Environmental Protection Agency (**FIG. 1**).

The goal is to enact a nationwide high-octane, 95-RON fuel standard that would meet the most stringent air quality standards in every state, including California, while delivering efficiency gains of 3%–4%—far more than the fractional improvements that typically come with vehicle design changes.

The standard would "reduce [$CO_2$] emissions more cost effectively for consumers than other options available," American Fuel & Petrochemical Manufacturers President and CEO Chet Thompson told a U.S. House Energy and Commerce subcommittee in December 2018.

The high-octane, 95-RON fuel would be added to pumps alongside existing fuel options and, when used in optimized engines, would allow vehicles to travel farther on each tank of gas less expensively than other options.

**Improving on current requirements.** Congress has explored implementing the new high-octane fuel standard in 2022 as an improvement over current requirements, such as the Renewable Fuel Standard (RFS), which mandates ethanol use in gasoline. The proposed rule changes coincide with automakers' efforts to diversify powertrains, making smaller engines that rely on turbocharging to increase output. Using the new fuel, carmakers can tune engines for higher compression, which boosts power while cutting emissions.

"If we really want to address $CO_2$, it's very important to address fuel as part of the system," said Dan Nicholson, General Motors' Vice President of electrification, controls, software and electronic hardware. "The fuels really need to go together with the vehicles and with the engine. It's time to take a look at the fuel for the next generation of low $CO_2$-emitting gasoline engines, and high octane has to be a part of that."

While automakers continue to develop electric vehicles—whose manufacture emits $CO_2$, as does the generation of power to charge EV batteries in many cases—most observers believe the internal combustion engine will remain dominant on the road for decades, for a variety of reasons that include cost and consumer acceptance. The U.S. Energy Information Administration (EIA), for example, projects that 80% of U.S. new vehicle sales in 2050 will be vehicles with internal combustion engines.

**Improved horsepower and efficiency.** Improvements in internal combustion engine vehicles—and the fuels and oils they run on—have already paid big dividends. From 2004–2017, vehicle $CO_2$ emissions decreased 23% and fuel economy increased 29%, according to the U.S. Environmental Protection Agency (EPA), meaning

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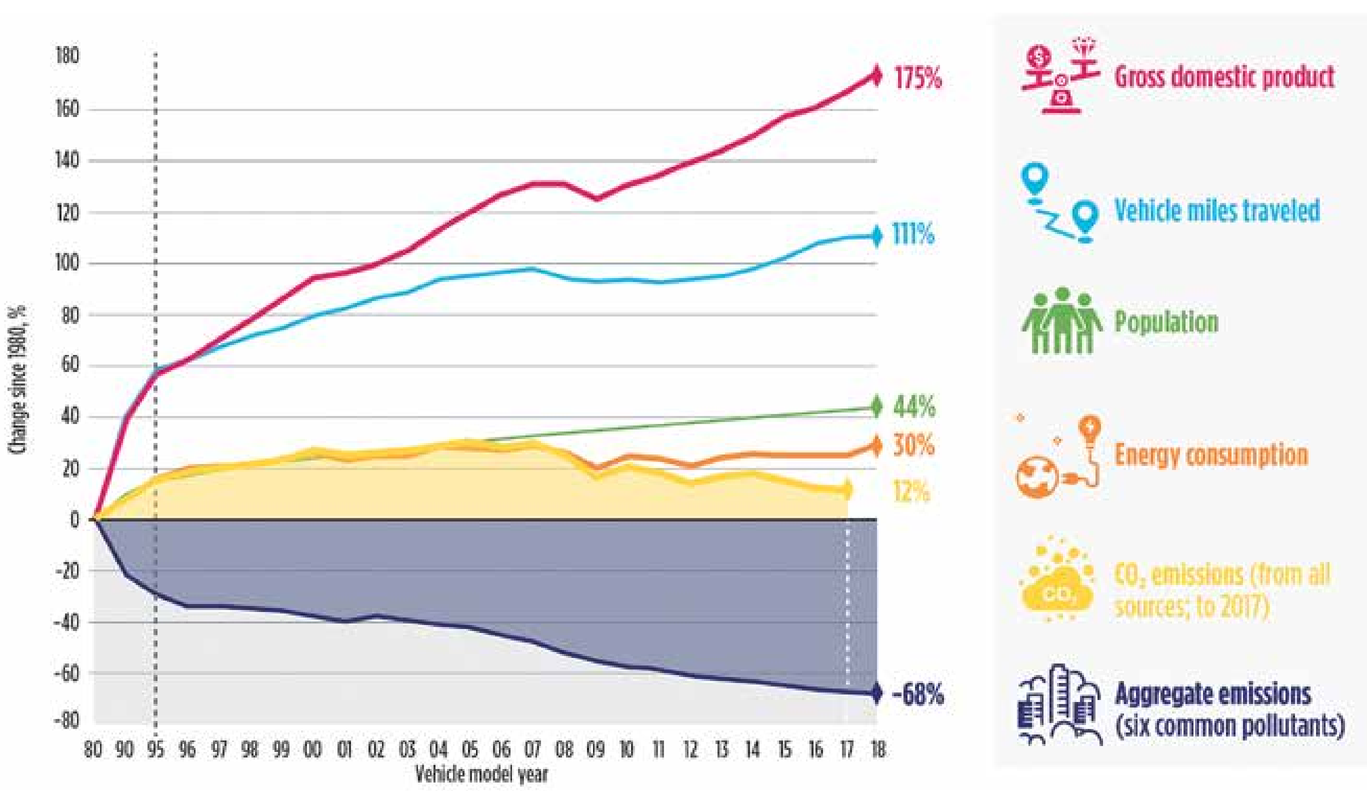


**FIG. 1.** Comparison of U.S. growth areas and emissions, 1980–2018. Source: U.S. Environmental Protection Agency.




AFPM

118TH ANNUAL MEETING CONFERENCE NEWS

Published by *Hydrocarbon Processing* as three daily electronic editions, March 23, 24 and 25. If you wish to advertise in future AFPM show daily newspapers or to submit articles or press releases, please contact the editor at Mike.Rhodes@HydrocarbonProcessing.com.

**Publisher**
Catherine Watkins

**AFPM Contacts**
Jaime Zarraby
Diana Cronan

**Editor**
Mike Rhodes

**Contributing Editors**
Adrienne Blume
Lee Nichols

**Production Manager**
Angela Bathe Dietrich

*Hydrocarbon Processing*
2 Greenway Plaza, Suite 1020
Houston, TX 77252-77046
713-529-4301

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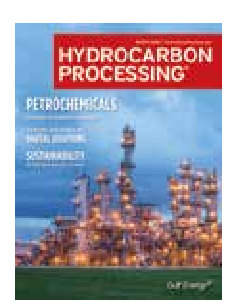

# Improving refinery turnarounds

**N. DALAL,** Emerson Automation Solutions

Most refineries perform turnaround activities every 3–5 years to maintain and upgrade plant assets and equipment. Minimizing the amount of time and expertise needed is always critical to the success of the turnaround to meet budgets and deadlines.

For example, the owner/operator of a 460,000-bpd Gulf Coast refinery felt that they were servicing too many control valves for maintenance during each turnaround. They asked, "Why are we pulling so many control valves, and how can we reduce the number?"

To find the answers to these and other questions, the refinery turned to Fisher, its control valve vendor. After running tests and determining if valves really needed to be pulled, the control valve scope for this site's turnaround was reduced from 309 valves to 218, resulting in a cost savings of $577,000.

**Which valves need service during a turnaround?** Analyzing data from valve smart positioners using built-in diagnostic tools can reduce the number of control valves that need service by identifying the valves that are working well (**FIG. 1**). Refinery staff or the control valve vendor can leverage smart positioners and diagnostic software to determine valve health and the need for service.

For those valves needing service, these tests can provide information regarding the nature of the required work, allowing it to be planned in advance. Unplanned work is one of the main problems routinely encountered during turnarounds, leading to cost and schedule overruns—so reducing it is critical. This information can often include parts needed for service, allowing ordering in advance to avoid any expediting fees from the valve vendor.

**FIG. 1.** A technician can run valve diagnostic tests from a handheld device, a laptop or the control room.

Using initial installation baseline test data when the valve was installed, the control valve vendor can determine if a valve needs to be pulled for maintenance. The diagnostic tools in the smart positioner can show alert records stored in the device. If the control valve assembly is not performing correctly, alerts such as travel deviation, drive signal problems and supply air irregularities can reveal issues with a valve and assist in repair activities.

With the valve in bypass mode, a technician can run a series of tests. For example, Fisher's valve diagnostic software executes a 25-step functional performance test that starts at 50% and changes in 0.25%, 0.5%, 1%, 2%, 5% and 10% increments in both directions. Data is acquired to determine the minimum signal required to attain valve response, and an assessment is made of valve tuning.

Another diagnostic generates a "valve signature" plot, showing the integrity of the valve and actuator assemblies. The input (actuator net pressure) is plotted on the y axis, while the output (travel) is plotted along the x axis. By plotting data in this fashion, any increase or decrease in force is shown as a vertical change on the graph.

Control valves showing no alerts, an acceptable valve signature test and no stroking issues do not need to be pulled for maintenance.

**Takeaway.** Using smart positioners and diagnostics to see if a control valve really needs to be pulled during a turnaround, and spreadsheet software to track the status of all valves in the refinery, can substantially reduce turnaround time and costs. Identifying healthy control valves can reduce the number of valves that actually need service. A control valve vendor can assist with these and other turnaround needs, including defining the control valve service scope, reviewing and testing control valves, and onsite valve repair. ●

NEIL DALAL is a Refining Senior Sales Engineer for Emerson flow controls products based in Marshalltown, Iowa. He holds a BBA degree in marketing and an MBA from University of Iowa.

## OIL PRODUCTS MARKETS IN TURMOIL AS CORONAVIRUS INFECTS DEMAND

The oil products markets globally are caught between a rock and a hard place as the impact of ultra-cheap oil, which should be a boon for refiners, is mitigated by record low prices for gasoline and jet fuel.

While major oil producers like Saudi Arabia vow to pump at record levels and offer hefty discounts on their barrels, refiners, in theory, should be producing at maximum capacity.

"The extent to which (refinery) runs increase will quickly become constrained as product cracks reach a ceiling due to high inventory levels and weak global demand," consultancy Wood Mackenzie said.

**Jet fuel.** Jet fuel is one of the markets hardest hit by the virus outbreak as more and more countries shut borders and travelers shun flying. Before the outbreak, jet was seen as a key market for oil demand growth globally. Last week, British Airways owner International Consolidated Airlines Group (ICAG.L) said it would cut its flying capacity by at least 75% in April and May. Low-cost carrier Ryanair (RYA.I) plans to ground most of its fleet in Europe over the next 7–10 days and expects to cut seat capacity by 80% for the next two months.

Consultancy Rystad Energy is expecting jet fuel demand to fall by 12% globally or at least 800,000 bpd compared with last year.

Refiners will likely curtail jet fuel output in part by switching more processing capacity to diesel production.

**Gasoline.** As more and more cities and countries go into lockdown and people work from home, a negative impact on motor fuel demand is inevitable. In Europe and Asia, profit margins for making gasoline at an oil refinery are negative, meaning that a refinery is losing money producing the fuel.

With projections of leisure driving falling by 50%, U.S. fuel demand could drop to roughly 2.5 MMbpd. For 2020, that would cut gasoline demand by roughly 300,000 bpd–400,000 bpd, according to Rystad.

Road fuel demand in China alone, for diesel and gasoline, was down 1.5 MMbpd year-on-year in February, Rystad said.

**Diesel.** With the outlook for global economic growth looking gloomy, diesel, which is heavily used in industry, remains under pressure. While margins in Europe are far outperforming gasoline and jet fuel, lockdowns in Italy and Spain have sapped demand there.

"The return of more than 1 MMbpd of the Middle East's refining capacity from maintenance over the coming months will add further downside pressure to middle distillate cracks," Wood Mackenzie said.

The consultancy estimates that 6 MMbpd in crude distillation capacity is offline globally, which is providing some support to refining margins. ●

## LYONDELL HOUSTON REFINERY FCCU TO BE SHUT THROUGH APRIL

The gasoline-producing fluid catalytic cracker (FCC) at LyondellBasell Industries' 263,776-bpd Houston refinery is expected to remain shut through April after more damage was found inside the unit, Gulf Coast market sources said.

The 90,000-bpd FCCU was shut by a February 16 fire, which led to the discovery of large cracks in the unit's reactor. Until the discovery of more damage this week, the inspection of and repairs to the unit were expected to finish in the first week of April. ●


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# Five key innovation concepts impacting frontline engineers

**D. MICKLEM,** KBC, a Yokogawa Company; and **K. FINNAN,** Yokogawa

Frontline engineers and managers in refineries represent the large cohort of people who are, and will continue to be, impacted the most by Industry 4.0 shifts and trends. Their decisions and actions affect operations significantly. To best deal with these changes, it is crucial that 12 key areas (**FIG. 1**) for effective operations are given appropriate consideration.

The five key innovations described here can help cut through the noise of the vast array of new technologies. These innovations will be essential to understand and adopt as they provide a head start for delivering effective operations.

**Outcome-orientation.** There is a strong risk of applying technology for the sake of technology, especially with the pressure to deliver on the latest buzzwords: the Industrial Internet of Things (IIoT), Industry 4.0, Cloud, Edge, Big Data and Analytics. Engineers and frontline managers must instead work backwards from business goals and constraints by defining the approach and technologies to deliver on outcomes, rather than starting with new technologies and looking for places to apply them.

Being focused on outcomes and value as your principal concern will ensure you do not fall into the "inputs" trap. Examples of valuable outcomes are:

- Efficient delivery of value
- Discovery and capture of new value
- Shorter time to achieve value
- Sustainment of value achieved
- Competitive advantage.

**Understanding how solutions or decisions are determined.** "Black-box thinking" (educated guesswork) is not the future. If you have defined your own personal identity around knowing all the answers and being the expert in the field based on your experience, rather than data, you may find yourself getting increasingly disrespected (unintentionally) by the younger generation of engineers. These engineers need to understand how solutions or decisions are determined, and instinct and experience are becoming less acceptable answers. Engineers will require the ability to see, tune and customize the inner workings of the tools they use to solve problems. The value of experience in managing abnormal situations and knowing what "good" looks like will continue to be treasured, but how "good" is achieved will require broader input, especially given new technologies and the pace of change.

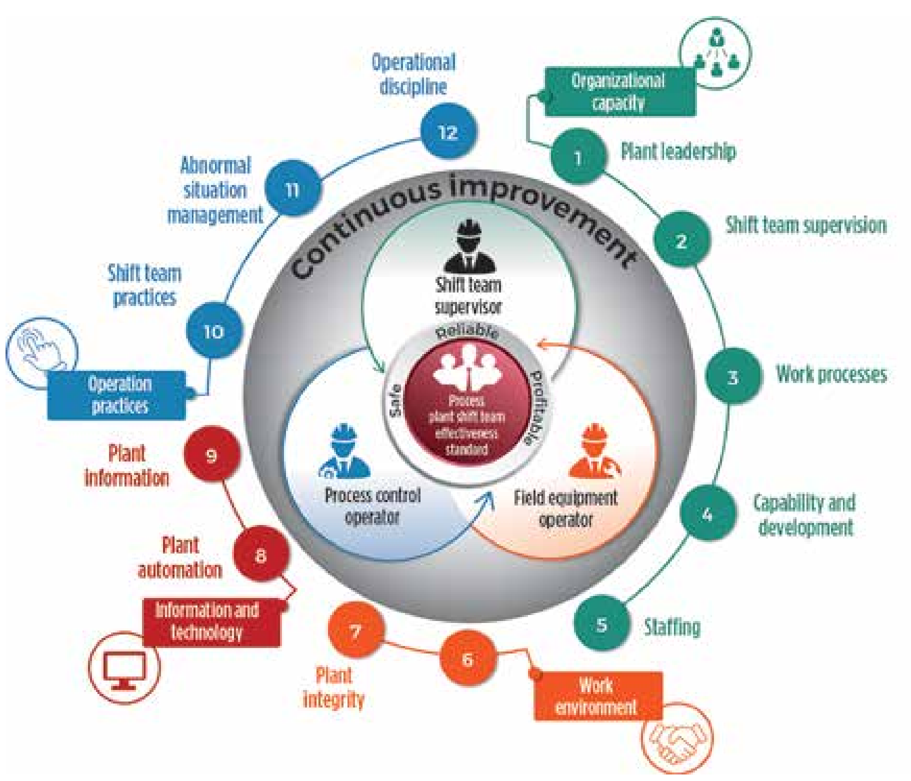



**FIG. 1.** To best face the impacts of Industry 4.0 shifts and trends, it is crucial that 12 key areas for effective operations are given appropriate consideration.



**Decisions made with expanded support from a scalable digital twin.** A digital twin is a virtual digital copy of a device, system or process that accurately mimics actual performance in real time, is executable and can be manipulated. It consumes data from connected sensors to tell a richer story—past, present and future—about an asset throughout its lifecycle. While individual point solution digital twins exist today, a future digital nirvana will use one multipurpose digital twin. It is unrealistic to achieve a future state in one step; more likely, it will be achieved by the connectivity of valuable, high-performing individual elements. Over time, these digital twins will become increasingly holistic and connected for multi-purpose and multi-dimensional deployment, using increasingly ubiquitous data sources. In this future world, no one vendor will have the best of everything; therefore, vendor agnosticism and high switch in/out capabilities in an enlarged digital twin platform will be key.

**Holistic, real-time actions through accessorizing.** Digital twin insights streamed in real time to wearable accessories will better equip frontline staff to make more holistic decisions. Sensory augmentation overlay of information on top of what is already observed and perceived by operators will deliver additional measured information to improve actions. New insights will become available for parts of assets where traditional measurements are not feasible or viable. This will increase instrumentation and asset productivity. The prediction of field device health and knowing the process interface conditions will allow frontline operators to make better decisions regarding shutdowns or failures. In the field, key operator actions will be captured, controlled and manipulated in real time through monitoring and control of work processes. This will minimize the learning curve for new operators, support change management and enable vastly improved scenario validation through operator training simulation and ISA106-compliant modular procedure automation solutions.

**Expert uses for less expert users, through new user interfaces.** Through native integration with new, commonly accepted visualization tools and user interfaces, complex technologies and associated capabilities will be made readily usable and accessible by less expert users. In many instances, the myriad technologies running behind the scenes will no longer be apparent to the user. This will, in turn, lower the barrier to entry for some engineering roles and enable additional engineering tasks to be undertaken more efficiently in other parts of the organization, thereby reducing complexity. Improved data connectivity will enable more efficient use of software and technology experts, potentially within a central global hub, to ensure that interfaces display the right data for users to digest and act upon. The outcome of this connectivity explosion will be improved efficiency of troubleshooting and optimization, as if the technology experts were present onsite.

Operational excellence will remain the desired outcome, but technological developments will continue to cause disruption for frontline personnel. Operations leaders across the refining and petrochemicals industry still believe that engineers' core skills are critical, but they also know that adaption in line with key innovation concepts is required. Frontline engineers and managers will continue to drive and deliver value sustainment, with adaptation to changes imperative for minimizing negative impacts. ●


**DUNCAN MICKLEM** is the Executive Vice President for strategy and marketing at KBC, a Yokogawa company. He began his career in the engineering industry with AMEC, where he provided health, safety, environment and liability advice on mergers and acquisitions. After moving to KBC, he has held business management roles focused on business development, strategy, restructuring and planning. Duncan holds a degree from the University of Exeter, UK, an MBA from Cass Business School, UK, and various marketing qualifications from Cornell University in New York.

**KEVIN FINNAN** is a System Consultant at Yokogawa Corporation of America with more than 30 years of experience with oil and gas measurement, process automation and SCADA systems. He was previously an independent consultant serving the automation and measurement industries, Vice President of marketing for CSE-Semaphore, and Director of Marketing at Bristol Babcock.

# Convert your refinery data into profits

**R. KAISER** and **R. JONES,** AIS Software

Crude oil is a mix of complex organic molecules, the composition of which is unique to its source. By itself, crude oil has little economic value. Its true value is realized only after it has been refined into usable commercial products. The art of refining seeks to optimize existing assets, processes and workflows to meet a dynamic product demand using shifting crude oil slates against a changing background of government regulations. Anything that can move the needle toward more production while using less energy to get there can make a significant improvement to the bottom line.

While digitalization has been touted as the next wave of industrial modernization, few are willing to risk their money and reputations on expensive new digital technologies like digital twins, robotics, drones, augmented realities, edge computing and the Internet of Things (IoT). The initial costs are high, the learning curves are steep and the returns on investment are uncertain. One proven, low-cost and low-risk opportunity that is frequently overlooked is extracting revenue from existing digital assets. According to a September 2019 *Forbes* article, "Refining the Oil and Gas Industry with IoT," oil and gas companies can realize a 5%–8% production improvement simply through the proper utilization of their data.

Your data is a complicated mix of sensor values, computed targets, alarms, lab results, rounds reports, text, images and end-of-shift notes unique to each refinery. By itself, this data has little value; however, real economic value is created when your data is refined into usable information streams that can be utilized by your personnel.

Your refinery operates like an army where each worker performs specific tasks: everyone's job is tightly interconnected with everyone working toward a set of common goals established by management. Success is measured by meeting these goals on time, within budget and with no harm to people, equipment or the environment. To achieve success, everyone must perform the right actions at the right times, and this requires two things: experience and information. Experience comes with time and training, and information comes from your data. The more you can do to enhance a worker's experience, as well as provide vital information they can access and use, the better the decision-making process becomes, leading to improved performance.

**Context.** Raw data does not equal information. Rather, it is nothing more than a collection of numbers and letters, and without context it has no value. Context imparts meaning, relevance, significance and understanding. Context is far more than just a descriptive name for a data point; it is a dynamic, multi-dimensional collection of critical metadata.

Adding context can be performed in many ways and imparts meaning, instructions and history. This dynamic process evokes a visceral resonance producing real effects. For context to be effective, the information must be filtered to meet the unique needs of each user.

In industry, context is the "tribal knowledge" used to make the right decisions and perform profit-generating actions. This context comes from many sources, is stored in many places, and is passed on verbally, added to drawings, documented in shift reports and recorded electronically in many different forms. It can take years to assimilate data and context into knowledge. Data changes frequently and context is unique to each location and job type. How information is processed and consumed varies greatly. Managing this context must be as effortless as possible. Rather than workers finding the right spreadsheet to populate, what if one central application collected and displayed this information and provided a simple, single-point-of-contact interface for viewing, inputting and editing this context?

The lowest-risk, highest-return method to extract the maximum value from your existing raw data is a process-monitoring-and-information-sharing platform. This is an enterprise-level software solution that aggregates your raw data across multiple stand-alone silos and provides specific, real-time, context-rich information to every worker, enabling them to make important process decisions and perform the correct profit-driven actions. At a minimum, it must:

- Be flexible enough to conform to your current work processes
- Use your existing IT and OT data infrastructure
- Adhere to increasingly vigilant industry standards and government regulations
- Access your stand-alone process historian, alarm console, lab data, rounds data and shift reports
- Provide fields where context can be viewed, input and edited
- Maintain single-point-of-truth data sources to avoid data duplication
- Provide fast and accurate search results for current and historical information

► See AIS SOFTWARE, page 9

# Improving crude unit overhead corrosion visibility and control

**C. CROSS,** SUEZ – Water Technologies & Solutions

Driving profitable refinery operations often requires owner-operators to balance feedstock flexibility and product optimization with asset availability and equipment reliability. Refineries today face periods of severe corrosion and fouling in overhead systems. An analysis report by NACE International states that the total annual estimated direct cost of corrosion in the U.S. is a staggering $276 B.

Often, these problems are tied to crude changes and are considered largely unavoidable, leading to overly conservative solutions at the exclusion of more complex but effective ones. This situation increases the costs and operational risks at a refinery. However, using modern equipment, sensors and techniques, it is possible to effectively mitigate overhead corrosion while maintaining flexibility, production and reliability. By taking advantage of available improved measurements, rapid testing and sophisticated analytics, much more granular and dynamic processing schemes can effectively be utilized where it was generally not possible previously.

**Root causes and modifications.** Introducing onstream measurement equipment, real-time monitoring and closed-loop control for chemical treatment helps reveal a variety of short-term episodic system fluctuations with significant impact on corrosion previously hidden from view. As an example, when considering a North American refinery that was experiencing an ongoing corrosion problem—but had apparently low chloride levels, as measured once per day by titration—after an onstream chloride analyzer/controller was added to the system, it was quickly realized that large chloride spikes were occurring intermittently and were not being detected by traditional means. The root cause for the spikes was later identified as the procedure used to dilute fresh caustic used before injection into the system. The practice was modified to eliminate the chloride spikes and improve corrosion protection. Further chloride control was achieved on this system by using the onstream controller to automatically control caustic injection, thereby greatly improving dynamic response to changing chloride concentrations. Such a method is dramatically more effective than manual adjustments performed a few times a day.

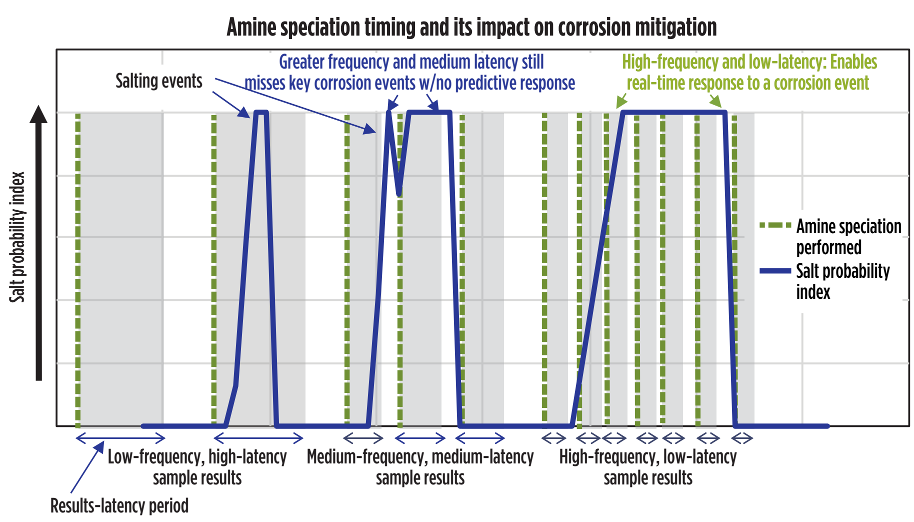



**FIG. 1.** Frequent and rapid amine speciation allows proactive mitigation opportunities.

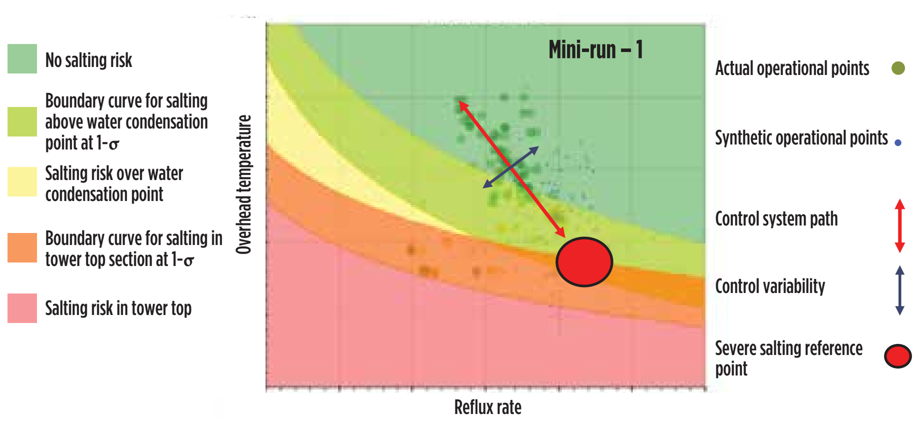



**FIG. 2.** Salting boundary map.

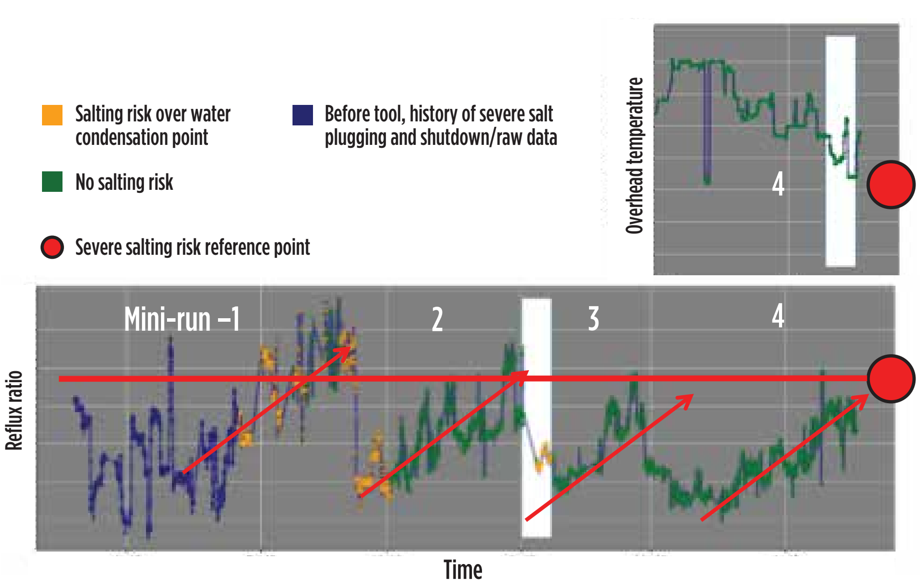



**FIG. 3.** Operational data mapping.

**Proactive corrosion control.** In parallel, more frequent and more rigorous amine speciation analysis with rapid generation of results provides a much larger amount of ongoing information about crude contaminant changes and their subsequent impacts on the corrosion behavior of the overhead system. To take advantage of the new information, digital platforms that effectively handle the data are used. Increasing the frequency and sophistication with which salt formation data is collected and analyzed allows refineries to proactively control corrosion and fouling while simultaneously achieving production and quality targets. **FIG. 1** illustrates how more frequent measurement of comprehensive salt formation probabilities, coupled with minimal time between measurements, calculations and results, enables enough granularity to resolve and identify individual corrosion events and their root causes. This capability, in turn, allows a more rapid and effective response to transient events.

Emerging opportunities or unforeseen events can quickly force changes to an existing crude diet. If the refinery has no previous experience with the challenges of the new crude slate, unforeseen problems with salt fouling and corrosion can occur. Traditional methods of salt point analysis do not provide enough information to mitigate salting proactively. The example here shows how SUEZ's SafeZone™ platform combines these technical advances to rapidly and effectively outline specific strategies to allow a refinery to reach production goals and prevent salt formation in the overhead system as it was processed. Initial runs on this system without the additional insight from SafeZone resulted in undetected aggressive corrosion, rapidly increasing delta P, a series of tube leaks, and significantly reduced naphtha rates over time. These events continued to worsen, eventually leading to an unplanned, early shutdown.

**FIGS. 2** and **3** show how correlated control changes during four mini-runs after restarting the unit led to initial aggressive salt fouling, and then to mitigation of the salting risk. This was accomplished by implementing the SafeZone platform and using it to make a series of small, dynamic operational changes in response to the improved visibility of corrosion risk in the system.

This crude unit, like many refinery overhead systems, uses circulating reflux for tower top temperature and pressure control. Independently changing the flow and temperature of the reflux circuit can cause simultaneous manipulation of both temperature and pressure, dramatically affecting salting potential. Additional dynamic variables affecting salt formation potential include steam rate, product rate, distillation profile, chloride concentration and amine concentration.

Salting in the air coolers is initiated characteristically as the water dewpoint (WDP) salting boundary, shown in **FIG. 2** by a yellow/orange shaded region, which is crossed as the temperature is lowered. In this specific case, the temperature was being lowered by increasing the reflux ratio to make additional diesel. As the temperature is further lowered and approaches the lower boundary curve, the probability of salting in the tower top also increases. This behavior can be characterized and quantified using a pair of dynamically changing salt point boundary curves with well-defined uncertainty bands, which change accordingly with dynamic fluctuations of controlling variables and their measurement uncertainties.

For mini-run 1, combined process changes initially caused the system to cross the WDP salt point boundary, indicated in yellow, and also begin to exhibit potential to form salts inside the tower top as the reflux ration rises above the red threshold. Color coding shows the degree of salting risk in both the tower top and condensing section, respectively, and compares the system's position on the salt point boundary map to key operational parameters that affect salting potential. The red dots on the salting map (**FIG. 2**) and reflux ratio chart (**FIG. 3**) show a system point with respect to these data where salting both in the air-cooler tubes and tower top is highly likely. This is a reference for comparison, but these data sets are not the only factors affecting the salting phenomenon, so these annotations are a loose reference. However, the salting boundary map and generalized salt relationships (including all drivers that significantly impact salting) are used to rigorously color-code the data to quantitatively evaluate salting risk.

Due to the combined impacts described above, as the reflux ratio approaches the red line, the probability of salt deposition over the WDP in the air cooler tubes increases dramatically. As the reflux ratio further increases in **FIG. 3,** the lower tower top boundary region is subsequently crossed in **FIG. 2.** When this occurs, the probability of salt deposition in the tower top also becomes likely.

During mini-runs 2–4, improvements to corrosion risk were achieved with minimal impact to overall production targets by using SafeZone to adjust these factors (and others) during ongoing operations. This case highlights how combining and applying several recent technical advances can improve visibility so that an ongoing series of small changes to the operational envelope can be used to dramatically lessen corrosion and fouling problems while simultaneously preserving production goals. ●

**DR. COLLIN CROSS** received his PhD in physical chemistry from the University of Oklahoma and completed a postdoctoral fellowship for the W.M. Keck Foundation. His work there entailed the synthesis, computational physics, modeling and NMR spectroscopy of self-ordering systems, including surfactants, liquid crystals, colloids and oligonucleotides. In 1996, Dr. Cross joined Betz Laboratories Inc., now SUEZ – Water Technologies & Solutions, as a Senior Scientist. During his time with SUEZ, he has occupied various roles as a process chemist including R&D Scientist, Process Chemical Group Manager, Enabling Technologies Project Lead, Project Management Lead and Product Line Management. All his roles have revolved around supporting the SUEZ process chemical business. He now occupies a position in the product applications organization supporting refinery corrosion as the Global Center of Excellence Leader.

## AIS SOFTWARE, continued from page 7

- Be accessible on any device to anyone on your intranet
- Allow authorized users to perform selected tasks
- Filter the displayed information by unit location and job assignment
- Recognize that users have unique requirements, and let them design the human-machine interfaces to meet their needs and optimize their actions
- Implement from the "top down" and operate from the "bottom up"
- Integrate context-rich information into end-of-shift reports and other important workflow documents.

In **FIG.1,** raw data is given context to generate usable information. When this information is used by experienced workers, it generates knowledge. A knowledgeable worker makes the right decisions that result in performing safe and correct actions. Performing more correct actions in a shift translates into fewer costly mistakes and improved productivity. Better decisions translate into higher profits. Operators who have worked in facilities where process-monitoring-and-information-sharing platforms have been implemented state emphatically that they will not go back to the way it was before.

**The promise of the Industrial IoT (IIoT).** Refinery assets are vast and interdependent networks. The size and scope of data being generated is already overwhelming. Variables that affect key business decisions no longer change every 30 days to 90 days; now, they change in a matter of minutes, or even seconds. The promise of the IIoT is to solve problems by generating more data to create a clearer picture. However, more data only generates more confusion for the end user. IIoT-enabled devices are here and are being installed in your refinery. It is important that the data they generate are properly filtered and given the right context to become a useful and profit-generating asset.

**Takeaway.** Production and quality improve when you provide your experienced workers with good information. You save money when the right decisions are made and good actions are performed. Your current data resources can be leveraged into substantial savings.

- Your raw data resources hold significant financial potential
- Raw data must first be given context to become useful information
- Context is multi-dimensional and comes from many different sources
- Good experience and good information result in good decisions
- A quality process monitoring and information-sharing platform provides a solid benefit to your refinery and your bottom line.

Considering your refinery's dynamic throughput and margins, what does a 5%–8% improvement in productivity and profitability actually mean to you? You just might find yourself saying, "We are never going back to the way it was before." ●

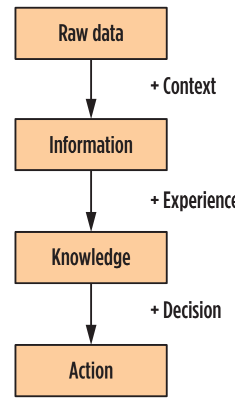



**FIG. 1.** Converting raw data into profit-generating actions.

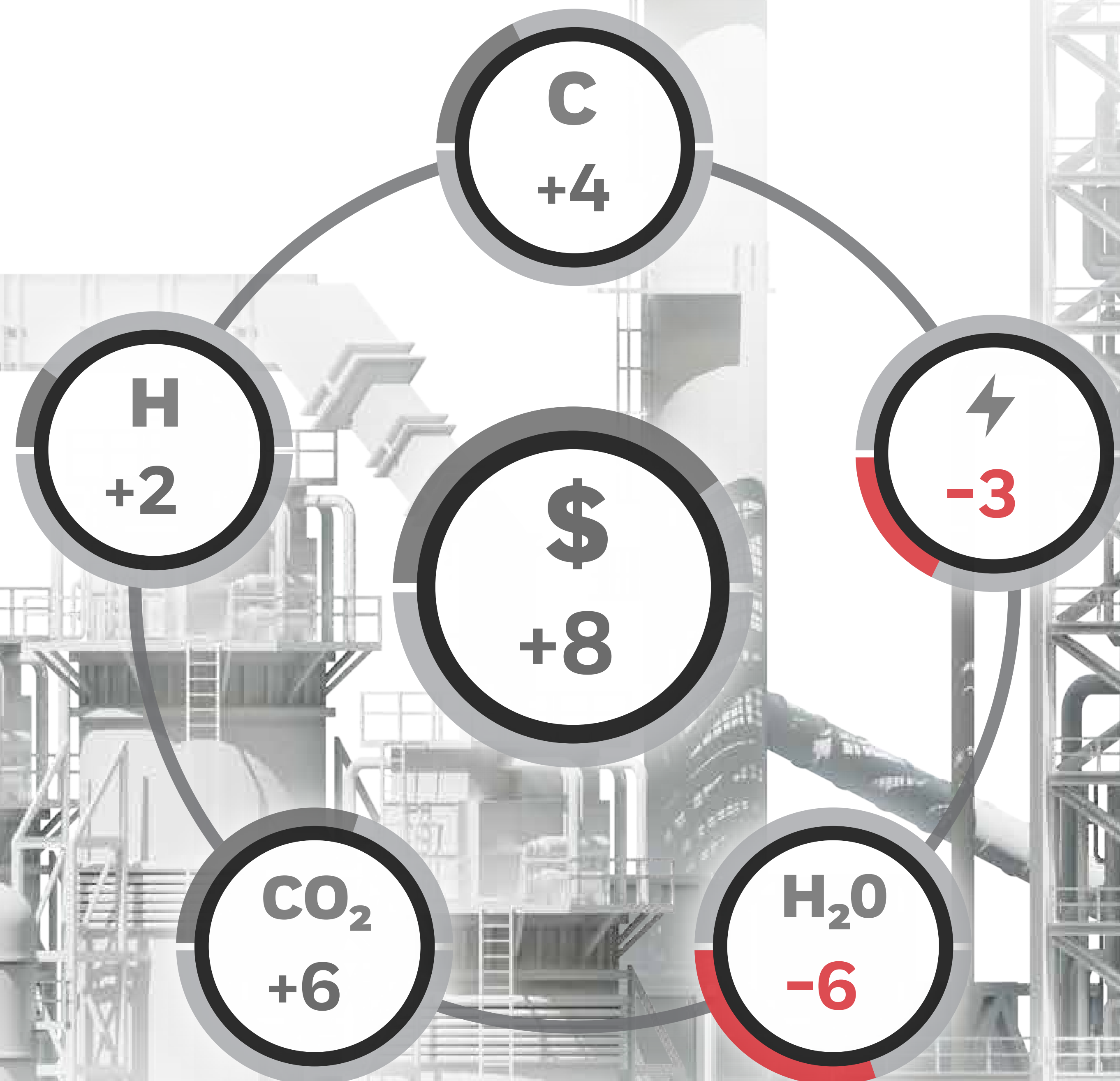
**RICK KAISER** is a licensed Professional Engineer with 30 years of experience in the oil and gas industry. He has extensive upstream and downstream experience as an automation engineer in the oilfields of northern Alaska and as a mechanical engineer at refineries in Washington State. He works for AIS Software in Bellingham, Washington as a Product Manager for software solutions used at oil, gas and petrochemical facilities around the world.

**ROGAN JONES** is Vice President and Co-founder of AIS Software in Bellingham, Washington. He graduated with a BS degree from California Polytechnic Institute (Cal Poly) in Pomona and has spent the last 27 years in the oil and gas industry. Mr. Jones has extensive coding and programming experience across multiple industries and has consulted with numerous clients around the world to improve operations management.

# TWELVE QUESTIONS TO DISCOVER A PATH TO GREATER PROFITABILITY

## Introducing a step-wise approach to the Refinery of the Future

To measure the performance of a refining and petrochemical facility investment, Honeywell UOP has identified six critical factors which form the basis of the UOP Six Efficiencies (E6) framework.




**UOP E6 is a framework and methodology that provides critical insights into an investment's profitability, guides better future investment decisions, and enables long-term competitive positioning.**

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## UOP E6 OPTIMIZED PROJECT PERFORMANCE

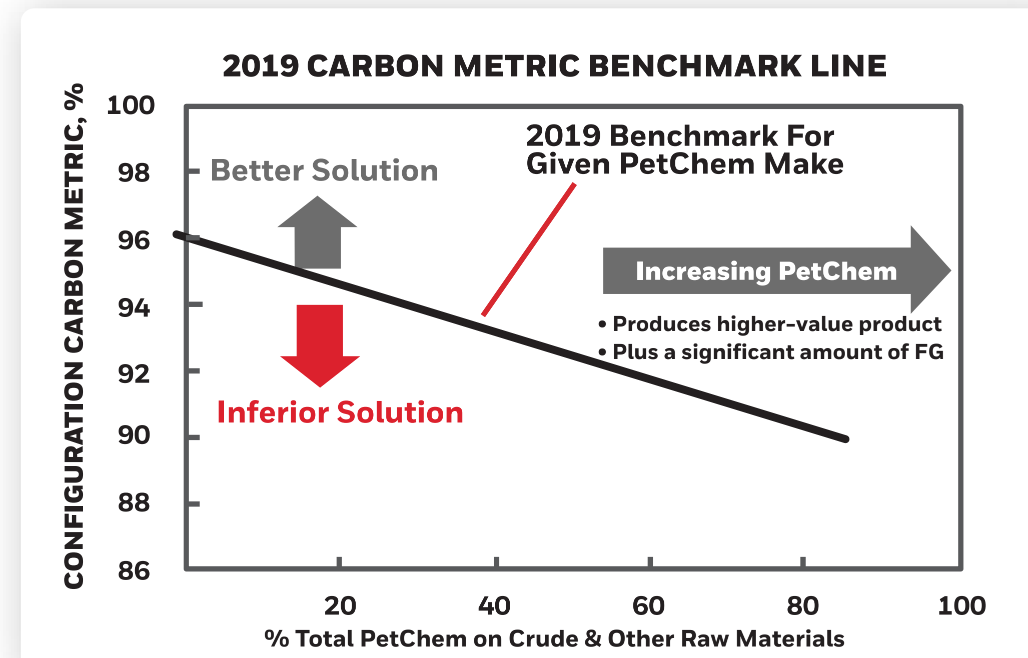
Designing a best-in-class facility or improving the operating performance of an existing asset requires a future-forward mindset. The UOP E6 framework is used to help firms develop their business vision while balancing six critical, scarce resources.

### Carbon Efficiency

The objective for any facility—new or existing—is to maximize the return on capital employed. This starts with carbon efficiency; put the right molecules in the right place.

To achieve optimum carbon efficiency:

- Minimize or avoid processes that reject carbon
- Implement technologies that are selective to high-value products and limit low-value byproducts



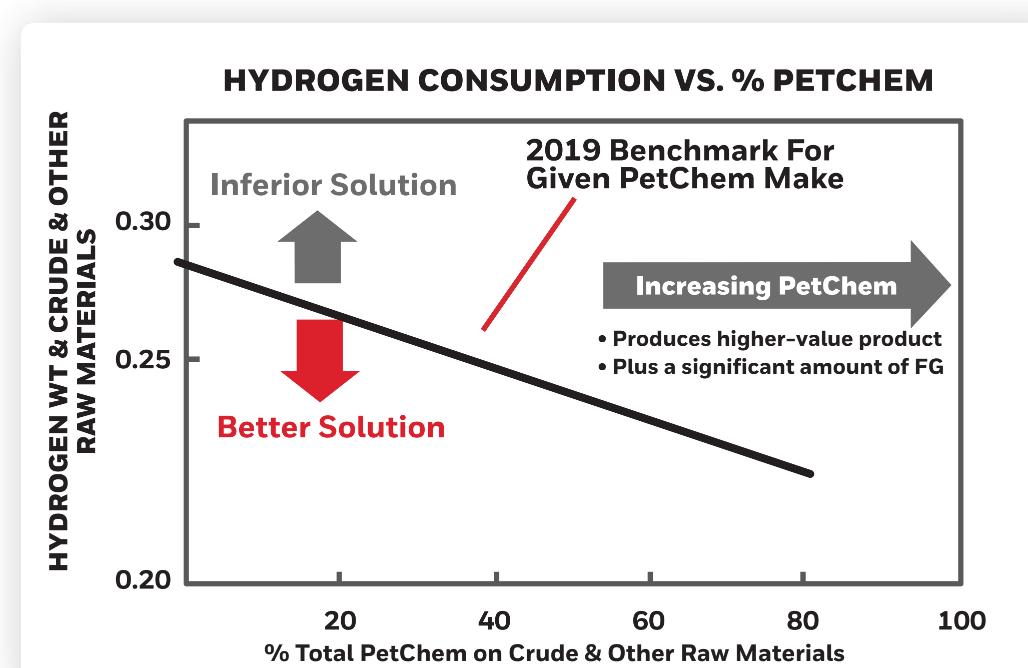

E6 best-in-class benchmark for carbon performance across the continuum from fuels to petrochemicals for an Arabian Light crude.

### Hydrogen Efficiency

Because hydrogen is an essential component of high-value materials produced from crude oil, the goal is to use as much intrinsic crude hydrogen as possible to make the desired product slate.

Efficient use of hydrogen depends on several factors, including:

- Level of petrochemical production which consumes less hydrogen than fuels production
- Crude quality, with lighter crude requiring a smaller hydrogen plant than heavier, lower-quality, lower-cost crude
- Vacuum oil gas (VGO) and residue upgrading strategy




Hydrogen is more efficiently used in petrochemical refining vs. fuels.

## TWELVE QUESTIONS TO SMARTER INVESTMENTS

The UOP E6 framework benchmarks performance in 6 critical areas. Ask yourself these 12 questions to help plan a path to sustainable, profitable integration.

C +4

1. Are you selling any products at a discount?
2. What streams do you want to create more of or avoid?

H +2

3. How constrained is your steam methane reformer?
4. Do you ever need to shift your operations based on hydrogen availability?

?

?

?

?

MORE Q&As RIGHT HERE TOMORROW

**Let's talk about the efficiency of your investments.**

# U.S. PET and aromatics markets face major restructuring

**M. BERMISH,** Wood Mackenzie Chemicals

Meeting current U.S. recycled plastics content goals by 2030 would significantly alter the region's polyethylene terephthalate (PET) resin and upstream aromatics markets, according to recent analysis from Wood Mackenzie.

The impact would be most felt in the PET resin market, with less of an effect on the upstream purified terephthalic acid (PTA) and paraxylene (PX) markets, although the influence would still be significant. Hitting brands' sustainability goals would require significantly less virgin PET resin, resulting in less PTA and PX needed to make virgin PET (VPET). Older and less efficient PET resin, PTA and PX plants would need to be closed to maintain balanced markets and operating rates. Monitoring industry progress towards these goals will also be crucial for all U.S. polyester chain players.

**Recycled PET bottles required to meet brand recycling targets.** Scenario #1: Recycled PET (RPET) is required to hit carbonated soft drink (CSD) and water PET bottles targets only. Wood Mackenzie's analysis estimates the amount of PET bottles required to meet the 25% RPET content goal for carbonated soft drink (CSD) and PET water bottles is equivalent to 1.5 MMt (millions of tons) in 2025 and 2.2 MMt in 2030 (**FIG. 1**). This would require an additional 400,000 t of PET bottles to be collected by 2025 and an additional 900,000 t of PET bottles collected by 2030. This is a 38% increase in PET bottle collections by 2025 and a 78% increase in PET bottle collection by 2030, as compared to our current baseline forecast. The country's recycling rate would need to sit at 45% by 2025 and 60% by 2030.

> The effects of meeting the content sustainability goals and displacing VPET in PET packaging are significant; however, they would be somewhat less intensive than the impact seen in the VPET market segment.

Scenario #2: RPET is required to meet target for all beverage PET bottles. The amount of PET bottles needed to meet the 25% recycled content goal for all beverage PET bottles is 1.7 MMt in 2025 and 2.9 MMt in 2030. In this scenario, current sustainability goals would require an additional 600,000 t of PET bottles collected and a 53% recycling rate by 2025. An additional 1.6 MMt of PET bottles would need to be collected, with a 78% recycling rate, by 2030. This is a 137% increase in PET bottle collections by 2025 and a 209% increase in PET bottle collection by 2030, as compared to our current baseline forecast (**FIG. 2**).

**What if recycled content goals are achieved?** Both scenarios suggest the current amount of PET bottles collected (on a tonnage basis) will fall far short of what is needed to meet the ambitious recycling goals set by many brands. Clearly, a large gap exists between existing corporate sustainability goals and the current state of the U.S. RPET market. Our previous analysis, undertaken earlier this year, found that up to $3 B in additional capital investment would be required to achieve current U.S. recycled plastics content goals by 2030. Nevertheless, major brand owners are committed to fulfilling these commitments in the face of consumer backlash.

**Impact on U.S. VPET market.** By meeting PET recycled sustainability goals, we expect the greatest impact to be on the U.S. VPET market. Based on our analysis, lost U.S. VPET production would be substantial by 2030.

In our first scenario, where RPET content goals are only met for CSD and PET water bottles, U.S. VPET production would decline by 400,000 t by 2025 and 900,000 t by 2030. With these assumptions in our baseline analysis, lost virgin PET resin production to RPET usage would equal 8% of total capacity in 2025 and rise to 19% by 2030. The loss of nearly 900,000 t of virgin PET resin production by the end of the next decade would be equivalent to nearly one Corpus Christi-sized plant, or two or more older legacy PET resin plants.

In Scenario #2, where content goals are met for all beverage bottles packaged in PET, U.S. VPET production would decline by 600,000 t by 2025 and by 1.6 MMt by 2030. Lost PET resin production to RPET usage would equal 13% of total capacity in 2025 and rise to 33% in 2030. The loss of nearly 1.6 MMt of virgin PET resin production by the end of the next decade would be equivalent to one Corpus Christi-sized plant, plus one to two legacy PET resin plants. In this scenario, approximately a third of total U.S. PET resin capacity would be replaced by RPET, resulting in a drastic change in the composition of the VPET resin industry.

All VPET producers would also need to be major PET recyclers to survive this transition. We have seen some activity in this space already, with Indorama's acquisition of Custom Polymers, DAK Americas' acquisition of Perpetual Solutions and FENC's acquisition of Phoenix Technologies. In addition, chemical recycling is a route that virgin PET resin producers are taking by introducing clean flake at the front end of the polymerization process. In fact, this may offset the decline in asset utilization rates due to greater use of RPET by downstream converters.

**Impact on the U.S. PTA market.** To make one metric ton of PET resin requires approximately 0.84 tonnes of PTA and 0.35 tonnes of monoethylene glycol (MEG). The effects of meeting the content sustainability goals and displacing VPET in PET packaging are significant; however, they would be somewhat less intensive than the impact seen in the VPET market segment. Lost U.S. PTA production would also be substantial by 2030.

In Scenario #1, U.S. VPET production would decline by 400,000 t by 2025 and by 900,000 t by 2030. This translates into a PTA production loss of 300,000 t by 2025 and 800,000 t by 2030. Lost PTA production would equal 7% of total capacity in 2025 and rise to 17% in 2030. The loss of nearly 800,000 t of PTA production by the end of the next decade would be equivalent to one large PTA production line in the U.S. This would likely result in significant U.S. PTA capacity rationalization over the next decade.

For scenario #2, U.S. VPET production would decline by 600,000 t by 2025 and 1.6 MMt by 2030. This translates into a PTA production loss of 500,000 t by 2025 and 1.3 MMt by 2030. Lost PTA production to RPET usage would equal 12% of total capacity in 2025 and rise to 30% in 2030. The loss of 1.3 MMt of PTA production by the end of the next decade would be equivalent to the output at the new Corpus Christi PTA plant. Nearly one third of total U.S. PTA capacity would be replaced, resulting in a major restructuring of the industry.

**Impact on the U.S. PX market.** To make one tonne (metric t) of PET resin requires approximately 0.57 tonnes of PX. Based on Wood Mackenzie's research, lost U.S. PX production would also be substantial by 2030.

U.S. VPET production would decline by 400,000 t by 2025 and by 900,000 t by 2030 in Scenario #1. This translates into a PX production loss of 200,000 t by 2025 and 500,000 t by 2030. Lost PX production would equal 6% of total capacity in 2025 and rise to 15% in 2030. The loss of approximately 500,000 t of PX production by the end of the next decade would be equivalent to one large PX production line in the U.S. Some PX capacity would likely be closed.

In the second scenario, U.S. VPET production would decline by 600,000 t by 2025 and by 1.6 MMt by 2030. This translates into a PX production loss of 400,000 t by 2025 and 900,000 t by 2030. Lost PTA production to RPET usage would equal 11% of total capacity in 2025 and rise to 27% in 2030. The loss of 900,000 t of PX production by the end of next decade would be equivalent to one large PX plant—similar to what is at Decatur, Alabama (Indorama)—or two smaller, older plants. In this scenario, more than one quarter of total U.S. PX capacity would be replaced. ●

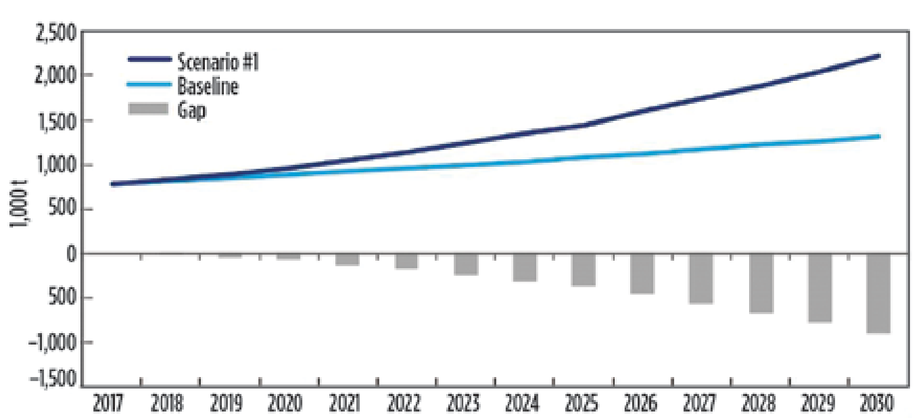



**FIG. 1.** RPET bottles baseline vs. required: Scenario #1.

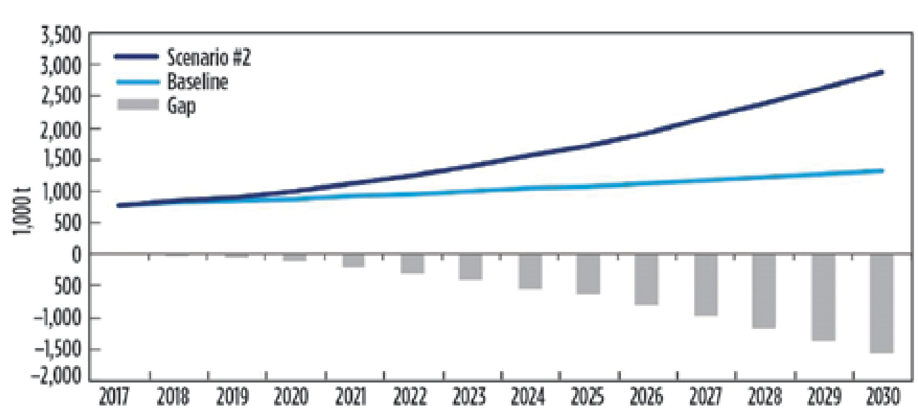



**FIG. 2.** RPET bottles baseline vs. required: Scenario #2.

**MICHAEL BERMISH** is a Senior Consultant with Wood Mackenzie Chemicals (formerly PCI). He has 36 yr of experience in the polyester industry. Based in the U.S., Dr. Bermish is primarily focused on the Americas markets for polyester and upstream raw materials. Prior to joining PCI, he was Director of Strategic Planning and Development and an Investor Relations Officer for Wellman Inc., a leading polyester producer.

**AFPM,** continued from page 3

today's bigger cars, trucks and SUVs are travelling about 5.6 miles more per gallon than cars from the last decade. During this same time, horsepower increased 11%, demonstrating that technology is allowing companies to meet consumer demand while also improving the environment. Electric vehicles represented less than 1% of auto sales during this time period.

The weight of recent vehicle models is similar to the weight of model year 1975 vehicles, but today's vehicles have significantly better fuel economy and more horsepower than their 1975 counterparts. Between 2004–2017 alone, vehicle fuel economy increased 29%, according to the EPA (**FIG. 2**).

While it will cost the industry to make modifications to produce the new, higher-octane fuel at a national scale, initial production can begin quickly at some refineries using existing hardware, enabling a consistent rollout nationwide, AFPM's Thompson said.

**Fluids and components.** Along with higher-octane fuels, refiners and petrochemical companies are also helping automakers produce more fuel-efficient engines and vehicles through improvements in engine oils and lightweight plastic and composite components.

While fuel is the most obvious contributor to fuel economy, motor oil is also critical. Viscosity, or the thickness of the oil, is the critical factor in reducing engine wear and can also be an impediment to increasing fuel efficiency.

"Viscosity is the real drag," said Mark Sztenderowicz, Global Manager of product development for automotive engine oils at Chevron's Oronite lubricant additives division. "Moving a thicker fluid takes more energy. If you reduce viscosity, less energy is consumed in the moving parts and in pumping the fluid around the engine."

In the early 1990s, most car engines required oil grades such as 10W-40 or 5W-20, with the lower number representing a lower viscosity. Newer formulations, such as 0W-20 and 0W-16 have even lower viscosity. Motorists could see an improvement in fuel economy just by switching from 10W-40 to 0W-20, Sztenderowicz said.

As refiners and chemical companies have focused on making fuel and motor oils cleaner and more efficient, petrochemical manufacturers have turned their attention to car components in the quest for higher fuel economy. The EPA estimates that every 100 lbs of weight removed from a vehicle increases fuel economy by 1%–2%.

Advanced composite (fiber reinforced plastic) components have become essential to controlling vehicle weight as consumers demand more gadgets and power from their cars. LyondellBasell works with automakers and suppliers to develop state-of-the-art compounds used in components that are as strong as steel, but far lighter. For example, Jeep replaced the steel liftgate on its Cherokee with a plastic one for the 2019 model year, saving 12 lbs of weight.

"Our innovation teams continuously partner with Tier-1 molders and original equipment manufacturers (OEMs) to unlock light-weighting opportunities in vehicle design," said Neil Fuenmayor, Market Development Manager for automotive products at LyondellBasell.

LyondellBasell is also helping to develop components that do not require painting, which reduces paint shop emissions at auto plants and improves the recyclability of components, Fuenmayor said.

The improvements in lubricants and vehicle light weighting, combined with enhanced engine design and high-octane fuel, are essential in developing cars that run more efficiently and safely, creating the most cost-efficient and consumer-friendly pathway to cleaner air. ●

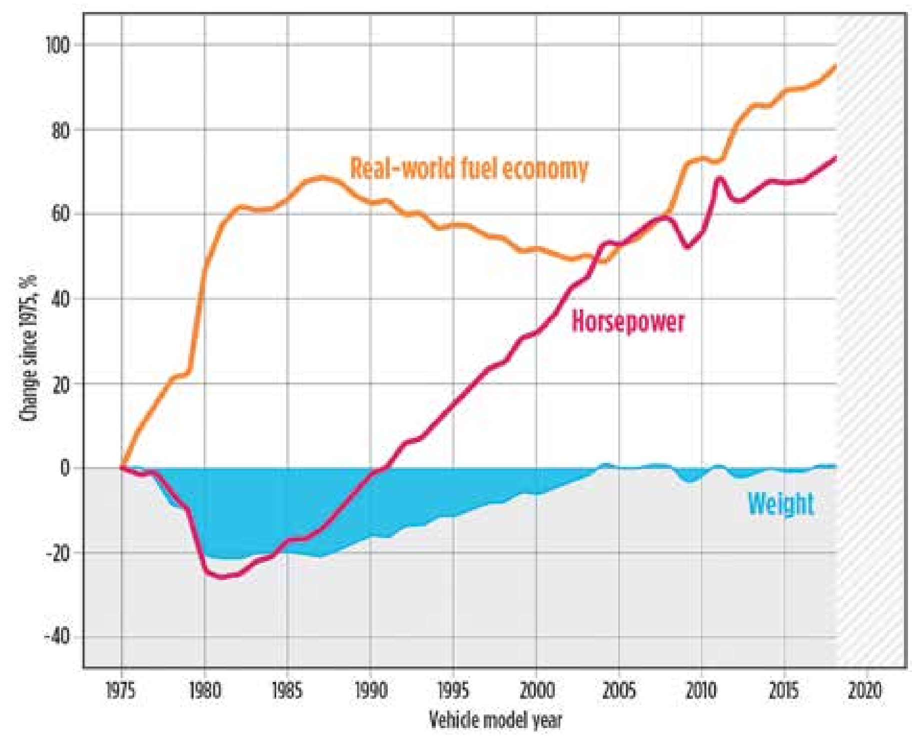



**FIG. 2.** Estimated real-world fuel economy, horsepower and weight since model year 1975. Source: U.S. Environmental Protection Agency.

# Get the most out of your logistics asset

**A. ROMERO** and **J. FENG,** KBR Technology

Refiners must adapt to changes in market demand and regulations. During revamps and expansions, considerable focus is placed on process units. Logistics assets such as storage tanks, pipelines, shipping and road traffic are often overlooked. This can lead to high demurrage charges, congested roads and even unscheduled shutdowns of process units. Therefore, it is important to cover the logistics aspects of the assets and have the ability to perform a complete and objective assessment on their capacities.

For refiners with multiple assets, logistics can be complicated. As illustrated in **FIG. 1,** crude oil is transported between refiners A and B, and the products are exported by vessels. Local consumption of refined products is met by pipelines and trucking. Often, the two assets have different processing capabilities (e.g., one refinery can process bottom-of-the-barrel streams and the other cannot). To take advantage of such processing capabilities, intermediate products are transported between the two assets by barge or shuttle tanker.

KBR uses logistics analysis to address all aspects of the logistics assets, ranging from tankage sizing to the entire pipeline/marine/tankage/trucking operation. The results of the analysis can help get the most out of your assets.

**Understand your asset.** The first step of the logistics analysis is to get an objective view of the assets. For example, it is common for a refinery to have tanks that are no longer in service. This is particularly true due to IMO 2020, where fuel oil demand will be lower or eliminated. Once the tanks are categorized, the next step is to develop a tank compatibility table like that shown in **TABLE 1.** In general, compatibility is based considering the product service or the component of service product—i.e., use the diesel component tanks as diesel tanks and use gasoline component tanks as gasoline tanks. A distinction can be made on whether the change of service is permanent or temporary.

**Logistics asset optimization.** After the assets are defined, KBR uses a computer-based logistics model to simulate the performance of the assets' logistics over time. For a refinery, the simulation model includes crude tanks, intermediate tanks, component tanks, export tanks, marine berths, vessels, pipelines and truck loadings. **FIG. 2** is a snapshot of a refinery logistics model.

Weather events, draft limitations, vessel arrival patterns, scheduled and unscheduled maintanance, tank switch-over during turnaround, competing traffic and product markets are included in the model. Model outputs can then be analyzed for conclusions, in particular the cost benefits of modifying an asset, such as a new storage tank.


**FIG. 1.** Integration of logistics assets.

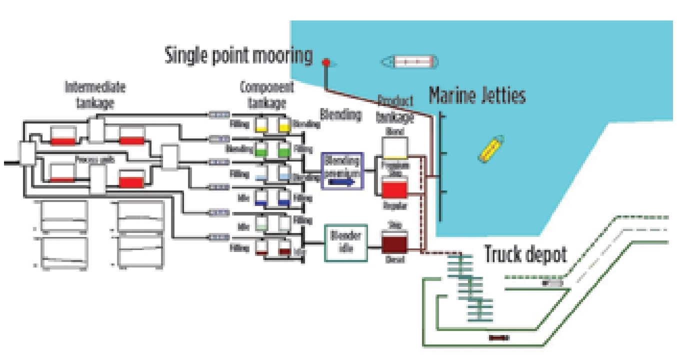



**FIG. 2.** Logistics simulation model.

The results of the analysis are the key performance indicators (KPIs), such as throughput and demurrage, and a ranking of events that have an adverse effect on the KPIs. Strategic investment can then be made to address the bottleneck.

Cost data can be assigned to each step of the logistics chain: for example, the cost of storage tanks, hourly labor rate, shipping cost, and value of feedstock and products. Comparsions can then be made on the CAPEX and OPEX of different options. For multisite refinery operations, swap contracts can also be evaluated. This is particularly useful in situations where sites are separated by distances and the assets have different processing capabilities and serve different markets.

Using the logistics analysis, the production and turnaround schedules for all assets can be evaluated against the seasonal demand of each market to ensure that the right product is produced at the right asset, at the right time and with proper contingency plans.

Benefits that were achived using our Logistics Analysis include:

- A 25% increase in crude product shipments for crude loading and shipping (rail and pipeline) using the existing infrasturcuture, resulting in savings of \$17.5 MM.
- A savings of 2%–3% API giveaway on crude blending for a 1.2-MMbpd crude blending and export terminal, saving \$87.6 MM annually.
- Saved demurrage charges and increased on-time product deliveries for a 300,000-bpd refinery by \$1 MM annually.
- An increased uptime of a 400,000-bpd refinery by 1% by optimizing the inter-unit tankage.
- Schedule assurance for a muli-billion-dollar project by continuously evaluating the shipment schedule and the near-term weather forcast.

> During revamps and expansions, the logistics aspects of the assets must be covered, and a complete and objective assessment of their capacities must be performed.

Another application for the logisitcs simulation model is to analyze the impact on adjacent communities due to the additional road traffic. In the U.S., many refining and petrochemical facilities are located in congested areas close to local communities. The logistics simulation model predicts the congestion in the road network during construction and after the facility is expanded.

Mitigating measures such as additional turn lanes and traffic lights can be planned for and permitted ahead of time to minimize the impact to local communities.

**Remote performance monitoring.** Near-real-time performance monitoring is a must to ensure the asset is performing well after revamp and expansion. The future trend of Logistics Analysis is to use near-real-time data to initialize the model and then predict the performance going forward. The ability to incorporate the real-time data makes the logistics analysis an important component of an integrated planning-scheduling-logistics solution for a refiner.

In addition to facilitating real-time advisory, remote performance monitoring is a vehicle for developing and deploying various algorithms to predict the behavior of the plant. This can be termed as proactive and predictive analysis and helps plant operators to prepare for changes beforehand due to the information provided by data analytics.

Developing a successful data analytical model must start with process knowledge. KBR uses first principle models to correlate and rank different parameters that can affect operation.

**Takeaway.** The benefits achieved from the logistics analysis go beyond just optimizing a few tanks. The results provide the foundation of a holistic, end-to-end cost/benefit analysis of the entire supply chain and identify the most effective contingency plan to de-risk the supply chain. For an operating asset, the logistics analysis can be a reality check for present operation, as well as a verification of the logistics capacity to support the expansion. U.S. refiners can benefit greatly from this analytical tool since adding tankage and pipelines are often cost-prohibitive and the existing logistics infrastructure must be fully utilized.

For information on KBR's suite of technical services, visit the KBR tabletop in the exhibition area or contact us at www.kbr.com/en/contact-us.

**TABLE 1.** Compatible services for the same tank

| Tank compatibility | | | Possible service | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type service | | | RON 97 | RON 93 | Regular diesel | Fuel oil | Reformate | HT diesel | Crude | Vacuum resid |
| 1 | Crude tank | Primary crude | | | | x | | | x | |
| 2 | Intermediate tank | Alkylate | x | X | | | x | | | |
| 3 | Intermediate tank | Heavy cat naphtha | | X | | | x | | | |
| 4 | Intermediate tank | Hydrotreated diesel | | | x | | | x | | |

# Process engineering, optimization and advanced process control

**A. KERN,** APC Performance LLC

A recent *Hydrocarbon Processing* "Industry Perspectives" survey found that process engineering and optimization is the number-one topic that readers want to read about most. Process engineering and optimization rated higher than the next-highest topic (maintenance and reliability) by a factor of 2:1, and higher than every other topic by a factor of at least 4:1. Process control and instrumentation made the top ten list, albeit below process engineering and optimization by a factor of 7:1.

These results suggest that managers and engineers want optimization more than ever, but also that optimization makes the most sense to them in the context of process engineering, rather than process control. Exactly how do optimization, process engineering and advanced process control (APC) work together in an industrial process operation environment?

**Optimization by the layers.** FIG. 1 is a common high-level view of process optimization. However, what does optimization look like from a more detailed, low-level view, especially for sites that consist of multiple interconnected units, such as oil refineries or petrochemical plants?

The top tier is site-wide production planning and optimization (PPO). PPO sets production plans and optimization goals for each unit based on feedstocks, prices, commitments, blendstocks, equipment in service, etc., in addition to (at least rudimentary) models of individual unit performance capabilities and the inter-relationships between units. From this activity, each unit receives its production "marching orders," usually on a daily basis. This tier is the best-known aspect of optimization, and is the only tier that can *generate* a complete site-wide optimization solution comprising updated production targets, optimization goals and constraint limits, across all units. Subsequent (lower) tiers ideally should *implement* or enforce the PPO optimization solution, not generate new or different solutions.

The second tier in optimization takes place at the unit operation level, where each unit operating team implements their piece of the site-wide optimization solution. This tier is perhaps best represented by process engineers (also sometimes called production or operation engineers), who are often the most active players when it comes to following up on production plans and optimization goals in actual operation throughout the day, week and month. They tend to ensure that targets, both short-term and long-term, are on track, and often pursue possibilities for exceeding targets, such as extra volume, higher yield or greater efficiency. When actual production either exceeds or falls short of PPO plans, it is often the process engineer who troubleshoots operation, identifies options and feeds this plant intelligence back to the business planning side for continuous improvement of the planning cycle. While the first tier is optimization *planning,* this tier is optimization *boots on the ground.*

A third tier of optimization activity is advanced process control (APC). The role of APC in operations and optimization is best understood as being ancillary to the role of process engineering—i.e., to implement the PPO optimization solution, rather than to generate new or different optimization solutions. Additionally, the important distinction between the role of APC and the role of the process engineer is that APC is closed-loop and on the job continuously, whereas process engineers (and other operating personnel) take breaks and have compet-

See APC, page 17

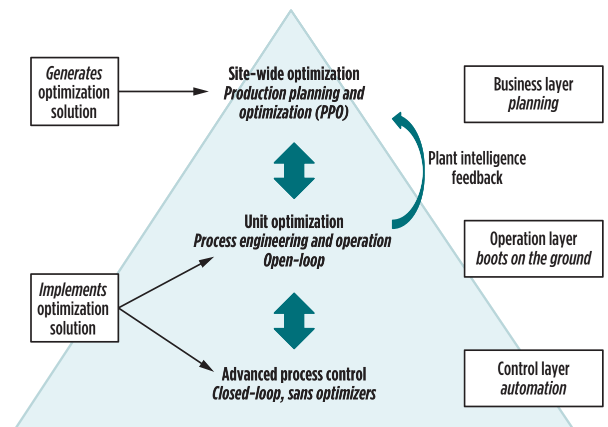



**FIG. 1.** A typical process optimization schematic, with additions to highlight important aspects of APC 2.0, especially the distinction between optimization solution generation vs. implementation, and the role of APC multivariable control in a closed-loop implementation support role, rather than acting as a separate, independent optimization activity.

# EIA: Less petroleum and other liquids consumed in the U.S. come from refineries

A recent U.S. Energy Information Administration (EIA) *Short-Term Energy Outlook* (*STEO*) forecasts that in 2021, U.S. consumption (as measured by product supplied) of total petroleum and other liquid fuels will average 20.71 MMbpd, surpassing the 2007 pre-recession level (**FIG. 1**). However, since the 2007–2009 recession, the fastest-growing components of U.S. liquids consumption growth have not been fuels such as motor gasoline or distillate fuel, but rather hydrocarbon gas liquids (HGLs) and ethanol—two components that are mostly produced outside of petroleum refineries. Petrochemical facilities consume HGLs as feedstocks in the growing production of plastics, resins and other materials, and ethanol is blended with gasoline.

HGLs and ethanol consumption have collectively grown from 2.6 MMbpd in 2007 to 4.1 MMbpd in 2019. The remaining portion of total petroleum and other liquids consumption—nearly all of which comes from petroleum refineries—has fallen from 18 MMbpd in 2007 to 16.4 MMbpd in 2019. In 2021, the EIA forecasts that U.S. demand for principally refinery-produced products will average approximately 16.3 MMbpd, similar to its 1997 level.

HGLs—a group of products that includes ethane, propane, normal butane, isobutane, natural gasoline and refinery olefins—have been the main driver of U.S. petroleum and other liquids demand growth since 2007. Domestic production and consumption of HGLs have increased with rising natural gas production and rising petrochemical sector demand. As a result, EIA forecasts that U.S. HGL consumption will average 3.45 MMbpd in 2021, or 1.27 MMbpd more than in 2007.

Except for jet fuel, EIA expects lower U.S. consumption of refinery-produced products in 2021 than in 2007. For example, declines in the use of heating oil for space heating and transportation efficiency gains have limited the increase in distillate consumption in the U.S. Consumption of the petroleum-based component of U.S. motor gasoline has yet to surpass pre-recession levels due to increased vehicle fuel efficiency and increased blending of ethanol, which is almost exclusively produced outside of petroleum refineries. EIA forecasts that the U.S. will consume 0.57 MMbpd less refinery-produced gasoline in 2021 than in 2007, but ethanol consumption will be 0.49 MMbpd higher.

Some HGLs can be produced by both crude oil refineries and natural gas processing plants (**FIG. 2**). HGL production at natural gas processing plants has risen along with U.S. natural gas production. EIA expects HGL production from natural gas processing plants to continue to increase to 5.5 MMbpd in 2021. Meanwhile, refinery HGL production has remained flat in recent years at about 0.6 MMbpd.

The large increase in U.S. HGL production and the resulting low prices have led to large investments in U.S. infrastructure to extract and transport HGLs to market and investments in petrochemical facilities to consume HGLs. Many of these facilities consume HGLs as feedstocks in the production of plastics, resins and other materials.

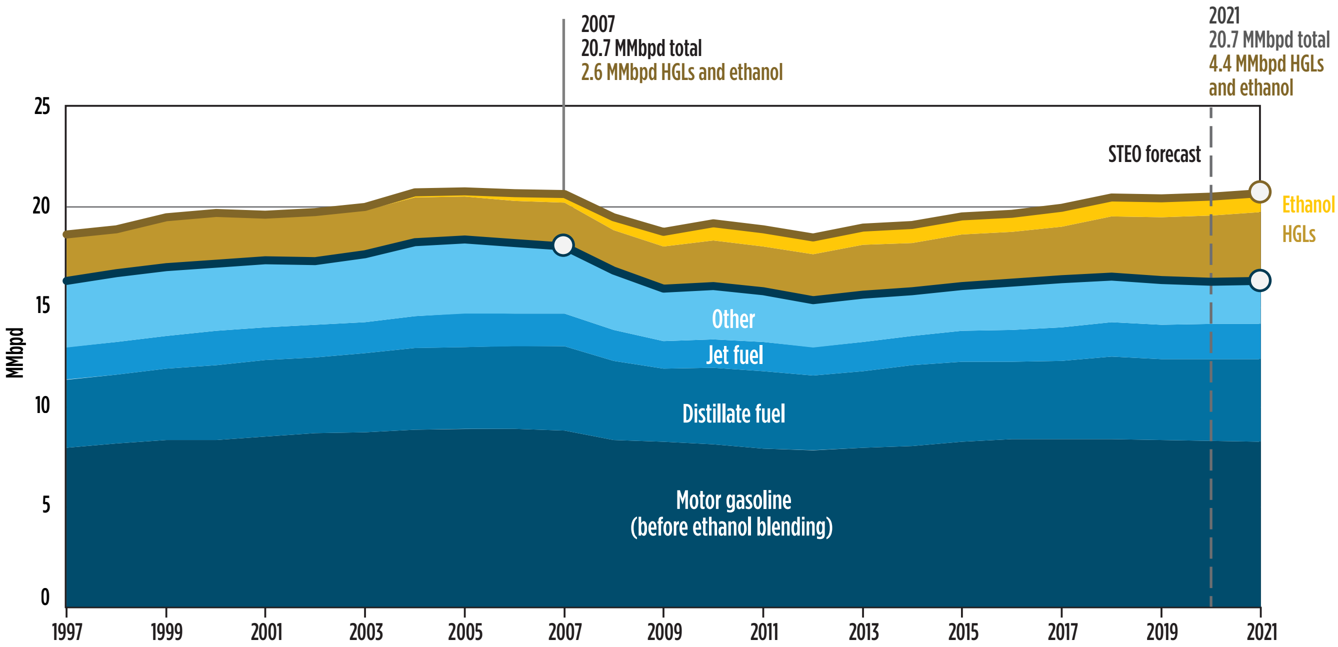



**FIG. 1.** U.S. total petroleum and other liquids consumption (1997–2021), MMbpd. Source: U.S. Energy Information Administration, *Short-Term Energy Outlook.*

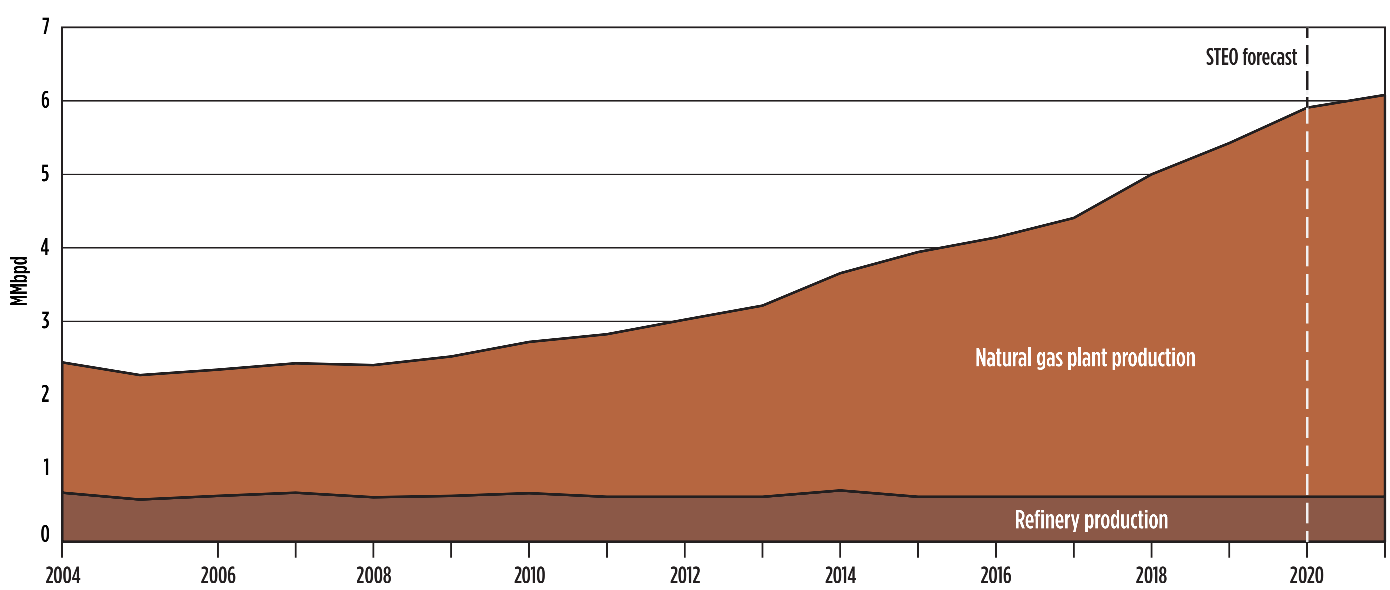



**FIG. 2.** U.S. hydrocarbon gas liquids production by source (2004–2021), MMbpd. Source: U.S. Energy Information Administration, *Short-Term Energy Outlook.*

## AFPM: IMPACT OF SMALL REFINERY EXEMPTIONS (SREs) ENTIRELY POSITIVE

A great deal of misunderstanding persists about the impact of small refinery exemptions (SREs). Some voices continue to push a narrative that relief-exempting qualified small refineries from Renewable Fuel Standard (RFS) compliance costs has destroyed ethanol demand and led to the idling and closures of several plants. In fact, the impact of SREs has been overwhelmingly positive for U.S. consumers and critical for many manufacturing facilities that produce the fuels that power America's economy.

To have the honest discussion Americans deserve about the RFS, we need to acknowledge three things:

1. **U.S. ethanol consumption reached all-time highs in 2019.** Official EIA data shows that ethanol blending and consumption reached record highs in 2019. In the wake of SREs, demand has actually increased.
2. **U.S. biofuel production has gone down.** The reason for these declines isn't a "lost market" for ethanol here at home. Rather, production ramped up in 2017 and 2018 on the expectation of growing exports to China, Mexico and Brazil—growth that never materialized while overall exports fell. Biodiesel experiences a severe price disadvantage in the market, costing as much as $1.50+ more per gallon than petroleum diesel, and the lapsed federal biodiesel tax credit (which has now been reinstated) likely contributed to lower production, as well.
3. **It is impossible today to absorb 15 Bgal of ethanol into U.S. gasoline.** Congress set RFS biofuel blending targets in 2007 with an expectation that the U.S. would be using 160+ Bgal of gasoline this year. We're using about 20 Bgal less. With lower fuel consumption and lack of consumer interest in higher-ethanol-content fuels (E15, for example), it is impossible to sell a full 15 Bgal of ethanol to U.S. drivers. Erasing SREs won't change that.

Congress created SREs at the outset of the RFS to provide relief when the mandate can't be achieved and compliance costs soar. Exemptions don't reduce demand for competitively priced biofuels like ethanol. They provide vital savings for facilities that would otherwise be required to purchase second-hand credits or import foreign biodiesel to satisfy the law. Waiving those burdensome compliance steps amounts to real savings for refineries and consumers.

The larger the RFS mandate, the bigger the frenzy is for second-hand RIN credits. SREs protect against RIN scarcity and price spikes without reducing actual demand for ethanol.

The record is clear that ethanol consumption has grown while SREs have worked to contain RFS regulatory costs for all refineries.

**APC,** continued from page 15

ing priorities. The closed-loop nature of APC brings many obvious opportunities to improve upon the task of optimization implementation, over what can be expected from the open-loop efforts of engineers and operators. APC brings the same well-understood benefits as closing single-loop controllers, except APC controllers in effect close multiple loops together, using multivariable control algorithms. This tier is optimization automation.

**Optimization in the control layer?** In this low-level look, the role of the conventional embedded APC optimizer at the control layer relative to the PPO solution at the business layer comes into question (noting that conventional APC comprises a multivariable *controller* and an embedded *optimizer*).

The embedded APC optimizer may have been necessary in the 1980s, when few other computer optimization programs existed in either the business or control layers, but today the embedded APC optimizer can be seen as extremely limited relative to modern business layer PPO solutions, which encompass more extensive (site-wide) information and employ modern planning and optimization tools that have kept better pace with technology. Can the PPO solution in the business layer be adequately leveraged by the APC controller in the control layer, thereby potentially eliminating the APC embedded optimizer—which (after model maintenance) has been one of the largest sources of APC's continued high maintenance and high total cost of ownership?

Experience has shown that communication requirements between the optimization solution and the APC controller are not nearly as extensive or time-sensitive as it was once thought they might become. APC *control* must run at high frequency, since process values change in real time, but *optimization* does not need to run at high frequency, because the optimization solution normally does not change in real time. Typically, the PPO plan is updated daily and affects only a handful of parameters that need to be pushed to the control layer, which are normally passed down through the operating chain of command rather than via network connectivity. This allows for vetting and awareness of planned changes before they are made, and allows operations to time the changes when necessary, based on conditions on the ground. This picture suggests that leveraging the PPO solution by APC is not only possible, but for many purposes has already become established as industry best practice.

Another rationale for the embedded APC optimizer is its role in arbitrating the use of manipulated variables (MVs) when more than one is available to address a particular constraint control or optimization objective. However, the majority of APC applications in industry resorted long ago to using APC optimizer prices as course tuning parameters, rather than real prices. This has the effect of simply *prioritizing* the use of MVs, rather than assigning them based on (often fragile) economics.

In industrial process operation, MV choice is primarily an operation question and not a purely economic question. This experience suggests that in many APC applications, a straightforward prioritization scheme may be a more reliable and effective approach to MV arbitration than an economic optimizer.

**New optimization and APC paradigm.** The reader survey results reflect sentiment for a more effective optimization paradigm, especially in view of several inefficient legacy aspects of the conventional "APC 1.0" paradigm. The APC 1.0 paradigm remains on a trajectory of high cost and maintenance, and end users are no longer confident that this trajectory can (or should) be overcome without fundamental changes.

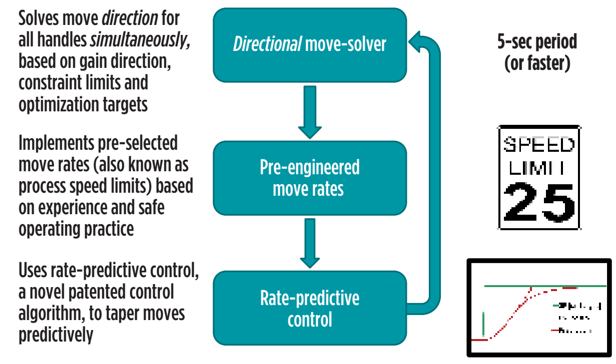



**FIG. 2.** A proprietary APC 2.0 solution implements multivariable control and optimization without reliance on detailed models or an embedded optimizer.

One potential change in a new "APC 2.0" paradigm, from an optimization standpoint, is elimination of the embedded APC optimizer in favor of better leveraging of the PPO solution. This has the potential to bypass problematic aspects of the embedded APC optimizer, while leveraging increased value from the PPO activity (**FIG. 2**).

Another potential change is an organizational change, wherein APC fills a straightforward closed-loop optimization implementation support role, rather than acting as its own optimization activity, separate and independent of PPO, which has led to several inefficiencies. ●

**Allan Kern** is a control engineering consultant with APC Performance LLC, where he is responsible for advanced process control, including XMC. He has 35 years of industrial process control experience and has authored numerous papers on a wide range of practical process automation solutions. He earned a BS degree in chemical engineering from the University of Wyoming and holds professional engineering licenses in chemical engineering and control systems engineering.

# Never settle: Continuous catalytic improvements deliver economic value

**H. RASMUSSEN** and **S. A. ROBLEDO,** Haldor Topsoe

Haldor Topsoe has been on the forefront of technological discoveries in hydroprocessing for the past 40 years and continues to explore the possibilities within this area.

In the late 1970s, Topsoe's researchers discovered that hydrodesulfurization (HDS) activity correlated with the presence of CoMoS active sites. In the 1980s, Topsoe was the first to determine that sulfide CoMo/NiMo slabs could be prepared with reduced interaction with the alumina surface, resulting in doubling the activity of the sulfided metals slabs. Haldor Topsoe named these active sites Type 1 and Type 2, which are synonymous today with high-activity and low-activity catalysts. In the early 2000s, Haldor Topsoe's researchers discovered the presence of yet another active site, which is located on the basal plane of the CoMo/NiMo sulfided slab. Using scanning tunneling electron microscopes, Topsoe was able to take pictures of these new active sites, which we named brim sites.

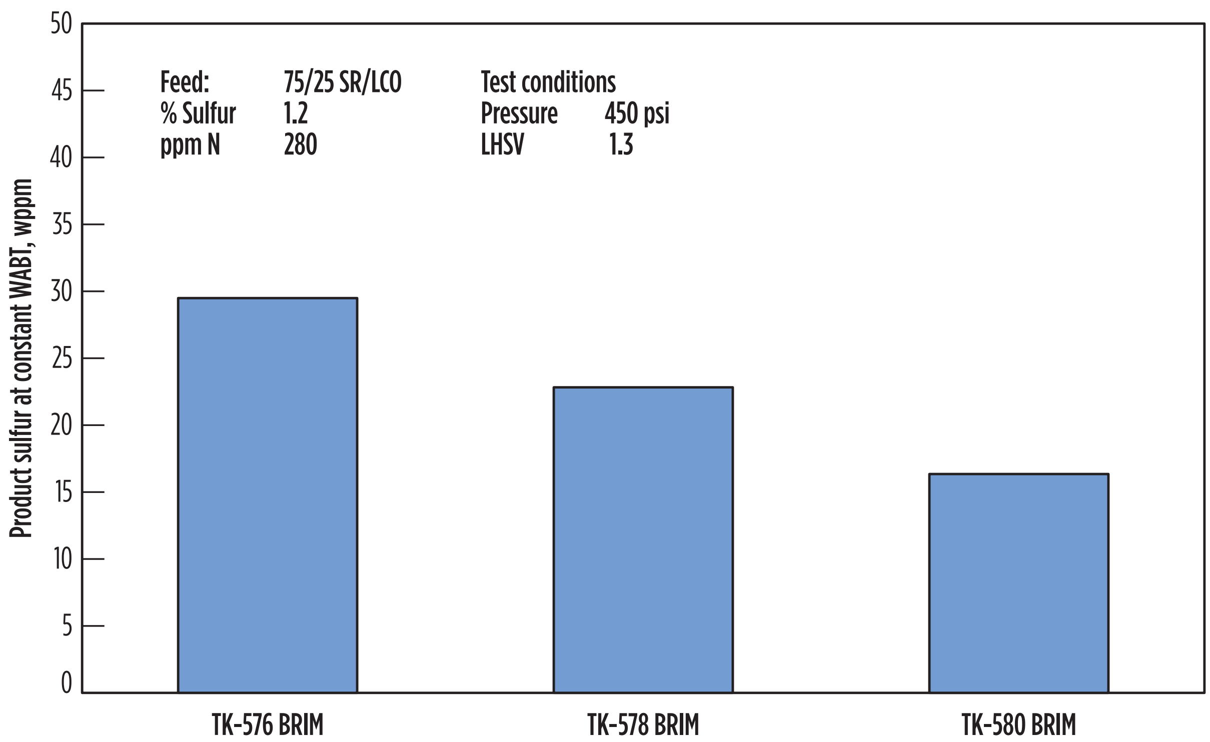



**FIG. 1.** Pilot plant data comparing the three generations of CoMo BRIM catalysts in ULSD service.

This nanotechnology-based discovery, BRIM, along with Haldor Topsoe's relentless pursuit of continuous improvement, led to the development of catalyst technologies, such as HyBRIM and HySwell. The improved HyBRIM technology, which combines the BRIM technology with an improved catalyst preparation step, has been applied to our latest catalyst development for low-pressure, ultra-low-sulfur diesel (ULSD) service, TK-580 HyBRIM CoMo catalyst. TK-580 HyBRIM shows an activity improvement of 12°F–14°F compared to our previous CoMo catalyst, TK-578 BRIM.

The pilot plant data in **FIG. 1** compares TK-580 HyBRIM with TK-578 BRIM and TK-576 BRIM. TK-576 BRIM was an industry leading CoMo catalyst for more than 8 years, only to be surpassed by TK-578 BRIM, which is still a best-in-class CoMo catalyst. TK-580 HyBRIM is now ready to take the crown. **FIG. 1** shows the reduction in product sulfur, while operating at the same weighted average bed temperature (WABT), gained from increased activity.

TK-578 BRIM has now been used in more than 500 units, with a total amount of more than 100 MM pounds sold. Since its launch, TK-580 HyBRIM is leading the industry in activity, while maintaining the same stable performance for which Haldor Topsoe catalysts are known. TK-580 HyBRIM has already been selected by several key refining organizations for use in their ultra-low-sulfur diesel (ULSD) units, based on in-house pilot plant testing. The number of references for TK-580 HyBRIM is greater than 10 and growing rapidly.

**FIG. 1** shows the results of pilot plant work performed on all three catalysts, processing a feed of 75% straight-run diesel with 25% light-cycle oil. The sulfur of the feed was 1.2 wt%, and the feed nitrogen was 280 wtppm. The pilot operated at a hydrogen partial pressure of 450 psi and 1.3 $hr^{-1}$ liquid hourly space velocity. As can be seen from the chart, TK-580 HyBRIM delivers significantly lower product sulfur at the same operating temperature.

This added activity can be used in several manners, including:

- Achieve longer cycles at the same feedrate
- Process more difficult feeds
- Increase throughput
- Increase conversion (volume swell).

The HyBRIM technology provides both our NiMo and CoMo with additional hydrogenation activity resulting in higher volume swell, which will provide our clients with additional profitability from their existing assets.

**Case Study.** TK-580 HyBRIM was loaded in a diesel unit processing a high percentage of LCO, replacing TK-578 BRIM, in early 2019. The added activity of the HyBRIM technology has translated into higher volume swell (**FIG. 2**), even when operating at a lower temperature. This unit processes a very difficult feed with a high amount of cracked stocks, and the operating pressure is a challenging 450 psig. Even more important, TK-580 HyBRIM is able to provide a very stable performance, with a deactivation rate of less than 2°F/month, which is impressive at the very low hydrogen partial pressure. This is illustrated in **FIG. 3.**

Volume swell is a measure of the extra barrels produced in the unit due to the hydrotreatment of the feed, creating more volume than fed to the unit. Therefore, these extra barrels are free, except for the cost of hydrotreating, as the refinery did not pay crude prices for these swell barrels. This significantly enhances the profitability of the unit.

This incremental volume swell generated by TK-580 HyBRIM, compared to TK-578 BRIM, paid for the entire load of catalyst in less than four months. This value represents only the incremental swell of switching to TK-580 HyBRIM and not the overall swell from the unit. The overall swell amounts to several million dollars per year, even for this small diesel unit.

TK-580 HyBRIM has proven to be substantially more active than TK-578 BRIM, which has been a leading CoMo catalyst in the marketplace for many years. Apart from an unmatched HDS activity and stability, TK-580 HyBRIM will provide the refinery with additional volume swell, significantly improving unit profitability. ●

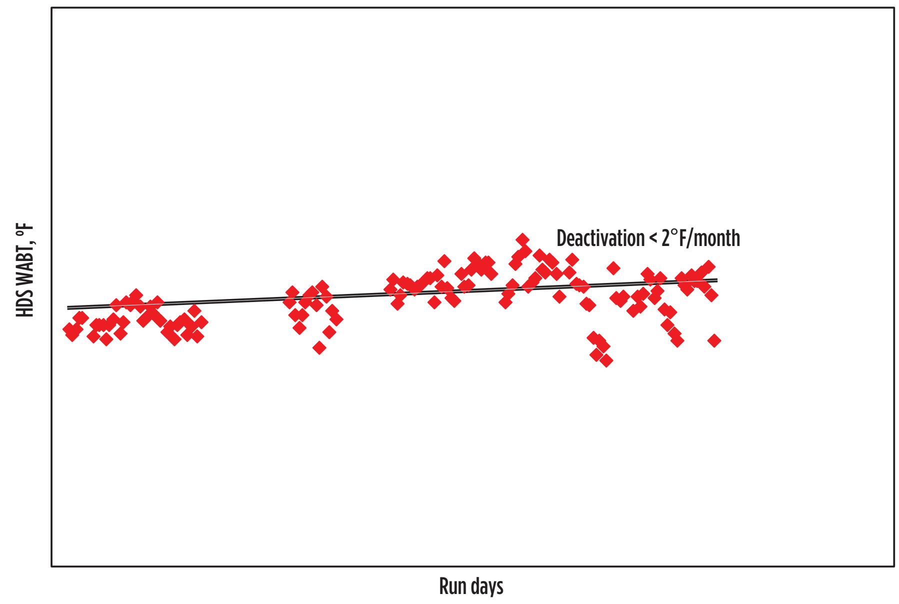



**FIG. 2.** Additional volume swell from switching to TK-580 HyBRIM operating at same or slightly lower WABT.

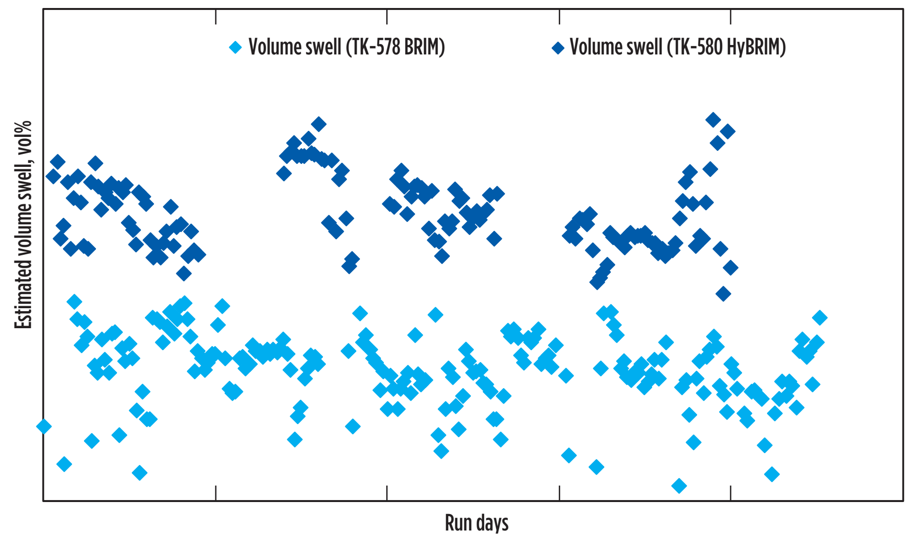



**FIG. 3.** HDS normalized WABT data.