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Meet EPA Tier 3 clean fuel regulations through improved blending processes

Gasoline refiners and distributors face multiple challenges that are becoming more difficult each year. Arguably, the biggest of these comes from the US Environmental Protection Agency (EPA), where Tier 3 regulations on gasoline sulfur content will make control of the blending process more critical and more challenging. Other countries are adopting similar, or even tighter, regulations.

The global economic environmental demands have increased the need to control costs, and poorly executed blending can add considerably to those. Errors can require batches to be touched up or completely re-blended, which can delay shipments and require additional tankage to hold excess work-in-progress components or semi-finished product—product that should have been shipped. This tankage is expensive to build and maintain.

This article will examine the impact of Tier 3 regulations on gasoline blending at refineries and terminals, and illustrate options that can contribute to compliance with these new regulations while keeping costs under control.

Clean fuel and the EPA Tier 3 challenge. The EPA's previous set of sulfur regulations, Tier 2, was published in 2000 and phased in over a number of years. By 2004, refiners and importers of gasoline were given an overall sulfur cap of 300 ppm, with an annual corporate average sulfur level of 120 ppm. In 2005, the refinery average limit fell to 30 ppm, with a corporate average limit of 90 ppm and a cap on any single batch of 300 ppm. In 2006, the average level remained at 30 ppm and the maximum cap was reduced to 80 ppm.

The EPA credits the Tier 2 regulations with reducing gasoline sulfur content by 90%, which not only directly reduced vehicle emissions of sulfur oxide (SO_x), but also enabled auto manufacturers to use new emissions reduction methods that would have been impossible with higher-sulfur fuel. But, states the EPA, "Subsequent research provides a compelling case that even (the Tier 2) level of sulfur not only degrades the emissions performance of vehicles on the road today, but also inhibits necessary further reductions in vehicle emissions performance to reach the Tier 3 standards."[1]

Tier 3 regulations go well beyond Tier 2. The annual average sulfur in gasoline sold moves from 30 ppm to 10 ppm across all company sites, and this extends to the point of sale. The sulfur cap on any single batch is set at 80 ppm at the refinery gate, while the distribution cap is 95 ppm. This applies not only to finished gasoline, but also to blendstocks like reformulated blendstock for oxygenate blending (RBOB). Large refineries must comply by 2017, and small refineries (those producing less than 75 Mbpd) by 2020. The caps may potentially be reduced in the future.

Time is of the essence. The phase-in schedule is shown in TABLE 1; the new standards essentially bring the entire country close to California's light-duty emissions (LEV 3) specifications.

FIG. 1 illustrates the schedule in more detail. Tier 3 products must be produced several months before the January 1, 2017, deadline for them to be available. Given the time required for planning and implementing the new blending infrastructure, now is the time to begin.

The EPA estimates that compliance with Tier 3 regulations will cost the average refinery \$0.065/gal of gasoline shipped, in addition to a capital investment of \$2.025 B in 2011 US dollars.[2]

Consequences of noncompliance. If the cost of compliance seems high, the cost of noncompliance is higher. Failing to meet specifications can result in fines and even prohibition from delivery into a market region. The EPA has promised stricter enforcement of the standards and

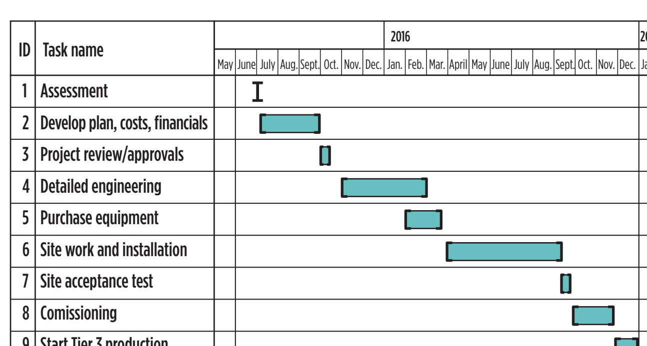

FIG. 1. Efforts must begin immediately for products to be in compliance with the January 1, 2017, Tier 3 requirements.

that those fines will increase in the future. In a recent court case, the EPA imposed a $2.9 MM civil penalty against a company that had committed a number of offenses, including excessive volatile organic compound (VOC) emissions from several of its facilities, failure to comply with the per-gallon sulfur standard for gasoline produced at one of its refineries, shipping gasoline with more than 10% ethanol, and exceeding Reid vapor pressure (RVP) standards for gasoline distributed from one of its terminals. The penalty also included the retirement of $200 M worth of sulfur credits, and it required that the refinery spend an additional $2.8 MM on pollution controls at several terminals.

Errors in blending can require re-blending, which includes sampling the blend tanks, analyzing the contents, touching up the mixture, and circulating and sampling again before the product can be shipped, adding to costs. Delays due to rework can result in demurrage costs for marine vessels.

Tier 3 sulfur limits are not the only challenge facing blenders today. Pipeline operators maintain strict specifications on the gasoline they will carry, including octane rating, drivability index and a range of volatility specs, such as distillation, vapor to liquid (V/L) ratio and RVP. Allowing a blend to stray outside these limits can jeopardize the facility's ability to blend directly onto the pipeline.

The upshot is that blending will continue to become more complex in the future, and the need to meet tighter specifications will increase the pressures on blending operations.

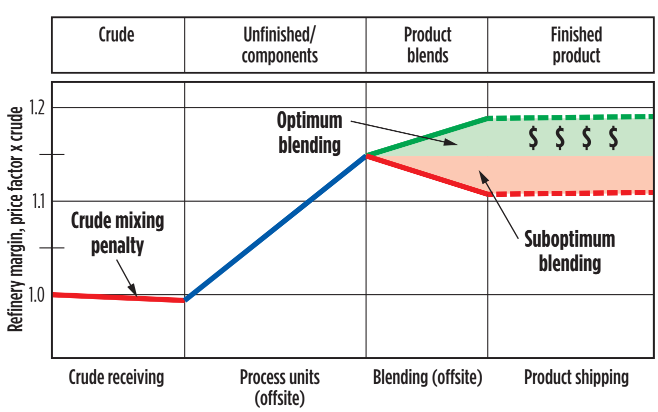

FIG. 2. A blender upgrade project will yield a reduction in the variability of the process, allowing operations that are closer to specifications and reducing giveaway.

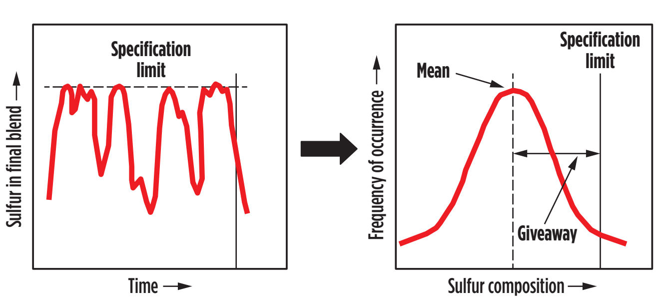

FIG. 3. The average sulfur content must be kept away from the specification limit to meet all batch requirements. However, that distance represents expensive giveaway.

Blending modalities. Blended product can be sent to a tank prior to its delivery to a pipeline, ship or terminal. In this case, the final blend specification is met at the tank by using conventional manual sampling and lab analysis. The end product can be any particular grade of gasoline ready to be delivered, or it can be sold as a gasoline blendstock like reformulated blendstock for oxygenate blending (RBOB), conventional blendstock for oxygenate blending (CBOB) or California RBOB (CARBOB) to be blended downstream into a finished-grade product.

Alternatively, the final tank can be eliminated and blending can be accomplished inline directly to a pipeline or ship. While this saves substantial money on tankage, blend control becomes more critical. Rather than meeting specifications at the final tank, where any needed adjustments can be made, an inline blender must meet specifications in real time for each blend segment (typically approximately 5,000 bbl). Blending directly to ships or pipelines requires custody-transfer-level measurement accuracy, with all the attendant calibrations, certifications and record keeping. In addition, there must be online analyzers that meet inline certification, calibration and accuracy standards.

The effect of blending improvements on profit margins. Upgrading the blending process can significantly improve the bottom line, as shown in **FIG. 2.** In a refinery producing 100 Mbpd of gasoline, a margin of $0.005/gal due to an upgraded blending system can be expected to increase profits by $7.4 MM/yr.

Upgrading a blending operation will generally involve improvements to field devices, blend meters, tankage, online analyzers, control systems and blend management systems. A blender upgrade project will yield a reduction in the variability of the process, allowing operations that are closer to specifications and reducing giveaway. A certified blend control solution can also blend directly to a pipeline or ship, thereby reducing required tankage and the inventory (working capital) previously held in them. The reduction in variability involves an upgrade to the process controls, including measurement systems. A side benefit can be improved reliability and availability by using

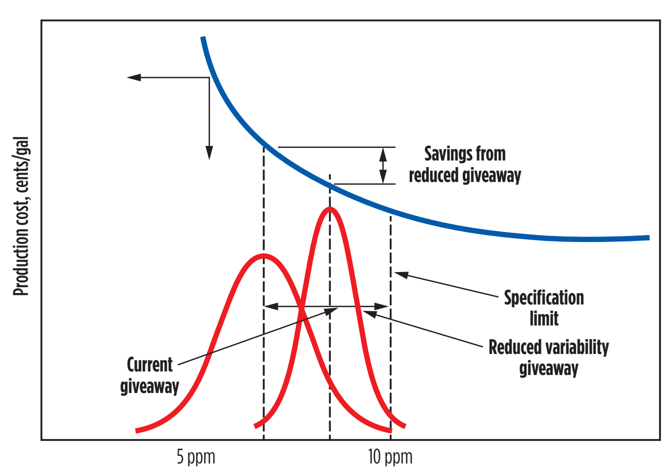

FIG. 4. As production costs increase exponentially as sulfur content decreases, shifting closer to the specification limit saves money.

TABLE 1. Schedule for sulfur reduction

	2014	2015	2016	2017	2018	2019	2020	2021
Federal		Tier 2 (30 ppm average; 80 ppm refinery capacity)			Large refineries—Tier 3 (10 ppm average; 80 ppm refinery cap; 95 ppm distribution cap)		Small refineries—Tier 3 (10 ppm average; 80 ppm refinery cap; 95 ppm distribution cap)	
California	LEV 2	LEV 3 (S—10 ppm average; 20 ppm refinery capacity)						

different technologies, e.g., utilizing Coriolis over turbine meters or pump health monitoring.

Variability is the enemy. The question facing the refinery blend planner or scheduler is, "What is the appropriate sulfur level at each point?" To meet the 10-ppm target, should the sulfur target in the blend be 7, 8 or 9 ppm at the refinery? The main enemy here is variability in real-time analysis, component composition and flow measurements. Operating close to the 10 ppm specification costs less than producing a 7 ppm average. The greater variability involved in the process, the greater the safety margin must be.

The effects of variations in sulfur content are shown in **FIG. 3.** To meet specifications for all batches, the average sulfur content must be kept away from the specification limit. However, that distance represents expensive giveaway. **FIG. 4** illustrates how narrowing the frequency distribution—reducing variability—significantly reduces giveaway and costs. Note that production costs increase exponentially as sulfur content decreases, so shifting closer to the specification limit saves money, with the amount increasing rapidly as the specification limit is reduced. A $0.01/gal increased margin in a refinery that produces 100 Mbpd will result in a gain of $14.8 MM/yr.

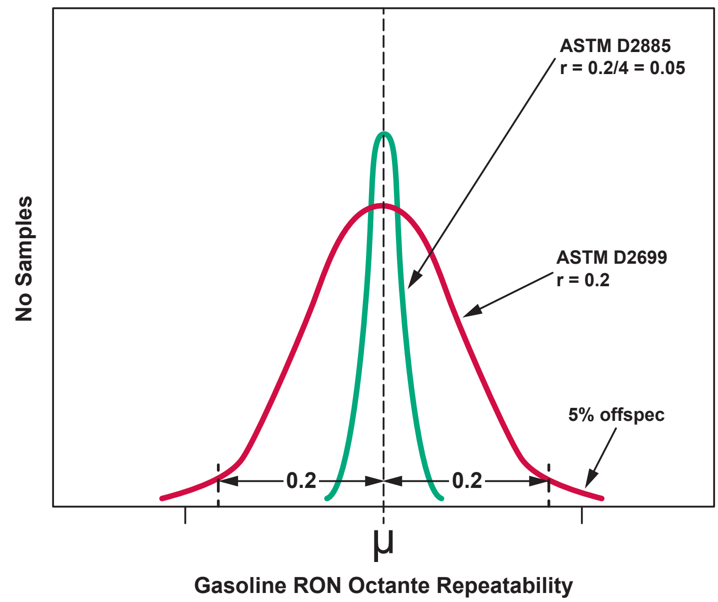

FIG. 5. Improving the accuracy of online analysis is one key to reducing variability.

One key to reducing variability is to improve the accuracy of online analysis. In **FIG. 5,** the octane engines using ASTM D2699 and ASTM D2885 have repeatability curves shown in red and green, respectively. Repeatability with an FT NIR analyzer is dramatically better, due to the significantly increased number of test results. (Typically, a result from FT NIR is provided in less than two minutes.)

Control valve performance, measurement accuracy and loop tuning also play significant roles in blender variability and reproducibility. As a result, a blender upgrade project will also need to verify that the field equipment is working properly; all control loops are tuned; and measurement devices have been properly selected, installed and calibrated.

Tier 3 impact on product logistics at the terminal level. It has long been a standard practice to carry out final ethanol blending at the terminal, but now there is increasing interest in blending other components like butane (C_4H_{10}), pentane (C_5H_{12}) and biofuels at terminals, as well. Additive management at the terminal is also more important. Some terminals are also processing transmix, and there is every indication that this complexity will continue to increase. Gasoline must then be recertified. Previously, terminals tended to have less-sophisticated instruments and measuring standards than refineries. Tier 3 has led to increasing interest in improved instrumentation and analytical measurements at terminals.

Tier 3 standards have not only reduced sulfur levels, but have also made quality tracking and contamination avoidance more critical. Allowing even a small amount of higher-sulfur gasoline to mix with a batch of 10 ppm product will push it out of spec and be very expensive to correct. Remember that the 10 ppm annual average specification applies at the refinery gate, and NOT at the blender.

TABLE 2 highlights the importance of not only reducing variability when producing gasoline, but also of tracking that gasoline and how its characteristics change as it moves toward the final delivery point, mostly long after the product leaves the refinery. A good deal of this can be attributed to the presence of higher-sulfur gasoline remaining in the system, including sulfur impregnating the walls of vessels, only to leach out and contaminate higher-tier product.

Why is blending so technically difficult? What makes blending so difficult and complex? First of all, there is the scale involved. A typical large refinery may have 50 different specifications that reflect regional and seasonal grade differences: summer, winter and transitional seasons. Certain areas (California, in particular) have very specific requirements. Also, a refinery may produce upward to 1,000 blends per year, ranging from 10 Mbbl to 200 Mbbl.

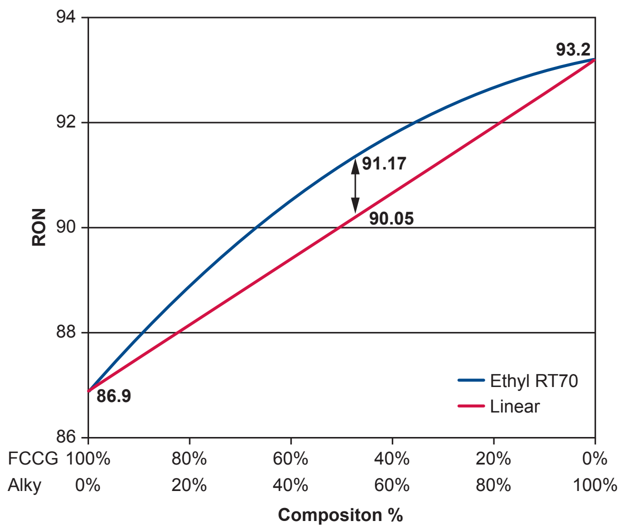

FIG. 6. Gasoline blending is non-linear, e.g., when blending FCC gasoline and alkylate.

TABLE 2. Potential contamination issues

Sulfur Measurement	Actual S (ppmw)	Target S (ppmw)
Sulfur at blend header	8.2	7.4
Pipeline to refinery gate	2.6	2.6
Sulfur at refinery gate	10.8	10.0
Pipeline contamination	2.8	2.8
Terminal contamination	0.8	0.8
Truck contamination	0.5	0.5
Retail station contamination	0.3	0.3
Sulfur at retail station	15.2	14.4
ASTM D7039 reproducibility at retail station	3.2	3.1
Worst case gasoline sulfur	18.4	17.5

Not only must the refinery be prepared to meet many different specifications, but the specifications themselves are also complex and interactive. Along with octane requirements, research octane number (RON) and motor octane number (MON), there are volatility requirements that are intended to balance ease of vehicle starting with reductions in evaporative emissions. Specifications that affect vehicle operation include RVP, distillation, V/L ratio and drivability index. Specifications dealing with environmental issues include sulfur content, oxygenate levels, benzene levels, VOC vapor emissions, percentages of aromatics and olefins, nitrogen oxides (NO_x) and sulfur emitted during vehicle operation, particulate emissions in vehicle exhaust and greenhouse gas emissions. All these specifications are part of the EPA Tier 3 standards and must be met simultaneously.

Adding to the difficulty is the fact that gasoline blending is not linear, e.g., when blending fluid catalytic cracking (FCC) gasoline and alkylate, as indicated in **FIG. 6.** The octane level does not follow a straight line; it more clearly follows the relationship given in the Ethyl RT70 equation.

Charting a path to Tier 3 compliance. An effective approach to reaching Tier 3 compliance begins with an analysis and benchmarking of the current performance of the facility. This blending assessment, which should take one or two days, begins with an in-depth overview of the refinery's normal overall operation, production, blend planning and scheduling functions. The consultants will also examine process unit operations, product blending and quality control-product/certification procedures. The assessment results will provide a first look at possibilities for improvements, along with the expected savings.

The next step is a detailed feasibility study, which is followed by the blending project execution using information from the feasibility study.

Achievable results and benefits. Implementing the latest methods has yielded ongoing savings of $0.15/bbl due to gasoline tank optimization, $0.10/bbl to $0.35/bbl in octane giveaway reduction, and $0.05/bbl to $0.15/bbl in volatility giveaway reduction. It has accounted for $1 MM in one-time savings due to component tank rationalization, with a subsequent $100,000 annuity; a $10 MM one-time savings in final product tank rationalization, followed by a $100,000 annuity; a $100,000 annuity due to the avoidance of marine demurrage; and a $1 MM savings from inventory reduction.

Any blender upgrade project should consider opportunities to take advantage of updated technologies to improve availability, reliability and safety. Examples include tank overfill protection, which can prevent costly spills, and equipment health monitoring of the major component pumps, which can improve safety and reliability by detecting changes in performance caused by developing equipment faults, such as seal leaks or cavitation.

Tier 3 is here, and it is time to consider upcoming blending challenges. It is vital to begin with a well-conceived plan that captures new business benefits and achieves compliance with the new regulations. HP

LITERATURE CITED

[1] "Control of air pollution from motor vehicles: Tier 3 motor vehicle emission and fuel standards; Final rule," *Federal Register*, Vol. 79, No. 81, April 2014.

[2] "Control of air pollution from motor vehicles: Tier 3 motor vehicle emission and fuel standards final rule: Regulatory impact analysis," US Environmental Protection Agency (EPA), pp. 5–61, March 2014.

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