White Paper
July 2020

The Impact of Blending Excellence in Clean Fuels Regulations

INTRODUCTION

Gasoline refiners and distributors face multiple challenges, which become more difficult as the years advance. Arguably, the biggest of these challenges will be meeting the EPA's new Tier 3 regulations on gasoline sulfur content, which will make control of the blending process more critical and more difficult. Other countries are adopting similar —or even tighter—regulations.

At the same time, the economic situation demands better control of costs, and poorly-done blending can add considerably to those. Errors can require batches to be touched up or completely re-blended, which can delay shipments and requires 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. IBLC or inline blend certification is the blending of product directly to pipelines or marine vessels. It requires tight control of final blend properties to guarantee quality assurance requirements, and to meet EPA regulations in the U.S. Furthermore, delays due to rework can result in demurrage costs for marine vessels or missed pipeline shipping schedules.

This whitepaper examines the impact of Tier 3 regulations on gasoline blending at refineries and terminals, and shows ways to meet these new regulations while keeping costs under control.

	2014	2015	2016	2017	2018	2019	2020	2021
Federal	Tier 2 (30 avg; 80 cap)			Large Refineries – Tier 3 (10 avg; 80 Ref cap; 95 Dist cap)			Small Refineries – T3 (10 avg; 80 Ref cap; 95 Dist cap)	
California	LEV II	LEV III (S–10 avg; 20 cap)						

Figure 1: Schedule for sulfur reduction

THE CLEAN FUEL—EPA TIER 3 CHALLENGE

The EPA's previous sulfur regulations, Tier 2, were 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 parts per million (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 percent, which not only reduced vehicle emissions of SOx directly, but also enabled auto manufacturers to use new emission 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 emission performance of vehicles on the road today, but also inhibits necessary further reductions in vehicle emissions performance to reach the Tier 3 standards."

Tier 3 regulations go well beyond Tier 2. Annual average sulfur in gasoline sold goes from 30 ppm to 10 ppm across all company sites, and 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 to blendstocks like RBOB (reformulated blendstock for oxygenate blending).

Large refineries must comply by 2017 and small refineries (those producing less than 75,000 bbl/ day) by 2020. In addition, the caps may be reduced in the future.

TIME IS OF THE ESSENCE TO GET READY FOR TIER 3

The phase-in schedule is shown in figure 1; the new standards essentially bring the entire country close to California's LEV III specifications.

Tier 3-compliant products must be produced several months before the January 1, 2017 deadline, in order to be in gas stations. As shown in figure 2, given the time required for planning and implementing the new blending infrastructure, the time to start is now.

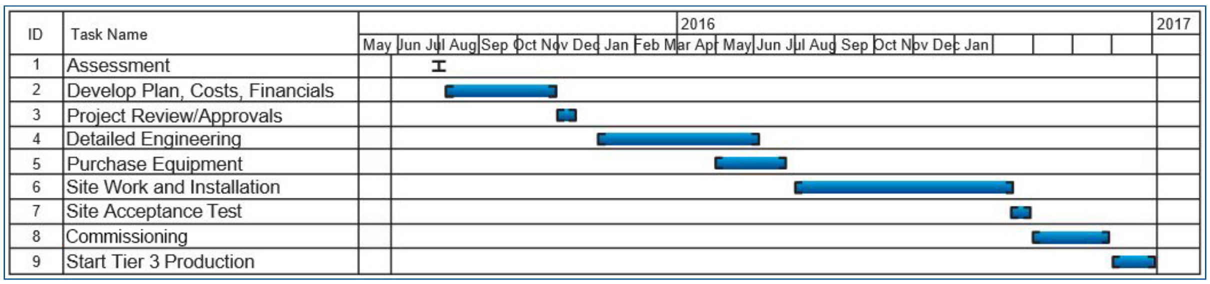

Figure 2: Recommended schedule for implementing new blending infrastructure

The EPA estimates that compliance with Tier 3 regulations will cost the average refinery $0.065 per gallon of gasoline shipped, on top of a capital investment of $2.025 billion in 2011 dollars.[ii]

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 mean a refiner is prohibited from delivering to a market region. The EPA has promised stricter enforcement of these new standards and intends to increase fines in the future. In a recent court case, the EPA imposed a $2.9 million civil penalty against a company that had committed a number of offenses, including excessive VOC (volatile organic compound) 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 percent ethanol, and exceeding Reid vapor pressure (RVP) standards for gasoline distributed from one of its terminals. The penalty also included the retirement of $200,000 worth of sulfur credits, and required that the refinery spend an additional $2.8 million on pollution controls at several terminals.

Errors in blending can require reblending: sampling the blend tanks, analyzing the contents, then touching up the mixture, circulating and sampling again before the product can be shipped, which adds to costs. Plus, 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, V/L and RVP. Allowing a blend to stray outside these limits can jeopardize the facility's ability to blend directly onto the pipeline.

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

THE EFFECT OF BLENDING IMPROVEMENTS ON PROFIT MARGINS

Upgrading the blending process can significantly improve the bottom line, as shown in figure 3. Consider a refinery producing 100,000 BPD of gasoline. An increase in margin of $0.005 per gallon due to an upgraded blending system can be expected to increase profits by $7.4 million per year.

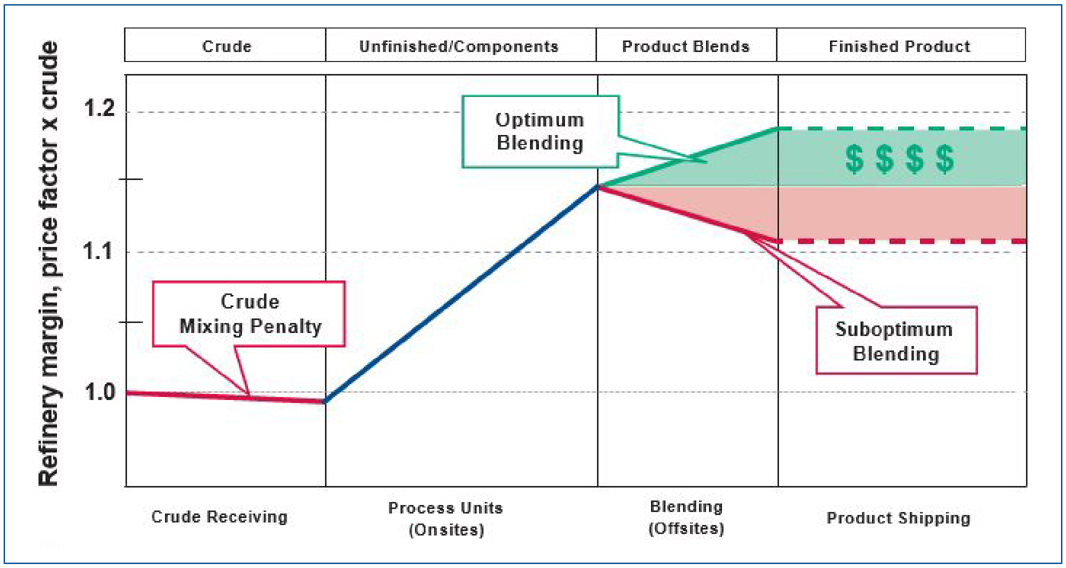

Figure 3: In a refinery producing 100,000 BPD of gasoline, an increase in margin of $0.005 per gallon due to an upgraded blending system can be expected to increase profits by $7.4 million per year.

WHAT IS INVOLVED IN A BLENDING UPGRADE

Upgrading a blending operation will generally involve upgrades to field devices, blend meters, tankage, online analyzers, control systems, and blend management systems. A blender upgrade project will yield, first of all, a reduction in the variability of the process, allowing operation closer to the specification, 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. Reduction in variability involves an upgrade to the process controls including measurement systems. A side benefit can be improved reliability and availability by using different technology, for example, by choosing Coriolis over turbine meters, or monitoring pump performance.

VARIABILITY IS THE ENEMY

The primary question facing the refinery blend planner or scheduler is: What is the appropriate sulfur level at each point? In order 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 in the process, the greater the safety margin must be.

Figure 4 shows the effect of variations in sulfur content. In order to meet specifications for all batches, the average sulfur content must be kept away from the specification limit. Unfortunately, that distance represents expensive giveaway.

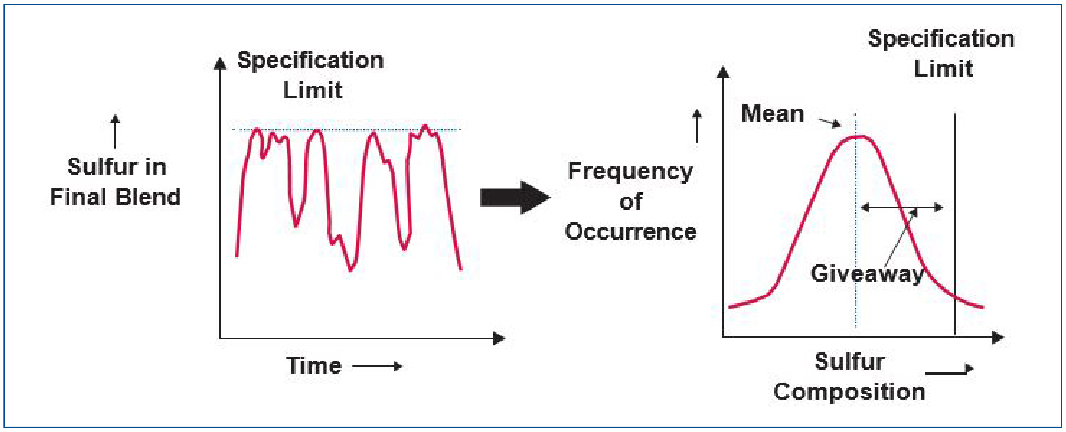

Figure 4: Effects of variations in sulfur content

As shown in figure 5, narrowing the frequency distribution— reducing variability—significantly reduces giveaway and costs. Note that the production cost increases 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. In a refinery producing 100,000 bbl/day, a $01/gallon margin increase would result in a gain of $14.8M per year.

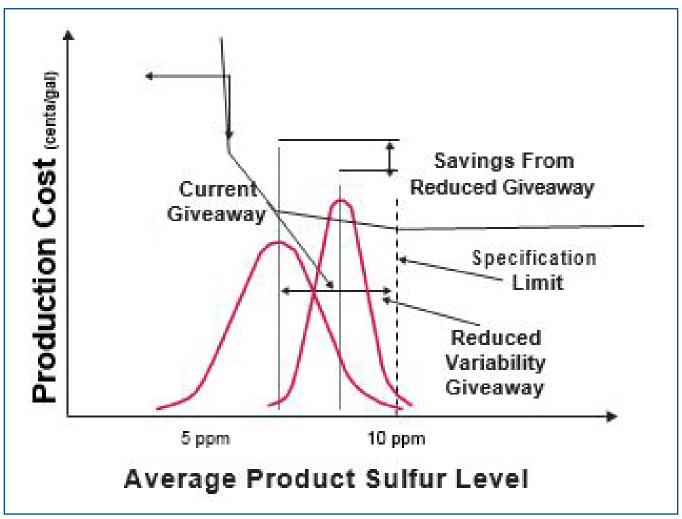

Figure 5: Reducing variability significantly reduces giveaway and costs

One key to reducing variability is to improve the accuracy of online analysis. As shown in figure 6, the octane engines using ASTM D2699 and ASTM D2885 have repeatability curves shown in blue and green, respectively. Repeatability with an FT NIR analyzer (red curve) is dramatically improved due to the significantly increased number of test results (typically a result from FT NIR is provided in less than two minutes).

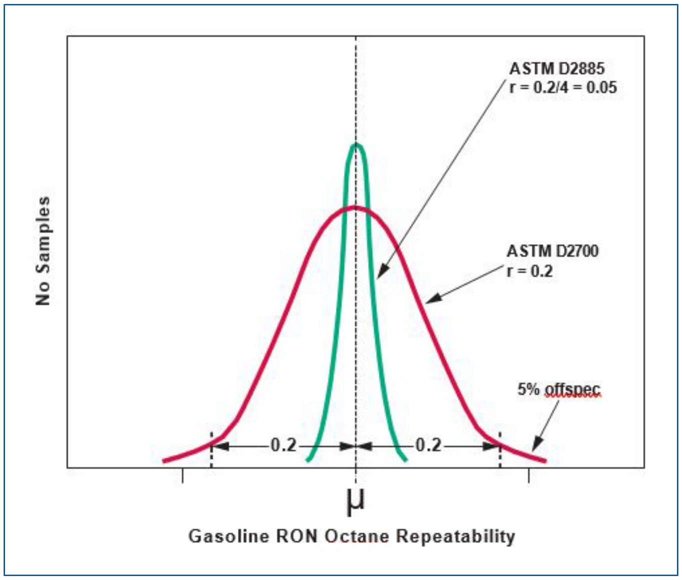

Figure 6: Online analysis is the key to removing variability

Control valve performance, measurement accuracy, and loop tuning also play a significant role in the 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.

BLENDING MODALITIES

Blended product can be sent to a tank prior to delivery to a pipeline, ship, or terminal. In this case, the final blend specification is met at the tank 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 RBOB (reformulated blendstock for oxygenate blending), CBOB (conventional blendstock for oxygenate blending), or CARBOB (California RBOB) to be blended downstream into a finished grade product.

Alternatively, the final tank can be eliminated and blending done in-line, 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 in-line blender must meet specifications in real time for each blend segment (typically approximately 5000 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 on-line analyzers that meet in-line certification, calibration, and accuracy standards.

TIER 3 IMPACT ON PRODUCT LOGISTICS AT THE TERMINAL LEVEL

It has long been standard practice to do final ethanol blending at the terminal, but now there is increasing interest in blending other components like butane, pentane, and biofuels at terminals as well. Additive management at the terminal is also more important. Some terminals are also processing transmix, as well, and this complexity will likely continue to increase. Gasoline must then be re-certified. In the past, terminals tended to have less sophisticated instruments and measuring standards than refineries. But Tier 3 has led to increasing interest in improved instrumentation and analytical measurements at terminals.

Tier 3 regulations 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 can be very expensive to correct.

Remember that the 10 ppm annual average specification applies at the refinery gate, not at the blender.

Figure 7 shows 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, often 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.

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**

Figure 7: Potential contamination issues

WHY IS BLENDING TECHNICALLY DIFFICULT?

As most refiners know, blending is extremely challenging and complex, particularly when you consider the scale involved.

A large refinery may have 50 different specifications that reflect regional and seasonal grade differences. Specifications required by California alone can be extensive. It is not uncommon for large refineries to produce up to 1000 blends per year, ranging from 10,000 to 200,000 bbl.

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

Adding to the difficulty is the fact that gasoline blending is not linear—for example, when blending FCC gasoline and alkylate, as shown in figure 8. Octane level does not follow a straight line; lab data shows that it peaks in accordance with the blue curve in the figure, and the bonus obtained from more closely approximating the true relationship is economically significant. The problem is even more complicated, because there are interaction terms among all the different components of gasoline.

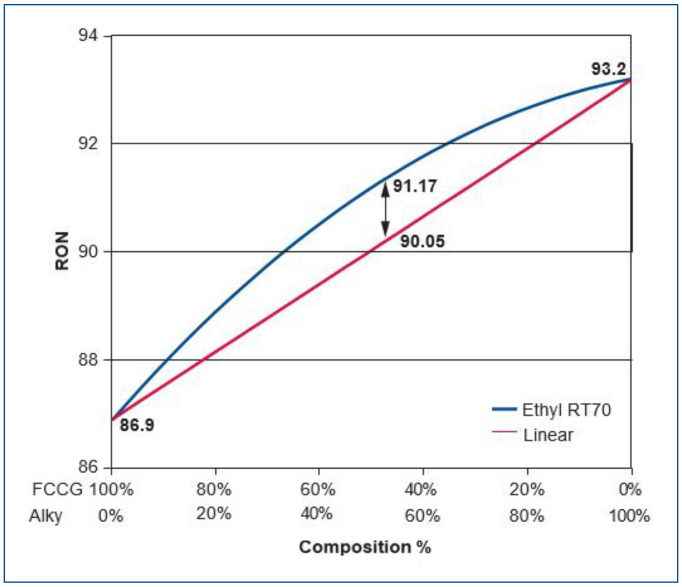

Figure 8: Example of the non-linear octane level when blending FCC and alkylate

THE PATH TO TIER 3: COMPLIANCE THE EMERSON WAY

Emerson has a proven approach to helping customers reach Tier 3 compliance. It begins with an analysis and benchmarking of the current performance of the facility. The blending assessment, which generally takes one or two days, begins with an overview of the refinery's normal overall operation and production, as well as blend planning and scheduling functions. The Emerson 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 improvement and the expected savings.

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

WHAT CAN BE ACHIEVED

Emerson's blending expertise has helped more than 90 refiners implement the latest blending technology, yielding:

- Ongoing savings of $0.15/bbl due to gasoline tank optimization
- $0.10 to $0.35/bbl reduction in octane giveaway and a $0.05 to$0.15/bbl reduction in volatility giveaway
- $1 million one-time saving due to component tank rationalization, followed by a $100,000 annuity
- $10 million one-time saving in final product tank rationalization, followed by a $100,000 annuity
- $100,000 annuity due to marine demurrage avoidance
- $1 million saving from inventory reduction

IMPROVING EQUIPMENT AVAILABILITY, SAFETY, AND PERFORMANCE

Any blender upgrade project plan should include opportunities to utilize updated technology to improve availability, reliability, and safety. Quite often, tank overfill protection is a logical project extension to prevent costly spills. Equipment health monitoring of the major component pumps is another technology that can improve safety and reliability by detecting changes in performance caused by developing equipment faults such as seal leaks or cavitation.

OVERFILL PROTECTION

Tank level measurement is crucial to the safety of the whole blending operation, and is closely tied to overfill protection. Marsh, Ltd., cites data from a U.S. operator that “overfilling of atmospheric storage tanks occurs once in every 3300 filling operations.” Prevention starts with the adoption of Safety Instrumented Systems (SIS/SIL), and adherence to IEC 61508/11 and ANSI/ISA-84 standards, which encompass the whole safety lifecycle and failure statistics, along with API Std 2350: Overfill Protection for Storage Tanks In Petroleum Facilities, the recommended best practice used throughout the United States.

For more information on API overfill protection guidelines, see www2. emersonprocess.com/en-US/brands/rosemounttankgauging/safety/ Documents/api2350/index.html.

There are multiple options to upgrade an automatic overfill protection system. Figure 9 shows both an automatic overfill protection system (AOP) and an automatic tank gauging (ATG) system. The AOP system includes a level gauge going to the SIS. The SIS has an alarming system and is connected to an actuator that, when activated, will immediately shut the inlet valve to the tank to prevent overfill.

FLOWMETERS

Typically, either turbine meters or Coriolis meters are chosen for metering flow on gasoline blending. Turbine meter performance is affected by fluid properties and process conditions; changes in process fluid density, viscosity, pressure, temperature, and require periodic recalibration. In addition, turbine meters have moving parts, and are susceptible to wear and damage. Flow surges and pulsations can damage them, and they eventually wear out. Turbine meter recalibration and maintenance costs for a blending system are typically about $30,000 per year, although it is not uncommon for refineries to forego spending money on the blender and just live with systematic errors in their component measurements. However, the benefits of a sophisticated quality control and optimization system will not be realized if the basic instrumentation is incorrect. As a result, blender upgrades should involve the needs of the blender instrumentation and controls.

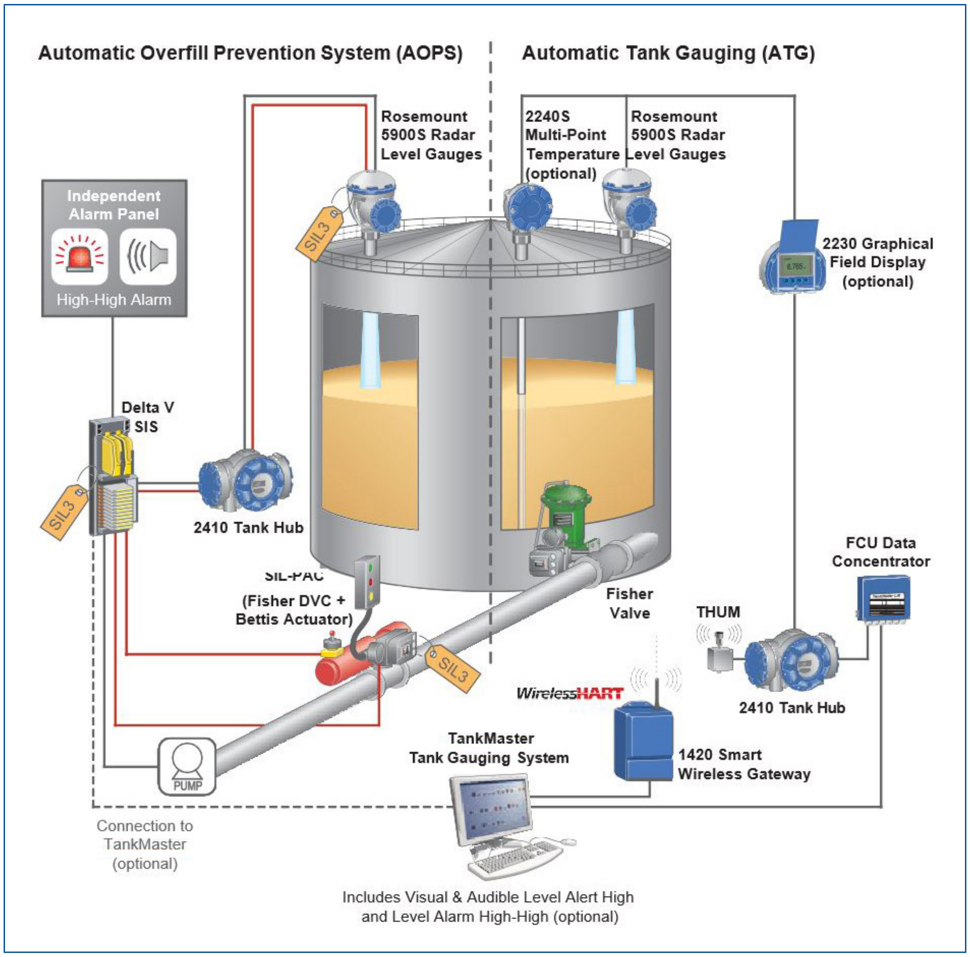

Figure 9: Options for automatic overfill protection

Coriolis meters, on the other hand, have many characteristics that benefit blending. They are extremely accurate, with uncertainties on the order of 0.1%, and are accepted for custody transfer applications. They have no moving parts so they do not wear out or require periodic maintenance. And perhaps most important, they are independent of changing fluid properties: they can measure the flow of FCC gasoline, butane, crude oil, or asphalt. This gives blending systems much greater flexibility, because any component in a blending system can be run through any meter without having to consider calibration or meter factors.

Coriolis meters are also multi-variable, simultaneously measuring mass flow, standard volumetric flow, and density. They are tolerant of two-phase flow. One of the common errors in flow measurement is caused by flashing of the lighter components, such as butane, which tends to occur when proper back pressure is not maintained.

In general, with almost any fluid a Coriolis meter can generally tolerate 5% entrained gas. It is important to note that the best measurement for two-phase flow is provided by dual-tube sensors with a low-tube frequency, such as Micro Motion ELITE Coriolis meters. If a sensor with high-tube frequency is used, the two-phase mixture does not vibrate directly with the flow tube, which results in large measurement errors.

Micro Motion Coriolis meters now have a software feature to let users know about the condition of their fluid, and provide notification of fluid being in one of three regimes: single phase, moderate entrainment, and severe entrainment. Some users set alarms on density, so if stratification or some other event occurs, the operator will be alerted before the blend goes out of spec.

Coriolis meters are also available with smart meter verification, which checks the meter’s tube stiffness and checks the condition of the sensor components and the transmitter electronics, all without interrupting the normal measurement function. This can be done on demand or periodically per schedule, and the results are recognized by a number of metrology standards organizations.

It is impossible to achieve accurate control of a process with malfunctioning or inaccurate final control elements. As seen in figure 10, a poorly-performing valve (top) will lead to inaccurate blending (especially when doing ratio control), while a healthy valve (bottom) with a digital valve controller will help ensure accurate control. A digital valve controller not only provides precise valve positioning, but also includes diagnostics for valve wear, air supply, mechanical failure, and calibration problems.

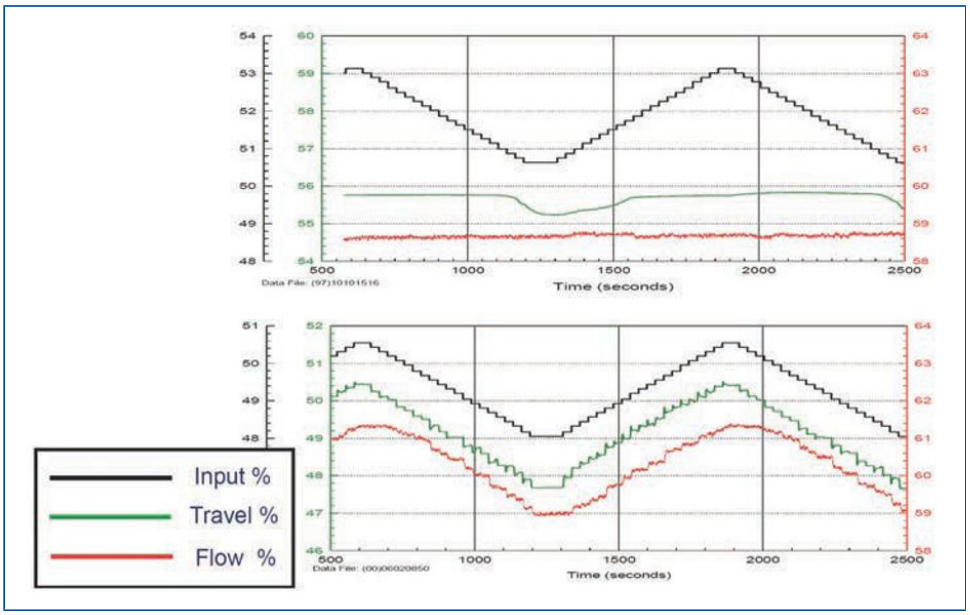

Figure 10: Value performance is critical to blender flow control

PUMPS

Pumps are critical to the success of a blending operation. They are often located in isolated areas, and monitored by periodic inspection, but unfortunately, these on-site checks may not pick up everything that might be going wrong, and they certainly cannot detect incidents that happen in between checks. A better method is to equip each pump with monitoring sensors. These devices monitor for cavitation, vibration, bearing temperature, strainer plugging, seal fluid leaks, and hydrocarbon leaks, and communicate wirelessly with operators and maintenance personnel so that any needed repairs can be scheduled without an unscheduled shutdown.

UPGRADING THE CONTROL SYSTEM

Surveys have shown that refinery operators want to get off the black boxes: the PLCs that were installed years ago that no one onsite currently understands, making it difficult to maintain them. Users also want local support. It is no longer acceptable to fly in remote experts for control systems or online analyzers. Refineries also have incentives to use certified inline blenders to eliminate blend tanks.

In many refineries, the applications used for refinery production planning, blend planning, blend scheduling, and online optimization are supplied by different vendors, often using different blend models. Users want to ensure the blending models they use are consistent across all platforms, with one set of validated coefficients that will produce the same answer on each platform. The design of Emerson's SmartProcess® Blender Control & Optimization Solution provides the ability to configure custom models to match blend planning and scheduling systems, or use one of the standard models provided with the system.

The advances in distributed control systems of the last few years have greatly simplified the architecture of today's blending systems. It is now possible to move most of the real-time blending applications down into the controller itself, gaining some natural redundancy and making it possible to integrate it with other field devices and data sources. Many customers have found it valuable to replace their PLC logic with DeltaV functions so that everything resides in a single, supportable platform.

Refiners achieve quantified business results with Coriolis. One of the first US refiners to change from mechanical meters to Coriolis meters calculated that the increased accuracy allowed them to optimize their blending more effectively and saved $200,000 per year.

They were also able to save in excess of $30,000 each year on turbine meter maintenance.

By replacing turbine meters with Coriolis, a second refiner was able to reduce rework of blend stocks by 40%. The same company installed digital valve controllers to monitor the health of the valves and reduce the variability in control. Improved blend control was one of the keys to reducing the amount of rework—which saved additional component costs, laboratory work, inventory costs, and tankage costs.

A third refinery decided to switch to Coriolis after the inaccuracies with their turbine meters caused so many problems with off-spec blends that it almost resulted in revocation of the company's license to blend directly into a pipeline. Replacing the flowmeters eliminated the problems with off-spec blends and saved about $300,000 per year. It also eliminated the need to have tankage available.

REFINERS ACHIEVE THE BENEFITS FROM INLINE CERTIFICATION

A European refinery wanted to go to inline blending and certification and to reduce tankage, but was saddled with obsolete blending system hardware, with multiple software interfaces for the operators. They were also getting inadequate system support from their current vendor.

The project involved replacing the old DCS in the blending area with a modern one, with modern controls for ramping, pacing, start/stop functions, operating sequences, and provisions for optimization. The project included new modules for tanks and routes, and interfaces for analyzers, as well as an online optimizer and the blend planning system. All this had to be installed under a very tight schedule.

The operations were cut over hot, and the entire cutover took only three days with no incidents or stoppages (including to other systems).The first blend met specifications. The refinery can now blend directly to ships, reducing touch-ups and reblends, and releasing tankage for other uses. In addition, giveaway has been significantly reduced.

A blending system in the southeast U.S. faced similar challenges in going to inline blending and certification in order to reduce tankage. Their blending system hardware and software were obsolete, and maintenance and support had become difficult.

The facility had a large number of blending recipes that had to meet tight specifications, and once again the schedule was tight.

Emerson installed a new DeltaV DCS and blending software with all attendant project services, and interfaces with third-party systems for production tracking. All blending recipes were migrated to the new system, which was much simpler than the old one to use and maintain, and there was no longer any need to call in outside experts. The system was cut over hot in just three days, and the first blend was on spec and shipped.

SUMMARY

Tier 3 is here, and it is time to consider your upcoming blending challenges. Start with a good plan that captures new business benefits and meets regulations. And check with Emerson Process Management and its local business partners; they will be able to help.

i "Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards; Final Rule," Federal Register, Vol 79, No. 81, Part II, April 28, 2014, page 23417.
ii "Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards Final Rule: Regulatory Impact Analysis," EPA, March, 2014, page 5-61.
iii Marsh Ltd, Risk Engineering Position Paper – 01, Atmospheric Storage Tanks, (London, 2013), p1.

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