WHITE PAPER

Three Disrupting Factors Are Changing the Refining Landscape

Economics have been favoring diesel over gasoline nearly year-round and refiners have been putting every last drop of heavy gasoline into distillate, unless there's something limiting them from doing so. This is a significant change from past practice where gasoline played a more significant role in the U.S. market. What's more, new and more stringent requirements for vapor pressure are on the way and these will almost certainly drive many refineries to change operating practices and initiate projects to maintain their market position.

Two gasoline specifications at the forefront are Reid vapor pressure (RVP) and driveability index.

Reid Vapor Pressure

RVP is an industry-accepted measurement that indicates volatility of gasoline, or more simply, the relative amount of volatile material contained in liquid gasoline. Vapor pressure has long been an important factor in the efficient operation of gasoline-fueled vehicles during the various seasons. Oil refiners commonly manipulate the RVP seasonally — raising RVP in winter and lowering it in summer — in order maintain consistent gasoline engine reliability.

RVP is determined by a lab test that measures the absolute vapor pressure of gasoline measured in pounds per square inch (PSI) at 100 degrees Fahrenheit. The higher the RVP, the more light hydrocarbons can diffuse into the surrounding air. These light hydrocarbons contribute to ground-level ozone as a pollutant, especially in urban areas. In 1990, the National Ambient Air Quality Standards (NAAQS), established under authority granted by the Clean Air Act, began regulating ground-level ozone, among other pollutants. This led to current RVP standards of 9.0 psi in rural areas, 7.8 psi in urban areas, and as low as 7.0 psi in dense urban areas.

In order to meet the low RVP requirements for gasoline in urban areas, refiners must remove high-RVP components such as normal butane and isopentane and sell them into the LPG or chemicals markets.

Driveability Index

The driveability index has become a standard industry metric for gasoline performance across the full range of operating conditions. Elements of the distillation profile for gasoline are incorporated and these account for ethanol content as well as varying evaporation percentages resulting from ambient temperatures. The driveability index is calculated from the following equation:

DI = 1.5 T10 + 3.0 T50 + 1.0 T90 + [2.4°F] x Ethanol Volume %

Low RVP / heavy gasoline blendstocks such as reformate tend to have a high driveability index. High RVP / light blendstocks such as isomerate tend to have a low driveability index. The typical driveability index specification is limited to DI=1,250, and meeting this can be more challenging with premium gasoline that requires a lot of reformate in the blend. This problem is exacerbated when premium gasoline must meet lower RVP specifications.

Future Challenges

The refining industry is facing at least three significant challenges related to gasoline specifications.

1. Ozone Nonattainment Areas

Beginning in the 1970s, the EPA began reviewing how the increasing presence of smog in heavily populated areas was contributing to human health issues. Regulators zeroed in on ozone as an agent that causes smog. It also is considered a lung irritant linked to certain human health problems.

Gasoline vapor is a contributor to excessive ozone and thus has become an area of concern for the EPA and other environmental authorities. Federal ozone standards were enacted under the 1970 Clean Air Act, and subsequent amendments have given the EPA authority to periodically monitor areas for attainment of ozone standards.

Despite much progress nationwide in reducing ozone as well as other agents causing air pollution, some major cities still struggle to reach the EPA's clean air attainment standards for ozone. In 2022, certain major metropolitan areas were named as nonattainment areas for federal ozone standards. Among these, the Dallas-Fort Worth and Denver metros are home to a number of counties that will see more stringent RVP specifications.

These heavy population centers made the list because of persistent inability to reduce ozone levels based on three-year averages. Consequently, these areas face tougher air pollution rules that will likely require gasoline refiners to begin selling less-volatile, lower-RVP fuel by the start of the 2024 summer ozone season.

Even though lower RVP standards have already been required during the summer months, allowable gasoline vapor pressures will be ratcheted down even more. These standards are likely to vary county by county, depending on the air quality data. For example, 9 PSI of vapor pressure as measured by RVP might meet specifications (spec) in one county, while in an adjoining county it might be 7.4 PSI.

2. E15 Could Be the New Standard

Nine states with relatively large agriculture economies are now pushing for approval from the EPA to permanently increase allowable ethanol blends in gasoline from 10% to 15% on a year-round basis. Currently, these so-called E15 blends are allowed during the winter months in the nine states leading this charge: Illinois, Iowa, Kansas, Minnesota, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin. The federal Office of Management and Budget (OMB) initiated an official review of the request in 2022, as required by law.

E15 blends already have been allowed in all 50 states during the winter driving season because vapor pressures are a lower concern during those periods. What's more, both the Trump and Biden administrations have given interim approval for year-round E15 blends. With that track record already established, the governors of the nine states named above are now pushing for permanent authorization in their states to put E15 on equal regulatory footing with E10 blends all year round. They are being strongly backed by the ethanol industry along with a number of agribusiness associations who support permanent expansion of this new standard to all 50 states.

As part of the push, the requesting states have suggested shelving the so-called 1-PSI waiver rule, which essentially says that 1 PSI of vapor pressure under the RVP measurement formula need not be counted in determining spec for gasoline in a given area. The EPA agreed to approve the waiver because ethanol is considered a biofuel, thus resulting in lower carbon intensity (CI) for blended gasoline.

To illustrate: If spec gasoline for a given county is 9 PSI, but the actual E10 gasoline is 10 PSI under the RVP formula, it could still be sold in that area because one PSI of vapor pressure is not counted.

If the waiver rule is ended, the compliance burden for meeting the EPA's rules for spec gasoline would shift completely to refiners. For example, in the same hypothetical 9-PSI area discussed earlier, spec gasoline would have to actually be 9 PSI instead of 10 PSI when it is trucked from the refinery.

If approved, refiners would face a number of issues, particularly those selling gasoline in severe nonattainment areas that will undoubtedly face very low RVP thresholds. Refiners would have to reduce RVP by more than 1 PSI for most types of commercial gasoline formulated for subsequent blending with ethanol — a process commonly known as before oxygenate blending (BOB). This would obviously vary widely by geography, depending on how tight the air quality rules turn out to be in certain jurisdictions, but is certain to be a huge new burden on refiners.

3. Growth of Diesel Market

A third disrupting factor called "dieselization" is already impacting refiners as market economics shift toward jet and diesel versus gasoline. It's all about the distillate that is needed for these various fuel types.

The spectrum for these different fuels is well-known within the industry, but bears repeating:

- Gasoline is the lightest on the spectrum, with a boiling range of approximately 100 to 400 degrees Fahrenheit (F), depending on the season and market factors.
- Jet fuel is next on the spectrum, with a boiling range of approximately 300 to 572 degrees F.
- Diesel occupies the last position, with an approximate boiling range between 300 and 700 degrees F.

There are molecules that can be directed to gasoline or to diesel and jet, and depending on market conditions can be directed into any of these fuel types. The truth is that market economics are shifting toward diesel production almost year-round. The days of winter as "diesel season" and summer as "gasoline season" appear to be coming to a close.

As ethanol is blended into gasoline at higher volumes, the growth rate of the gasoline market is generally lower than for jet and diesel, which are more difficult for biofuels to penetrate. With more money to be made producing diesel, more refineries — particularly those already dealing with tight margins — will continue to shift refinery capacity away from gasoline.

Another factor is ongoing electrification of the surface transportation fleet. Though electric vehicles (EVs) have not currently lessened demand for gasoline by significant amounts, they are slowing growth. It's a factor that will gain importance over time as more EVs hit the road.

All these factors are likely to mean market share for diesel will grow over the long term, reducing market share for gasoline.

Although biodiesel, renewable diesel, and sustainable aviation fuel (SAF) projects have been increasing their market share in recent years, these campaigns are generally considered feedstock constrained. Electric trucks and hydrogen may also penetrate the distillate market as time moves forward, but development of these markets faces a number of challenges and requires significant time to overcome the technical and logistical hurdles.

Study Execution Plan

To recap, these three factors are looming as significant disruptors for refiners:

1. EPA regulations dealing with ozone and smog are about to become tougher.
2. The ethanol industry is likely to gain nationwide approval for E15.
3. Strong diesel economics will increasingly attract light distillates away from gasoline production.

Operators who are unsure of their game plan should be considering some studies looking at their refinery makeup with respect to how they are producing gasoline. Gasoline blending is primarily a function of RVP and octane. 1898 & Co. generally begins its studies by determining the size of the prize. In this case, the refiner is producing multiple gasoline BOB (before oxygenate blending) sales streams, each requiring different specifications. Moving forward, those specifications will change. Figure 1 illustrates an example of how summer specifications will change.

Size of the Prize

		CURRENT	FUTURE
	FLOW RATE	RVP	RVP
	BPD	PSIA	PSIA
Low RVP Regular BOB	3,000	7.8	6.4
Low RVP Premium BOB	27,000	7.8	6.4
High RVP Regular BOB	63,000	9.0	9.0
High RVP Premium BOB	7,000	9.0	9.0
TOTAL	**100,000**	**8.64**	**8.24**

Figure 1: *The gasoline pool that the refinery produces will be reduced by approximately 0.40 PSI due to changes in the specification of some of the refinery's gasoline sales streams.*

These changes are a significant impact to the refinery gasoline pool that may lead to less butane blending, sales of high RVP streams such as light straight run (LSR), and purchase of gasoline components to meet market demands. In addition, the loss of light components from the gasoline pool make the driveability index more difficult to achieve, especially for low-RVP premium gasoline. As a result, a significant impact to refinery gross margin is expected. The impact is complex, and these complexities can be handled within a well-tuned refinery LP, which is the refining industry's long-established tool for refinery optimization.

The refinery LP can reveal strategies that are less obvious to operators that are focused on day-to-day operations. These strategies may include:

- Crude optimization.
- Sales of low-RVP gasoline components.
- Changes in fractionation strategy.
- Opportunities for RVP improvement on specific gasoline blendstocks.
- Debottlenecking of low-RVP gasoline blendstock units, such as the alkylation unit.
- Addition of new tankage.
- Separation of full-range blendstocks into light and heavy blendstocks.
- Segregation of commingled gasoline blendstocks.

Along with LP analysis, a closer look at refinery operations is warranted as well. Individual evaluation of the gasoline blendstocks is warranted to determine if there are any gaps in operating practices, or if there is a need for a capital project solution. The gasoline blendstocks that are normally available at the refinery include the following:

- Alkylate
- Light reformate
- Heavy reformate
- Isomerate
- Light straight run
- Light FCC gasoline
- Hydrotreated heavy FCC gasoline
- Sweet naphtha
- Benzene saturate
- Light hydrocracker naphtha
- Heavy hydrocracker naphtha
- Isopentane
- Poly gasoline

Some of the above gasoline blend components are high-octane and low-RVP. Some are low-octane and high-RVP and there are other variants. Refiners have an opportunity to look at each of these blendstocks to see if RVP improvement can be obtained via optimization or via a capital project.

Swing components like butane and pentane deserve careful consideration because of their relatively high vapor pressures: approximately 52 for butane, 20 for isopentane and about 15 for pentane.

Process simulation can reveal opportunities for some of the streams; for example, increasing reflux in a refinery stabilizer can improve separation of normal butane from isopentane and pentane. Generally speaking, components such as normal butane should be rejected to LPG while maintaining as much isopentane and pentane in the pool as possible. Changes in RVP specifications are likely to warrant improved separation relative to past practices.

Communicating Study Results

The study objective should be to quantify options. Results from LP analysis may include the variable margin improvement for investing in a distillation tower, addition of new tankage or debottlenecking an existing low-RVP blendstock unit. Figure 2 shows an example of output from an LP study.

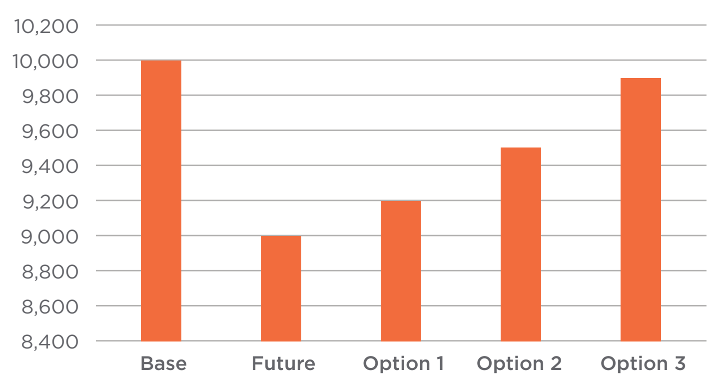

Figure 2: Variable margin for LP cases.

The output from the LP analysis alone can be combined with corresponding capital cost estimates to determine if the economics of each project will provide sufficient return on investment.

To support the LP evaluation, process simulation work can be used to determine what optimization or capital project improvements can be made to existing distillation equipment to support improvements to gasoline pool RVP. In Figure 3, operational and capital project improvements are made to three streams in order to improve the overall gasoline pool.

Blendstock Improvements

		CURRENT	FUTURE
	FLOW RATE	RVP	RVP
	BPD	PSIA	PSIA
Isopentane	2,500	25.2	22.0
Isomerate	15,000	12.8	12.8
Medium Straight Run	13,000	3.0	3.0
Reformate	20,500	3.8	3.8
FCC Gasoline	30,000	7.2	6.5
Alkylate	19,000	6.8	6.3
TOTAL	**100,000**	**7.43**	**7.02**

Figure 3: *Impact of gasoline blendstock RVP improvements.*

Conclusion

Future ozone regulations, loss of the 1-psi ethanol waiver, and dieselization are three disrupting forces now on the horizon. While "do-nothing" is a tempting option for those who are diverting strong oil refining returns toward stock dividends or low-carbon fuel investments, some will be faced with substantial lost opportunity without thoughtful planning. Refiners should be making plans now to quantify that potential lost opportunity and identify commercial and capital project solutions that will recover those losses and perhaps capture opportunities that their competitors forgo.

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