Assuring the Proper Utilization of Ethanol

Ronald K. Fricke
June, 2010
Useful Nomenclature

- **CAFE** – Corporate Average Fuel Economy – weighted average fuel economy of one automaker’s annual vehicle sales

- **Denaturant** – component that makes ethanol unsuitable for consumption

- **Driveability** – qualitative assessment of good driving performance. A driveability index is calculated for a gasoline based on its distillation properties. Ethanol affects the calculation.

- **ETBE** - Ethyl Tertiary Butyl Ether – ester made from ethanol that blends more easily into gasoline

- **EU** – European Union

- **Exx** - xx percent ethanol in gasoline

- **FFV** - Flexible Fuel Vehicle – vehicle designed to run on 85% ethanol, 15% gasoline blends
  - Brazil FFV run on ~96% ethanol
US Specific Nomenclature

**CARBOB** – CARB BOB – sub-octane gasoline blended for use in California RFG
MTBE - Methyl Tertiary Butyl Ether – ester that was used as an oxygenate component in gasoline that has now been banned in some localities

**CBOB** – Conventional BOB – sub-octane gasoline blended for areas not requiring RFG

**EPACT 2005** – Energy Policy Act of 2005 – along with other items set the renewable fuel standard for the United States

**RBOB** – Reformulated BOB – sub-octane gasoline blended for use in National RFG

**RFG** – Reformulated Gasoline – gasoline formulated to provide lower emissions when combusted


**xBOB** – Blendstock for Oxygenate (ethanol) Blending – sub-octane gasoline specifically formulated for blending with denatured ethanol
Ethanol - Motor Fuel

- Why use ethanol?
- How is it produced?
- Regional implementation

Potential concerns with the use of ethanol
  - Handling
  - Blending
  - Vehicle concerns
Ethanol’s Main Drivers

Ethanol usage is on the rise, with the main drivers being:
- U.S. EPACT 2005 (Energy Policy Act of 2005) – along with other items set the renewable fuel standard for the United States
- Significant rise in crude oil prices
- Desire to reduce dependency on foreign crude
- Reduction of urban air pollution
- Support of agricultural sector – increased employment
- Politics and price supports
- Demise of MTBE as an oxygenate blend component
Ethanol Overview

- Ethanol is the most widely used renewable fuel
- Ethanol is a viable substitute for gasoline
- Produced from a variety of renewable plant resources
- Ethanol has been used as a neat fuel and as a blend component for 30 years
- In 2005 the U.S. surpassed Brazil as the world leader in fuel ethanol usage
Ethanol As Transportation Fuel

Ethanol is used:

- As a blend component with gasoline
  - i.e., E10 is 10% ethanol and 90% gasoline

- To make ETBE (ethyl tertiary butyl ether) for blending into a gasoline
  - Ethers are less water soluble than alcohols
  - Can be blended at the refinery and finished gasoline shipped in a pipeline

- As a neat fuel (usually in anhydrous form) 95% ethanol and 5% water

- To blend alternative fuel – E85
  - 85% ethanol and 15% gasoline
  - Only for use in flexible fuel vehicles (FFVs) designed to handle high concentrations of alcohol

- As an octane source for increasing the octane number of finished gasoline
  - Ethanol Blend Octane Values
    RON ~124
    MON ~102
Ethanol Variability

- Ethanol is available from multiple plant sources
  Grains, sugar cane, fruits, biomass, etc.

- Starches converted to fermentable sugars
  Distilled and purified to 200-proof ethanol

- Two general milling approaches
  - Dry-milling – starts with dry ground grains
    By-product is dried grain and solubles
  - Wet-milling - water is introduced in the processing
    More valuable by-products including gluten, starches, and corn syrup

- Fuel-grade ethanol is usually denatured with up to 8% gasoline or naphtha and treated with corrosion inhibitors
**Ethanol Production Process**

1. Corn
2. Wet or Dry Milling
3. Enzyme Conversion
4. Fermentation
   - By-product Drying
   - Distillation
     - By-products (animal feeds)
     - Drying & Clean-up
       - Ethanol
Alternate Ethanol Production—“Cellulosic Ethanol”

- Best potential for future cost reduction in production of ethanol and reducing greenhouse gases

- Conversion of biomass feedstock (corn stalks, straw, wood) to ethanol
  - Currently uses sulfuric acid to hydrolyze cellulose into fermentable sugars
  - Potential for enzymatic hydrolysis rather than acidic
    - Currently an expensive proposition

- Issues: Large amount of byproducts, acid handling, cost of enzymatic hydrolysis
Differences Between Gasoline & Ethanol

- Gasoline is a mixture of chemical species with a range of boiling and ignition temperatures, ethanol is one chemical with distinct properties.

- Gasoline is not water soluble, ethanol is water soluble.

- Gasoline delivers more energy per kilogram or liter than ethanol.
  Ethanol has 66% volumetric energy content of gasoline.

- Gasoline is lower in octane value than ethanol.
Ethanol Pros and Cons

**Pros:**
- Renewable resource
- Reduced CO and CO\(_2\) emissions
- Higher octane
- Potential for more power (charge cooling)

**Cons:**
- Reduced range (lower energy content)
- Higher percentages of ethanol result in greater reduction in kilometers/liter
- Currently subsidized in the U.S.
- Potential issues when used at higher than 10% in gasoline
- Water soluble so gasoline blended with ethanol cannot be shipped via pipeline
- E85 only applicable in flex fuel vehicles
- E85 availability limited to a few service stations
- Increase in some emissions
- In the U.S., ethanol is not produced in many areas where it is needed for RFG
- High energy input required to make grain ethanol
Regional Trends
North America
North America Outlook

2005 output: ~3.9 billion gallons

2009 actual: ~ 9.0 billion gallons

Ethanol/gasoline blends have been used since the 1890s
Gasohol (10% EtOH) was first defined in 1978

Interest is growing in higher ethanol blends
E15 under review by EPA
E20 mandate proposed in Minnesota (requires EPA waiver)
E85 for flex fuel vehicles only (classified as an alternative fuel)
Most conventional gasoline detergents have limited solubility in E85
More expensive, more ethanol-soluble options are available

There are questions as to if the EPA detergency rules require additive use in E85
May not be required
May only be required in the gasoline portion
  – Effect of very low doses of gasoline additive in E85 on deposit formation not yet determined

Older FFV control schemes may have difficulty sensing ethanol contents between 10 and 85%
Could lead to poor driveability when fueling with both E85 other pump gasoline
Limited availability and cost
North America Ethanol Usage

Ethanol is typically blended at terminals with sub-octane blend stocks specifically designed for blending with ethanol

- CBOB – used in regions where emissions are not a major concern
- RBOB – used in areas where Reformulated Fuel is required for emission controls
- CARBOB – Required for ethanol blending in California

**Typical available RBOB**

- 85.4 Octane (R+M)/2 for blending with 5.7% ethanol
- 83.7 Octane (R+M)/2 for blending with 10% ethanol

**xBOBs have specific physical and chemical properties for blending with ethanol and meeting regional regulatory requirements**
Fuel Ethanol / Renewable Fuels Usage in the US

![Bar chart showing actual and projected ethanol usage in the US from 1997 to 2012. The chart includes a legend indicating 'Actual/Projected Ethanol' and 'RFS Requirement.' The usage grows steadily over the years, with projected values surpassing actual values by 2012.]
Regional Trends
Europe
Europe Outlook

2004 output: ~440 million gallons
2009 actual: ~1.04 billion gallons
  Most goes into making ETBE
  Ethanol blending has begun
  Spain and France are the largest producers
  Sugar beet and grains are the primary feed stocks

EU countries voluntarily agree to use biofuels
  2% today, up to 5.75% in 2010
  Majority will be biodiesel or e-diesel
  Sweden currently using E5 and rapidly increasing use of E85
Regional Trends
Latin America
Latin America Outlook

- **2004 output:** ~3.8 billion gallons primarily by Brazil
- **2009 actual:** ~ 6.5 billion gallons
- **In addition to Brazil, several Latin America countries have initiated ethanol blending programs**
  - Brazil’s long experience with ethanol and ethanol blends, E24-E100
  - Colombia at E10 levels
  - Paraguay E20
  - Argentina E5
- **Others to follow include Peru, Ecuador, Mexico, Uruguay, Chile**
### Latin America Outlook - Brazilian Experience

#### Current Brazilian vehicle fleet:
- 20% FFV capable of running on hydrated ethanol (95% ethanol and 5% water)
- 80% conventional vehicles run on an alcohol blend
- Over half of new car sales are FFVs bought to maximize potential for consumer savings

#### Alcohol content of gasoline varies by supply and demand for ethanol and sugar cane and is set by the government
- Varies from E20 to E25

#### Sugar cane currently most economical source of ethanol
- Agriculture shifted to mainly sugar cane production as result of demand for ethanol

Sources: International Fuel Quality Center & Energy Bulletin, 2005
Regional Trends
Asia Pacific
Asia Pacific Outlook

- **2004 Output:** ~96 million gallons
  - China, India, Australia

- **2009 actual:** ~1.2 billion gallons
  - China, India, Australia, Thailand

- **Several Asian countries have initiated ethanol blending programs**

- **China, India and Thailand leading the way**
  - China E10 mandate in select cities
  - India E5 in mandate many states
  - Thailand E10 widely available

- **Others include Japan, Philippines, Australia**
Ethanol/Gasoline Technical Overview
Discussion Topics

- Impact of ethanol on emissions
- Distribution and properties
- Problems associated with sulfates in ethanol
- Deposit forming tendencies of gasoline formulated with ethanol
Impact of Ethanol on Emissions
Effect of Ethanol Blends on Emissions

- Effects vary with different ethanol levels and base fuel properties
- Emissions reductions CO and CO$_2$ are possible
  - Significant energy is used to grow, harvest, process and distribute ethanol
- NMOG (non-methane organic gases) and air toxics increases are likely
- Difficult to separate volatility from ethanol effects
  - Fuel distillation and volatility play an important role
- Older vehicles or vehicles with less sophisticated emission control schemes may behave differently than newer vehicles
Ethanol and Automotive Concerns

Primary concerns are evaporative emissions and loss of driveability performance

Driveability (smooth driving performance) is affected by the boiling distribution of the fuel, which is influenced by ethanol blending

E85 and the Automotive Industry

- Largest inroads in Europe and the United States
- Only recommended for Flex-Fueled Vehicles (FFVs) specifically designed to use E85
- Auto makers have manufactured FFVs capable of operation on E85 for years
  - More FFV models are available each year
  - More recently auto makers have been advertising their FFV vehicles
  - Collaborative work on new technologies to enable E85
- Benefits to the auto companies
  - Green marketing to the consumer
  - CAFE (Corporate Average Fuel Economy) credits in the US
Deposit Forming Tendencies of Gasoline Formulated with Ethanol
Impact of Ethanol Source on Intake Valve Deposits Ford 2.3L IVD Results on E10 blends

![Graph showing average IVD (mg) for different ethanol sources.](graph.png)

- Ethanol 1
- Ethanol 2
- Ethanol 3

Standard RUL Base Fuel additized with Afton GPA Technology

**Passion for Solutions™**
Impact of Ethanol Source on Combustion Chamber Deposits  Ford 2.3L CCD Results on E10 blends

<table>
<thead>
<tr>
<th>Ethanol 1</th>
<th>Ethanol 2</th>
<th>Ethanol 3</th>
</tr>
</thead>
</table>
| Standard RUL Base fuel additized with Afton GPA Technology

Passion for Solutions™
BMW IVD Results - Standard RUL – 5000 miles

Afton's GPA Technology
Intake Valve Deposit, mg

- w/o EtOH
- w/10% EtOH

5000 mile inspection

Intake Valve Deposit, mg

- 13 mg (w/o EtOH)
- 5 mg (w/10% EtOH)
Ethanol Impacts on IVD Formation

Evaluate the IVD forming tendencies of gasoline performance additives in gasoline containing 24% ethanol

Ford 2.3L IVD test (ASTM D6201)

Test Fuel
  - Fuel A: commercial unleaded with similar properties to Brazilian certification fuel

Neat base fuel vs. “splash” blend with 24% ethanol
Ford 2.3L IVD Results - Fuel A

Afton's GPA Technology Treat Rate, ppm v/v

- **Intake Valve Deposit, mg**
  - w/o ethanol
  - w/24% ethanol

<table>
<thead>
<tr>
<th>Afton's GPA Technology Treat Rate, ppm v/v</th>
<th>Intake Valve Deposit, mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>545.8</td>
</tr>
<tr>
<td>160</td>
<td>441</td>
</tr>
<tr>
<td>205</td>
<td>251.8</td>
</tr>
<tr>
<td>255</td>
<td>123.6</td>
</tr>
</tbody>
</table>

- **Intensity Levels:** 0, 100, 200, 300, 400, 500, 600, 700
Ford 2.3L CCD Results - Fuel A

Afton's GPA Technology Treat Rate, ppm v/v

Average CCD, mg

- w/o ethanol
- w/24% ethanol

Base: 160, 205, 255

1653 1826 1970 2088 1665 1724 1593 1576
Ford 2.3L IVD Results - Fuel B

Intake Valve Deposit, mg

- Base: 565 mg
- w/o EtOH: 549 mg
- w/24% EtOH: 27 mg

Avg of 2 runs – 122 and 48 mg

Afton’s GPA Technology Treat Rate, ppm v/v

255 ppm v/v
Brazilian E24 Fleet Test

- Demonstrate the IVD performance of Afton’s GPA in Brazilian market conditions

- Three identical vehicles
  - GM Brazil Celta 1.0L FFV

- Test Matrix
  - 250 cycles
  - 15 min at 80 km/h; 45 min soak

- Brazilian gasoline with 24% EtOH
  - Base with no additive
  - Base + 250 µl/l detergent additive
Brazilian E24 Fleet Test – IVD Results

Intake Valve Deposit, mg

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Base</th>
<th>Additive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle 1</td>
<td>91</td>
<td>0</td>
</tr>
<tr>
<td>Vehicle 2</td>
<td>133</td>
<td>10</td>
</tr>
<tr>
<td>Vehicle 3</td>
<td>224</td>
<td>16</td>
</tr>
</tbody>
</table>
FFV Program Objective

- Understand the deposit forming tendencies of Flexible Fuel Vehicles (FFV) and E85 Fuel

- Determine if different sources of ethanol have different deposit forming tendencies
  - Causes of differences if any

- To understand how conventional GPAs perform in E85 fuels
### Ethanol Characteristics

<table>
<thead>
<tr>
<th>Inspection</th>
<th>Ethanol “A”</th>
<th>Ethanol “B”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol, Wt. %</td>
<td>94.86</td>
<td>96.81</td>
</tr>
<tr>
<td>Methanol, Wt. %</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>Denaturant, Wt. %</td>
<td>4.07</td>
<td>2.34</td>
</tr>
<tr>
<td>Water Content, Wt. %</td>
<td>1.04</td>
<td>0.84</td>
</tr>
<tr>
<td>pH of Ethanol</td>
<td>7.71</td>
<td>9.86</td>
</tr>
<tr>
<td>Sulfates, ppm m/m</td>
<td>3.8</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Corrosion Inhibitor, ppm (m/m)</td>
<td>116</td>
<td>3</td>
</tr>
<tr>
<td>Heating Value, Gross Kjoule/kg</td>
<td>Sample being analyzed</td>
<td>Sample being analyzed</td>
</tr>
</tbody>
</table>
Baseline FFV on Conventional Gasoline

- **Commercial (E0) Regular gasoline**
  - Unadditized
  - Additized with conventional GPA
  @ TOP TIER treat rate

- **Vehicle on E0 responds in a normal fashion**

![Graph showing IVD levels for unadditized and additized vehicles on E0 gasoline.](image)
ASTM D6201 - 2.3 L IVD Test on Similar Gasoline

- **Commercial (E0) Regular gasoline**
  - Unadditized
  - Additized with conventional GPA @ TOP TIER treat rate

- FFV on E0 responds in a similar fashion to ASTM IVD test
**FFV Ethanol Effects on IVD – E85**

- **E85 blended from two commercial sources of ethanol**
  - Ethanol A and Ethanol B

- **One commercial E85**

- **Conclusions**
  - IVD from Ethanol A and Commercial E85 were higher than would be expected from hydrocarbon only portion
    - 429 mg x 15% = 64 mg
  - IVD from Ethanol B more in line with expectations
GPA Additive Effects on E-85 in FFV

Testing conducted in
- E85 blended from Ethanol “A”
- Conventional GPA

Conclusions
- LAC in 15 percent gasoline portion only does not significantly reduce IVD
- Additizing E85 at Top Tier treat rates significantly reduces IVD

1. LAC treat in gasoline portion only
2. Top Tier treat in gasoline portion only
3. Top Tier treat in E85
Corrosion Inhibitor Effects on IVD

<table>
<thead>
<tr>
<th></th>
<th>E85 - No GPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ethanol “A” that contains buffered Cl as received</td>
</tr>
<tr>
<td>2</td>
<td>Ethanol “B” that does not contain a Cl as received</td>
</tr>
<tr>
<td>3</td>
<td>Ethanol “B” additized by Afton with the same buffered Cl as Ethanol A</td>
</tr>
<tr>
<td>4</td>
<td>Ethanol “B” + Afton’s Cl</td>
</tr>
</tbody>
</table>

**Conclusion**
- Buffered corrosion inhibitors tend to increase IVD
Distribution and Properties
Ethanol Blending

When used as a blend stock, ethanol will:
- Increase octane
  - E10 increases octane by ~3.5-4.5 RON depending on the octane number of the base gasoline
- Increase the volatility of base fuel
  - Affects driveability and evaporative emissions
- Provide additional solvency
- Increase a fuel’s affinity for water
- Excess water could cause water and ethanol to separate in storage or vehicle fuel tanks
- Can affect cold startability

Ethanol may require different concentrations and types of corrosion inhibitors

Conducted at terminals in the U.S. due to contamination issues with pipelining ethanol/gasoline blends

There are standard specifications for denatured fuel ethanol for blending with gasoline
  - ASTM D4086 is one standard
  - EU looking to formalize a unified specification

Passion for Solutions™
Ethanol in Distribution

- Care must be taken to insure product quality to the ultimate customer – the vehicle owner

- Logistical issues in the U.S. due to finished gasoline containing ethanol not being allowed in the pipeline system

- Most ethanol production is not in regions where most ethanol is used
  Significant transportation cost and availability of equipment

- Common concerns:
  - Contamination during transportation
  - Water contamination – phase separation
  - Corrosion
  - Sulfates contaminants cause filter plugging and fuel injector fouling or sticking

- EERC (Ethanol Emergency Response Coalition)
# Properties of Ethanol and Gasoline

<table>
<thead>
<tr>
<th>Property</th>
<th>Ethanol</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
<td>C₂H₅OH</td>
<td>C₄ to C₁₂</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>46.07</td>
<td>100-105</td>
</tr>
<tr>
<td>Composition, weight %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>52.2</td>
<td>85-88</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>13.1</td>
<td>12-15</td>
</tr>
<tr>
<td>Oxygen</td>
<td>34.7</td>
<td>0</td>
</tr>
<tr>
<td>Specific gravity, 60°F/60°F</td>
<td>0.794</td>
<td>0.72-0.78</td>
</tr>
<tr>
<td>Density, lb/gal @ 60°F</td>
<td>6.61</td>
<td>6.0-6.5</td>
</tr>
<tr>
<td>Boiling temperature, °F</td>
<td>172</td>
<td>80-437</td>
</tr>
<tr>
<td>Reid vapor pressure, psi</td>
<td>2.3</td>
<td>8-15</td>
</tr>
<tr>
<td>Octane Number/Blending value (R + M) /2</td>
<td>113</td>
<td>84-93</td>
</tr>
<tr>
<td>Water solubility, @ 70°F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel in water, volume %</td>
<td>100</td>
<td>Negligible</td>
</tr>
<tr>
<td>Water in fuel, volume %</td>
<td>100</td>
<td>Negligible</td>
</tr>
<tr>
<td>Viscosity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centipoise @ 68°F</td>
<td>1.19</td>
<td>0.37-0.44</td>
</tr>
<tr>
<td>Centipoise @ 4°F</td>
<td>2.84</td>
<td>0.60-0.77</td>
</tr>
<tr>
<td>Flash point, closed cup, °F</td>
<td>55</td>
<td>-45</td>
</tr>
<tr>
<td>Auto ignition temperature, °F</td>
<td>793</td>
<td>495</td>
</tr>
<tr>
<td>Flammability limits, volume %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>4.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Higher</td>
<td>19.0</td>
<td>7.6</td>
</tr>
<tr>
<td>Latent heat of vaporization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Btu/gal @ 60°F</td>
<td>2,378</td>
<td>900 (approx.)</td>
</tr>
<tr>
<td>Btu/lb @ 60°F</td>
<td>396</td>
<td>150 (approx.)</td>
</tr>
<tr>
<td>Heating value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower (liquid fuel-water vapor)</td>
<td>11,500</td>
<td>18,000-19,000</td>
</tr>
<tr>
<td>Lower (liquid fuel-water vapor) Btu/gal @ 60°F</td>
<td>76,000</td>
<td>109,000-119,000</td>
</tr>
<tr>
<td>Stoichiometric air/fuel, weight</td>
<td>9.00</td>
<td>14.7</td>
</tr>
</tbody>
</table>

Differences Between Gasoline & Ethanol

- Gasoline is a mixture of chemical species with a range of boiling and ignition temperatures, ethanol is one chemical with distinct properties.

- Gasoline is not water soluble, ethanol is water soluble.

- Gasoline delivers more energy per kilogram or liter than ethanol. Ethanol has 66% volumetric energy content of gasoline.

- Gasoline is lower in octane value than ethanol.
Ethanol Storage and Handling

The solvency effect of ethanol and gasoline/ethanol blends will loosen rust, varnish and gum in tanks that have stored other products.

Storage tanks should be thoroughly cleaned and dried before the introduction of ethanol.

Most materials of construction used in retail sales of gasoline are compatible with gasoline/ethanol blends.

Not all vehicles around the world will have the appropriate elastomer compatibility to handle gasoline/ethanol blends.

Gasoline containing ethanol may cause vehicle fuel filter plugging in older vehicles.
Problems Associated with Sulfates in Ethanol
Ethanol Source Variability

Bench Test demonstrates Relative Performance in Different Ethanol Field Samples

<table>
<thead>
<tr>
<th>Sample Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Ethanol</td>
</tr>
<tr>
<td>U.S. Mid-Continent Ethanol-1</td>
</tr>
<tr>
<td>U.S. Mid-Continent Ethanol-1 +10ppm Ammonium Sulfate</td>
</tr>
<tr>
<td>Canadian Ethanol-1</td>
</tr>
<tr>
<td>Canadian Ethanol-2</td>
</tr>
<tr>
<td>U.S. Mid-Continent Ethanol-2</td>
</tr>
<tr>
<td>Brazilian Ethanol</td>
</tr>
<tr>
<td>Thailand Ethanol</td>
</tr>
<tr>
<td>Unfiltered pipeline fuel plus 10% Ethanol</td>
</tr>
</tbody>
</table>
Effect of Ethanol Source

Ethanol quality determines filter plugging tendency

Commercial US Gasoline with Gasoline Additive 10% vol Ethanol
Effect of Gasoline Detergents on Filter Plugging

Additives can help overcome the effect of high sulfate concentrations
Ethanol and Dispenser Filter Plugging - Fuel Filter Analysis in E10 Gasoline

Premature filter plugging at service stations caused by sodium and ammonium sulfates
   Ethanol appears to be the primary source of sulfates

Some gasoline additives and unknown components in some ethanol cause sulfate particles to agglomerate

Specifically formulated additives can prevent agglomeration, prolonging filter life

Proper QC measures are required to insure product quality
Reference Materials

  www.ethanolrfa.org
- Renewable Fuel Association Publication #930601 “Gasoline Ethanol Blends-Program Operations Guide”
- API Recommended Practice 1626 “Storing & Handling Ethanol and Gasoline/Ethanol Blends at Distribution Terminals and Service Stations”
- API Recommended Practice 2015 “Cleaning Petroleum Storage Tanks”
- API Recommended Publication 4261, 2nd ed. “Alcohols & Ethers, A Technical Assessment of their applications as Fuels & Fuel components”
- Downstream Alternatives Inc. document # 970302 “Driveability and Performance of Reformulated and Oxygenated Gasolines”
- Literature Reviews “Environmental Aspects of higher blend Ethanol Fuels”
- Harts Publications “Renewable Fuels News” & “Octane Weekly” various
Key Point Summary

The use of ethanol as a gasoline blend component is increasing around the world as the most viable biofuel.

Flex Fuel Vehicles are gaining market share in the US and Brazil and do require additives to control IVD.

All ethanol is not necessarily equivalent.

Corrosion inhibitors do impact IVD.

Gasoline/ethanol blends will vary in performance depending on the source of the ethanol.

Caution must be taken when blending and handling ethanol and gasoline/ethanol blends.

Afton’s HiTEC® and BioTEC® family of additives provide excellent performance enhancements with and without ethanol.