



Ethanol : Fuel Quality

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October 2022

Today's Presentation, Discussion

- Ethanol Market Development
- Fuel Specifications
 - ASTM International
 - Global Specifications
- Fuel Quality issues
 - Fuel Cleanliness
 - COAs
- Final Thoughts
- Questions



Just a bit about me....



1994: Started at largest distillery in the world.

2000: Transferred to largest corn processing plant in the world.

2007: Worked for ethanol trade association.

2015: KMoore Consulting formed.

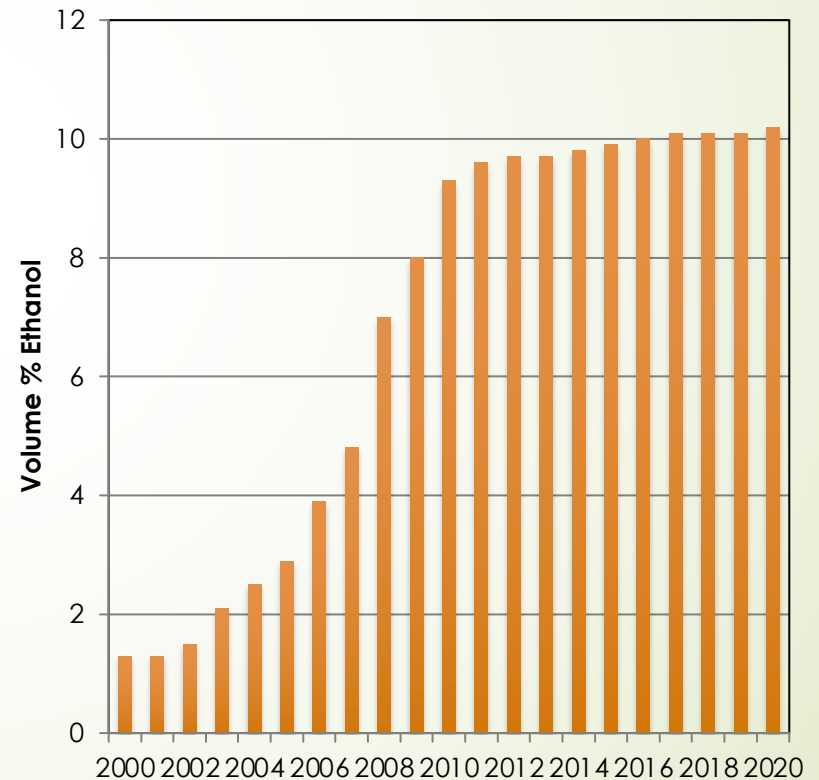
2019: Changed up my client list, working for Growth Energy building domestic and global markets.

- ▶ Clean Air Act of 1970
 - ▶ Creation of EPA
- ▶ Ban of tetra-ethyl lead 1974
 - ▶ Creates need for new octane source
- ▶ Clean Air Act of 1990
 - ▶ Create evaporative and exhaust emissions controls and RFG
- ▶ Winter Oxygenate Fuel Program (1992)
 - ▶ Program includes Colorado (elevation)
- ▶ Gasoline Detergents (1995)
 - ▶ Deposit control additive requirement
- ▶ Phase 1 Reformulated Gasoline (1995)
 - ▶ Required 17% reduction in VOCs.
- ▶ Mobile Source Air Toxics of 2002, 2011
 - ▶ Reduction in benzene, etc.
- ▶ Tier 2, 3 Sulfur Standards (2004, 2017)
 - ▶ Gasoline to 30ppm first, then 10ppm.
- ▶ Energy Policy Act of 2005
 - ▶ Initiated funds from Department of Agriculture and Energy for alternative fuel sources
- ▶ Energy Independence and Security Act of 2007 (Renewable Fuels Standard 1 & 2)
 - ▶ Required blending volume of renewable fuels into fossil fuels.

Why Ethanol?

Nearly every policy since the creation of the EPA requires a clean oxygenate like ethanol.

Ethanol as a Percent of U.S. Motor Gasoline Pool



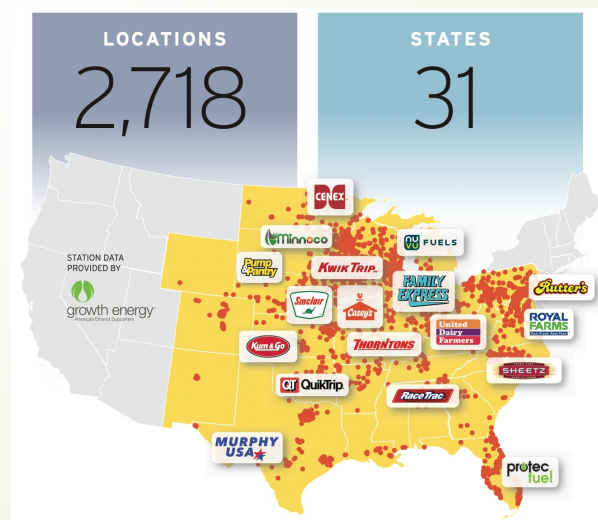
United States Gasoline- Ethanol Logistics

Logistics

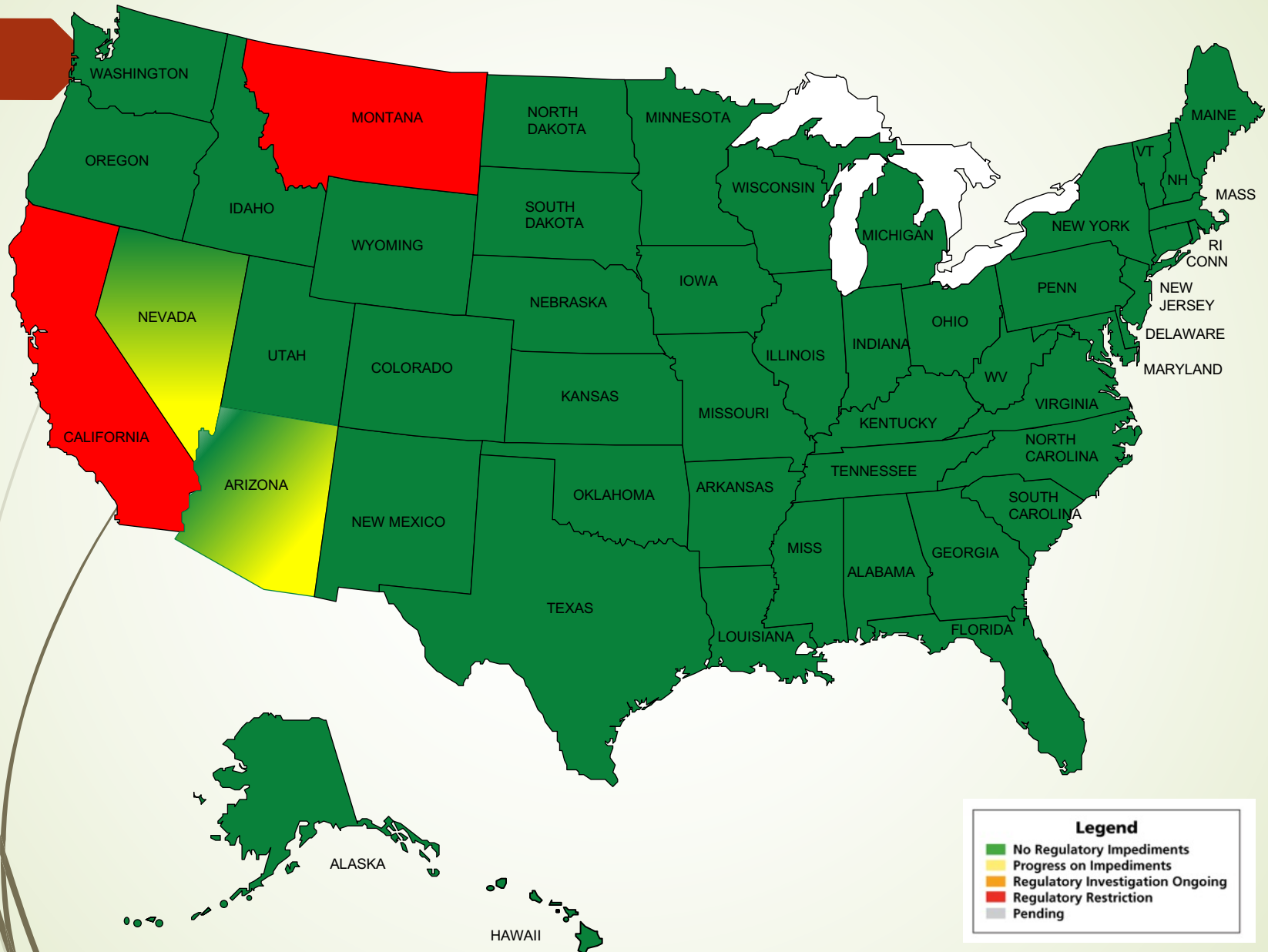
- Largest in the World:
Consumes ~145BGY of gasoline.
 - 16BGY ethanol blending.
- 1,331 terminals in the U.S.
 - Government tracked, published.
 - ~90% handle ethanol.
 - Example: terminals w/out ethanol are airport, jet fuel only.
- Gasoline travels in pipelines, railcars, trucks, barges, ships.
 - Ethanol travels in the same.

Retail Stations

- ~145,000 retail stations.
 - 60% are single store owners. <5% of the stations are oil company owned.
- 36% sell branded fuel; half are independent brands.
- 10% ethanol now 98% of all gasoline across all octane grades, (87/89/91AKI.)
- 15% ethanol at ~2,700 stations.



E15 Regulatory Impediments as of August 2022



Ethanol at Retail: New Fuel E15

- Most common gasoline blend contains 10% ethanol.
- New fuel: 15% ethanol approved in 2011, 2012.
 - It's not really that new...
- Approved for use in 2001 and newer vehicles. 96% of the vehicles on the road today.
- U.S. Drivers have completed more than 30 billion miles on the fuel without failure.
- Fuel is still not legal in CA, MT.



Ethanol Use Globally

- 1970s: Brazil started a robust ethanol program to reduce fuel imports, create energy security.
- 1978: U.S. EPA approval for 10% ethanol blends with gasoline. 2010, 2011: U.S. EPA approval for 15% ethanol blends with gasoline. 2017: ~97% of all U.S. gasoline contains 10% ethanol.
- 2017: China allows use of E10 in 8 provinces. 2021: Nationwide use E10.
- 2021: Latin, South America moving to E10.

Rank	Country	Gasoline Consumption	Ethanol Use?
1	United States	388KMMT	E10, moving to E15
2	China	90KMMT	E10
3	Japan	39KMMT	3%, 11% ETBE use.
4	Russia	36KMMT	None.
5	Mexico	33KMMT	E5.8
6	Brazil	33KMMT	E27 and E95.
7	Indonesia	24KMMT	E7 and E3.
8	Saudi Arabia	22KMMT	None.

Global Ethanol Specifications

- ▶ Each country, each state, each customer may have their own specifications.
- ▶ Two common protocols for fuel specs:
 - ▶ Adopt an international fuel specification developed by a Standards Development Organization.
 - ▶ Originate a fuel specification for country's specific needs.
- ▶ Important to know the exact version.
- ▶ Changing national/ state fuel specifications can take a long timeline.

This is where I am spending a lot of research time and effort to understand and influence.



International Fuel Specifications

Gasoline, Motor Fuel

- Ensure the country petroleum specifications allow a minimum of 10% ethanol (3.5% O₂ wt.)
- Recognize the effects of ethanol on volatility.
- Allow blending, sampling, certification of final gasoline-ethanol blend is not burdensome.

Ethanol

- Recognize D4806 as the acceptable fuel spec.
- Allow for denaturants or other indications to ensure fuel applications without taxation.
- Allow ethanol blending any where in downstream.



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Anhydrous Fuel Ethanol Specifications

ASTM Fuel Ethanol, D4806-21a**

- Ethanol, min%: 92.1 (v)
- Methanol, max%: 0.5(v)
- Water, max%: 1.0 (vol.)*
- Acidity, max, mg/L: 70
- pHe: 6.5-9.0
- Sulfur, max: 30 (wt.)
- Denaturant: NMT 2.0% (EPA)
- Other parameters to ensure highest quality.

ANP#19 (2015), #764 (2018)

- Ethanol, min%: 98.0(v)
- Methanol, max%: 0.5(v)
- Water, max%: 0.7 (wt.)*
- Acidity, max, mg/L: 30
- pHe: 6.0-8.0
- Sulfur: Report
- Denaturant: 3%
- Other parameters to ensure highest quality.

* Greatest difference is the water content. 0.7% (wt) = 0.56% (v).

** There is no similar specification at ASTM for hydrous ethanol.

Fuel Ethanol Specifications

ASTM Fuel Ethanol, D4806

- Ethanol, min%: 92.1 (v)
- Methanol, max%: 0.5(v)
- Water, max%: 1.0 (vol.)*
- Acidity, max, mg/L: 70
- pHe: 6.5-9.0
- Sulfur, max: 30 (wt.)
- Other parameters to ensure highest quality.

ISO Fuel Ethanol, EN15376

- Ethanol, min%: 98.7 (v)
- Methanol, max%: 0.5(v)
- Water, max%: 0.3 (wt.)*
- Acidity, max, mg/L: 70
- pHe: 6.5-9.0
- Sulfur, max: 10 (wt.)
- Other parameters to ensure highest quality.

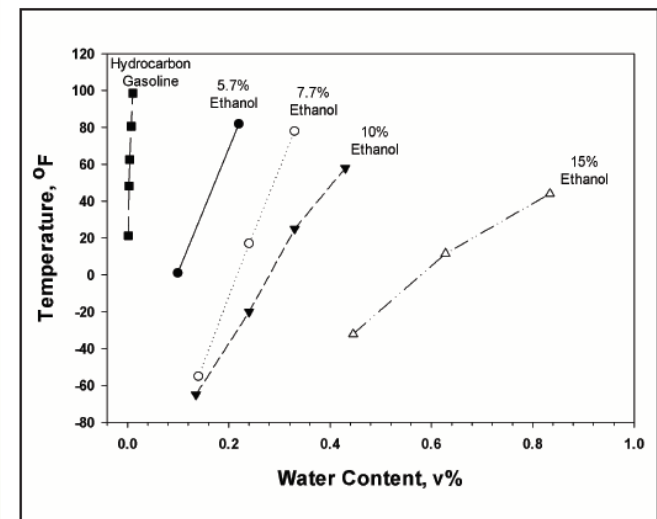
* Greatest difference is the water content. ISO specification water limit is based on ethanol for use in esterification processes. ASTM water limit is for direct ethanol blending.

Importance of Ethanol Parameters

Parameter	Importance
Ethanol Content, min.	A minimum ethanol content is specified to ensure blenders of ethanol can accurately achieve targeted ethanol concentrations in the final gasoline/ ethanol blend.
Methanol Content, max.	Small amounts are corrosive.
Water Content, max.	Control water content added to gasoline.
pHe, Chlorides, Sulfates, Copper, Metals, Residue, etc.	Manages corrosion potential, limits potential precipitates, manages contamination.
Acidity, max.	Control organic acids, limit corrosivity.
Sulfur, max	Limit contribution to gasoline. From denaturant, ethanol contains no sulfur.
Appearance, Color	Indication of contamination (should be water-white), indication of dye/ tax status.

- The water limit in the fuel ethanol specification for direct blending in gasoline is determined by the water tolerance of the finished gasoline-ethanol blend.
- “Water tolerance” is the ability of a fuel to absorb small quantities of water without creating a separate phase in the fuel.
- Gasoline and ethanol form homogeneous mixtures; ethanol and water form homogeneous mixtures. However, gasoline and water phase separate when more than ~150ppm water is present.
- *Even at extreme cold temperatures, near -51°C (-60°F), 10% ethanol- gasoline blends have a water tolerance above 0.1%.*
- Looking for a technical discussion on the Brazil water limit.

Discussion: Brazil Water Limit in Ethanol Specification



Source: National Renewable Energy Laboratory

Ethanol, not Methanol


- ▶ Both the U.S. and Brazil have suffered with Methanol contamination; both purposeful and accidental.
- ▶ Even though both are in the alcohol chemical family, there are important differences.
- ▶ Human toxicity risk creates additional safety concerns for methanol. Chronic exposure to methanol can cause developmental toxicity and blindness. Ethanol is actually an antidote for methanol poisoning.
- ▶ Methanol will create vapor pressure (hot start, vapor lock problems) as well as corrosion concerns that are far beyond using an inhibitor to treat.

Not Recommended by Automobile Manufacturers

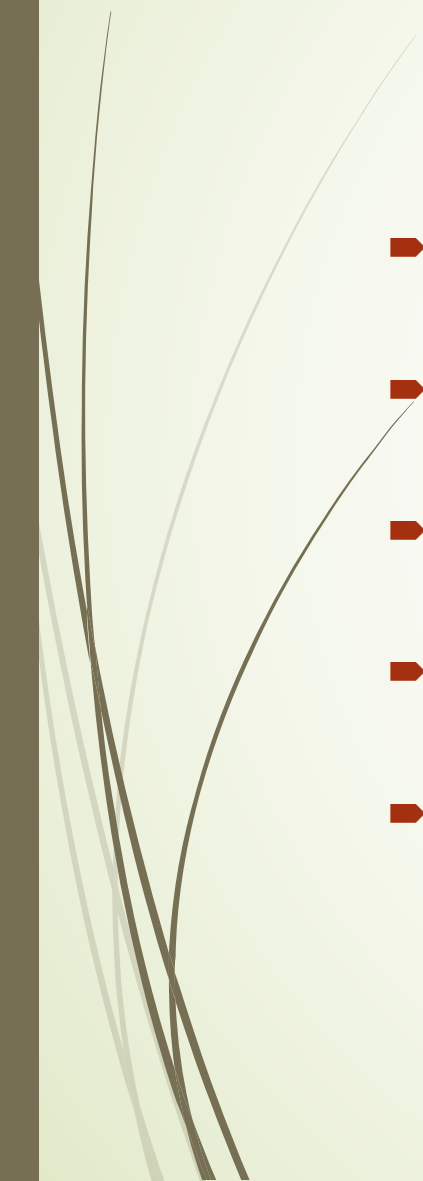
For decades, automobile manufacturers have warned of the vehicle failures that can occur due to the use of methanol. Auto manufacturers use stern warning statements such as:

- “Never use leaded gasoline, fuel containing methanol...”⁴
- “Vehicle damage or drivability problems may not be covered by manufacturer’s warranty if they result from the use of of: gasoline or gasohol containing methanol.”⁵

Failures due to methanol will not be honored by the manufacturer’s vehicle warranty. Methanol is considered “highly” corrosive to automobile fuel systems and therefore the allowable concentration of methanol is restricted to very low levels.^{6,7} Methanol “accelerates the deterioration” of elastomers that are used in hoses and gaskets in vehicle fuel systems.⁸ Conversely, vehicles are designed to utilize gasoline blended with a minimum of 10% ethanol for many decades.



Fuel Ethanol Specification: Parameters should be based on ultimate blend percentage.

- ▶ There are different specifications for ethanol dependent on the blending target in gasoline.
 - ▶ ASTM D4806 has been reviewed and approved for ethanol blending up to 15% ethanol.
 - ▶ ISO standard lags behind ASTM, especially in biofuel specifications.
 - ▶ CGSB standard is under review, approval for blending up to 15% ethanol.
 - ▶ Looking for an opportunity to discuss ASTM and ANP fuel specifications.
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ASTM International Adopted Globally

- ▶ ASTM Standards are important to all of us!
- ▶ Domestic and commercial contracts typically reference consensus standards for motor fuels such as ASTM D4806 for denatured fuel ethanol.
- ▶ International specifications are based on ASTM test methods.
- ▶ Are you a member? I actually have a list of who is and who isn't. 😊

Global Ethanol Specs: These parameters should be set on the ethanol blend rate; instead some of these limits are protectionist.

Parameter	United States ASTM D4806	Canada CGSB 3.516	EU EN15376	China NG18	Brazil ANP #764
Ethanol, % vol.	92.1	92.0	98.7	92.1	98.0
Methanol, % vol.	0.5	0.5	1	0.5	0.5
Water, % vol.	1.0	0.8	0.300	0.8	0.56
Acidity, mg/ kg	70	70	0.005% wt.	56	30

Current Fuel Quality Questions

- Ensure you are using the correct temperature compensation. EPA codified this in 40CFR1090.1350. (API General Products Table 51.5)
- Fuel Cleanliness: Reports of sediment, rust, etc. This is a transportation issue in most cases. Recommend 10micron nominal filters at the plant.
 - There are temporary filtration devices that can be used. (Bullet filters)
 - Remember gasoline is hardly ever filtered once it leave the refinery; many times the water bottoms in gasoline tanks are used to collect sediment.
 - Ethanol will never have a water bottom; ensure the product is “clear, bright, free”.

6. Workmanship

6.1 At the point of custody transfer, the denatured fuel ethanol shall be visually free of sediment, suspended, or undissolved matter. It shall be clear and bright at the product temperature at the point of custody transfer or at a lower temperature agreed upon by the purchaser and seller.

A couple more Quality thoughts:

- ▶ Magellan news: monthly COAs are not being “handled correctly.” Approved suppliers are not submitting monthly COAs. Check frequency (skip lot testing.)
- ▶ Certificates of Analysis: Know what you are making/ selling.
- ▶ Ensure the COA details match the fuel spec to which the order was sold.
 - ▶ For example: D4806 is NOT D5798.
 - ▶ D4806 is denatured fuel ethanol for blending into gasoline.
 - ▶ D5798 is an E85, Ethanol Flex Fuel that goes directly into a vehicle.

TABLE 1 Requirements for Ethanol Fuel Blends^A

Properties	Class 1 ^B	Class 2	Class 3	Class 4	Test Methods
Vapor pressure, kPa (psi)	38–62 (5.5–9.0)	48–65 (7.0–9.5)	59–83 (8.5–12.0)	66–103 (9.5–15.0)	D4953 or D5191
		All Classes ^C			
Ethanol Content, volume %		51–83			D5501
Water, % by volume (% by mass), max		0.8 (1.0)			D7923, E203, or E1064
Methanol Content, max, volume %		0.5			D5501
Sulfur Content, max, mg/kg		80			D5453 or D7039
Acidity, (as acetic acid CH ₃ COOH), mass % (mg/L) [mg/kg], max		0.005 (40) [50]			D7795
Solvent-washed gum content, max, mg/100 mL		5			D381
Unwashed gum content, max, mg/100 mL		20			D381
pH		6.5 to 9.0			D6423
Inorganic chloride content, max, mg/kg		1			D7319 or D7328
Copper content, max, mg/L		0.07			D1688

^A For information on alternative fuels, see 4.1.2.1.

^B See 5.3.1 for volatility class criteria.

^C Ethanol content and selection of hydrocarbon blendstock are adjusted by the blender to meet vapor pressure requirements. See X1.3.2 for additional information and guidance for blending.

Final Thoughts



- There are no dumb questions. I have lived my career asking questions.
- Embrace the change that this industry will be making over the next 2, 5, 10 years.
- *Mark my words: You all will become “wet-millers.”*
- Bring your ideas, we have resources to help make you successful.



Questions?

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