CRC Report No. E-85

NATIONAL SURVEY OF E85 QUALITY

November 2009

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Executive Summary

Market penetration of E85, nominally 85 volume % ethanol in gasoline or other hydrocarbons, has increased dramatically in recent years. This fuel is commonly known as E85, although the ethanol content is limited to no more than 83 vol% by the specification. The quality of E85 is specified under ASTM D5798. E85 properties vary with time of year, geography, and ambient temperature. Previous E85 surveys showed significant problems with high ethanol content and low volatility. The goal of this project was to collect samples from each volatility class and analyze for key properties from D5798. The samples representing each volatility class were collected between summer 2008 and summer 2009 and tested against key properties in D5798, such as ethanol content, water content, sulfur, vapor pressure, acidity, pHe, inorganic chloride, and sulfate. Selected samples were also tested for stability, octane, peroxides, and silver corrosion.

Class 1 samples were collected in the summer of 2008. Results showed almost 90% of the samples were off-specification for ethanol content and 50% of the samples were below the minimum vapor pressure. An additional subset of samples was collected and tested in the summer of 2009. The 2009 samples were on-specification for ethanol content more often, but continued to be below the specification minimum for vapor pressure. Similar trends were observed for Class 2 and Class 3 samples. For the other properties tested, only a handful of samples were off-specification, most often for acidity than any other property. Due to the continued observations of off-specification fuel, it is recommended that an additional survey of E85 quality be conducted.

Table ES-1. Summary of Vapor Pressure and Ethanol Content Compliance by Volatility Class

D5798 Class	# of Samples	Vapor Pressure			Ethanol Content		
		Below Minimum, %	Above Maximum, %	On Specification, %	Below Minimum, %	Above Maximum, %	On Specification, %
1 (2008)	47	53.2	0	46.8	4.3	89.4	6.3
1 (2009)	10	90.0	0	10.0	10.0	10.0	80.0
1 (All Data)	57	60.0	0	40.0	5.3	66.7	28.0
2	26	61.5	7.7	30.8	3.8	38.5	57.7
3	40	87.5	0.4	12.1	12.0	5.0	83.0
All	*123*	*73.1*	*0.7*	*26.2*	*7.5*	*35.7*	*56.8*

Abbreviations

°C: degrees Celsius

CRC: Coordinating Research Council

DVPE: dry vapor pressure equivalent

E85: Nominally 85% ethanol by volume and 15% gasoline or other hydrocarbons

EISA: Energy Independence and Security Act of 2007

EPAct: Energy Policy Act of 1992

°F: degrees Fahrenheit

FFV: Flexible Fuel Vehicle

inch-lbs: inch pounds

mg/100mL: milligrams per 100 milliliters

min: minutes

PADD: Petroleum Area Defense Districts

ppm: parts per million

psi: pounds per square inch

vol %: percent by volume

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Introduction

High content ethanol fuel became a reality in the U.S. due to the Alternative Motor Fuels Act of 1988[1], which created research and development and demonstration programs for both alternative fuels and vehicles to run on them, and also provided fuel economy credits to the automakers to make Flexible-Fuel Vehicles (FFVs). The Energy Policy Act of 1992 (EPAct)[2] defines E85, nominally composed of 85 vol % ethanol and 15 vol % gasoline or other hydrocarbons, as an alternative fuel for automotive spark-ignition engines that are designated as FFVs.

The market penetration of E85 has been increasing rapidly in recent years, with nearly 1,600 stations in 2008. Additionally, the Energy Independence and Security Act of 2007 (EISA) mandates increasing usage of renewable fuels in the United States to significantly higher levels than in previous years. This, coupled with discontinued use of methyl tert-butyl ether (MTBE) as an oxygenate blend component in U.S. gasoline and other drivers (like the need to reduce sulfur, aromatics, and olefin content in the gasoline pool), has sparked an interest in increased usage of ethanol as a transportation fuel component. In order to utilize this projected increase in ethanol, there are two realistic paths forward. The first path is to increase the ethanol content in conventional gasoline; the second path is to increase market penetration of E85. The quality of the E85 in the market is an important factor in increasing the utilization of E85 as an alternative fuel and is the focus of this report.

E85 quality was specified by ASTM D5798-08 when this survey program was initiated, but the current version is D5798-09b[3]. The fuel is typically called E85, although the specification does not allow 85 vol% ethanol in the fuel, but caps the ethanol content at 83 vol% in summer months. Much like gasoline, E85 volatility is adjusted seasonally to improve the cold start and warm-up performance of vehicles using this fuel. Thus, fuel specifications are dynamic and will change based on the minimum ambient temperature expected for the month at that locale. The purpose of D5798 is to ensure E85 is fit for this purpose. The specification covers three volatility classes, determined by the 6-hour tenth percentile minimum ambient temperature. These classes vary across season and geographic area throughout the year. Class 1 fuels are used in areas with ambient minimum temperatures greater than 5°C (41°F). Class 2 fuels are for areas and seasons with ambient temperatures between 5°C and -5°C (23°F and 41°F), and Class 3 fuels are used when ambient temperatures drop below -5°C (23°F). During transition or shoulder seasons, either of the two acceptable classes is allowed (e.g., 2/3 is the transition between classes 2 and 3, where E85 meeting class 2 or 3 is acceptable.)

Each volatility class has different minimum ethanol content and vapor pressure (DVPE) limits to ensure cold starting and warm-up driveability. Class 1 fuels have a minimum alcohol content of 79 vol % with a vapor pressure of 5.5 – 8.5 psi, Class 2 fuels have a minimum 74 vol % alcohol content with a vapor pressure of 7.0 – 9.5 psi, and Class 3 fuels have a minimum 70 vol % alcohol content with a vapor pressure of 9.5 – 12.0 psi. Of note here is that the database used by ASTM to develop these volatility and compositional limits is over 13 years old. Recently, CRC

[1] http://thomas.loc.gov/cgi-bin/bdquery/z?d100:SN01518:@@@L&summ2=m&
[2] http://thomas.loc.gov/cgi-bin/query/z?c102:H.R.776.ENR:
[3] ASTM D5798 technical standard, ASTM (www.astm.org)

has issued two reports, CRC Report No. 652[4] and CRC Report No. 654[5], which investigated vapor pressure and ethanol content on cold-start and warm-up driveability for all three E85 volatility classes. The results from these programs support the current vapor pressure limits. With lower summertime federal and state vapor pressure limits for both conventional and reformulated gasoline now in effect for many locations, it can be difficult to blend the required amount of commercial gasoline into denatured fuel ethanol and meet the minimum vapor pressure limits set out in D5798. Thus ethanol content and vapor pressure are two key properties to investigate.

The goal of this project was to understand the extent to which the fuel quality requirements were being met by collecting E85 samples across volatility classes throughout the United States. Sampling locations and testing methodologies were based on the recent E85 surveys that the Coordinating Research Council (CRC) obtained from SGS Germany GmbH. In the first of these surveys, CRC Report No. E-79, 47 samples were collected in the spring of 2006 from retail locations in 10 states. The number of samples collected in each Class 1, 2/1, 2, and 3/2 were 3, 5, 17, and 22, respectively. No Class 3 samples were captured. The sample geography was centered in the Midwest, where ethanol use is typically highest. Each of the three samples collected for Class 1 were from only one geographical area and passed the D5798 specification, while significantly higher failures were observed in the other classes. All samples collected in the Class 2 campaign failed to meet the specification due to low vapor pressure and/or low ethanol content. For the shoulder month samples, 40% of the Class 2/1 samples did not meet specification (due to low vapor pressure, low ethanol content, or high unwashed gum content) and 18% of Class 3/2 samples did not meet specification (due to low vapor pressure). In general, all samples met specifications for all other properties.

A follow-up E85 survey, CRC Report No. E-79-2, was conducted in January and February of 2007 to focus on wintertime E85 fuels. Fifty-five samples were collected from retail outlets in 15 states, predominantly in the Midwest, plus Texas, North Carolina, and South Carolina. Three Class 2 fuels and 52 Class 3 samples were collected. Similar to the previous study, the samples rarely passed the D5798 specification. 67% of the samples were off-specification in each case. In Class 2, the samples either had high vapor pressure or low ethanol content. In Class 3, the failure modes were more diverse, with either high or low vapor pressure, low ethanol content, low pHe, or off-specification for trace contaminants (like inorganic chloride or gums). In general, all samples met specifications for all other properties.

Test Methodology

In this study, samples were collected throughout the United States during each of the three sampling campaigns. The samples were balanced between Petroleum Area Defense Districts (PADDs) to ensure broad coverage of the E85 in the market. Figure 1 shows the locations of each sample collected during the survey. Table 1 lists the properties tested for these samples. All samples were tested against a list of routine properties, derived from the D5798 specification, with a subset tested for additional properties of interest. Samples were analyzed by a contractor

[4] http://www.crcao.org/publications/performance/index.html
[5] http://www.crcao.org/publications/performance/index.html

following ASTM test methods with no deviations, with the exception of D5501, which was modified to extend the calibration to cover the expected range of ethanol for E85.

Table 1. Test Properties for E85 Samples

Property	ASTM Method	Notes
Ethanol/methanol	D5501	All samples
Dissolved water	D6304	All samples
Vapor pressure	D5191	All samples
Sulfur	D5453	All samples
Washed and unwashed gums	D381	All samples
pHe	D6423	All samples
Inorganic chloride and sulfate	D7319	All samples
Appearance	D5798	All samples
Distillation	D86	Select samples
Density/API Gravity	D4052	Select samples
NACE corrosion	TM0172-2001	Select samples
RON/MON	D2699/D2700	Select samples
Peroxides	D3703	Select samples
Oxidation stability	D525	Select samples
Silver corrosion	D4814 Annex	Select samples

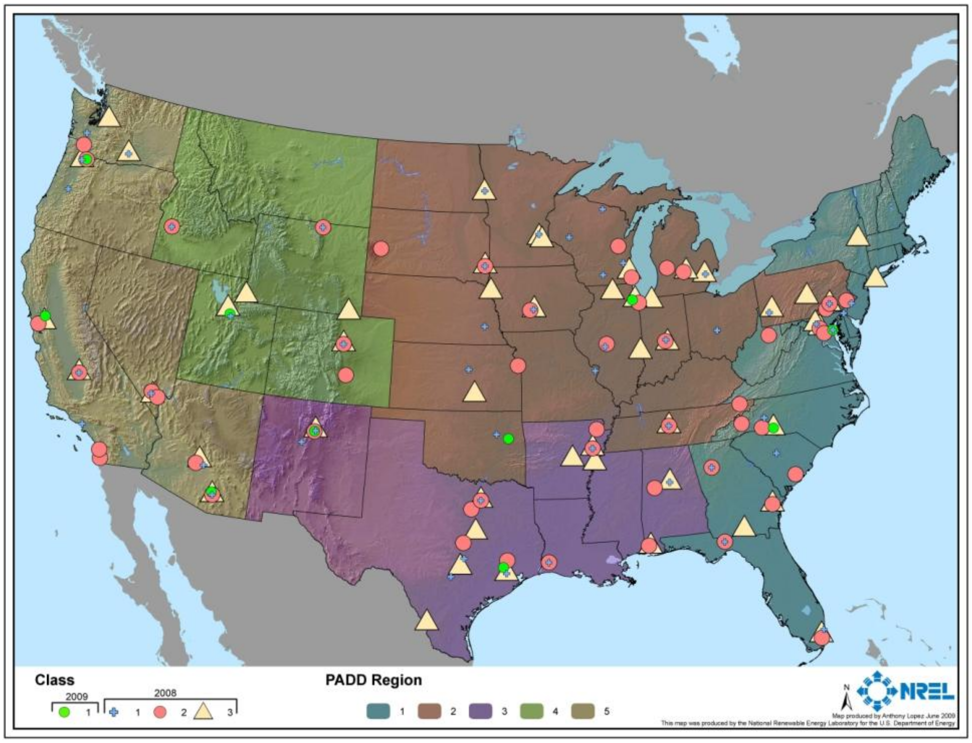

Figure 1. Sampling locations for CRC E85 survey in 2008

Results and Discussion

Numerical results are summarized in Table 2, showing the properties of interest and mean, median, 10^{th} percentile, and 90^{th} percentile values. Tables A-1 to A-4 provide the individual inspections for the E85 samples. Table A-5 shows special test results for selected E85 samples. Table 3, from D5798, lists the class dependence of ethanol content and vapor pressure. Additional discussion of each property is presented below.

Table 2. Summary of Numerical Results

	2008 Class 1 samples				2009 Class 1 samples				Class 2 samples				Class 3 samples			
	Mean	Median	10th Percentile	90th Percentile	Mean	Median	10th Percentile	90th Percentile	Mean	Median	10th Percentile	90th Percentile	Mean	Median	10th Percentile	90th Percentile
DVPE, psi	5.45	5.42	4.83	5.88	5.29	5.20	4.98	5.53	6.95	6.73	5.83	7.56	8.11	7.97	6.30	9.56
Acidity, mg/100mL	0.0024	0.0023	0.0020	0.0029	0.0034	0.0034	0.0026	0.0041	0.003	0.003	0.002	0.004	0.032	0.029	0.021	0.046
Unwashed gum, mg/100mL	3.47	3.00	1.50	6.50	3.30	3.00	1.90	4.40	3.54	2.75	2.00	5.50	4.40	3.00	1.50	8.05
Washed gum, mg/100mL	0.564	0.500	0.500	0.500	0.643	0.500	0.500	1.000	0.558	0.500	0.500	0.750	0.692	0.500	0.500	1.000
Specific gravity at 60°F	0.783	0.785	0.781	0.786	0.784	0.784	0.781	0.787	0.781	0.783	0.777	0.786	0.776	0.777	0.772	0.783
Sulfur, ppm	7.50	5.90	3.92	11.88	10.19	7.75	2.55	13.62	7.88	6.85	5.10	11.45	10.44	8.85	5.47	16.16
Ethanol, vol %	82.91	84.34	82.28	86.40	79.90	81.38	7781	82.49	79.86	81.84	75.00	83.99	75.13	73.91	69.10	82.00
Methanol, vol %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.00	0.00	0.16	0.005	0.005	0.00	0.12
Water, vol %	0.578	0.574	0.469	0.658	0.518	0.577	0.284	0.661	0.613	0.577	0.430	0.805	0.578	0.588	0.457	0.654
pHe	7.59	7.69	7.13	7.87	7.60	7.58	7.17	8.03	7.76	7.74	7.39	8.10	7.76	7.78	7.47	8.07
Inorganic chloride, ppm	0.081	0.000	0.000	0.200	0.150	0.150	0.110	0.190	0.140	0.100	0.100	0.210	0.515	0.100	0.100	0.560
Inorganic sulfate, ppm	0.979	0.600	0.160	1.740	0.450	0.350	0.190	0.680	0.988	0.900	0.240	1.800	0.695	0.400	0.160	1.240
Potential sulfate, ppm	-	-	-	-	0.530	0.450	0.200	0.800	0.988	0.900	0.240	1.800	0.945	0.800	0.200	1.710

Table 3. Allowable Ethanol Content and Vapor Pressure as a Function of ASTM D5798 Volatility Class

Property	Class 1	Class 2	Class 3
Ethanol content, vol %	79-83	74-83	70-83
Vapor pressure, psi	5.5-8.5	7.0-9.5	9.5-12.0

Sampling

This survey was designed to collect 50 samples in each of the three volatility classes (150 samples total). Class 1 fuels are predominant in the summer months throughout the United States, and 47 samples were collected in the first round of testing during the summer of 2008. A second round of testing was initiated to collect 10 additional samples during the summer of 2009, for a total of 57 samples over the project. Class 3 fuels are predominant in winter months; 40 samples were collected in this project. The intent was to collect Class 2 samples between October and November, although shoulder seasons dominate during these months. The difficulty in collecting Class 2 samples was evident, with only 26 samples collected in the survey. Thirteen samples inadvertently collected during shoulder seasons were Class 1/2 or 2/1, while 24 samples were Class 2/3.

Data Analysis

Two data sets were captured for Class 1 – a 2008 sample and a 2009 sample. It was necessary to determine if these data sets could be handled independently or as a single data set. To compare the means of the two samples, the Mann-Whitney Rank Sum Test was used. For the DVPE, the test showed a highly insignificant p-value (0.299), indicating that the means of the samples were similar and that the data sets could be treated together. For the ethanol content of the samples, the p-value was highly significant, <0.001, indicating a significant difference between the two sets.

The data were handled as a single set for the DVPE but as two sets for the ethanol content. The rationale behind this was that conclusions drawn about DVPE did not change with the inclusion of the 2009 Class 1 data, while conclusions about ethanol content were significantly different from 2008 to 2009 and will be discussed in more detail later in the report.

Vapor Pressure

The D5798 specification requires the dry vapor pressure equivalent (DVPE) of E85 to increase as ambient temperatures decrease to ensure vehicle cold starting and warm-up driveability. The mean DVPE was below the specification minimum for all three classes as outlined in Table 3.

In the combined 2008 and 2009 Class 1 samples, 60% of the samples had vapor pressure below the specification minimum (34 out of 57 samples). The vapor pressure range for Class 1 has been illustrated through the histogram in Figure 2. The mean and median values for Class 1 were 5.4 psi, indicating that the data followed a normal distribution, as expected, although these values are slightly below the specification minimum of 5.5 psi. No samples had vapor pressures exceeding the specification upper limit of 8.5 psi. The 10^{th} percentile vapor pressure was 4.8 psi and the 90^{th} percentile vapor pressure was 5.9 psi, a clear indication that these samples have quite low vapor pressures, although the vapor pressure of denatured fuel ethanol is around 3 psi.

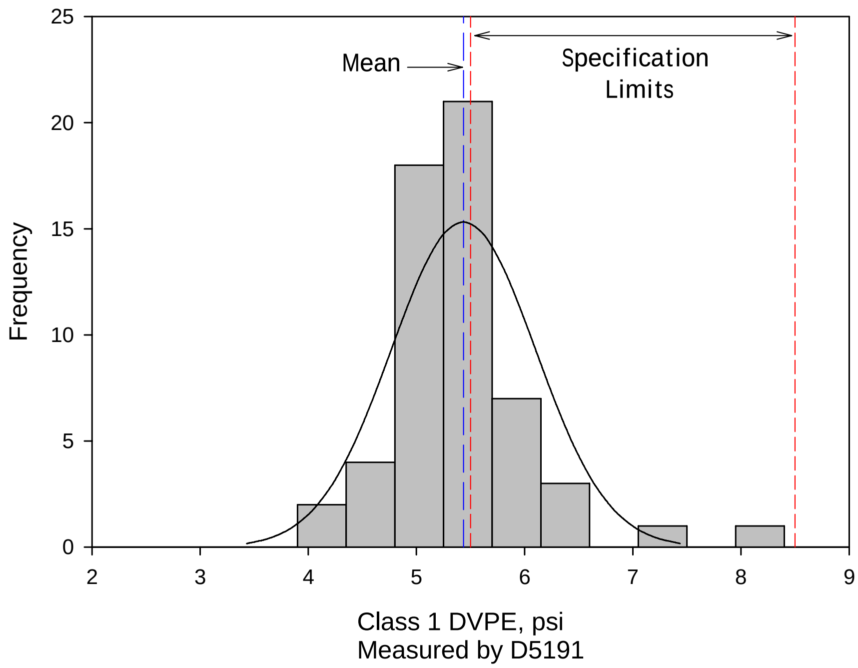

Figure 2. Histogram of DVPE for Class 1 samples

The Class 2 samples also had the mean (7.0 psi) and median (6.7 psi) vapor pressure below the 7.0 psi minimum specification limit (Figure 3). As with Class 1, few samples exceeded the maximum vapor pressure specification in Class 2, although one sample was more than 2 psi above the limit. The 10th percentile DPVE was 5.8 psi and the 90th percentile was 7.6 psi, just above the minimum specification limit.

The largest difference between the mean vapor pressure and the specification limits was observed in the Class 3 samples (Figure 4), where 35 samples (70%) were below the minimum limit. The mean DVPE of 8.1 psi was below the specification minimum of 9.5 psi. Similar to the other volatility classes, the 10th and 90th percentiles (6.3 psi and 9.6 psi, respectively) were below the specification limits and right at the limit, respectively. One sample had volatility above the 12.0 psi maximum.

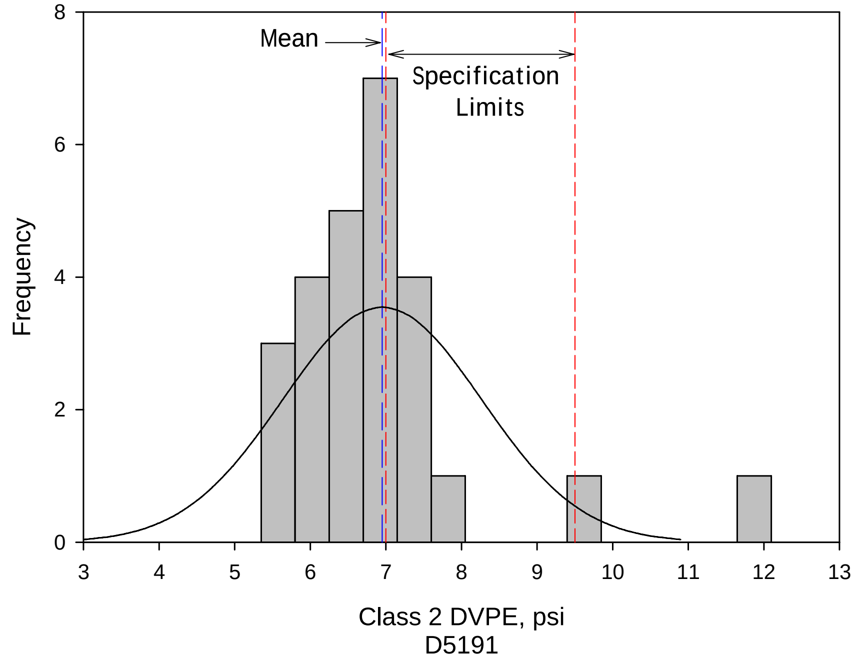

Figure 3. Histogram of DVPE for Class 2 samples

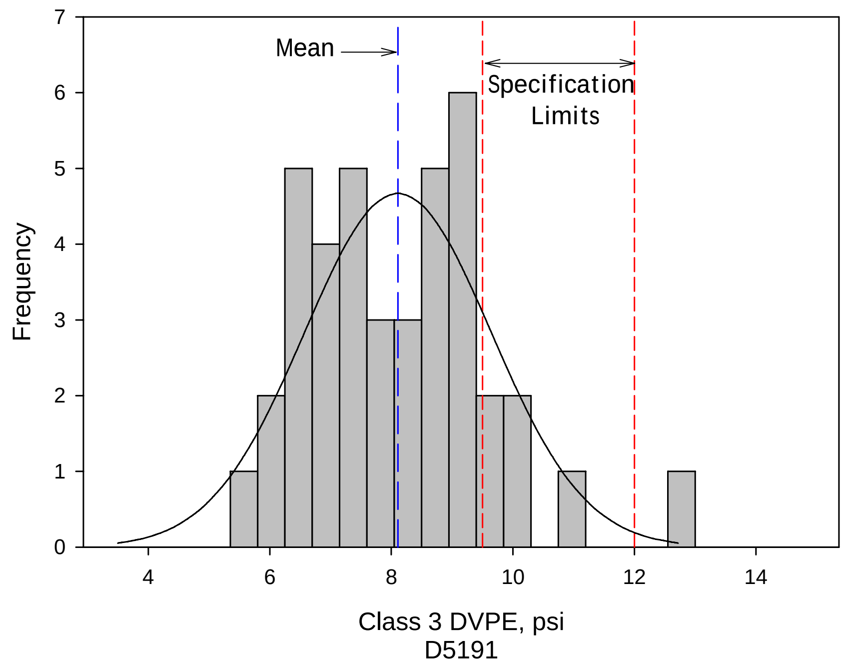

Figure 4. Histogram of DVPE for Class 3 samples

Overall, the DVPE for the samples collected in the E85 project is consistently at or below the specification minima. The low volatility illustrates a significant quality problem with the E85 collected for this survey.

Acidity

Acids in fuels are corrosive and can degrade metallic components. Only 7 of 157 samples had elevated acid content (0.005 mass % maximum as acetic acid). The samples with elevated acidity were distributed as follows: four samples in the shoulder seasons, two samples in Class 3, and one sample in the 2009 Class 1 set.

Unwashed and Washed Gums

Elevated gum content in E85 may lead to plugged filters or deposits on fuel injection components and the intake system. In this survey, every sample met both the washed and unwashed gum content specification limits. One sample had elevated unwashed gum content of 19.5 mg/100mL, just below the limit of 20 mg/100mL. This sample was also off-specification for acidity and vapor pressure.

Sulfur Content

Excess fuel sulfur can damage emission control equipment and is limited in E85, depending on volatility class. For every sample collected, the sulfur content was at least an order of magnitude below the specification limit.

Ethanol and Methanol Content

The ethanol content in E85 varies with the season, with higher minimum ethanol content being allowed in the warm summer months and lower minimum ethanol content allowed in the colder winter months (see Table 3). This allows higher levels of higher vapor pressure gasoline to be blended in winter for meeting the DVPE requirements.

As discussed earlier, the ethanol content of the Class 1 samples was treated independently. The data from the 2008 Class 1 had 81% of the samples off-specification for ethanol (38 of 47 samples). In 2009, only 1 sample in 10 (10%) was off-specification for ethanol content, but not for vapor pressure. This dramatic improvement in meeting the specification, albeit for a limited sample size, is lost when the Class 1 data from 2008 and 2009 are pooled. Thus, the data were handled independently to illustrate the dramatic differences for this parameter from year to year.

In the 2008 Class 1 samples, the mean ethanol content was 83 vol %, at the specification upper limit, and the median value was 84 vol % (Figure 5). Forty-two samples (89%) had elevated ethanol content and were not on specification. One sample was notable in that it had 94 vol % ethanol and a correspondingly low vapor pressure of 4.1 psi. Two samples (4%) were below the specification minimum. One of these samples appeared to be conventional gasoline, with 9 vol % ethanol (DVPE for this sample was 8.4 psi). The other sample with low ethanol content contained 73 vol % ethanol, more similar to a Class 2 or 3 sample than a Class 1 sample.

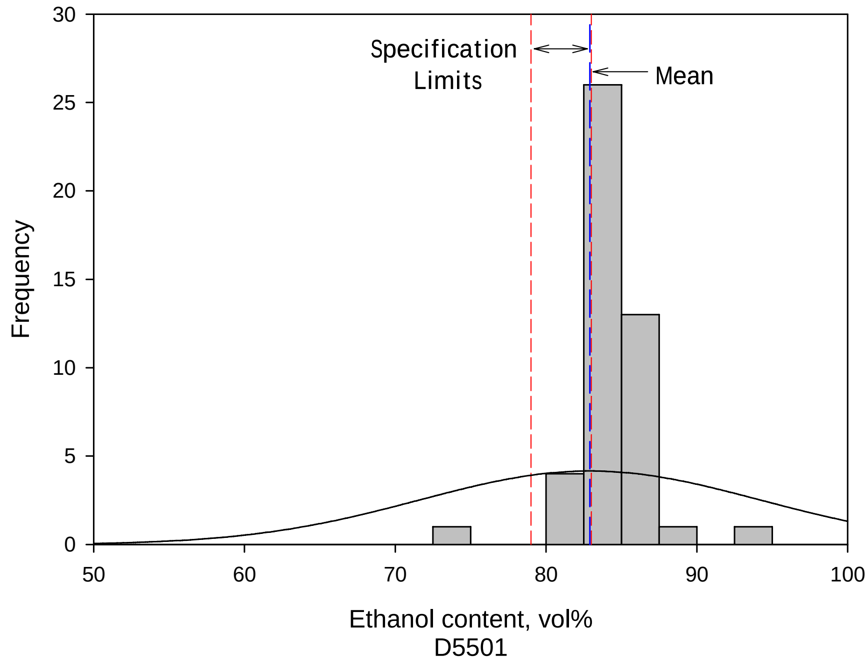

Figure 5. Volume percent ethanol content for 2008 Class 1 samples

The 2009 Class 1 samples had a mean ethanol content of 80 vol % ethanol, within the specification limits (Figure 6). One sample had low ethanol content (68 vol %). This sample was collected from the same region of the country (Utah) as the 73 vol % ethanol content sample in the 2008 Class 1 samples, indicating that this might be an area of interest in subsequent surveys. The ethanol content of E85 is not rigorously specified, rather, it depends on the levels of hydrocarbons and water in the sample. One sample had 0.5% water and a maximum hydrocarbon content of 21 vol%. Thus, this sample, with 83 vol% ethanol, contained greater than the allowable mathematical limit of 82.5 vol%.

The Class 2 samples showed notable improvement, with only 1 sample in 26 (4%) having low ethanol content (Figure 7). Ten samples (39%) exceeded the maximum amount of ethanol allowed. The other 15 samples were on specification. In Class 3, 20% of the samples (8 of 40) were outside the ethanol range of 70–83 vol % (Figure 8) with six (12%) being below the minimum. All of the samples with elevated ethanol content had low vapor pressures (less than 7.3 psi).

All samples from all classes had methanol content below the specification limit of 0.5 vol %.

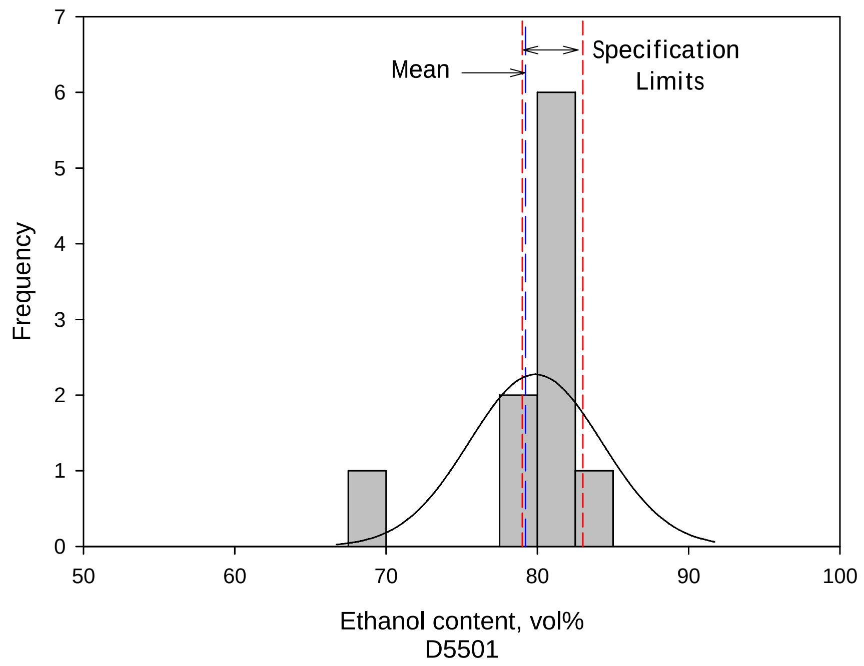

Figure 6. Volume percent ethanol content for 2009 Class 1 samples

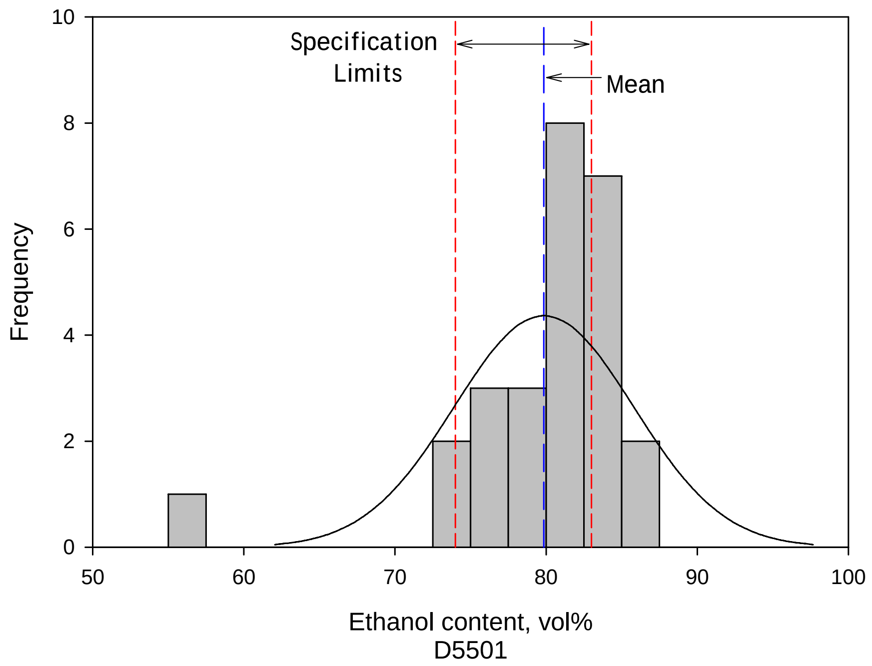

Figure 7. Volume percent ethanol content for Class 2 samples

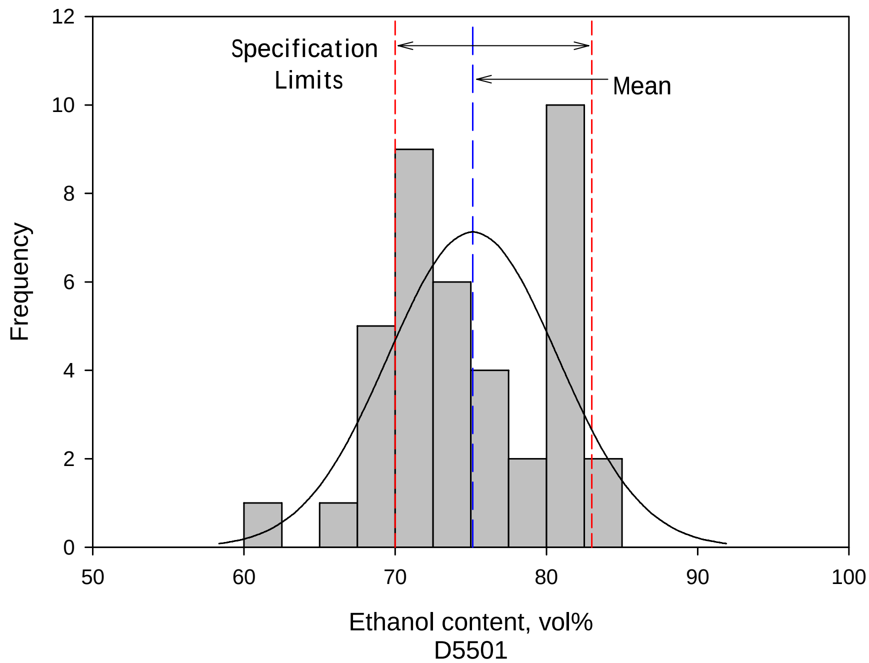

Figure 8. Volume percent ethanol content for Class 3 samples

Water Content

The ethanol component of E85 is miscible with water while the hydrocarbon portion is not. The presence of water in the fuel can cause separation of the hydrocarbon from the ethanol. Four fuels of the 157 collected had water content greater than the specification limit of 1.0 vol %. Three of the four fuels were also off-specification with low vapor pressure, while the final fuel was off-specification for chloride.

Inorganic Chloride, Inorganic Sulfate, and Potential Sulfate

Inorganic chloride is corrosive to fuel injection systems and is limited to ensure adequate engine durability and performance. Although inorganic sulfate was not originally specified by the D5798 method, it now has a maximum limit of 4 ppm. Inorganic sulfate can plug fuel filters and can also lead to injector fouling issues that can adversely impact performance. The project scope requested D7319 for chloride and sulfate determination. Two-thirds of the data was complete when the contract lab stopped running the method and needed to switch chloride and sulfate determination to D7328. Only three samples had elevated chlorides: one sample from Class 1 and two samples from Class 3. The potential sulfate was also measured for Class 2 and Class 3 samples. For Class 2, the potential sulfate ranged from 0.1 ppm to 3.7 ppm, with a mean of 1.0 ppm. Similar results were reported for Class 3, with a mean potential sulfate of 0.9 ppm and a maximum of 4.8 ppm. The inorganic sulfate mirrored the potential sulfate results, such that the sample with the highest potential sulfate (4.8 ppm) also had the highest inorganic sulfate (4.9 ppm).

pHe

The pHe is another measure of the acidity of E85. The pHe range in D5798 ensures that the fuel is not corrosive to the engine. Every sample collected in this project met the pHe specification of 6.5–9.0, in contrast to the acidity measurement, where several samples exceeded the acidity specification maximum.

Distillation

Denatured fuel ethanol can be blended with a wide range of hydrocarbons to produce E85 fuel. The D5798 specification limits these hydrocarbons to have boiling points less than 225°C (437°F). Figure 9 shows the distillation results from the Class 1 samples. A typical E85 distillation curve is relatively "flat" until the T90, where the hydrocarbon fraction begins to distill. A typical gasoline-ethanol blend distillation profile is also illustrated by the dashed curve, for a sample with 9 vol % ethanol. The results indicate that hydrocarbon blending components boil below 225°C (437°F) in all cases.

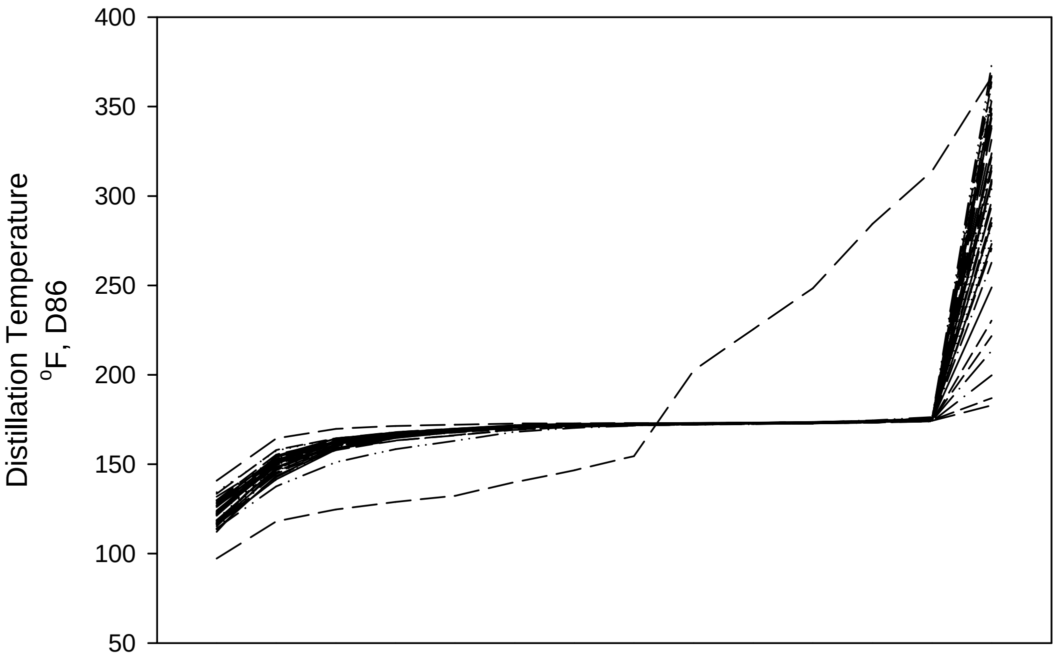

Figure 9. Distillation profile for Class 1 samples

NACE

The corrosivity of fuels on pipelines is measured through NACE TM0172. The results are reported as alpha ratings (A, B++, B+, …E), where the A is the highest rating indicating no corrosion on a test strip. Every E85 sample in this study had a NACE corrosion rating of A.

Octane Number

A select set of samples was chosen for additional testing, including octane rating. Ten samples were selected from each sample class. The Research and Motor octane values remained nearly constant over the three volatility classes at 101 RON and 90 MON. Although there are some differences in ethanol content in the samples selected for octane testing, these results were nearly constant. For relatively large changes in ethanol content (E60 compared to E70), the influence on octane will be negligible.

Peroxide Content

Fuel peroxides are highly reactive and can be corrosive to engine systems. The selected Class 1, 2, and 3 samples were tested for peroxides, with most samples having 1 ppm or less of peroxides. One sample had a somewhat elevated peroxide content of 3 ppm.

Oxidation Stability

The oxidation stability test measures the resistance of E85 to form degradation products. The test charges a vessel with fuel and oxygen at elevated pressure and temperature. As the fuel oxidizes, the pressure drop is measured at specified intervals. The test is complete when the pressure drop meets specific conditions, indicating a "break", which is related to the induction period. None of the samples showed a "break" after 1440 min, the typical duration of the test.

Silver Strip Corrosion

The silver strip corrosion test measures the corrosivity of fuels to silver and silver alloy components in the fuel system. The fuel corrosivity is related to the amount and types of sulfur compounds in the fuels. Although the fuels in the survey readily met the sulfur specification, the types of compounds present may still be corrosive. All of the fuels tested in this project had silver corrosion of "0", which indicates no tarnish on the test strip

Conclusions

This project sampled 157 E85 samples from around the country in each of the three volatility classes. The goal was to test 50 samples in each volatility class. The volatility classes are determined by the lowest ambient temperature around the country and will vary with season and geography. Samples were relatively easy to find in Class 1, with 47 samples collected. Class 2 samples were more difficult to obtain, partly because of the limited distinct Class 2 season throughout the U.S. Thus, only 26 samples were obtained. Class 3, similar to Class 1, has a more distinct class, with 39 samples collected. The remaining samples were from the shoulder seasons.

Similar to previous CRC E85 surveys, most of the samples collected did not meet the D5798 specification. Samples were most often off-specification for low DVPE and/or low ethanol content. In Class 1, 53% of the samples had vapor pressure below the 5.5 psi minimum. More than 80% of the samples were off-specification for vapor pressure in Class 2 and 3 (69% and 88%, respectively). The highest failure rate for vapor pressure was observed in 2009 Class 1 samples, with almost 90% of the samples not meeting the specification limits. The 2008 Class 1 samples had a failure rate exceeding the allowed amount of ethanol in 89% of the samples. Class 2 exceeded the maximum ethanol content for 39% of the samples. Table 4 summarizes by volatility class the percentage of samples in compliance with vapor pressure and ethanol content. Other specification properties (water, pHe, acidity, chloride, and gums) were met with few exceptions.

Table 4. Summary of Vapor Pressure and Ethanol Content Compliance by Volatility Class

D5798 Class	# of Samples	Vapor Pressure			Ethanol Content		
		Below Minimum, %	Above Maximum, %	On Specification, %	Below Minimum, %	Above Maximum, %	On Specification, %
1 (2008)	47	53.2	0	46.8	4.3	89.4	6.3
1 (2009)	10	90.0	0	10.0	10.0	10.0	80.0
1 (All Data)	57	60.0	0	40.0	N/A	N/A	N/A
2	26	61.5	7.7	30.8	3.8	38.5	57.7
3	40	87.5	0.4	12.1	12.0	5.0	83.0
All	*123*	*73.1*	*0.7*	*26.2*	*7.5*	*35.7*	*56.8*

A subset of samples was selected for additional testing, including peroxide content, oxidation stability, and octane number. Compared to the other samples in their class, the samples selected for additional testing were either typical or had some unusual property, such as low ethanol content or vapor pressure. Samples typically had peroxide content less than 1 ppm, with one sample having 3 ppm. The samples all showed very high oxidation stability, regardless of volatility class, vapor pressure, or ethanol content. The octane numbers of the samples were also similar, with a Research octane number around 101 and a Motor octane number around 90. None of the test results indicate any concern for the quality of the hydrocarbon content of the E85 samples, either from the denaturant added to the original ethanol or the gasoline used to blend with the ethanol to make E85. All samples readily passed NACE corrosion and silver strip corrosion tests.

The results of this survey show significant quality problems with E85 across all three volatility classes and throughout the United States. A follow-up survey should be conducted to reassess the quality to see if improvements have been achieved. Although the goal of this survey was to avoid shoulder seasons, samples in Class 2 were difficult to obtain. The follow-up survey should reduce the geographic area of Class 2 samples in an effort to reduce the number of shoulder season samples.

Appendix

Table A-1. 2008 Class 1 Data

ID#	D5191, DVPE, psi	Appearance	Acidity, D1613, mg KOH/mL	D381, Unwashed Gum, mg/100mL	D381, Washed Gum, mg/100 mL	D4052, Specific Gravity @ 60°F	D5453, Sulfur, ppm	D5501, Ethanol, vol%	D5501, Methanol, vol%	D6304, Water, vol %	D6423, pHe	D7319, Inorganic Chloride, ppm	D7319, Inorganic Sulfate, ppm	D7328, Potential Sulfate, ppm	D86, IBP, F	D86, T50, F	D86, T90, F	D86, FBP, F	NACE, TM0712
54268	5.01	1	0.002	6.0	0.5	0.785	4	83.82	0	0.49	7.80	0.00	1.70	-	126	172	174	346	A
54281	6.00	1	0.002	8.5	0.5	0.782	6	85.01	0	0.53	7.69	0.10	0.70	-	114	173	174	284	A
54266	5.33	1	0.003	6.0	0.5	0.780	7	83.16	0	0.60	6.75	0.20	4.70	-	123	172	173	230	A
54276	5.57	1	0.003	3.5	0.5	0.786	10	83.65	0	0.63	6.70	0.00	5.80	-	118	172	174	308	A
54257	4.91	1	0.002	1.0	0.5	0.784	2	83.91	0	0.53	7.90	0.00	0.20	-	127	172	174	295	A
54381	4.77	1	0.002	2.5	0.5	0.785	2	86.19	0	0.53	6.87	0.00	1.80	-	129	172	173	263	A
54273	5.42	1	0.002	2.5	0.5	0.785	8	84.14	0	0.62	7.71	0.10	1.40	-	122	172	174	325	A
54263	5.05	1	0.002	1.0	0.5	0.785	5	84.59	0	0.57	7.70	0.10	0.80	-	128	172	174	249	A
54311	5.54	1	0.002	6.0	0.5	0.785	6	84.11	0	0.66	7.56	0.00	0.00	-	119	173	174	346	A
54318	4.99	1	0.002	2.5	0.5	0.788	6	85.53	0	0.50	7.82	0.00	0.00	-	130	173	174	187	A
54271	5.82	1	0.002	2.5	0.5	0.783	17	82.97	0	0.63	7.77	0.10	0.30	-	119	172	174	297	A
54350	5.85	1	0.002	8.0	0.5	0.785	9	84.77	0	0.87	7.73	0.00	0.30	-	117	172	174	339	A
54274	5.61	1	0.002	1.5	0.5	0.781	6	83.33	0	0.60	7.74	0.10	0.30	-	121	172	173	213	A
54282	5.69	1	0.003	3.0	0.5	0.783	11	84.94	0	0.56	7.23	0.00	4.80	-	117	172	174	271	A
54279	5.18	1	0.003	3.0	1	0.784	6	83.94	0	0.53	7.75	0.20	0.50	-	127	172	174	324	A
54293	4.80	1	0.002	2.0	0.5	0.784	7	85.07	0	0.57	7.67	0.30	0.50	-	130	172	174	304	A
54294	4.49	1	0.003	3.5	1	0.785	6	85.76	0	0.59	7.71	0.20	0.50	-	134	172	174	364	A
54255	5.28	1	0.002	7.0	0.5	0.786	5	84.22	0	0.63	7.85	0.00	1.00	-	126	172	174	367	A
54297	5.27	1	0.002	10.5	0.5	0.784	5	84.06	0	0.57	7.79	0.00	0.90	-	112	173	174	338	A
54286	4.87	1	0.003	6.5	0.5	0.779	5	81.50	0	0.48	7.51	0.00	0.70	-	123	172	173	295	A
54295	5.61	1	0.002	3.0	0.5	0.785	8	84.16	0	0.62	7.82	0.10	0.80	-	118	172	174	349	A
54275	5.87	1	0.002	5.0	0.5	0.783	11	84.01	0	0.62	7.78	0.10	0.10	-	114	173	174	309	A
54261	5.55	1	0.003	3.5	2	0.782	6	83.92	0	0.41	6.79	1.10	0.90	-	122	172	174	362	A
54260	5.57	1	0.002	1.5	0.5	0.782	1	82.17	0	0.58	7.77	0.00	0.30	-	117	172	174	353	A

Table A-1. 2008 Class 1 Data, continued

ID#	D5191, DVPE, psi	Appearance	Acidity, D1613, mg KOH/mL	D381, Unwashed Gum, mg/100mL	D381, WasheD Gum, mg/100mL	D4052, Specific Gravity @ 60°F	D5453, Sulfur, ppm	D5501, Ethanol, vol%	D5501, Methanol, vol%	D6304, Water, vol %	D6423, pHe	D7319, Inorganic Chloride, ppm	D7319, Inorganic Sulfate, ppm	D7328, Potential Sulfate, ppm	D86, IBP, F	D86, T50, F	D86, T90, F	D86, FBP, F	NACE, TM0172
54256	5.89	1	0.003	3.0	0.5	0.784	6	85.45	0	0.81	7.71	0.00	1.20	-	118	173	174	373	A
54267	5.60	1	0.003	6.5	0.5	0.789	19	82.35	0	1.38	7.94	0.20	0.40	-	121	173	174	307	A
54277	5.02	1	0.002	4.0	0.5	0.786	14	85.68	0	0.58	7.66	0.00	0.60	-	127	172	173	200	A
54290	8.38	1	0.001	5.0	0.5	0.731	45	9.37	0	0.09	-	0.10	0.20	-	97	155	284	367	A
54296	7.50	1	0.003	3.0	0.5	0.786	6	86.13	0	0.66	7.69	0.00	0.60	-	123	172	173	273	A
54259	5.82	1	0.002	2.5	0.5	0.785	5	83.74	0	0.50	7.66	0.00	1.10	-	116	173	174	353	A
54269	5.24	1	0.002	3.5	0.5	0.787	6	86.71	0	0.60	7.89	0.10	0.30	-	122	172	174	222	A
54312	5.21	1	0.002	3.0	0.5	0.785	5	84.97	0	0.52	7.96	0.00	0.00	-	124	172	174	317	A
54292	5.61	1	0.003	2.0	0.5	0.784	14	84.80	0	0.57	7.64	0.20	0.60	-	117	173	174	325	A
54272	5.42	1	0.002	2.0	0.5	0.786	7	84.60	0	0.56	7.68	0.10	0.80	-	128	173	174	346	A
54252	4.06	1	0.002	1.5	0.5	0.790	4	93.88	0	0.48	7.59	0.40	1.60	-	141	173	174	183	A
54265	5.17	1	0.003	2.5	0.5	0.784	6	85.84	0	0.45	7.67	0.00	1.90	-	122	173	174	285	A
54287	4.33	1	0.002	1.0	0.5	0.785	8	87.96	0	0.58	7.57	0.00	0.40	-	134	172	174	276	A
54280	4.85	1	0.002	3.0	0.5	0.784	7	86.73	0	0.66	7.67	0.00	0.60	-	130	172	173	288	A
54317	6.17	1	0.002	3.0	0.5	0.780	9	72.68	0	0.50	7.02	0.00	0.00	-	114	172	175	354	A
54291	5.39	1	0.002	1.0	0.5	0.785	4	84.34	0	0.55	7.33	0.00	0.90	-	124	172	174	331	A
54288	5.11	1	0.002	2.0	0.5	0.784	6	84.06	0	0.43	7.38	0.00	0.90	-	128	172	174	322	A
54298	5.72	1	0.002	3.0	0.5	0.784	5	84.89	0	0.55	7.55	0.00	0.60	-	115	172	174	346	A
54251	5.87	1	0.002	1.5	0.5	0.783	5	84.10	0	0.43	7.58	0.00	0.70	-	116	172	174	308	A
54253	5.64	1	0.002	1.5	1	0.785	3	84.53	0	0.59	7.43	0.00	1.70	-	122	172	174	357	A
54270	5.70	1	0.002	3.0	0.5	0.783	6	81.91	0	0.52	7.37	0.00	1.40	-	117	172	174	314	A
54258	5.02	1	0.003	3.5	0.5	0.786	5	85.93	0	0.65	7.72	0.00	0.30	-	132	172	174	316	A
54397	5.25	1	0.002	2.0	0.5	0.786	4	87.04	0	0.61	7.95	0.00	0.20	-	124	173	174	344	A

Table A-2. 2009 Class 1 Data

ID#	D5191, DVPE, psi	Appearance	Acidity, D1613, mg KOH/mL	D381, Unwashed Gum, mg/100mL	D381, WasheD Gum, mg/100mL	D4052, Specific Gravity @ 60°F	D5453, Sulfur, ppm	D5501, Ethanol, vol%	D5501, Methanol, vol%	D6304, Water, vol %	D6423, pHe	D7319, Inorganic Chloride, ppm	D7319, Inorganic Sulfate, ppm	D7328, Potential Sulfate, ppm	D86, IBP, F	D86, T50, F	D86, T90, F	D86, FBP, F	NACE, TM0172
55387	4.78	-	0.005	3.5	1.0	0.784	10	82.43	0	0.61	7.55	<0.1	1.40	1.7	132	173	174	274	A
55388	5.25	-	0.004	1.0	0.5	0.787	8	82.09	0.01	0.65	7.97	<0.1	0.30	0.4	123	172	174	354	A
55393	5.08	-	0.004	4.0	<0.5	0.786	7	81.70	0	0.54	7.57	<0.1	0.50	0.5	124	172	174	323	A
55391	5.43	-	0.003	8.0	0.5	0.787	11	81.43	0.01	0.67	7.58	<0.1	0.60	0.7	120	173	174	289	A
55401	5.05	-	0.003	3.0	1.0	0.784	3	83.00	0	0.47	6.85	<0.1	0.40	0.5	124	172	174	322	A
55386	5.15	-	0.003	2.5	<0.5	0.781	9	78.90	0.01	0.66	8.08	<0.1	0.30	0.3	126	172	174	348	A
55397	5.00	-	0.003	3.0	0.5	0.784	8	81.21	0.01	0.55	8.02	0.20	0.20	0.2	127	172	174	340	A
55395	5.33	-	0.002	2.0	<0.5	0.785	2	81.32	0.01	0.60	7.55	0.10	0.10	0.2	124	172	174	274	A
55380	5.39	-	0.004	3.5	0.5	0.784	37	78.93	0.01	0.30	7.62	<0.1	0.30	0.3	125	173	177	289	A
55389	6.45	-	0.003	2.5	0.5	0.778	8	67.97	0.01	0.13	7.20	<0.1	0.40	0.5	115	171	175	357	A

Table A-3. Class 2 Data

ID#	D5191, DVPE, psi	Appearance	Acidity, D1613, mg KOH/mL	D381, Unwashed Gum, mg/100mL	D381, Washed Gum, mg/100mL	D4052, Specific Gravity @ 60°F	D5453, Sulfur, ppm	D5501, Ethanol, vol%	D5501, Methanol, vol%	D6304, Water, vol %	D6423, pHe	D7319, Inorganic Chloride, ppm	D7319, Inorganic Sulfate, ppm	D7328, Potential Sulfate, ppm	D86, IBP, F	D86, T50, F	D86, T90, F	D86, FBP, F	NACE, TM0172
54716	6.80	1	0.003	4.0	0.5	0.786	6	82.33	0.2	0.874	8.12	<0.1	<0.1	<0.1	112	172	173	341	A
54627	5.55	1	0.003	2.0	1.0	0.786	6	86.55	0.0	0.532	7.79	0.10	0.20	1.00	121	172	173	298	A
54668	6.62	1	0.004	7.0	0.5	0.779	8	76.94	0.0	0.745	7.70	0.20	0.30	0.30	111	172	174	311	A
54667	5.57	1	0.005	4.5	1.0	0.782	7	78.38	0.0	0.790	7.37	<0.1	0.40	0.30	118	172	174	337	A
54637	5.99	1	0.002	1.5	0.5	0.785	6	84.48	0.1	0.585	7.62	0.10	0.30	0.60	114	173	174	305	A
54666	6.16	1	0.004	2.5	0.5	0.784	6	83.01	0.0	0.719	7.63	<0.1	0.40	0.40	117	172	174	350	A
54648	6.72	1	0.003	2.5	0.5	0.783	6	81.76	0.0	0.629	7.73	<0.1	0.80	1.00	115	172	174	356	A
54651	6.73	1	0.003	2.0	0.5	0.781	6	81.92	0.0	0.567	7.71	0.10	0.70	0.90	111	172	174	341	A
54674	7.74	1	0.003	4.0	0.5	0.781	8	74.94	0.0	0.806	7.68	<0.1	<0.1	0.20	104	172	174	341	A
54655	9.76	1	0.002	4.5	0.5	0.765	9	55.46	0.0	0.412	7.21	<0.1	0.50	0.30	97	169	175	361	A
54650	7.34	1	0.002	2.0	0.5	0.776	7	75.06	0.0	0.477	7.32	<0.1	1.40	1.20	108	171	174	335	A
54748	6.97	1	0.004	3.5	1.0	0.786	7	78.70	0.2	1.440	7.74	0.10	<0.1	0.10	110	172	174	341	A
54754	6.50	1	0.003	2.5	0.5	0.786	7	82.85	0.0	0.535	8.27	<0.1	<0.1	1.40	115	173	174	343	A
54749	6.96	1	0.003	2.0	0.5	0.784	7	81.93	0.0	0.803	7.99	0.10	<0.1	0.30	111	172	174	334	A
54753	6.67	1	0.004	3.0	0.5	0.787	3	83.01	0.1	0.614	7.95	<0.1	0.20	0.30	114	172	174	293	A
54652	5.66	1	0.004	4.0	0.5	0.785	23	81.52	0.0	0.548	7.69	<0.1	1.70	1.80	118	173	174	282	A
54842	7.28	1	0.005	2.5	0.5	0.782	5	82.81	0.0	0.449	8.07	<0.1	0.10	0.10	112	172	174	246	A
54796	7.37	1	0.003	2.0	0.5	0.783	8	82.64	0.1	0.570	8.23	<0.1	1.50	1.80	107	173	174	298	A
54806	7.27	1	0.004	1.5	0.5	0.779	8	74.69	0.2	0.665	7.84	0.10	0.20	1.00	105	171	174	345	A
54845	11.92	1	0.001	5.0	0.5	0.757	9	83.49	0.0	0.216	7.63	0.20	1.30	1.40	84	166	321	368	A
54810	6.69	1	0.003	6.0	0.5	0.783	8	82.23	0.4	0.675	7.95	<0.1	1.30	1.70	110	172	174	283	A
54811	6.03	1	0.004	2.0	0.5	0.784	5	85.50	0.2	0.521	7.91	<0.1	2.00	2.70	115	172	173	177	A
54837	6.97	1	0.003	2.0	0.5	0.781	18	79.40	0.1	0.534	7.86	0.10	0.80	1.00	108	172	174	267	A
54807	6.81	1	0.003	3.0	0.5	0.780	14	80.22	0.1	0.146	7.74	<0.1	1.40	3.70	109	172	174	264	A
54820	5.99	1	0.000	13.5	0.5	0.777	6	75.90	0.0	0.589	7.40	0.30	0.60	0.70	115	172	174	301	A
54870	6.68	1	0.002	3.0	0.5	0.782	3	80.59	0.1	0.495	7.54	<0.1	0.50	0.50	110	172	173	258	A

Table A-4. Class 3 Data

ID#	D5191, DVPE, psi	Appearance	Acidity, D1613, mg KOH/mL	D381, Unwashed Gum, mg/100mL	D381, Washed Gum, mg/100mL	D4052, Specific Gravity @ 60°F	D5453, Sulfur, ppm	D5501, Ethanol, vol%	D5501, Methanol, vol%	D6304, Water, vol %	D6423, pHe	D7319, Inorganic Chloride, ppm	D7319, Inorganic Sulfate, ppm	D7328, Potential Sulfate, ppm	D86, IBP, F	D86, T50, F	D86, T90, F	D86, FBP, F	NACE, TM0172
54843	7.60	1	0.027	2.0	<0.5	0.782	10	76.05	0	0.555	8.1	<0.1	0.50	0.50	107	172	174	346	A
54814	7.84	1	0.060	5.5	<0.5	0.777	7	74.64	0.08	0.595	8.0	0.20	0.20	0.90	101	171	173	326	A
54818	8.30	1	0.047	5.0	<0.5	0.774	8	71.81	0.1	0.624	7.8	0.30	0.50	0.80	100	171	174	337	A
54857	9.13	1	0.036	2.5	0.5	0.770	12	67.88	0.05	0.460	8.0	0.10	0.20	0.20	97	171	174	356	A
54819	6.85	1	0.038	3.0	<0.5	0.782	6	81.89	0.14	0.638	8.0	<0.1	0.20	0.40	109	172	173	182	A
54799	7.50	1	0.036	4.0	<0.5	0.783	8	79.93	0.08	0.621	8.0	0.10	0.30	0.60	106	172	174	286	A
54824	7.46	1	0.025	1.0	<0.5	0.781	7	80.04	0	0.536	7.9	0.10	1.30	2.00	103	172	174	326	A
54803	6.32	1	0.025	3.0	<0.5	0.784	6	82.13	0.1	0.687	8.3	<0.1	0.50	1.20	107	172	174	261	A
54822	9.20	1	0.020	1.5	<0.5	0.774	16	73.58	0.06	0.506	7.7	0.10	0.30	0.80	95	172	174	336	A
54805	6.81	1	0.036	3.0	<0.5	0.783	7	81.99	0.15	0.701	8.1	<0.1	0.40	0.90	108	172	173	297	A
54809	8.31	1	0.030	2.5	<0.5	0.774	13	71.35	0.13	0.389	7.8	0.20	0.20	0.80	99	172	174	362	A
54804	8.92	1	0.037	1.0	<0.5	0.774	9	71.08	0.07	0.544	7.5	<0.1	0.10	0.30	95	172	174	360	A
54827	7.72	1	0.068	19.5	0.5	0.779	12	75.81	0	0.612	7.9	0.10	1.00	1.80	101	172	174	341	A
54841	8.90	1	0.025	1.5	0.5	0.776	9	73.80	0	0.437	7.6	0.10	0.10	0.20	96	172	174	367	A
54828	9.18	1	0.032	2.0	<0.5	0.775	9	71.82	0.05	0.543	8.0	<0.1	0.30	1.10	94	172	174	347	A
54825	9.44	1	0.029	3.5	<0.5	0.773	22	72.41	0	0.535	7.9	0.20	0.30	1.40	92	171	174	337	A
54795	9.52	1	0.046	2.5	0.5	0.776	34	72.80	0.1	0.593	7.9	<0.1	0.30	0.70	94	172	174	322	A
54800	8.81	1	0.043	3.5	0.5	0.777	8	74.01	0.05	0.554	8.1	0.10	0.40	0.50	98	172	173	316	A
54817	9.25	1	0.024	8.5	0.5	0.773	13	72.01	0.08	0.634	8.0	<0.1	<0.1	0.50	98	172	174	363	A
54816	9.91	1	0.027	7.5	0.5	0.773	12	69.17	0	0.630	7.9	<0.1	<0.1	0.20	91	172	174	352	A
54815	12.90	1	0.027	4.0	0.5	0.737	24	69.41	0	0.239	7.3	<0.1	0.30	0.50	82	161	315	405	A
54798	9.35	1	0.025	8.0	0.5	0.774	9	68.48	0.08	0.550	7.7	<0.1	0.80	1.30	94	171	174	358	A
54821	9.29	1	0.028	3.0	0.5	0.773	10	69.73	0.06	0.624	7.8	0.10	1.00	1.70	92	172	174	363	A
54836	7.31	1	0.028	3.0	1.0	0.783	8	83.77	0.06	0.571	7.7	<0.1	1.20	1.00	113	172	173	321	A

Table A-4, Class 3 Data, continued

ID#	D5191, DVPE, psi	Appearance	Acidity, D1613, mg KOH/mL	D381, Unwashed Gum, mg/100mL	D381, Washed Gum, mg/100mL	D4052, Specific Gravity @ 60°F	D5453, Sulfur, ppm	D5501, Ethanol, vol%	D5501, Methanol, vol%	D6304, Water, vol %	D6423, pHe	D7319, Inorganic Chloride, ppm	D7319, Inorganic Sulfate, ppm	D7328, Potential Sulfate, ppm	D86, IBP, F	D86, T50, F	D86, T90, F	D86, FBP, F	NACE, TM0172
54847	10.17	1	0.016	6.5	0.5	0.766	12	60.11	0.02	0.422	-	0.10	1.00	1.10	94	170	175	365	A
54797	8.10	1	0.024	6.5	0.5	0.775	9	71.05	0.08	0.582	7.5	<0.1	0.80	1.10	99	171	174	355	A
54823	6.55	1	0.029	1.5	0.5	0.784	6	81.63	0	0.572	7.5	<0.1	4.90	4.80	111	172	174	310	A
54829	6.85	1	0.029	2.0	0.5	0.781	3	77.71	0.12	0.633	7.7	<0.1	0.40	0.70	108	172	173	181	A
54844	6.03	1	0.030	3.0	1.0	0.783	8	77.23	0.05	0.590	7.7	<0.1	0.20	0.30	118	172	175	368	A
54839	7.67	1	0.032	3.5	0.5	0.783	6	81.95	0.13	0.611	7.7	<0.1	0.90	1.00	107	172	173	313	A
54812	6.81	1	0.037	3.0	0.5	0.783	4	81.70	0.08	0.575	7.7	<0.1	1.70	1.10	109	172	174	250	A
54808	6.30	1	0.025	3.0	0.5	0.779	7	73.71	0.03	0.481	7.4	<0.1	1.10	1.60	138	172	174	317	A
54801	6.26	1	0.019	12.5	0.5	0.783	6	82.10	0.09	0.636	8.2	<0.1	0.20	0.50	108	172	173	249	A
54833	10.76	1	0.022	2.0	1.0	0.759	14	71.67	0	0.644	7.7	0.30	0.70	1.30	94	172	173	180	A
55143	5.83	1	0.043	14.0	4.0	0.785	14	81.49	0	0.652	8.1	5.40	0.10	0.50	120	172	174	331	A
55080	6.41	1	0.025	2.0	0.5	0.782	5	83.54	0	0.665	7.6	0.10	0.20	0.20	111	172	173	178	A
55089	5.71	1	0.022	4.0	0.5	0.782	3	80.63	0	0.624	7.7	0.10	0.20	0.30	120	172	174	265	A
55018	7.18	1	0.049	4.0	0.5	0.775	29	77.09	0	0.460	6.1	0.40	2.80	2.70	106	172	173	177	A
55321	8.95	1	0.024	4.0	<0.5	0.773	6	66.50	0	0.586	7.7	0.20	0.10	0.20	98	172	175	361	A
55322	8.95	1	0.019	4.0	0.5	0.777	9	71.66	0	1.003	7.9	2.00	<0.1	0.10	102	172	174	342	A

Table A-5. Additional Testing Data, All Rounds

ID#	D2699, RON	D2700, MON	D3703, Peroxides, mg/kg	D4814, Annex A1, Rating	D525, Run Time, min	D525, Break?	D525, Break point, min	D525, Maximum Pressure, psi	D525, Maximum Time, min	D525, Minimum Pressure, psi	D525, Minimum Time, min	D525, Pressure drop, psi
54281	101.3	89.7	0.00	0	1440	NO BREAK	N/A	157.4	523.0	153.7	1439.0	3.7
54276	101.0	89.9	0.00	0	1440	NO BREAK	N/A	146.7	220.0	139.2	1439.0	7.5
54381	101.4	90.0	3.68	0	1440	NO BREAK	N/A	156.2	244.0	154.0	1439.0	2.2
54273	101.2	90.1	0.00	0	1440	NO BREAK	N/A	144.0	279.0	138.1	1439.0	5.9
54311	101.4	89.8	0.00	0	1440	NO BREAK	N/A	156.2	524.0	152.6	1440.0	3.6
54269	101.2	90.1	0.00	0	1440	NO BREAK	N/A	137.3	506.0	134.3	1439.0	3.0
54292	101.4	90.1	0.64	0	1440	NO BREAK	N/A	150.1	172.0	142.7	1439.0	7.4
54272	101.1	89.7	0.00	0	1440	NO BREAK	N/A	133.0	194.0	128.4	1438.0	4.6
54280	101.1	90.0	0.00	0	1440	NO BREAK	N/A	140.9	524.0	139.4	1438.0	1.5
54665	101.4	90.0	0.00	0	1440	NO BREAK	N/A	158.4	534.0	153.9	1439.0	4.5
54384	101.3	89.7	0.00	0	1440	NO BREAK	N/A	155.1	264.0	140.7	1439.0	14.4
54674	101.3	89.8	0.00	0	1440	NO BREAK	N/A	156.5	392.0	152.5	1439.0	4.0
54655	101.5	89.7	0.63	0	1440	NO BREAK	N/A	160.6	529.0	153.3	1439.0	7.3
54749	101.5	90.0	1.59	0	1440	NO BREAK	N/A	155.2	469.0	153.0	1439.0	2.2
54652	101.6	90.3	0.64	0	1440	NO BREAK	N/A	151.4	526.0	146.8	1438.0	4.6
54845	101.8	90.3	1.27	0	1440	NO BREAK	N/A	146.7	186.0	143.9	1440.0	2.8
54811	101.7	89.7	1.91	0	1440	NO BREAK	N/A	153.5	283.0	148.5	1439.0	5.0
54658	101.6	90.1	1.91	0	1440	NO BREAK	N/A	140.5	643.0	138.4	1435.0	2.1
54676	101.5	90.2	0.00	0	1440	NO BREAK	N/A	150.4	1106.0	149.3	138.0	1.1
54649	101.5	88.9	1.43	0	1440	NO BREAK	N/A	137.5	338.0	135.7	1439.0	1.8
54857	101.7	89.5	1.6	0	1440	NO BREAK	N/A	157.7	192.0	139.4	1440.0	18.3
54799	101.7	89.8	1.6	0	1440	NO BREAK	N/A	153.6	643.0	148.6	1437.0	5.0
54824	101.6	89.7	1.1	0	1440	NO BREAK	N/A	146.5	503.0	144.1	1439.0	2.4
54822	101.6	89.8	1.6	0	1440	NO BREAK	N/A	156.4	308.0	142.2	1440.0	14.2
54815	101.8	90.4	1.9	0	1440	NO BREAK	N/A	157.0	1166.0	155.6	1434.0	1.4
54798	101.8	89.7	1.6	0	1440	NO BREAK	N/A	159.3	288.0	148.4	1439.0	10.9
54836	101.9	90.0	1.1125	0	1440	NO BREAK	N/A	147.3	300.0	145.9	1438.0	1.4
54823	101.6	89.8	1.1135	0	1440	NO BREAK	N/A	155.1	762.0	152.8	91.0	2.3