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Blender Pump Fuel Survey: CRC Project E-95

Teresa L. Alleman

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
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July 2011

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Prepared under Task No. FC08.0075

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Abbreviations and Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
ASTM	ASTM International
CRC	Coordinating Research Council
DVPE	dry vapor pressure equivalent
Ex	nominally x% ethanol by volume and (100-x)% gasoline or other hydrocarbons
EPA	U.S. Environmental Protection Agency
FFV	flex fuel vehicle
mass%	percent by mass
mg/100mL	milligrams per 100 milliliters
pHe	acid strength of high ethanol content fuel
ppmw	parts per million by weight
psi	pounds per square inch
$T_{V/L=20}$	temperature where vapor-liquid ratio is 20
vol%	percent by volume

Executive Summary

Ethanol production for fuel has increased significantly in recent years. In 2010, fuel grade ethanol production in the United States reached 13.2 billion gallons and accounted for almost 9% of the gasoline pool, mainly used as a blend of 10 volume percent (vol%) and below. Approximately 10% of the fuel grade ethanol is blended into “E85,” which is nominally 85 vol% fuel grade ethanol in a balance of gasoline or other hydrocarbons. To increase the number of ethanol blends available in the United States beyond these two markets, several states have provided incentives for the installation of so-called “blender pumps” that can blend gasoline with “E85.” At the writing of this report, there is no specification or standard practice that governs the properties of these blended fuels and little information is available about the content or qualities of fuels sold at blender pumps. No labeling conventions exist for blender pumps. However, efforts are underway within ASTM to develop a standard guide for mid-level ethanol blends and the Federal Trade Commission has proposed regulations designed to improve the consistency and uniformity of blender pump labeling.

Gasoline and “E85” were collected from 15 stations in eight states across the Midwestern United States. The survey samples included fifteen samples each of the parent base gasoline and “E85.” These two fuels were presumed to be used in the other ethanol blends, where only the two lowest blends, if available, were collected at each station. The gasoline and “E85” samples were tested against the applicable ASTM specifications. All the blender pump ethanol fuels (25 total) were tested for key parameters, such as vapor pressure and ethanol content.

Overall, the gasoline samples met the ASTM D4814-10 specification for vapor pressure and ethanol content, although one sample had an ethanol content in excess of the maximum. By blending additional ethanol into these gasolines, the vapor pressure was affected. When a gasoline without ethanol (E0) was blended with ethanol, the vapor pressure increased for the ethanol concentration range in this study. Gasolines already containing ethanol saw a vapor pressure decline with the addition of ethanol. The lowest vapor pressure was observed for the “E85” samples, on average, and one sample failed to meet the minimum D5798-10 specification.

For the “E85” samples, the acidity and pHe were typically low, with few failures noted. There was no correlation between acidity and pHe failures for these samples. Inorganic ions were typically near the method detection limit. All samples met the water content specification maximum of 1.0 mass%.

Although it was not a specific goal of the study, a common observation made of the stations surveyed was a lack of consistency in labeling conventions, formats, etc. at the blender pumps. In the absence of national requirements or guidance, a variety of labels were found in this study. Within Wisconsin, where two stations were photographed, intrastate consistency in labeling was not observed.

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Introduction

Ethanol production for fuel has increased significantly in recent years. In 2010, the last year this data was available, fuel grade ethanol production was 13.2 billion gallons and accounted for almost 9% of the gasoline pool in the United States, mainly used as a blend of 10 volume percent (vol%) and below.[1] Approximately 130 million gallons is blended at higher blend levels, which is nominally 85 vol% fuel grade ethanol in a balance of gasoline (commonly called “E85”), and is used in flex fuel vehicles (FFVs). The quality of “E85” is set by the ASTM D5798-10 specification. Although increasing amounts of ethanol are being consumed and the EPA recently ruled that gasoline containing up to 15% ethanol could be used in some non-FFVs, many observers expect that either ethanol as a fraction of the total gasoline pool will have to grow beyond 10 vol% or the “E85” demand will have to greatly expand in order to meet the consumption requirement of the federal Renewable Fuel Standard by 2022.[2] Another potential solution which has been advocated by some is to increase the number of ethanol blends available in the United States.

Several states have offered incentives for the installation of so-called “blender pumps.” These blender pumps typically blend “E85” and gasoline to produce fuels with ethanol content greater than gasoline but below “E85” (ASTM D5798-10 limits ethanol content in “E85” between 68 vol% and 83 vol%). There is no specification to govern the properties of these blended fuels, blended to between 11 vol% and 67 vol% ethanol, presumably, and little information is available about the fuels sold at blender pumps. However, FFV manufacturers state that their FFVs can operate on fuel containing ethanol content from zero to 85 vol% (E0 to “E85”).

The Coordinating Research Council (CRC) has undertaken several surveys of “E85” in recent years.[4–6] The most recent of these surveys,[6] led by the U.S. Department of Energy’s National Renewable Energy Laboratory, showed significant difficulties meeting the ASTM specification. In that survey, 53% of the Class 1 samples were below the specification minimum vapor pressure. Over 90% of the samples had ethanol content above the specification maximum.

The goal of this survey was to sample blender pumps from stations around the Midwest and to quantify the properties of the blends sold. The survey samples included the base gasoline and “E85” used in the blends as well as the two lowest blends, if available, offered at each station.

Test Methodology

Samples were collected in July 2010 from 15 stations in eight different states. At that time, an estimated 150 blender pumps were in use throughout the Midwestern U.S. Although the most common on-line database of blender pumps is widely available, [7] each station was contacted prior to sampling to ensure that it was still operable. Two stations originally targeted for sampling no longer sold ethanol blends, even though they were still listed in the on-line database.

During the summer months, the volatility of the gasoline in these areas and used in the blends must meet the Class A requirements in ASTM specification D4814-10. The “E85” must meet the Class 1 specification requirements of ASTM specification D5798-10. Figure 1 shows the locations of the stations visited in this study. The gasoline samples were tested against a select set of properties from ASTM D4814-10. “E85” samples were tested for a select set of properties in ASTM D5798-10. All other samples were tested for critical operability parameters because no specification or standard practice exists for ethanol-containing fuels between conventional gasoline and ethanol fuel blends (presumably 11 vol% to 67 vol% ethanol). The sample property test matrix is given in Table 1. Samples were analyzed by Southwest Research Institute in San Antonio, TX following ASTM test method protocols.

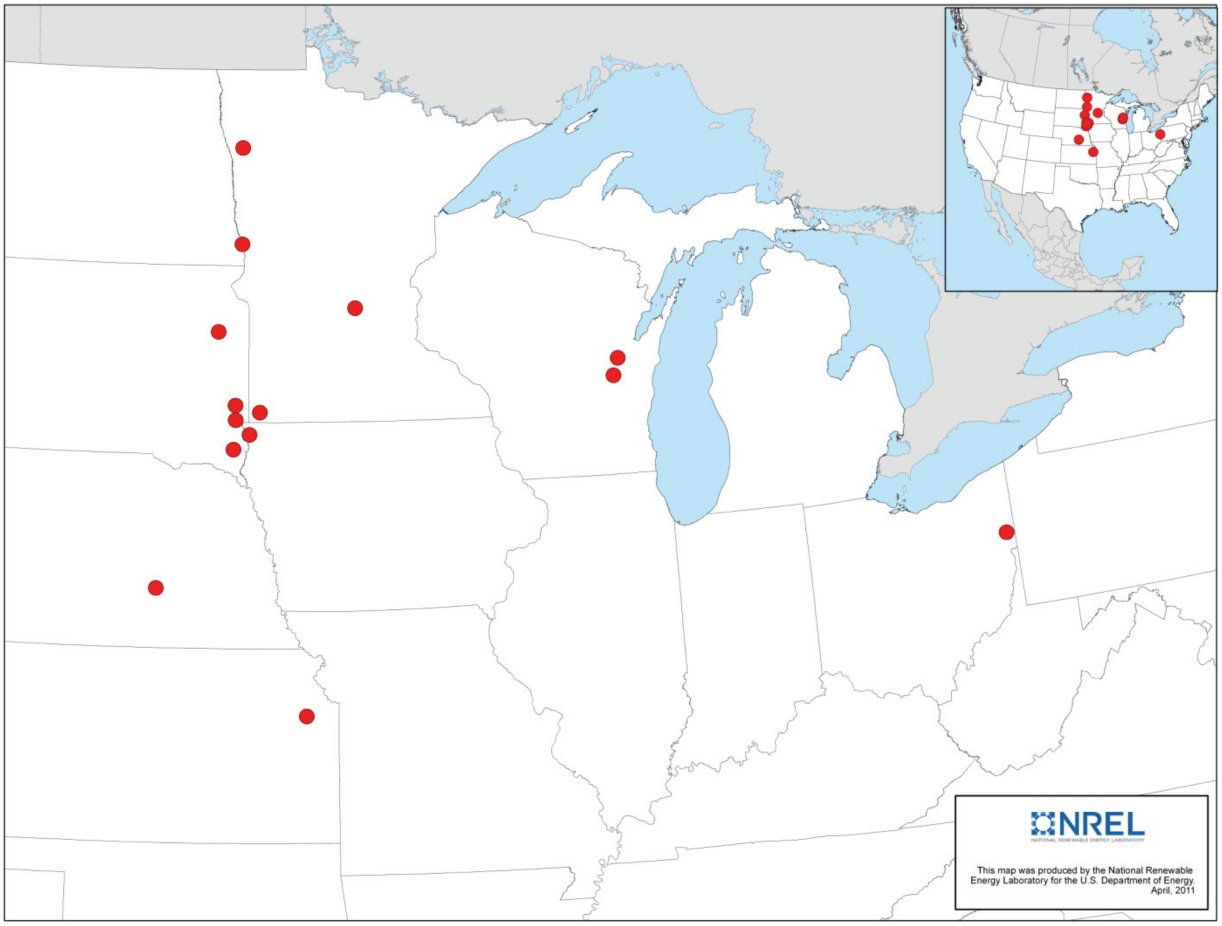

Figure 1. Locations of stations sampled

Table 1. Test Properties for Survey Samples

Property	ASTM Method	Notes	D4814-10 Specification Limits	D5798-10 Specification Limits
Ethanol content, vol%	D5599	Samples with E50 or below only	10, maximum	NA
Ethanol content, vol%	D5501	Samples above E50	NA	68–83
DVPE, psi	D5191	All samples	9, maximum, prior to ethanol blending[a]	5.5–8.5
Temperature for V/L=20	D5188	Gasoline samples only	Multiple grades	NA
Water content, mass%	E203	E30, E50, and FFV fuel samples	NA	1.0
Distillation, °C	D86	All samples	Multiple grades	NA
Gums, mg/100mL	D381	All samples	5, maximum for washed gum	20, maximum for unwashed gum 5, maximum for washed gum
pHe	D6423	"E85" samples only	NA	6.5-9.0
Acidity, mass%	D1613	"E85" samples only	NA	0.005, maximum
Inorganic chloride, ppmw	D7328	"E85" samples only	NA	1.0, maximum
Inorganic sulfate, ppmw	D7328	"E85" samples only	NA	NA
Potential sulfate, ppmw	D7328	"E85" samples only	NA	NA
Specific Gravity	D4052	All samples	NA	NA

NA: not applicable
[a] 9 psi DVPE maximum determined from geographic region where samples were collected, based on ASTM D4814-10

Results and Discussion

Simple statistics (sample size, mean, median, and standard deviation) for each of the measured fuel parameters are presented in Table 2. The complete analytical results are provided in the appendix.

Table 2. Result Summary for Samples Collected

Property	Sample Type	# Samples	Mean	Median	Standard Deviation
DVPE, psi	Gasoline (E0)	7	8.7	8.7	0.15
	Oxygenated gasoline	8	9.6	9.6	0.12
	E20 (blender pump)	12	9.4	9.4	0.14
	E30 (blender pump)	12	9.2	9.1	0.20
	E50 (bender pump)	1	8.7	8.7	NA
	"E85"	15	6.3	6.0	0.97
Ethanol Content, vol%	Gasoline (E0)	7	<0.1	<0.1	NA
	Oxygenated gasoline	8	8.2	9.7	4.0
	E20 (blender pump)	12	21.4	21.2	3.8
	E30 (blender pump)	12	31.5	31.1	4.1
	E50 (blender pump)	1	43.7	43.7	NA
	"E85"	15	79.7	80.3	3.6
Water Content, mass%	Gasoline (E0)	7	NA	NA	NA
	Oxygenated gasoline	8	NA	NA	NA
	E20 (blender pump)	12	NA	NA	NA
	E30 (blender pump)	12	0.291	0.291	0.061
	E50 (blender pump)	1	0.45	0.45	NA
	"E85"	15	0.643	0.615	0.114
pHe	"E85"	15	7.2	7.3	0.41
Acidity, mass%	"E85"	15	0.006	0.003	0.012
Specific gravity	Gasoline (E0)	7	0.739	0.739	0.004
	Oxygenated gasoline	8	0.745	0.745	0.006
	E20 (blender pump)	12	0.751	0.751	0.005
	E30 (blender pump)	12	0.755	0.754	0.005
	E50 (blender pump)	1	0.758	0.758	NA
	"E85"	15	0.782	0.784	0.005
T10, °F	Gasoline (E0)	7	124.	124.	3.1
T50, °F	Gasoline (E0)	7	206.	202.	7.7
T90, °F	Gasoline (E0)	7	326.	324.	4.5
FBP, °F	Gasoline (E0)	7	411.	413.	6.0
T10, °F	Oxygenated gasoline	8	121.	120.	1.7
T50, °F	Oxygenated gasoline	8	180.	182.	21.8
T90, °F	Oxygenated gasoline	8	325.	326.	8.8
FBP, °F	Oxygenated gasoline	8	403.	403.	11.4
T10, °F	E20	12	124.	123.	2.9
T50, °F	E20	12	161.	162.	2.1
T90, °F	E20	12	316.	315.	5.3
FBP, °F	E20	12	397.	399.	8.1
T10, °F	E30	12	127.	126.	3.1
T50, °F	E30	12	164.	164.	1.9
T90, °F	E30	12	307.	307.	6.9
FBP, °F	E30	12	393.	393.	9.1
T10, °F	E50	1	130.	130.	NA
T50, °F	E50	1	166.	166.	NA
T90, °F	E50	1	269.	269.	NA
FBP, °F	E50	1	376.	376.	NA
T10, °F	"E85"	15	157.	161.	7.9
T50, °F	"E85"	15	172.	172.	0.4
T90, °F	"E85"	15	174.	174.	0.7
FBP, °F	"E85"	15	286.	297.	68.1

Samples Collected and Pump Labeling

In this study, we collected samples from 15 stations throughout the Midwestern United States. Gasoline and "E85" samples were collected at every station. A total of 12 samples of E20 and E30 and 1 E50 blend were also collected from the blender pumps. Ten of the stations visited sold more than one blend between conventional gasoline and "E85," typically E20 and E30; however, one station sold E30 and E50. The contractor took photographs at several of the stations visited to understand the pump labeling. The Federal Trade Commission requires fuel pump labeling to inform consumers about the product being purchased. Labeling for conventional gasoline and FFV fuel pumps is well defined and must meet specific requirements. [8] No such labeling conventions exist for blender pumps, although relevant rules are being developed.

Figures 2 through 5 show photographs taken at several of the blender pump stations visited in this survey. The blender pump in Figure 2 was located in Kansas. The labeling on this pump clearly indicates the blends are not intended for use in conventional vehicles. It is worth noting that the pump pictured in Figure 2 offers two grades of conventional gasoline, labeled as "unleaded" and "mid-grade," but does not offer "premium grade."

Figure 2. Blender pump in Kansas

Figure 3 shows a blender pump in Iowa. Although the higher ethanol blends have been identified by their blend level (E20, E30, and “E85”), there is no clear indication these fuels are intended for use in FFVs only. These fuels are dispensed from the yellow nozzle on the right and are labeled as “Super Unleaded.”

Figure 3. Blender pump in Iowa

Figure 4 shows two examples of blender pumps in Wisconsin. These pumps show the octane number of the E20 blend, in contrast to the pumps in Iowa and Kansas. Both pumps show that the E20 and "E85" blends are for use in FFVs only; however, there is no consistency to the labeling used. In the top photograph, the FFV label is black text on yellow, while the label in the bottom photograph is yellow/orange text on black.

Figure 4: Blender pumps in Wisconsin

Figure 5 shows a blender pump in South Dakota. Similar to the pumps in Wisconsin, this pump lists the octane rating of all the fuels sold, including the "E85." Although the other pumps carried some indication that the higher ethanol blends may not be for use in all vehicles, this was the only pump with a warning label for consumers. The warning label is required in South Dakota to inform consumers about the fuels being dispensed.[9]

Figure 5. Blender pump in South Dakota

Ethanol Content

The locations of the blender pumps in this survey were typically rural, in areas not subject to mandatory reformulated gasoline or oxygenate blending. However, some of the gasoline samples contained various amounts of ethanol (Figure 6). Data in the figures are presented by station, showing the change in fuel properties as increasing amounts of ethanol are added. Conventional gasoline fuels were limited to 10 vol% ethanol by the EPA at the time the study was conducted (July 2010). One gasoline sample exceeded this limit, four samples contained 10 vol% ethanol, seven samples contained no ethanol, and three samples contained some ethanol (1.4 vol%, 4.7 vol%, and 6.2 vol% ethanol). The samples with ethanol content between 0 vol% and 10 vol% are likely due to gasolines with different levels of oxygenates being added to the same retail tank.

Overall, the E20, E30, and E50 blends were close to the labeled ethanol content. A few notable samples were significantly different than the published blend level. For example, the E20 from station 10 was very similar to the E30 in ethanol content. This could have been due to misblending or there may have been an error in sample collection by the contractor. As shown in Table 2, the mean and median were very similar for these fuels, indicating little bias either above or below the published blend content.

"E85" is required to be between 68 vol% and 83 vol% ethanol per ASTM specification D5798-10. All of the samples met the current specification limits for ethanol content. The specification changed in 2010 to reduce the minimum ethanol content in all volatility classes. For the "summer season," Class 1, in the older version of the specification (D5798-09b), required ethanol content to be between 79 vol% and 83 vol%. The reduction in allowable ethanol content meant three of the samples in this study that would have previously failed the specification are now within acceptable limits.

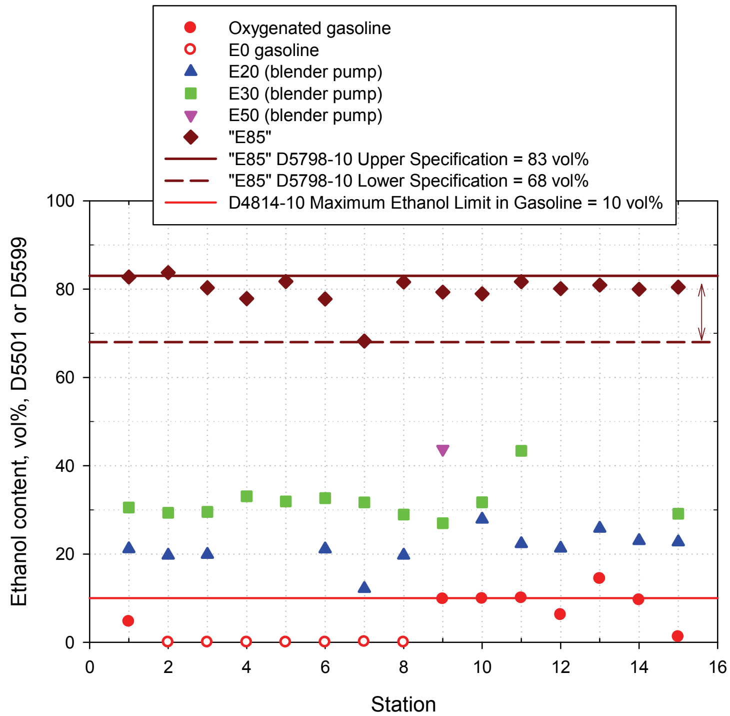

Figure 6. Ethanol content for samples collected in this survey

Vapor Pressure

Gasolines and "E85" have to meet strict volatility requirements depending on location and time of year. For the gasoline samples from the regions surveyed, the maximum vapor pressure was 9 psi before ethanol blending. There is a 1-psi waiver (to a maximum of 10 psi) for conventional gasoline samples containing 10 vol% ethanol. The "E85" samples are required to have volatilities between 5.5 psi and 8.5 psi; however, no standards exist for other levels of ethanol blends. The 1-psi waiver does not apply to fuels with greater than 10 vol% ethanol.

Figure 7 shows the vapor pressures for the samples collected in this survey. The E0 samples all met the 9-psi maximum limit in D4814-10. The gasoline samples containing ethanol have slightly higher volatilities, but were all below 10 psi. The vapor pressures of the higher ethanol blends show the impact of blending with ethanol. In E0 samples, adding ethanol increases the vapor pressure for these blend levels. In samples already containing ethanol, adding additional ethanol starts to reduce the vapor pressure. The "E85" samples, which contain the most ethanol, have the lowest volatilities. Only one "E85" sample had a volatility below the specification minimum. This is a marked improvement compared to previous surveys.[4]

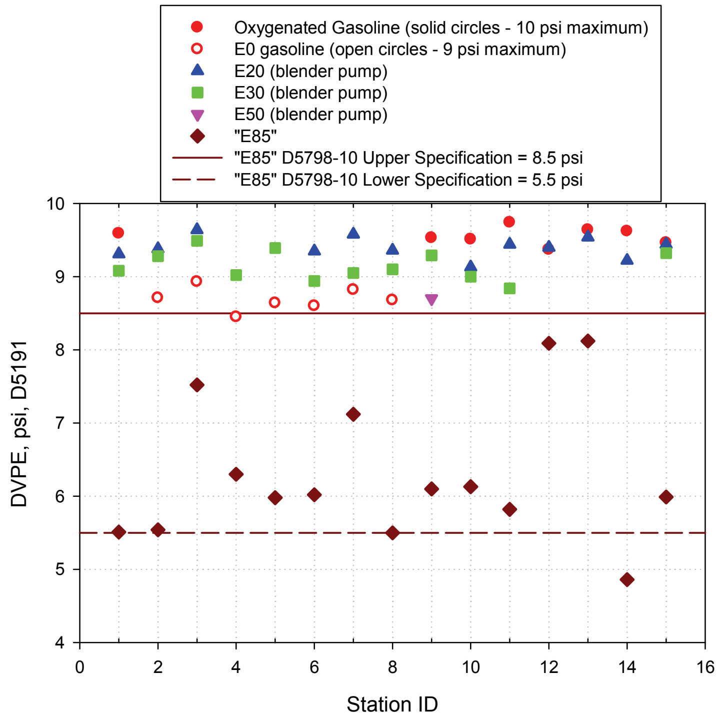

Figure 7. Sample volatilities for gasolines, FFV fuels, and other blends collected

Vapor-Liquid Ratio

Suitable volatility in gasoline samples is measured by the temperature where a vapor-liquid ratio of 20 ($T_{V/L=20}$) is achieved, to ensure adequate vapor lock protection. The specification limit is driven by time of year (ambient temperature) and geographic location. The gasoline samples collected in this survey represent vapor lock protection Class 2 (Stations 1–7) and Class 3 (Stations 8–15). All samples readily met the specification minimum (50°C for Class 2 and 47°C for Class 3).

Washed and Unwashed Gum

Every sample was tested for washed and unwashed gum content, a measure of oxidation products formed that may lead to engine deposits. The washed gum content is limited in both the ASTM D4814 and D5798 specifications, while unwashed gum is only limited in D5798. The washed gum was at or very near the detection limit for every sample tested. In most cases, the unwashed gum content was also low. At Station 9, the gasoline and E30 samples had unwashed gum twice as high as similar samples from other stations.

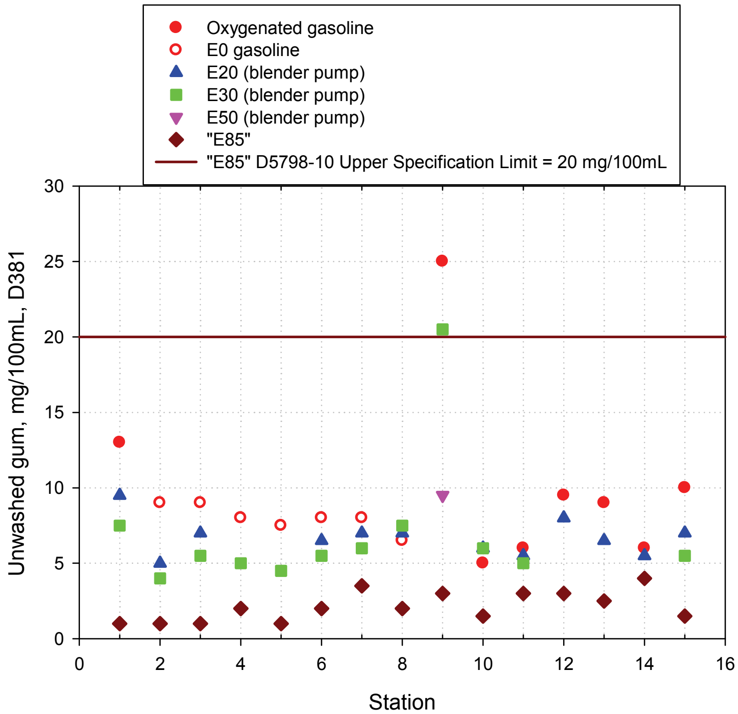

Figure 8. Unwashed gum content for all samples

Specific Gravity and Distillation

The specific gravity and distillation curves were measured for all samples. A data summary is presented in Table 2, and the complete data is in the Appendix. No further analyses were conducted for this data, it is simply presented for completeness.

"E85"-Specific Analyses

Acidity

The acidity of "E85" samples is an important measure of low-level organic acids left over from production and is limited to 0.005 mass%. Figure 9 illustrates the acidity of the "E85" samples collected in this study. One sample (station 3) showed acidity slightly above the limit, and one sample (station 5) grossly exceeded the specification limit.

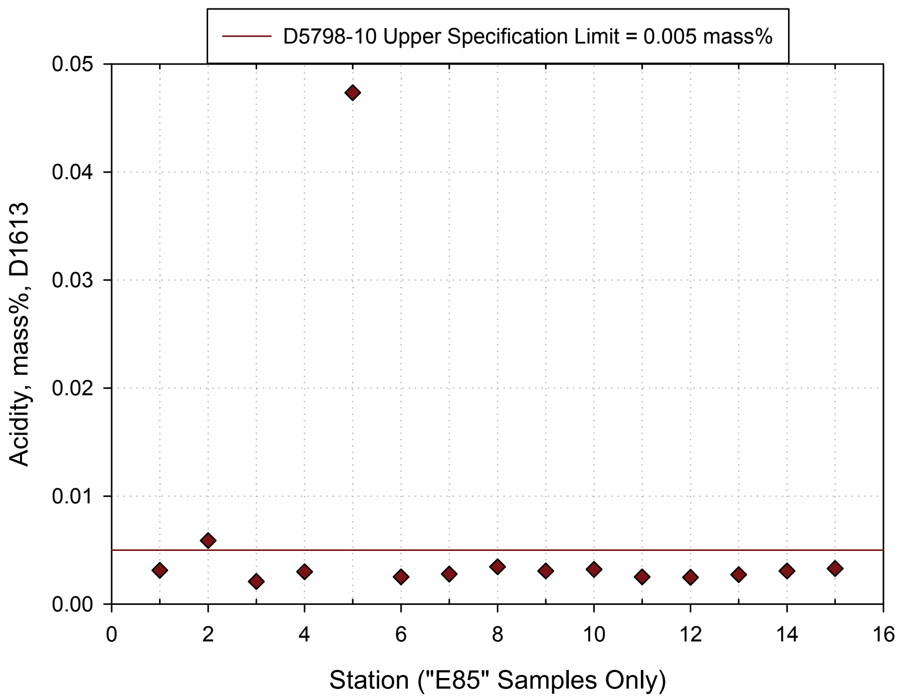

Figure 9. Acidity for "E85" samples only

pHe

The pHe of “E85” is another measure of the acidity and corrosivity of the fuel (Figure 10). One sample had a pHe slightly below the specification limit, but all the other samples readily met the limit. The samples that had elevated acidity met the pHe specification, and the sample with slightly low pHe readily met the acidity specification, showing no correlation for these parameters based on this study.

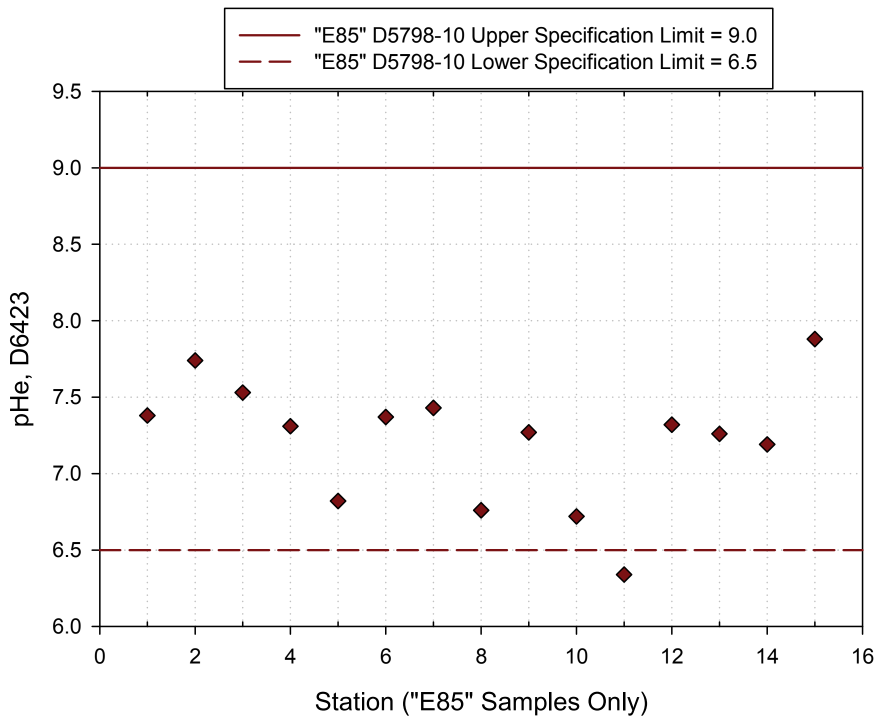

Figure 10. pHe of “E85” fuel samples only

Inorganic Chloride, Inorganic and Potential Sulfate

In “E85” samples, inorganic chloride and sulfate can be left over from processing and increase the corrosivity of the fuel. Excessive inorganic chlorides can lead to durability and performance issues by damaging the fuel injection system. Sulfates can plug fuel filters and also lead to injector fouling. Figure 11 illustrates the inorganic chloride and sulfate and potential sulfate results from the “E85” samples collected in this study. Overall, the concentrations are very low and are similar to results from recent “E85” surveys.[5]

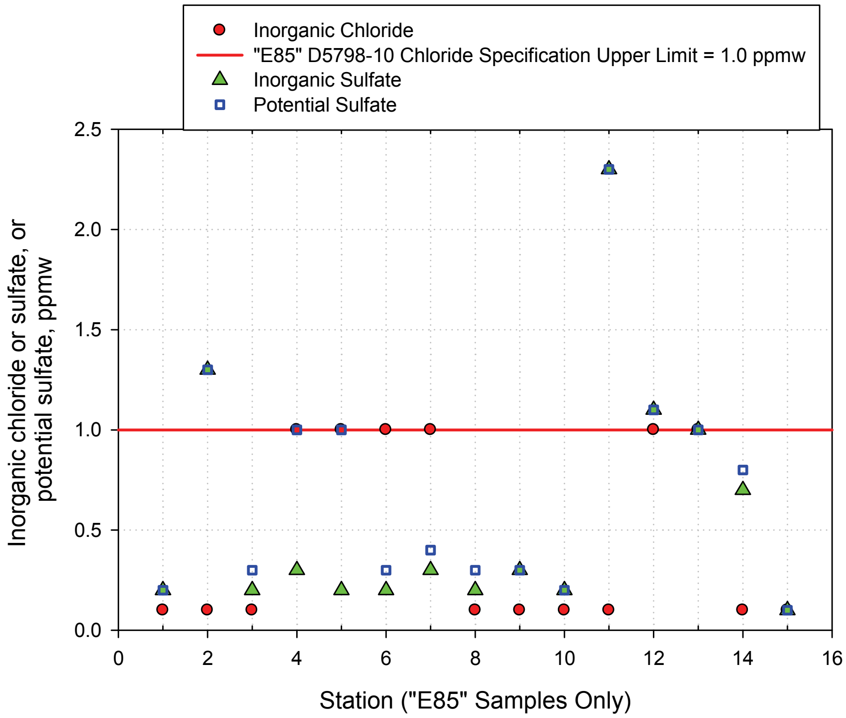

Figure 11. Inorganic ions from “E85” samples.
The solid line shows the chloride specification limit. ASTM D5798-10 does not limit potential or inorganic sulfate.

Water Content

The presence of water in fuels and in storage tanks can be problematic, regardless of the fuel used. Water in "E85" fuels can cause more significant problems than water in traditional fuels. The water can cause separation of the ethanol portion of "E85" fuel. The water content was only measured for the E30, E50, and "E85" samples. Without exception, the samples met the specification maximum limit of 1.0 mass% water.

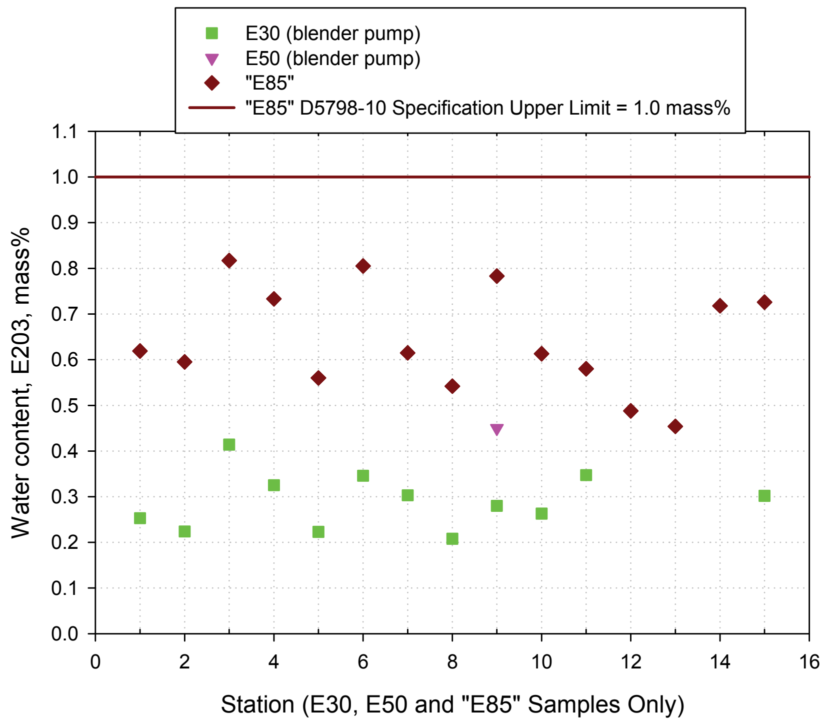

Figure 12. Water content of E30, E50, and "E85" fuels only

Conclusions

With fuel ethanol volumes expected to eclipse demand in coming years, new strategies will likely be developed for utilization. Several avenues are being explored, including potentially increasing the amount of ethanol allowed in gasoline, increasing "E85" market penetration, and introducing ethanol fuel blends with ethanol less than those allowed under D5798. These fuels are being sold, mainly in the Midwestern United States, through so-called blender pumps. No specification exists for these fuels, and the fuel quality was unknown. Fifteen stations were visited in July 2010 to collect samples for the first known quality survey of blender pump fuels. Conventional gasoline, "E85," and the two lowest ethanol blends were collected, if available, at every station. Each sample was tested for critical operability properties.

Photographs taken at several stations reveal no consistent labeling convention at blender pumps. Some stations list higher ethanol blends as "Super Unleaded," without notification to consumers that these blends are not approved for use in conventional vehicles. Other stations use labeling to inform consumers that these fuels are for FFVs only.

The ethanol content varied greatly over the samples taken. Half the gasoline samples contained some ethanol, while the other half of the samples contained none. The “E85” samples were all within the specification limits for ethanol content. By looking at the higher ethanol blends at a single station, measured ethanol content compared to labeled ethanol content appeared random. It was not uncommon to find one blend that matched the posted ethanol content, and another blend that was significantly higher or lower than the posted ethanol content. Although a protocol was outlined to ensure purging between sample collection, human error does occur. Thus, no conclusions can be drawn whether this was due to sample collection error or blending error at the pump.

As increasing ethanol content was added to gasoline, the vapor pressure changed. If the base gasoline did not contain ethanol (E0), the vapor pressure of the blend increased. If the base gasoline was oxygenated, the vapor pressure decreased. If these fuels are intended for use in FFVs, the vapor pressure of the samples exceeded the specification maximum set forth in ASTM D5798-10. All the gasoline samples met the specification requirements for the $T_{V/L=20}$ measure of volatility. One gasoline sample had excessive unwashed gums, possibly due to additive interaction.

Other properties tested were specific to higher ethanol blends. The water content of the E30 and E50 samples and the “E85” fuels was measured. All samples were below the 1.0 mass% water content maximum given in ASTM D5798-10. The specification properties for pHe and acidity were measured for the “E85” samples. Two acidity failures and one pHe failure was observed. There was no correlation between failing acidity and pHe. Overall, the inorganic ion content of the fuels was low.

This survey also tested the properties of fuels containing ethanol levels above conventional gasoline but below “E85” fuels. Because there is no specification, no robust assessment of quality could be made, but the analytical results are reported here. If these fuels are indeed intended for use in FFVs, their properties differ significantly from current “E85” fuels and their impact on handling and utilization needs to be quantified.

This survey is the first comprehensive assessment of fuel quality for blender pumps. Future work is highly recommended to better understand the fuels dispensed from blender pumps. This work may include sampling in a wider geographic area and through multiple gasoline and “E85” volatility classes.

Blender pumps may become more prevalent as the Renewable Fuel Standard mandates drive increasing volumes of ethanol and other biofuels in the marketplace in the future. Historically, the installation of blender pumps has been limited to the Midwestern U.S., although new pumps are being installed in a broader geographic range, including Colorado and Nevada. Future work should include these new stations, which will have different base gasoline properties and should assess the impact on these fuels.

This work focused only on summertime fuels, using Class 1 “E85” and Class A gasoline. Future work needs to consider fuels in different volatility classes, for both “E85” and gasoline. Depending on the region, base gasoline may or may not contain ethanol. This work has shown that the vapor pressures for fuels from blender pumps are marginally higher when the base gasoline contained ethanol for the range of ethanol content in this study. To further validate this conclusion, additional work should be conducted at more locations with a wider variety of base gasolines.

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Appendix

Table A-1 Fuel Property Results

Station ID	Date	State	Type	DVPE, psi D5191	Acidity, mass% D1613	Unwashed gum, mg/100mL D381	Washed gum, mg/100mL, D381	Specific gravity, at 60°F, D4052	$T_{V/L=20}$, D5188	Water, mass%, E203	Ethanol, vol%, D5501 or D5599	pHe, D6423	Chloride, ppm, D7328	Sulfate, ppm, D7328	Potential Sulfate, ppm, D7328
1	7/17/2010	KS	Gasoline	9.59		13	1	0.7422	129.5		4.6652				
			E-20	9.31		9.5	<0.5	0.7503			21.1573				
			"E-85"	5.51	0.0031	1	<0.5	0.7853		0.619	82.73	7.38	<0.1	0.2	0.2
			E-30	9.08		7.5	0.5	0.7552		0.253	30.52				
2	7/19/2010	NE	Gasoline	8.71		9	0.5	0.7369	143.1		<0.1				
			E-20	9.38		5	<0.5	0.7469			19.7037				
			E-30	9.28		4	<0.5	0.7521		0.224	29.32				
			"E-85"	5.54	0.0059	1	<0.5	0.7853		0.595	83.74	7.74	<0.1	1.3	1.3
3	7/14/2010	ND	Gasoline	8.93		9	<0.5	0.7478	141.1		<0.1				
			E-20	9.64		7	0.5	0.7529			19.8689				
			E-30	9.49		5.5	<0.5	0.7561		0.414	29.52				
			"E-85"	7.52	0.0021	1	0.5	0.7745		0.817	80.31	7.53	<0.1	0.2	0.3
4	8/1/2010	SD	Gasoline	8.45		8	<0.5	0.7357	140.6		<0.1				
			E-30	9.02		5	<0.5	0.7529		0.325	33.07				
			"E-85"	6.3	0.003	2	<0.5	0.7812		0.733	77.85	7.31	<1	0.3	<1
5	8/1/2010	SD	Gasoline	8.64		7.5	<0.5	0.7381	142.1		<0.1				
			E-30	9.39		4.5	<0.5	0.7541		0.223	31.89				
			"E-85"	5.98	0.0473	1	<0.5	0.7852		0.56	81.74	6.82	<1	0.2	<1
6	7/18/2010	SD	Gasoline	8.6		8	<0.5	0.7424	146.9		<0.1				
			E-20	9.35		6.5	<0.5	0.752			21.1254				
			E-30	8.94		5.5	<0.5	0.7577		0.346	32.64				
			"E-85"	6.02	0.0025	2	<0.5	0.7842		0.805	77.77	7.37	<1	0.2	0.3

Station ID	Date	State	Type	DVPE, psi D5191	Acidity, mass% D1613	Unwashed gum, mg/100mL D381	Washed gum, mg/100mL, D381	Specific gravity, at 60°F, D4052	$T_{V/L=20}$, D5188	Water, mass%, E203	Ethanol, vol%, D5501 or D5599	pHe, D6423	Chloride, ppm, D7328	Sulfate, ppm, D7328	Potential Sulfate, ppm, D7328
7	7/17/2010	SD	Gasoline	8.82		8	<0.5	0.7366	136.2		0.1142				
			E-20	9.58		7	<0.5	0.7427			12.1622				
			E-30	9.05		6	<0.5	0.7532		0.303	31.66				
			"E-85"	7.12	0.0028	3.5	<0.5	0.7764		0.615	68.21	7.43	<1	0.3	0.4
8	7/17/2010	IA	Gasoline	8.68		6.5	<0.5	0.7387	143.2		<0.1				
			E-20	9.36		7	<0.5	0.7479			19.6928				
			E-30	9.1		7.5	<0.5	0.7524		0.208	28.93				
			"E-85"	5.5	0.0034	2	0.5	0.7842		0.542	81.6	6.76	<0.1	0.2	0.3
9	7/14/2010	MN	Gasoline	9.53		25	<0.5	0.7353	126.1		9.78625				
			E-30	9.29		20.5	<0.5	0.7462		0.28	26.95				
			E-50	8.7		9.5	<0.5	0.7581		0.45	43.74				
			"E-85"	6.1	0.0031	3	<0.5	0.7833		0.783	79.29	7.27	<0.1	0.3	0.3
10	7/15/2010	MN	Gasoline	9.51		5	<0.5	0.7558	130.7		9.8753				
			E-20	9.13		6	1	0.7633			27.875				
			E-30	9		6	0.5	0.7645		0.263	31.7				
			"E-85"	6.13	0.0032	1.5	<0.5	0.7856		0.613	78.93	6.72	<0.1	0.2	0.2
11	7/19/2010	MN	Gasoline	9.74		6	<0.5	0.7469	125.5		10.01				
			E-20	9.44		5.5	<0.5	0.7531			22.3392				
			E-30	8.84		5	<0.5	0.7642		0.347	43.37				
			"E-85"	5.82	0.0025	3	0.5	0.7855		0.58	81.67	6.34	<0.1	2.3	2.3
12	7/18/2010	WI	Gasoline	9.37		9.5	<0.5	0.7449	127.2		6.2198				
			E-20	9.4		8	0.5	0.7498			21.3132				
			"E-85"	8.09	0.0025	3	1	0.7729		0.488	80.11	7.32	<1	1.1	1.1

Station ID	Date	State	Type	DVPE, psi D5191	Acidity, mass% D1613	Unwashed gum, mg/100mL D381	Washed gum, mg/100mL, D381	Specific gravity, at 60°F, D4052	$T_{V/L=20}$, D5188	Water, mass%, E203	Ethanol, vol%, D5501 or D5599	pHe, D6423	Chloride, ppm, D7328	Sulfate, ppm, D7328	Potential Sulfate, ppm, D7328
13	7/18/2010	WI	Gasoline	9.64		9	0.5	0.7455	126.5		14.3952				
			E-20	9.54		6.5	<0.5	0.7496			25.7981				
			“E-85”	8.12	0.0027	2.5	<0.5	0.7723		0.454	80.89	7.26	<1	1	1
14	8/1/2010	OH	Gasoline	9.62		6	0.5	0.7503	127.6		9.568				
			E20	9.22		5.5	0.5	0.7566			23.0157				
			“E85”	4.86	0.0031	4	<0.5	0.7848		0.718	79.97	7.19	-0.1	0.7	0.8
15	7/18/2010	IA	Gasoline	9.46		10	1	0.7397	135.6		1.2105				
			E-20	9.44		7	<0.5	0.7509			22.71				
			E-30	9.32		5.5	<0.5	0.7538		0.302	29.1				
			“E-85”	5.99	0.0033	1.5	<0.5	0.7835		0.726	80.45	7.88	<0.1	0.1	0.1

Table A-2 Distillation (ASTM D86) Results

Station ID	State	Sample Type	IBP, °C	T5, °C	T10, °C	T15, °C	T20, °C	T30, °C	T40, °C	T50, °C	T60, °C	T70, °C	T80, °C	T90, °C	T95, °C	FBP, °C	Recovered	Residue	Loss
1	KS	Gasoline	89.5	112.4	120	125.5	130.3	143.5	174.8	203.2	227.4	252.2	282.6	323.6	356	401.4	98.1	1	0.9
		E-20	95.5	118.3	125.9	131.7	137.3	147.4	155.7	161.4	165.7	218.5	268.6	312.9	346	400	98.5	0.8	0.7
		“E-85”	120.8	154	163.7	167.8	169.8	171.6	172.4	172.7	172.9	173.2	173.4	174.1	175.3	303.2	98.5	0.8	0.7
		E-30	95.9	118.3	127	133.6	140.3	151.1	158.8	164.1	167.7	170.2	248.4	306.5	339.6	393.3	98.1	0.8	1.1
2	NE	Gasoline	91.1	112.6	123.6	131.8	139.5	156.6	177.3	201.6	227.2	253.7	284.5	322.5	354.9	400.8	97.3	0.9	1.8
		E-20	90.3	112.5	122.2	128.2	133.7	144	153.1	160	164.8	214.4	270.9	313.2	343.9	385.7	97.4	1	1.6
		E-30	95.8	117.2	125.4	131.8	137.7	148.5	157.2	163.2	167.5	170.3	251.6	308	340	390.3	97.9	0.9	1.2
		“E-85”	121	153.2	163.9	168	170.2	171.9	172.6	172.9	173.2	173.4	173.6	174.3	175.4	297.1	98.6	0.7	0.7
3	ND	Gasoline	86.1	111.9	123.2	132.5	141.4	160.9	185	212.6	240.4	268.2	299.1	334.2	366.1	412.4	98.4	0.8	0.8
		E-20	89.4	113.8	122.2	128.2	134	144.5	153.9	161.1	166.2	233.3	279.4	320.8	352.6	401.9	98.1	1hed	0.9
		E-30	92.9	114.6	123.2	129.6	136	147.8	157.3	163.9	168.2	171.9	263.4	313.7	347.9	397.9	98.3	0.8	0.9
		“E-85”	98.7	132.9	147.5	158.2	165.1	170.1	171.5	172	172.2	172.4	172.6	172.9	173.5	182.1	99.2	0.4	0.4
4	SD	Gasoline	90.5	108.6	121.6	130.4	138.5	154.9	175.3	198.8	223.2	249.2	280	321.9	351.4	412.8	96.2	1	2.8
		E-30	95.6	112.1	123.3	130.4	136.3	147.7	156.6	162.6	166.8	169.7	172.5	300.6	334	391.6	96.3	1	2.7
		“E-85”	112.1	136.3	153.6	161.9	166.4	170.2	171.6	172.2	172.6	172.9	173.3	174.2	175.4	342.4	97.1	1	1.9
5	SD	Gasoline	87.9	105.4	119.5	128.3	136.2	153.6	174.6	200.3	226.7	254.8	287	328.3	361.2	416.4	96.1	1	2.9
		E-30	98	114.4	124.4	131.3	137.7	148.5	157.7	164.1	168.2	171.5	249.7	312.3	346.3	405	96.7	1	2.3
		“E-85”	115.4	149	161.9	166.5	168.7	170.7	171.5	172	172.2	172.6	172.9	173.9	175.6	349.8	97.9	1	1.1

Station ID	State	Sample Type	IBP, °C	T5, °C	T10, °C	T15, °C	T20, °C	T30, °C	T40, °C	T50, °C	T60, °C	T70, °C	T80, °C	T90, °C	T95, °C	FBP, °C	Recovered	Residue	Loss
6	SD	Gasoline	86.2	114.9	129.4	142	154.1	178	200.3	219.9	238.9	261.1	288.3	324.2	351.1	404.1	98	0.6	1.4
		E-20	95	119.8	129	136.5	142.6	152.2	158.8	163.3	167.3	242.1	271.8	313.8	342.6	392.3	98.2	0.9	0.9
		E-30	95.4	120.6	131.8	140.3	146.8	156.1	161.9	165.5	168.3	170.8	257.6	308.1	336.3	388.1	98	0.6	1.4
		"E-85"	115.8	148.7	160.3	165.4	168.3	170.8	171.9	172.5	172.8	173.2	173.6	174.6	176	358.8	98.3	0.8	0.9
7	SD	Gasoline	87.8	112.7	123.5	131.9	139.8	157.1	177.6	201.6	227.4	253.2	283.9	321.9	353.1	415.5	97.7	0.9	1.4
		E-20	90.6	114.5	121.6	126.7	131.6	140.7	149.3	156.7	198.3	243.4	275.3	316.1	344.6	398.3	98.2	1	0.8
		E-30	92.3	117.8	126.5	132.8	138.5	149.2	157.5	163.3	167.3	170.6	221	305	337.3	383.2	98	1.2	0.8
		"E-85"	104.7	133.1	145.9	154.6	161.1	167.6	170.1	171.5	172.2	172.7	173.4	174.6	176.9	353.3	98.2	0.8	1
8	IA	Gasoline	87.9	113.9	125.3	134	142.3	160.3	181.8	205.2	229.6	254.7	286.2	327.1	356.9	413.6	97.9	0.7	1.4
		E-20	94.9	115.9	123.1	128.9	134.4	144.6	153.5	160.2	165.2	227.9	268.1	314.1	346.3	402.8	98.3	0.8	0.9
		E-30	92.6	117.6	126.7	132.8	138.8	148.9	157.1	162.8	166.7	170	255.1	306.5	340.1	393.5	98.3	0.8	0.9
		"E-85"	112.1	154.3	162.8	166.8	169	170.9	171.7	172.2	172.4	172.7	173	173.8	175	178.6	98	1.6	0.4
9	MN	Gasoline	92.5	112.9	120.1	124.9	129.1	138.5	146.6	154.8	209	236.6	266.1	307.1	337	381.9	97.8	1.1	1.1
		E-30	96.6	114.8	123.2	129.1	135	145.4	154.4	160.9	165.3	169	242.1	296.2	328.2	378.4	97.2	1.1	1.7
		E-50	96.2	120.4	129.9	135.8	143	154.4	162.2	166.4	169.1	171	172.8	268.6	316.4	375.8	98.3	0.9	0.8
		"E-85"	108.5	151	160.4	165.2	167.8	170.3	171.3	171.8	172.2	172.4	172.8	173.5	174.8	296.4	98.1	1.3	0.6

Station ID	State	Sample Type	IBP, °C	T5, °C	T10, °C	T15, °C	T20, °C	T30, °C	T40, °C	T50, °C	T60, °C	T70, °C	T80, °C	T90, °C	T95, °C	FBP, °C	Recovered	Residue	Loss
10	MN	Gasoline	87	115.4	124.3	130.8	136.9	146.7	154.6	197.6	235.9	262.8	295.9	336	373.3	421.4	98.2	0.9	0.9
		E-20	91.1	120	130	137.6	143.9	154.1	160.9	165.4	168.5	172.3	274.7	324.3	363.1	413.9	98.2	1	0.8
		E-30	90.2	121.6	131.8	139.4	145.9	155.5	162	166.2	169.2	171	270.8	323.4	362.1	411.9	98.3	1	0.7
		“E-85”	113.4	152.9	162.1	166.4	168.6	170.7	171.6	172.2	172.5	172.9	173.4	174.4	176.3	326.8	97	2.2	0.8
11	MN	Gasoline	87.7	110.8	118.7	123.9	128.5	138.3	147.4	158.2	216.4	251.6	286.4	327.3	362.3	403.6	98.1	0.9	1
		E-20	94.8	114.2	122.4	127.5	133.3	144.6	154.5	162.3	167.2	172.1	274.7	322	353.3	402.3	97.7	0.9	1.4
		E-30	97.7	120.7	129.6	137.4	144.2	156.1	163.9	168	170.9	172.8	173.9	303.2	339.1	393.6	98.7	0.6	0.7
		“E-85”	120.5	151.3	161.9	166.8	169.2	171.3	172.1	172.5	172.7	172.9	173.2	173.9	175.2	349.5	98.4	0.7	0.9
12	WI	Gasoline	91.6	112.5	119.6	124.1	128.9	137.6	153.1	194.8	225.7	252.6	285.2	327.2	353.4	404.1	98.2	0.8	1
		E-20	90.9	113.9	122.1	127.2	132.6	143.2	152.8	159.8	164.9	169.7	267.8	315.1	342.6	393.1	98.4	0.5	1.1
		“E-85”	101.3	127.7	143.4	155.7	163.8	169.9	171.5	172	172.3	172.5	172.6	172.8	173.3	197.6	98.7	0.1	1.2
13	WI	Gasoline	85.2	113.1	121.3	126.8	131.8	141.8	150.7	158.2	181.6	245.3	281.3	324	355.9	397.4	98.1	1.2	0.7
		E-20	87.8	114.2	122.3	128.5	134.5	145.1	154.5	162	166.3	170.2	262.8	314.4	348.2	392	98.3	1.1	0.6
		“E-85”	95.3	121.6	142.8	156	164.1	169.8	171.2	171.7	172	172.1	172.2	172.4	172.8	179.7	97.9	0.1	2
14	OH	Gasoline	93.2	113.7	120.9	126.1	131.7	141.4	150.4	170.1	226.9	257.9	291.3	333.1	365.8	411.7	98.3	0.9	0.8
		E20	91.1	117.2	125.8	132	137.9	148	156.6	162.7	166.9	182.8	277.3	323.2	356.8	401	98.2	1	0.8
		“E85”	121.7	157.2	163	166.1	168	170	171	171.6	172	172.4	172.7	173.5	174.8	278.8	98.1	1.3	0.6

Station ID	State	Sample Type	IBP, °C	T5, °C	T10, °C	T15, °C	T20, °C	T30, °C	T40, °C	T50, °C	T60, °C	T70, °C	T80, °C	T90, °C	T95, °C	FBP, °C	Recovered	Residue	Loss
15	IA	Gasoline	87.6	109	119.4	128.8	137.7	157.5	179.7	204.3	228.5	253.5	283.1	320.2	350	399.6	98.4	0.9	0.7
		E-20	90	116	124.8	131.1	136.6	147.1	155.6	161.7	166.1	170.9	266.3	305.7	340.1	385.2	98.3	1.1	0.6
		E-30	92.8	117	125.6	131.8	138.6	149.2	157.7	163.2	167.3	170.2	253.8	304.9	337.5	386.7	98.1	1	0.9
		"E-85"	116.1	148.4	161.1	166.1	168.5	170.8	171.8	172.2	172.6	172.7	173	173.6	174.7	293.5	98.8	0.6	0.6