

ENERGY AND OTHER FUEL PROPERTY CHANGES WITH ON-ROAD ULTRA-LOW SULFUR DIESEL FUEL



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December 2008



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Acknowledgements

The American Transportation Research Institute would like to express our appreciation to the trucking companies that collected and donated the diesel fuel samples used in this analysis. We also want to acknowledge the contribution of Robert L McCormick, Principle Engineer, Fuels Performance, National Renewable Fuels Laboratory, for his comments and suggestions on the draft report.

Abstract

The process used to remove sulfur from on-road diesel fuel was expected to reduce the amount of energy in the fuel. The U.S. Environmental Protection Agency (EPA) anticipated an energy loss of as much as 1.5 percent to result from refining fuel to meet the new ultra-low sulfur diesel (ULSD) fuel standard. Thus, it was expected that refiners would need to produce, and trucking companies would need to purchase, 1.5 percent more ULSD to travel the same number of miles as before. ATRI initiated this study to investigate what actual changes in energy content and other fuel properties have occurred as a result of the transition to ULSD.

This study collected diesel fuel samples from multiple trucking fleet locations throughout the United States. Fuel samples were collected at the same on-site or primary fueling locations prior to and after implementation of the federal ULSD standard. A total of 15 diesel fuel samples were collected from each location during April - June 2006 and again during May - June 2007.

As expected, dramatic reductions in the sulfur content of on-road diesel fuel were found (mean = -97.4%, $p = 0.0002$) with the sulfur content of all ULSD samples being below 10 ppm. In addition to sulfur, aromatics had the largest percentage change of all other mean fuel properties (mean = -29%, $p = 0.0001$) when comparing ULSD to the prior on-road diesel fuel.

Contrary to EPA's anticipation of an energy loss, the mean energy content of the ULSD samples was slightly higher than the same location non-ULSD samples (mean = +0.4%, $p = 0.15$). Individually, the energy content of the ULSD samples ranged from -0.4 percent to +1.8 percent compared to the same location, prior year samples. A per-gallon energy content variation of 2.2 percent was found among all ULSD samples collected in 2007. This "across country" variation in the energy content of ULSD was greater than the variation found when comparing same location ULSD to the prior year samples.

Comparing ATRI's mean federal and state boutique diesel fuels for the two sampling periods reveals that in addition to the overall decrease in sulfur levels, the aromatic content of federal ULSD has been reduced to the levels previously found in boutique diesel fuels. Additional decreases in aromatics were also observed among the mean boutique ULSD fuel. While quantification of the potential emissions impacts associated with fuel property changes are beyond the objectives of this study, it is important to recognize that potential reductions in oxides of nitrogen (NO_x), particulate matter (PM) and hydrocarbon (HC) emissions from in-use diesel vehicles may have occurred from ULSD-related fuel property changes.

Further research is needed to better assess impacts resulting from the interaction of ULSD with in-use engines performance. Research is also needed to determine whether any ULSD-related fuel properties changes have a discernable emissions impact on engines with advanced emissions control systems.

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Background

Beginning in June 2006, the U.S. Environmental Protection Agency (EPA) implemented a regulation requiring that at least 80 percent of the diesel fuel refined or imported into the United States for on-road use meet a sulfur standard of 15 parts per million (ppm).¹ Diesel fuel that meets this new standard, which is 97 percent lower than the previous on-road sulfur standard of 500 ppm, is commonly referred to as ultra-low sulfur diesel (ULSD).

U.S. retail outlets selling ULSD were required to ensure compliance with the 15 ppm specification beginning in October 2006. Retail outlets are currently not *required* to sell ULSD but are *likely* to sell ULSD since it represents the majority of the on-road diesel fuel being refined or imported. The final phase of the regulation requires all on-road diesel fuel sold in the U.S. to meet the ULSD standard by December 2010. By removing most of the sulfur in on-road diesel fuel, new diesel vehicles are able to employ advanced emission control systems to meet more stringent emission standards.

The process used to remove sulfur from on-road diesel fuel (*i.e.* desulfurization) was expected to reduce the amount of energy in the fuel. Vehicular fuel economy is directly proportional to the amount of energy contained in fuel. In other words, while many factors can influence fuel economy, a fuel with a lower amount of energy will produce lower fuel economy, with everything else being equal.

EPA expected the amount of energy lost during the desulfurization process to be as much as 1.5 percent.² Therefore, it was expected that refiners would need to produce, and trucking companies would need to purchase, 1.5 percent more ULSD to travel the same number of miles as before. ATRI initiated this study to investigate what changes in energy content and other fuel properties have occurred as a result of the transition to ULSD.

Research Methodology

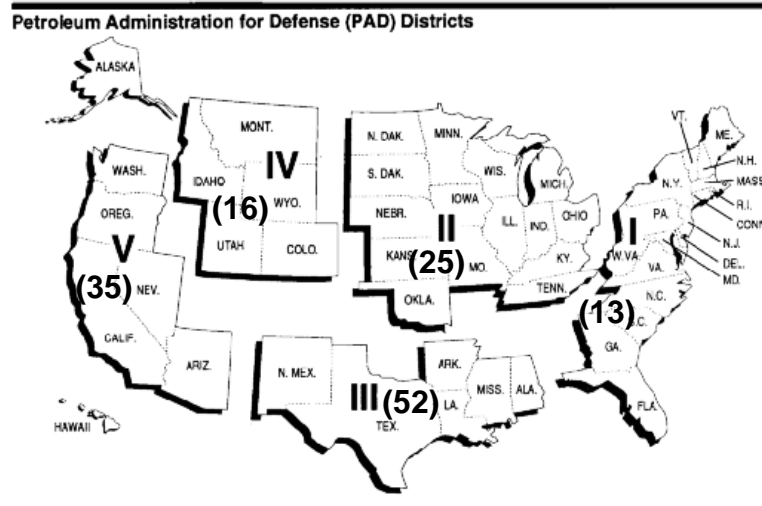
This study collected diesel fuel samples from multiple trucking fleet locations throughout the United States. Fuel samples were collected at the same on-site or primary fueling locations prior to and after implementation of the ULSD standard (*e.g.*, spring 2006 and spring 2007). After being collected by fleet personnel, each sample was given to a representative of a nationally-recognized fuel research lab for shipping and testing. The following ASTM tests were conducted: D240 heat of combustion, D4052 density, D5453 sulfur, D86 distillation, D1319 aromatics, D4737 cetane index, and D613 cetane number. An evaluation of the interaction between ULSD and engine performance was not part of this study.

¹ U.S. Environmental Protection Agency, *Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, Final Rule*, 40 CFR Parts 69, 80, and 86 (January 18, 2001).

² U.S. EPA, *2004 Heavy-Duty Highway Rule, Regulatory Impact Analysis*, EPA420-R-00-026, p. IV-41 (December 2000).

Fuel Sample Collection

To achieve a wide sampling of diesel fuel, samples from each of the five Petroleum Administration for Defense Districts (PADD) were collected (see Figure 1 for PADD locations and the number of refineries within each PADD). During this sampling period, more than 140 petroleum refineries producing a variety of petroleum products were operating throughout the United States. Due to differences in crude oil properties as well as differences in the types of process units and product balances, refined fuel properties tend to vary from refinery to refinery.



**Figure 1:
Petroleum Administration for Defense Districts
(Number of Refineries within PADD)**

A total of 15 diesel fuel samples were collected from the same locations across the five PADDs during April - June 2006 and again during May - June 2007. This collection period was chosen to avoid the possibility of collecting No. 1 diesel which is sold during the winter months throughout the northern United States.

The distribution of collected samples sought to mirror the sales distribution of diesel fuel by PADD. However, samples were also collected in each state which had implemented a boutique diesel fuel standard. State boutique fuel standards are generally implemented to achieve reductions in tailpipe emissions or encourage domestic fuel production. To account for boutique diesel fuels, the collection plan was adjusted to accommodate state-specific samples. State-specific samples included:

California: Two samples were collected in California. One sample was collected in northern California which is primarily served by refineries located in the San Francisco Bay area. The other sample was collected in southern California which is primarily served by refineries located in the Los Angeles area.

While the sulfur standard for on-road diesel fuel in California is the same as the federal standard, the state also requires the aromatic hydrocarbon content of the diesel fuel sold in the state not to exceed 10 percent by volume. Alternative diesel fuel formulations can be used to demonstrate equivalent compliance without actually meeting the aromatic limit.

Minnesota: One sample was collected in Minnesota which required all diesel fuel sold in the state to be blended with 2 percent biodiesel.

Texas: Two samples were collected in Texas, one from the eastern portion of the state, which is subject to a Texas Low Emission Diesel (TxLED) requirement, and one from the western portion of the state which is not subject to this requirement. The sulfur standard for on-road diesel fuel throughout Texas is the same as the federal standard. However, TxLED requires that the aromatic hydrocarbon content of on-road diesel fuel not exceed 10 percent by volume and the cetane number be at least 48. Alternative diesel fuel formulations can be used to demonstrate equivalent compliance without actually meeting the aromatic or cetane limits.

After adjusting for state-specific samples, the final distribution of collected samples roughly mirrors the sales distribution of diesel fuel by PADD. A comparison between the PADD location of the collected fuel samples and the 2006 U.S. On-Highway – No. 2 Diesel Sales is shown in Table 1.

**Table 1
PADD Location of Diesel Fuel Samples Compared
to 2006 U.S. On-Highway – No. 2 Diesel Sales**

Location	# of Samples	% of Samples	Sales Volume (x 1,000)	% of U.S. Total
PADD I	4	27%	11,758	30%
PADD II	3	20%	12,360	32%
PADD III	3	20%	7,346	19%
PADD IV	1	7%	1,942	5%
PADD V	4	27%	5,713	15%
U.S. Total	15		39,118	

Source: Energy Information Administration

April - June 2006 Sampling Period

Fourteen of 15 samples were collected from April through May 2006, prior to implementation of the ULSD fuel standard. All fourteen of these samples had sulfur levels considerably greater than 15 ppm and, therefore, were typical of the diesel fuel sold prior to the implementation of ULSD. The other sample was collected in late June

after the first phase of the ULSD standard had begun. This sample's sulfur level was below 15 ppm and qualified as ULSD.

May - June 2007 Sampling Period

Fifteen samples were collected from May through June 2007 – at least 11 months after ULSD implementation had begun. Eleven of the 15 samples collected qualified as ULSD. All four non-ULSD samples were collected in PADD 1.

Analysis

Fuel Property Changes Associated with Ultra-Low Sulfur Diesel

Ultimately, ten of the 15 locations provided samples which were *non-ULSD* in 2006 and *ULSD-compliant* in 2007. A comparison of the mean properties of these samples is shown in Table 2.

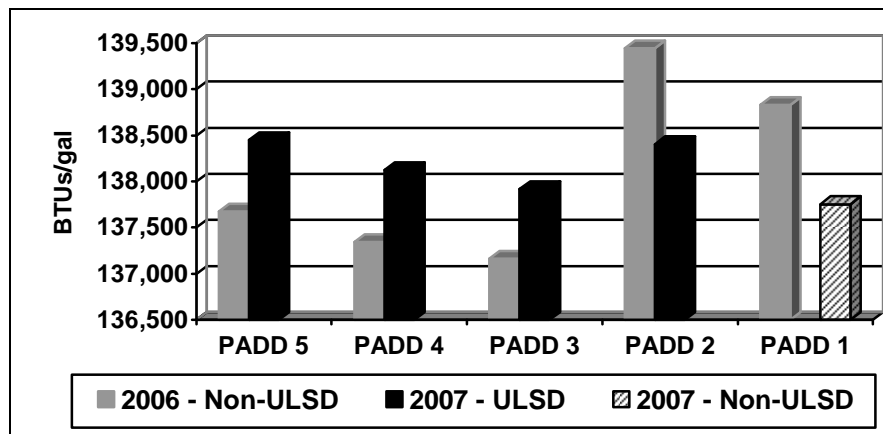
Table 2
Mean Properties of Same Location, non-ULSD vs. ULSD

N = 10	2006 Mean Non-ULSD	2007 Mean ULSD	Percentage Change from Non-ULSD	P-Value
Cetane number	48.6	49.8	+2.6%	0.28
Aromatics, vol. %	32.2	22.9	-29.0%	0.0001
Energy Content, BTUs/gal	137,843	138,368	+0.4%	0.15
Specific gravity	0.845	0.845	0.0%	0.92
Sulfur, ppm	241	6	-97.4%	0.0002
T10, °F	396	401	1.4%	0.23
T50, °F	495	498	0.6%	0.69
T90, °F	603	604	0.2%	0.78
End Point, °F	654	653	-0.1%	0.83

As expected, dramatic reductions in the sulfur content of on-road diesel fuel were found – with the sulfur content of all ULSD samples being below 10 ppm. In addition to sulfur, aromatics had the largest percentage change of all other mean fuel properties when comparing ULSD to the prior year fuel. As discussed later, this reduction in aromatics may reduce tailpipe emissions from existing diesel engines.

Contrary to EPA's anticipation of an energy loss, the mean energy content of the ten ULSD samples was slightly higher than the mean for the same location non-ULSD samples. Individually, the energy content of the ULSD samples ranged from -0.4 percent to +1.8 percent compared to the same location, prior year samples.

The distribution of mean per-gallon energy content across PADDs is shown in Figure 2. It is interesting to note that the 2007 samples collected in PADD I had the lowest mean per-gallon energy content even though all of the samples were non-ULSD. Surprisingly, the 2007 sample with the highest sulfur level (a non-ULSD sample) had the lowest per-gallon energy content and the sample with the highest per-gallon energy content was a ULSD sample. A per-gallon energy content variation of 2.2 percent was found among all ULSD samples collected in 2007.³ This “across country” variation in the energy content of ULSD was greater than the variation found when comparing same location ULSD to the prior year samples.



**Figure 2:
Mean BTUs Per-Gallon by PADD – 2006 & 2007**

Fuel Property Differences Among Federal Diesel and State Boutique Diesels

A comparison of fuel properties between those samples collected in areas with a state boutique fuel requirement and samples collected outside of these areas (“federal diesel”) was also made.⁴ For those samples collected in states with state boutique diesel fuel requirements, none of the fuels met the numerical minimum or maximum standards for aromatics or cetane. This is likely attributed to the use of alternative diesel fuel formulations which can be used to demonstrate equivalent compliance without actually meeting the state standards.

In 2001, the U.S. EPA published a report which identified baseline federal diesel fuel properties as well as average California fuel properties for the years 1995 to 2000.⁵ A comparison of EPA’s baseline non-ULSD fuel properties to the 2006 mean federal non-

³ This is similar to the 2.3 percent variance found among non-ULSD samples in 2006.

⁴ In this section, state boutique fuels include only those samples collected in California and Texas. The samples collected in Minnesota have not been included because a non-ULSD comparison sample was not collected in 2006.

⁵ U.S. Environmental Protection Agency, Air and Radiation, *Strategies and Issues in Correlating Diesel Fuel Properties with Emissions – Staff Discussion Document*, EPA420-P-01-001. (July 2001)

ULSD samples collected by ATRI is provided in Table 3. With the exception of sulfur, ATRI's mean 2006 federal non-ULSD is within 5 percent of each baseline non-ULSD fuel property identified by EPA.

Table 3
Comparison of ATRI's Mean Federal Non-ULSD to EPA Baseline Non-ULSD

	2006 ATRI Mean Federal Non-ULSD (N = 7)	U.S. EPA Baseline Non-ULSD 1995 - 2000
Cetane number	46.4	--
Natural cetane number	--	44.1
Cetane number increase due to additives	--	0.8
Aromatics, vol %	35.3	34.4
Specific gravity	0.848	0.850
Sulfur, ppm	295	333
Oxygen, wt%	--	0
T10, °F	400	422
T50, °F	497	505

A comparison of the fuel properties of the mean boutique non-ULSD samples collected by ATRI to those properties found by EPA to be average California non-ULSD is shown in Table 4. A variance of as much as 16 percent is found in this comparison. Besides the limited number of samples which comprise ATRI's mean 2006 *boutique* non-ULSD, another difference is that the EPA's average California non-ULSD was based on samples collected in one California city (Los Angeles), while the ATRI samples were collected in southern California, northern California and eastern Texas. Despite these differences, the fuel property differences between ATRI's mean federal and boutique non-ULSD fuels are directionally consistent with the differences found in EPA's baseline and average California non-ULSD fuels.

Table 4
**Comparison of ATRI's Mean Boutique Non-ULSD to
Average California Non-ULSD**

	2006 ATRI Mean Boutique Non-ULSD (N = 3)	U.S. EPA Average California Non-ULSD 1995 - 2000
Cetane number	53.7	--
Natural cetane number	--	47.9
Cetane number increase due to additives	--	4.4
Aromatics, vol %	25.4	21.9
Specific gravity	0.836	0.837
Sulfur, ppm	115	130
Oxygen, wt%	--	0
T10, °F	386	418
T50, °F	490	502

As shown above, there is fairly good agreement between the fuel properties of ATRI's mean federal non-ULSD and EPA's baseline non-ULSD while a greater variation exists between the fuel properties of ATRI's mean boutique non-ULSD and EPA's average California non-ULSD.

Comparing ATRI's mean federal and state boutique diesel fuels for the two sampling periods reveals that in addition to the overall decrease in sulfur levels, the aromatic content of federal ULSD has been reduced to the levels previously found in boutique diesel fuels (see Figure 3). Further decreases in aromatics were also observed among the mean boutique ULSD fuel.

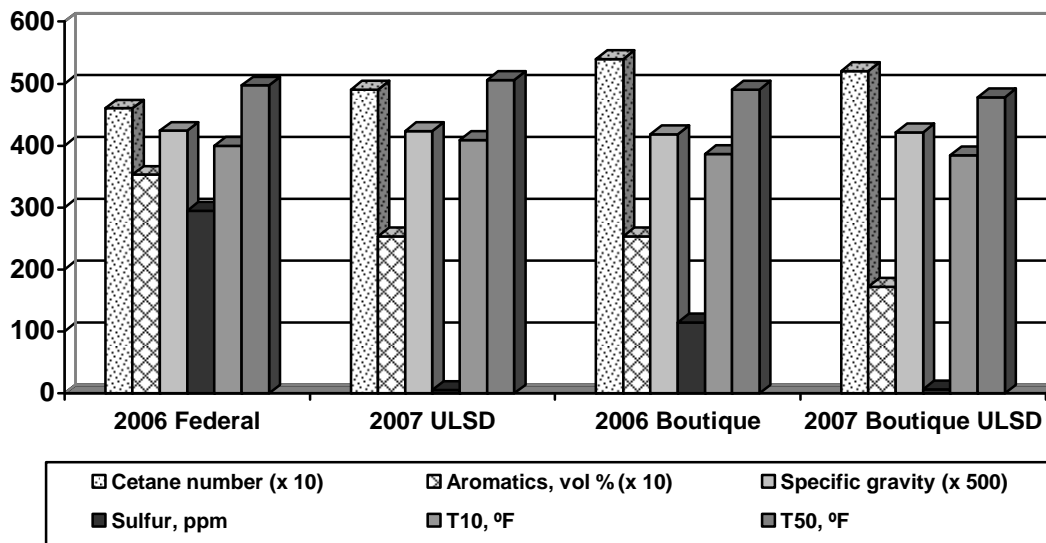


Figure 3:
Comparison of ATRI Mean Federal and State Boutique Fuel Samples

The potential impacts of diesel fuel property changes on tailpipe emissions have previously been reviewed by EPA.⁶ Although not without controversy, EPA, as a result of this review, granted the State of Texas approximately a 5 percent reduction in NOx emissions for implementing its TxLED program.⁷ While quantification of the potential emissions impacts associated with fuel property changes are beyond the objectives of this study, it is important to recognize that potential reductions in oxides of nitrogen (NOx), particulate matter (PM) and hydrocarbon (HC) emissions from in-use diesel vehicles may have occurred from ULSD-related fuel property changes. To illustrate the potential emission impacts associated with these fuel properties changes, Table 5

⁶ Ibid

⁷ Memorandum regarding Texas Low Emission Fuel (LED) Benefits from Robert Larson, Acting Director, Transportation and Regional Air Quality Programs, U.S. EPA to Karl Edmund, Director, Multimedia Planning, U.S. EPA Region VI (September 27, 2001).

reproduces EPA’s previous prediction of the percent emission reductions associated with discrete changes to diesel fuel properties.⁸

Table 5
Predicted Percent Emission Changes for Discreet Changes in Fuel Properties
(Relative to EPA Baseline Fuel)

	Pollutant		
	NOx	PM	HC
Increase natural cetane by 5 numbers		- 1.8	- 17.4
Increase additized cetane by 5 numbers	- 1.4	- 1.9	- 15.3
Decrease aromatics by 10 vol%	- 2.9	- 2.1	
Decrease specific gravity by 0.05	- 6.7	- 11.2	
Decrease sulfur by 100 ppm		- 0.8	
Increase oxygen by 1 wt%		- 6.9	
Decrease T10 by 10° F			+ 1.0
Decrease T50 by 10° F	+ 0.4		+ 2.5

Source: U.S. EPA

The applicability of EPA’s estimates of emission changes to the current in-use diesel fleet is questionable, however. For example, less than 6 percent of the engines which EPA used to develop their estimates employed the exhaust gas recirculation technology which was introduced in late 2002 and is commonly used in today’s on-road diesel engines. In addition, engines incorporating diesel particulate filters, which were introduced in 2007, were not part of EPA’s analysis. As a result, there is no method for determining the emissions responsiveness of today’s in-use diesel fleet to changes in fuel properties.

With further reductions in the on-road diesel engine emission standards occurring in 2010, it is likely that future diesel engines will be even less sensitive to changes in diesel fuel properties (other than sulfur). For example, engines manufactured in 2010 will meet on-road engine emissions standards for PM, NOx and HC that are 90 percent below the 2006 standards. These stringent emission standards will be met primarily through the introduction of diesel engines which incorporate sulfur-sensitive advanced emissions control systems, rather than through changes to diesel fuel.

Conclusion

Based on 10 diesel fuel samples collected from the same locations prior to and after implementation of the federal ULSD standard, dramatic reductions in the sulfur content of on-road diesel fuel were found (mean = -97.4%, p = 0.0002) with the sulfur content of all ULSD samples being below 10 ppm. In addition to sulfur, aromatics had the largest

⁸ U.S. EPA, (July 2001) p. 43.

percentage change of all other mean fuel properties (mean = -29%, $p = 0.0001$) when comparing ULSD to the prior on-road diesel fuel.

Contrary to EPA's anticipation of an energy loss, the mean energy content of the ULSD samples was slightly higher than the same location non-ULSD samples (mean = +0.4%, $p = 0.15$). Individually, the energy content of the ULSD samples ranged from -0.4 percent to +1.8 percent compared to the same location, prior year samples. A per-gallon energy content variation of 2.2 percent was found among all ULSD samples collected in 2007. This "across country" variation in the energy content of ULSD was greater than the variation found when comparing same location ULSD to the prior year samples.

There was fairly good agreement between ATRI's 2006 mean federal non-ULSD and EPA's estimate of baseline non-ULSD fuel properties. A greater variance was found among the fuel properties of ATRI's 2006 mean boutique non-ULSD and EPA's estimate of average California non-ULSD; however, ATRI's limited samples encompassed a wider geographic area.

Comparing ATRI's average federal and state boutique diesel fuels over the two sampling periods revealed that in addition to the overall decrease in sulfur levels, the aromatic content of federal ULSD has been reduced to the levels previously found in boutique diesel fuels. Additional decreases in aromatics were also observed among the mean boutique ULSD fuel. While quantification of the potential emissions impacts associated with fuel property changes are beyond the objectives of this study, it is important to recognize that potential reductions in oxides of nitrogen (NO_x), particulate matter (PM) and hydrocarbon (HC) emissions from in-use diesel vehicles may have occurred from ULSD-related fuel property changes.

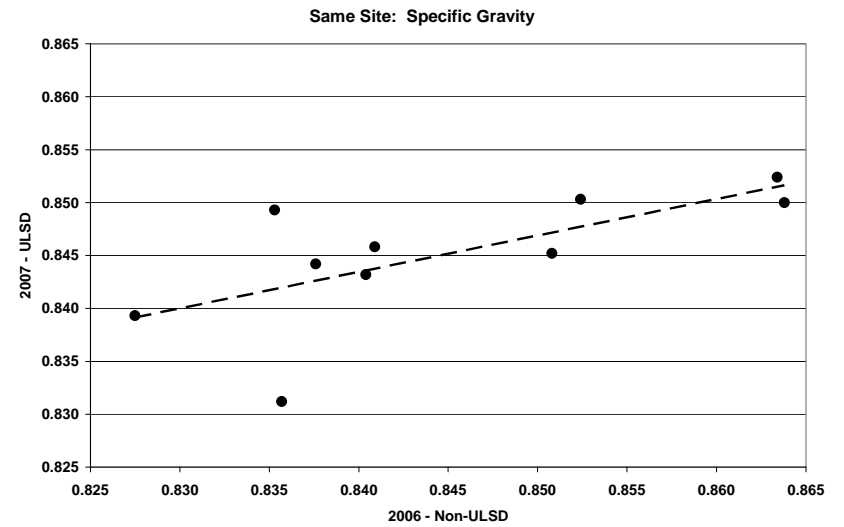
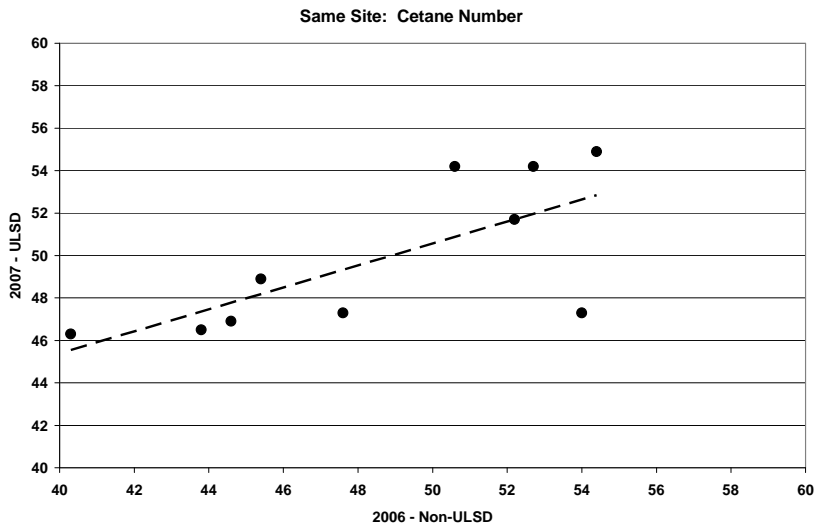
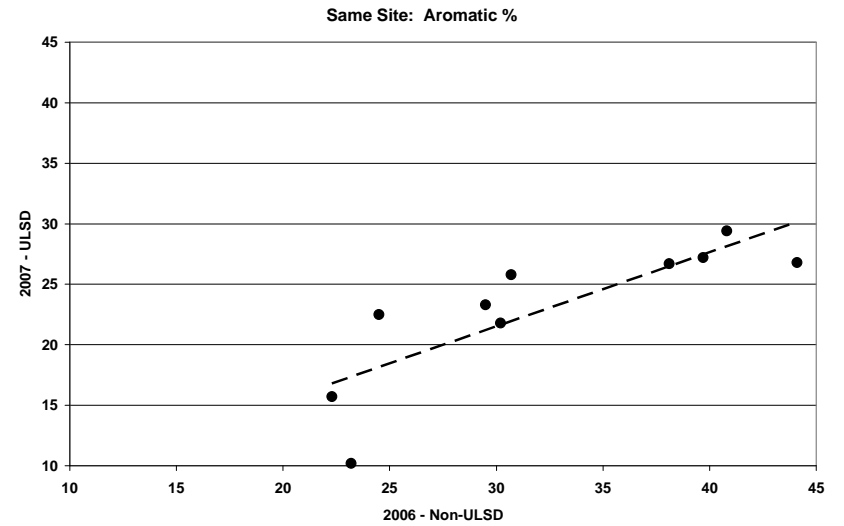
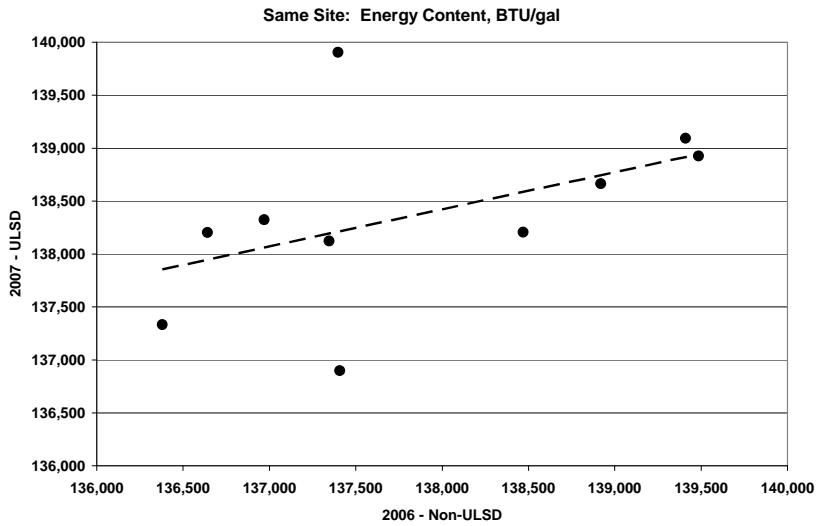
For those samples collected in states with state boutique diesel fuel requirements, none of the fuels met the numerical minimum or maximum standards for aromatics or cetane. This is likely attributed to the use of alternative diesel fuel formulations which can be used to demonstrate equivalent compliance without actually meeting the state standards.

Despite this study's limited sample size, the findings identify several important issues for further research. While little change in per-gallon energy content of ULSD was observed, further research is needed to better assess impacts resulting from the interaction of ULSD with in-use engines performance. Research is also needed to determine whether any ULSD-related fuel properties changes have a discernable emissions impact on engines with advanced emissions control systems. Finally, the research creates some basis for further analyzing the emissions-related benefits that derive from boutique fuels, given the net benefits now associated with ULSD.

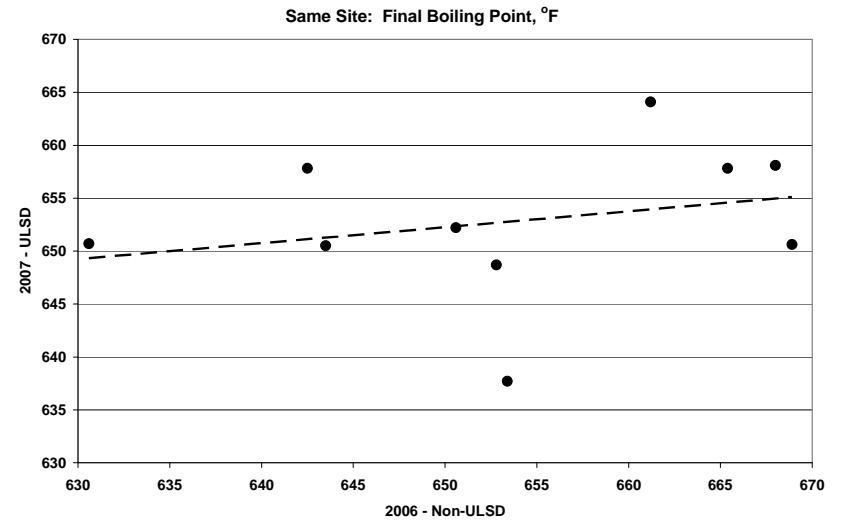
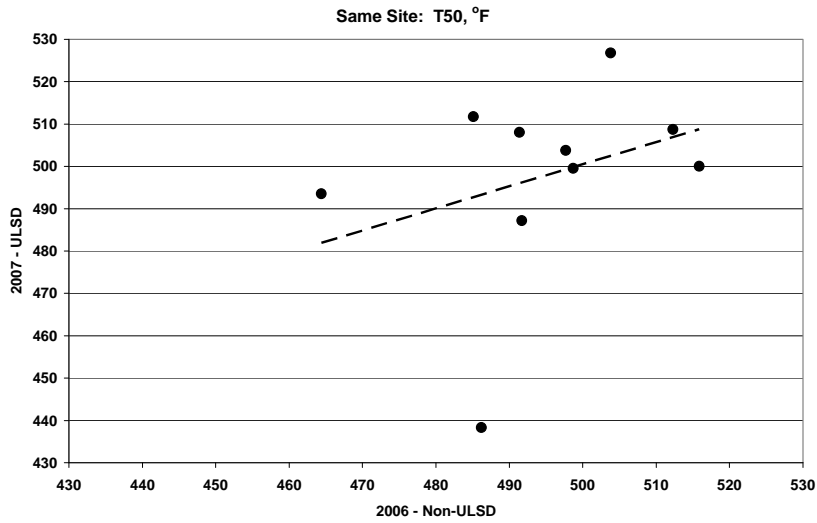
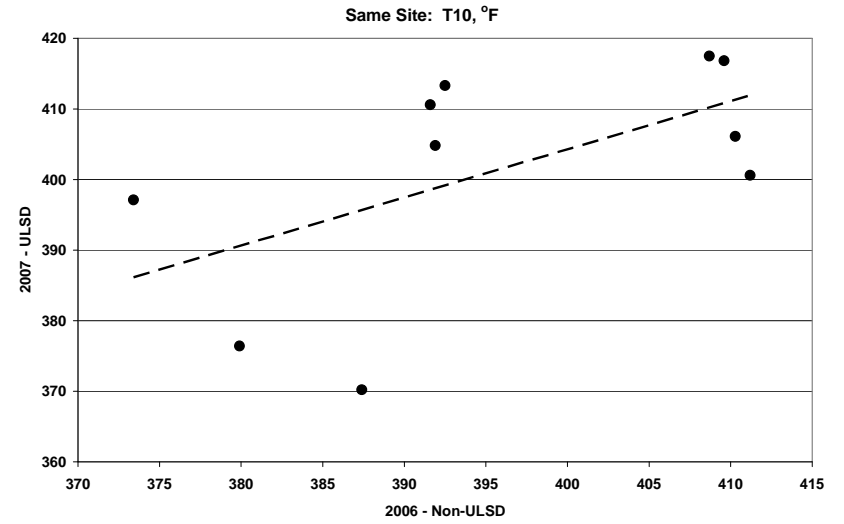
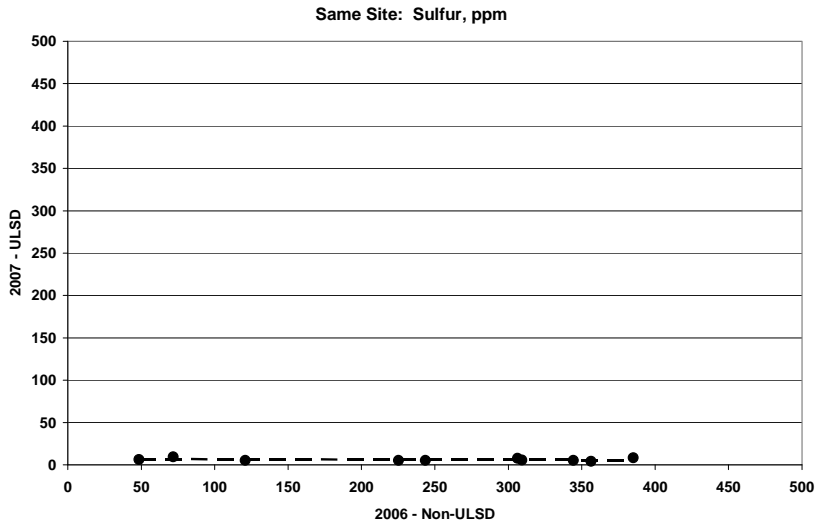
APPENDIX A:

COMPARISON OF SAME LOCATION NON-ULSD AND ULSD FUEL
PROPERTIES

Comparison of Same Location Non-ULSD and ULSD Fuel Properties



Comparison of Same Location Non-ULSD and ULSD Fuel Properties (cont.)



APPENDIX B:

RESULTS FOR INDIVIDUAL FUEL SAMPLES – 2006 & 2007

Results for Individual Fuel Samples - 2006

Sample ID No.	PADD	State	Fuel Type	Fuel Standard	Aromatic, D 1319, %	Olefins, D 1319, %	Saturate, D 1319, %	Gross Heat of Combustion, D 240, BTU/gal at 15 degree C	API @ 60F, D 4052	Specific Gravity @ 60F, D 4052	Density @ 15C, D 4052	Cetane Index, D 4737A	Cetane Number, D 613	Sulfur, D 5453, PPM
670648	I	SC	LSD	Fed	39.6	2.5	57.9	138865.1	34.3	0.8537	853.2	46.5	45.6	373.9
672435	I	VA	LSD	Fed	34.5	2.1	63.4	138792.9	34.3	0.8533	852.7	45.6	47.0	414.7
672437	I	NJ	LSD	Fed	38.1	2.2	59.7	138561.2	34.4	0.8531	852.5	44.9	47.7	302.8
667696	I	GA	LSD	Fed	41.2	3.2	55.6	139099.8	34.0	0.8548	854.2	46.8	47.1	365.6
670647	II	MN	ULSD	MN – B2	40.4	1.2	58.4	139218.3	33.3	0.8584	857.9	46.0	45.5	8.9
672196	II	WI	LSD	Fed	40.8	0.7	58.5	139410.4	32.4	0.8634	862.9	41.4	40.3	306.3
672436	II	MO	LSD	Fed	44.1	1.3	54.6	139484.4	32.3	0.8638	863.3	40.9	43.8	309.4
667700	III	AK	LSD	Fed	38.1	1.1	60.8	138469.7	34.8	0.8508	850.3	47.1	45.4	344.3
672197	III	TX	LSD	TxLED	30.7	2.0	67.3	136641.9	37.4	0.8376	837.0	48.9	54.0	225.3
672198	III	TX	LSD	Fed	24.5	3.2	72.3	136380.0	39.5	0.8275	827.0	52.0	52.2	243.5
670649	IV	UT	LSD	Fed	29.5	1.6	68.9	137345.2	36.9	0.8404	839.9	49.0	50.6	385.2
667695	V	CA	LSD	CARB	23.2	0.9	75.9	137407.5	37.8	0.8357	835.2	49.3	54.4	71.8
667697	V	CA	LSD	CARB	22.3	1.1	76.6	137397.4	37.9	0.8353	834.8	49.7	52.7	48.4
667698	V	AZ	LSD	Fed	30.2	2.1	67.7	136969.0	36.8	0.8409	840.4	44.0	44.6	356.4
667699	V	OR	LSD	Fed	39.7	3.2	57.1	138919.4	34.5	0.8524	851.9	46.2	47.6	120.9

Results for Individual Fuel Samples - 2006 (cont.)

Sample ID No.	PADD	State	Fuel Type	Fuel Standard	Distillation, D 86, Degree F							
					Initial Boiling Point	10% Evaporated	50% Evaporated	90% Evaporated	Final Boiling Point	% Recovered	% Residue	% Loss
670648	I	SC	LSD	Fed	353.4	423.2	519.4	615.6	656.9	97.8	1.5	0.7
672435	I	VA	LSD	Fed	343.5	409.6	508.9	613.6	658.2	97.6	1.2	1.2
672437	I	NJ	LSD	Fed	319.9	399.9	505.9	611.5	661.6	98.0	1.0	1.0
667696	I	GA	LSD	Fed	365.1	426.6	520.9	618.0	662.4	97.2	1.4	1.4
670647	II	MN	ULSD	MN – B2	358.8	425.9	524.8	627.2	676.1	97.5	1.2	1.3
672196	II	WI	LSD	Fed	338.8	409.6	498.7	600.1	650.6	96.9	1.3	1.8
672436	II	MO	LSD	Fed	338.7	408.7	497.7	599.1	653.4	97.3	1.2	1.5
667700	III	AK	LSD	Fed	350.5	411.2	515.9	618.6	665.4	97.7	1.3	1.0
672197	III	TX	LSD	TxLED	342.8	391.9	491.4	595.3	643.5	97.6	1.3	1.1
672198	III	TX	LSD	Fed	329.0	391.6	485.1	581.7	630.6	98.1	1.0	0.9
670649	IV	UT	LSD	Fed	316.3	392.5	503.8	607.5	652.8	97.7	1.4	0.9
667695	V	CA	LSD	CARB	342.9	387.4	486.2	613.0	668.9	97.2	1.2	1.6
667697	V	CA	LSD	CARB	316.6	379.9	491.7	614.2	668.0	97.5	1.1	1.4
667698	V	AZ	LSD	Fed	321.0	373.4	464.4	587.7	642.5	97.9	1.4	0.7
667699	V	OR	LSD	Fed	348.0	410.3	512.3	608.6	661.2	97.1	1.4	1.5

Results for Individual Fuel Samples - 2007

Sample ID No.	PADD	State	Fuel Type	Fuel Standard	Aromatic, D 1319, %	Olefins, D 1319, %	Saturate, D 1319, %	Gross Heat of Combustion, D 240, BTU/gal at 15 degree C	API @ 60F, D 4052	Specific Gravity @ 60F, D 4052	Density @ 15C, D 4052	Cetane Index, D 4737A	Cetane Number, D 613	Sulfur, D 5453, PPM
744690	I	SC	LSD	Fed	27.1	5.1	67.8	138909.3	33.9	0.8553	854.8	45.0	47.1	272.4
747934	I	VA	LSD	Fed	27.7	1.7	70.6	135477.7	39.0	0.8300	829.5	53.8	48.0	304.2
746006	I	NJ	LSD	Fed	31.1	1.3	67.6	138176.3	34.9	0.8502	849.7	45.4	45.9	299.5
744686	I	GA	LSD	Fed	26.5	1.2	72.3	138458.0	35.5	0.8473	846.8	46.8	47.7	262.9
744692	II	MN	ULSD	MN-B2	15.2	5.2	79.6	137190.6	34.5	0.8526	852.1	47.4	48.7	7.2
747932	II	WI	ULSD	Fed	29.4	2.2	68.4	139092.9	34.5	0.8524	851.8	45.1	46.3	7.5
746007	II	MO	ULSD	Fed	26.8	2.3	70.9	138927.1	35.0	0.8500	849.5	46.1	46.5	5.6
744689	III	AK	ULSD	Fed	26.7	2.3	71.0	138207.7	35.9	0.8452	844.7	47.3	48.9	5.2
746009	III	TX	ULSD	TxLED	25.8	3.3	70.9	138203.9	36.1	0.8442	843.7	48.6	47.3	5.3
746008	III	TX	ULSD	Fed	22.5	2.5	75.0	137334.1	37.1	0.8393	838.8	51.0	51.7	5.1
757198	IV	UT	ULSD	Fed	23.3	1.8	74.9	138121.7	36.3	0.8432	842.7	51.4	54.2	8.2
744685	V	CA	ULSD	CARB	10.2	1.7	88.1	136899.4	38.7	0.8312	830.7	45.1	54.9	9.4
744687	V	CA	ULSD	CARB	15.7	1.5	82.8	139904.2	35.1	0.8493	848.8	44.6	54.2	6.3
744688	V	AZ	ULSD	Fed	21.8	2.0	76.2	138324.9	35.8	0.8458	845.3	46.4	46.9	4.2
744739	V	OR	ULSD	Fed	27.2	1.7	71.1	138664.9	34.9	0.8503	849.8	46.4	47.3	5.3

Results for Individual Fuel Samples - 2007 (cont.)

Sample ID No.	PADD	State	Fuel Type	Fuel Standard	Distillation, D 86, Degree F							
					Initial Boiling Point	10% Evaporated	50% Evaporated	90% Evaporated	Final Boiling Point	% Recovered	% Residue	% Loss
744690	I	SC	LSD	Fed	355.8	419.7	512.7	603.9	645.1	98.2	1.0	0.8
747934	I	VA	LSD	Fed	348.7	402.3	502.4	604.5	646.6	97.5	1.1	1.4
746006	I	NJ	LSD	Fed	325.7	393.5	501.0	612.7	656.9	97.2	1.5	1.3
744686	I	GA	LSD	Fed	343.2	402.1	502.3	607.7	654.8	97.5	1.0	1.5
670647	II	MN	ULSD	MN – B2	369.2	421.0	519.5	622.9	664.9	97.3	1.5	1.2
747932	II	WI	ULSD	Fed	359.0	416.8	499.5	606.0	652.2	97.8	1.5	0.7
746007	II	MO	ULSD	Fed	341.1	417.5	503.8	593.9	637.7	97.8	1.3	0.9
744689	III	AK	ULSD	Fed	338.0	400.6	500.0	609.4	657.8	97.5	1.4	1.1
672197	III	TX	ULSD	TxLED	344.7	404.8	508.0	605.7	650.5	97.4	1.3	1.3
746008	III	TX	ULSD	Fed	335.1	410.6	511.7	605.9	650.7	97.6	1.5	0.9
757198	IV	UT	ULSD	Fed	353.4	413.3	526.8	612.0	648.7	97.0	1.3	1.7
744685	V	CA	ULSD	CARB	322.9	370.2	438.3	583.6	650.6	96.6	1.2	2.2
744687	V	CA	ULSD	CARB	318.4	376.4	487.2	605.9	658.1	96.5	1.0	2.5
744688	V	AZ	ULSD	Fed	338.7	397.1	493.5	603.3	657.8	97.2	1.5	1.3
744739	V	OR	ULSD	Fed	343.3	406.1	508.7	613.6	664.1	97.4	1.5	1.1