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2008 CRC COLD-START AND WARMUP E85 AND E15/E20 DRIVEABILITY PROGRAM

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2008 CRC Cold-Start and Warm-Up E85 and E15/E20 Driveability Program

(CRC Project No. CM-138-08)

Prepared by the

CRC Volatility Group

October 2008

CRC Performance Committee
of the
Coordinating Research Council, Inc.

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ABSTRACT

The 2008 CRC Cold-Start and Warm-Up E85 and E15/E20 Driveability Program was conducted in Yakima, Washington, from January 14 through February 22, 2008. The objective of the program was two-fold: (1) to determine the effect of vapor pressure of E85 fuel ethanol, volatility Classes 1 and 2, on cold-start and warm-up driveability performance under cool ambient conditions in a large group of late-model E85 flexible-fuel (flex-fuel) vehicles equipped with fuel injection systems, and (2) to determine the effect of E15 and E20 on cold-start and warm-up driveability performance under cool ambient conditions in a six-vehicle group of late-model and older conventional vehicles. There were twenty late-model (2006 – 2008) E85 vehicles, and six 1981 – 2007 conventional vehicles which were chosen from a larger fleet of twelve 1981 – 2008 vehicles. The test fuel design consisted of eight test fuels: two hydrocarbon-only fuels; three E85 blends, one below the minimum vapor pressure for Class 1, one meeting the Class 1 minimum vapor pressure, and one meeting the minimum vapor pressures for Class 2 E85 fuel ethanol in ASTM Specification D5798; two E15 blends at nominally 7 and 10 psi; and one E20 blend at nominally 7 psi. Testing was conducted at 20°F - 29°F to cover the low end ambient temperature of D5798 volatility Class 2, and 30°F - 40°F to cover the low end ambient temperature of D5798 volatility Class 1. All fuels for both portions of the program were tested at both temperatures. Temperature conditions at the test site made it possible to also conduct some limited E85 testing at 45°F - 50°F. It should be noted that no Class 3 testing was performed, and this should be taken into account when reviewing any data. It should also be noted that this study is not comprehensive in representing the entire fleet and may not reflect all situations that may be encountered in the legacy fleet.

Results showed that driveability of the flex-fuel vehicles improved with increasing vapor pressure of E85 fuels, whereas the vapor pressure of gasoline had no effect on driveability for the conditions tested in this program. The highest average total weighted demerits averaged across all temperatures resulted from the lowest vapor pressure (4.7 psi) E85 fuel. At comparable vapor pressures (the range of 5.7 to 8.1 psi), E85 blends resulted in higher total weighted demerits than gasoline. There is no statistically significant effect of temperature on driveability with either E85 blends or gasolines for the temperature range tested in the program.

For the conventional vehicles tested with both gasoline (E0) and E15/E20 fuels, there were no significant effects of vapor pressure or fuel type on driveability. Driveability improved with increasing ambient temperature for E15/E20 fuels. There was no statistically significant effect of ambient temperature on driveability with gasolines for the range of conditions tested. On average, the conventional vehicles generated higher total weighted demerits than the E85 flex-fuel vehicles as determined in this program.

I. INTRODUCTION

The Coordinating Research Council (CRC) conducted a two-part program in January and February 2008 to investigate cold-start and warm-up driveability of flexible fuel vehicles on nominal 85 volume percent denatured ethanol blends (E85), and conventional vehicles on 15 and 20 volume percent ethanol blends (E15 and E20). Gasoline (E0) was included in the program as a reference.

The ASTM D5798 Specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines[(1)] specifies minimum vapor pressure limits for three volatility classes. The volatility classes are assigned based on the six-hour minimum ambient temperature expected for the month. For the warmer ambient temperature class, the amount of hydrocarbon is allowed to range from 17 to 21 volume percent (includes denaturant). For the intermediate temperature class, the amount of hydrocarbon is allowed to range from 17 to 26 volume percent (includes denaturant). For the coldest ambient temperature class, the amount of hydrocarbon is allowed to range from 17 to 30 volume percent (includes denaturant). Now with the lower summertime federal and state vapor pressure limits for both conventional and reformulated gasoline, it is difficult to blend 15 or 20 volume percent commercially available gasoline into denatured ethanol and meet the minimum vapor pressure limits in D5798. Vehicle designs have changed since the specification was first issued in 1999, and the data base used to develop the volatility and compositional limits is over twelve years old.

Prior to the 2008 CRC program, Chevron worked with the assistance of the Honda R&D Americas Ohio laboratory, Transportation Research Center (TRC), Beth Evans, and Harold Archibald to conduct a pilot E85 cold-start and warm-up program using four 2006 – 2007 vehicles. The results from this pilot program were used to design the E85 fuel set for the CRC full-scale program.

The State of Minnesota has mandated the sale of gasoline containing a minimum of 20% ethanol beginning in August 2013 pending submission and approval of a waiver request from the U.S. EPA. Others have suggested that a more practical higher ethanol content blend would be E15 which would be more compatible with existing fuel system materials and with less change in stoichiometric fuel-air ratio than E20. The National Renewable Energy Laboratory (NREL) was asked to conduct driveability tests on E15 and E20 blends, and they requested CRC to allow them to conduct testing in conjunction with the E85 program.

It should be noted that the study described in this report is not comprehensive in representing the entire fleet and may not reflect all situations that may be encountered in the legacy fleet. Issues concerning the long-term effects of E15/E20 blends on engines, fuel systems, and emissions control systems in conventional vehicles are also not addressed in this program.

Members of the Data Analysis Panel and on-site participants in the program are listed in Appendices A and B, respectively. Appendix C outlines the program as approved by the CRC Performance Committee. Appendix D includes the driveability test procedure along with the draining and flushing procedures used with the conventional vehicles, as well as the draining and flushing procedures which were specifically developed for and used with the E85 flex-fuel vehicles.

II. CONCLUSIONS

The conclusions of the 2008 CRC Cold-Start and Warm-Up E85 and E15/E20 Driveability Program are as follow:

E85 Flex-Fuel Vehicle Fleet

Recent driveability programs have indicated levels of total weighted demerits have decreased from the older technology vehicles. In this program, the data noise level for trained raters is considered to be approximately 20 total weighted demerits or less. Average total weighted driveability demerits across all temperatures in this program for all fuels ranged from 17 to 39 total weighted demerits.

The vapor pressures for the three E85 blends were 4.7, 5.7, and 7.0 psi. The vapor pressures for the two E0 gasolines were 5.9 and 8.1 psi. A six-vehicle sub-fleet was also tested on an E85 fuel with a vapor pressure of 8.6 psi.

- Driveability improved (total weighted demerits decreased) with increasing vapor pressure of E85 fuels at the 98.8% confidence level. The effect of the gasoline vapor pressure on driveability was not significant.

- The highest average total weighted demerits averaged across all temperatures (36 total weighted demerits) resulted from the 4.7 psi E85 fuel.

- At comparable vapor pressures (the range of 5.7 to 8.1 psi), E85 blends resulted in higher total weighted demerits than gasoline at the 98.6% confidence level. At these conditions, average total weighted demerits for E85 blends and gasolines were 24 and 19, respectively.

- The six-vehicle sub-fleet which was tested at a nominal temperature of 33°F with an extended E85 vapor pressure range (8.6 psi) showed higher total weighted demerits relative to gasoline at the 91.7% confidence level.

The data were grouped into three average ambient temperature categories: 23°F, 33°F, and 47°F.

- There was no statistically significant effect of temperature on driveability with either E85 blends or gasolines within the range tested.

- Across the temperature range and at comparable vapor pressures, there was no statistically significant difference between the total weighted demerits for E85 blends and gasolines. When the 4.7-psi data were included in the analysis, E85 blends resulted in more total weighted demerits (27 versus 19) than gasoline at the 95% confidence level.

E15/E20 Conventional Vehicle Fleet

The vapor pressures for the E15 blends were 7.1 and 9.9 psi. The vapor pressure for the E20 blend was 7.1 psi. The vapor pressures for the two E0 gasolines were 5.9 and 8.1 psi. This fleet consisted of six conventional (non-flex-fuel) vehicles including two older vehicles.

- There was no significant effect of vapor pressure or fuel type on driveability.

The data were grouped into three average ambient temperature categories: 23°F, 33°F, and 47°F.

- E15/E20 driveability improved with increasing ambient temperature. This effect was observed at the 93.1% confidence level. There was no statistically significant effect of ambient temperature on driveability with gasolines.

The six-vehicle fleet consisted of various fuel-delivery system technologies. The two older vehicles included a feedback-control carburetor and a throttle-body-injection system. The remaining vehicles were equipped with port-fuel-injection.

- On average, the conventional vehicles generated higher total weighted demerits than the E85 flex-fuel vehicles. The two older vehicles had noticeably higher demerits on all fuels.

It should also be noted that this study is not comprehensive in representing the entire fleet and may not reflect all situations that may be encountered in the legacy fleet.

III. RECOMMENDATIONS

- The fuel flushing procedure for E85 vehicles should be reviewed and updated in light of the lessons learned from this program. (See Section VIII. L, Lessons Learned During This Program, for details.)
- It is imperative to have OEM-specific scan tools and OEM assistance to monitor input variables and understand whether the vehicle is operating correctly.
- The coolant temperature of the vehicles should be recorded with a scan tool to determine the effective ambient soak temperature.

IV. TEST VEHICLES

There were twenty late-model (2006 – 2008) E85 flex-fuel vehicles, and six 1981 – 2007 conventional vehicles chosen from a larger fleet of twelve 1981 – 2008 vehicles in the program. The E85 vehicles were used exclusively for testing with E85 and E0 fuels, while the conventional vehicles were used exclusively for testing with E15, E20, and E0 fuels.

The twelve conventional vehicles were screened for fuel sensitivity by testing them first on the E20 test fuel (Fuel 4), and then testing them on the typical summer conventional gasoline with a vapor pressure of 8.1 psi (Fuel 8). NREL made the final decision which vehicles would be tested on all fuels during the entire length of the program based upon fuel system, production volume, mechanical condition, and fuel sensitivity.

One of the E85 flex-fuel vehicles and six of the older conventional vehicles were loaned to CRC for testing by The Lubrizol Corporation. One of the older conventional vehicles was loaned to CRC for testing by Automotive Testing Laboratories (ATL). The remainder of the test fleet was obtained from a rental agency.

One of the E85 rental vehicles was found to have a hardware and/or software problem which prevented it from properly learning the percent of ethanol fuel on which it was operating. Every effort was made to correct this problem so that the vehicle could be kept in the program; however, it was not possible to do so, and the vehicle was dropped from testing.

General Motors, Ford, and Chrysler vehicles comprised the E85 fleet. There was one 2006, four 2007, and fifteen 2008 E85 flex-fuel vehicles. The twelve-vehicle conventional fleet was made up of General Motors, Chrysler, Honda, Toyota, Nissan, and Mazda vehicles ranging from 1995 through 2008 model years, with one carbureted vehicle from 1981. The conventional fleet was all port-fuel-injected, with the exception of the 1981 carbureted and the 1995 throttle-body-injected vehicle. All 32 vehicles in the combined fleet were equipped with air conditioning and automatic transmissions. Engine displacements in the E85 fleet ranged from 3.3 to 5.4 liters, and from 1.6 to 5.0 liters for the conventional vehicles. The vehicle fleet is described in Table 1.

V. TEST FUELS

The test fuel matrix consisted of eight test fuels: two hydrocarbon-only fuels; three E85 blends, one below the minimum vapor pressure for Class 1, one meeting the Class 1 minimum vapor pressure, and one meeting the minimum vapor pressure for Class 2 E85 fuel ethanol in ASTM Specification D5798; two E15 blends; and one E20 blend.

The vapor pressures of the E85 blends (Fuels 1 – 3) were 4.7, 5.7, and 7.0 psi, and the volume percent ethanol content of the three nominal E85 blends were 82.4, 82.4, and 82.9. The vapor pressure of the E20 blend (Fuel 4) was 7.1 psi, while the vapor pressures of the E15 blends (Fuels 5 and 6) were 7.1 and 9.9 psi. One of the hydrocarbon-only fuels (Fuel 7) was a full-boiling range gasoline with 5.9-psi vapor pressure made from 100 volume percent CARBOB, was a low vapor pressure gasoline reference and was used to make Fuel 1. The other hydrocarbon-only fuel (Fuel 8) was a typical summer conventional gasoline with a vapor pressure of 8.1 psi and was included as a reference. It consisted of 51 volume percent 10-psi commercial gasoline and 49 volume percent CARBOB. The two gasolines were also reference fuels for the E15/E20 portion of the test program.

Fuel 9 was an E85 blend with a vapor pressure of 8.6 psi. This fuel came from the pilot program run by Chevron and was to be used in the event the highest vapor pressure E85 blend developed for the CRC program (7.0 psi) resulted in too many driveability demerits. This fuel was tested in only six vehicles.

Average dry vapor pressure equivalent (DVPE), distillation temperatures, ethanol content, and other property inspection results as determined by the supplier (Laboratory A) and Fuel Acceptance Panel (Laboratories B, C, D, and E) are shown in Table 2. Individual test results obtained by each inspecting laboratory are shown in Appendix E.

VI. TEST SITE

The test program was conducted at the Renegade Raceways near Yakima, Washington, in the valley of the Yakima River. The raceways are at an altitude of 990 feet. The test site was a 0.7-mile long, 60-foot wide, flat paved, two-lane drag strip, along with several adjacent single-lane, paved, auxiliary roads normally used for racecar preparation. A large, rectangular, paved area suitable for defueling/refueling and vehicle storage also was utilized. The race staging area at the base of the track was used for soaking the vehicles overnight.

The program was conducted from January 14, 2008, through February 22, 2008. Site set-up and vehicle preparation was done during the first week beginning January 7, 2008.

Testing was conducted at 20°F - 29°F to cover the low end ambient temperature of D5798 volatility Class 2, and 30°F - 40°F to cover the low end ambient temperature of D5798 volatility Class 1. All fuels for both portions of the program were tested at both temperatures. Temperature conditions at the test site made it possible to also conduct some limited E85 testing at 45°F - 50°F.

Because of unusually cold temperatures early in the program, a decision was made several days into the program to change the way the soak temperatures were being determined. Traditionally, overnight soak temperatures were determined from the minimum overnight ambient temperature recorded at the test site. During this program, it was decided to investigate with a scan tool what the vehicle coolant temperatures were after a traditional overnight soak. It was found that throughout the fleet, the coolant temperatures were typically several degrees above the minimum ambient temperature recorded for the night, and the coolant temperatures were mostly uniform. It was decided to sample four vehicles for coolant temperatures with a scan tool each morning and average those readings for the soak temperature. That is what is recorded as the soak temperature in the data set. The average coolant temperatures were compared against the ambient overnight minimum temperatures, but no definite pattern could be found. The rationale for using the coolant temperatures for the soak temperature was that coolant temperature has the largest temperature effect on the starting time of the vehicle. The rationale for using ambient temperature for the run temperature was that the temperature of ambient air taken in through the intake port has the primary temperature effect on the cold driveability of the vehicle.

VII. TEST PROGRAM

A. Test Procedure

The test fuels were evaluated as prescribed in the CRC Cold-Start and Warm-Up Driveability Procedure (E-28-94). Duplicate tests were performed on every vehicle and fuel combination at both planned temperature ranges. Temperature conditions at the test site made it possible to also conduct some limited E85 testing at warmer ambient temperatures.

The CRC Cold-Start and Warm-Up Driveability Procedure is presented in Appendix D. Briefly stated, the procedure consists of a series of light, moderate, and wide-open-throttle maneuvers mixed in with idles to obtain as many evaluations of driveability in a cold engine as possible. Malfunctions are recorded and evaluated as being trace, moderate, heavy, or extreme. The demerit rating details used in this program are shown in Appendix D of this report.

All E85 vehicles and the selected conventional vehicles were tested each day using two raters, with each rater assigned to exclusively test the same vehicles for the entire program. Both raters were constant throughout the program. The E85 fleet was balanced; there were duplicates of each of the E85 makes and models, and each rater tested one vehicle out of each pair. The only exception to this was the one vehicle found to have a hardware and/or software problem that was dropped from testing.

For the conventional fleet, the raters were each assigned six of the twelve vehicles at the start of the program. When the vehicles were screened down to the selected fleet, the raters continued testing the same vehicles, which meant that one of the raters had four of the conventional vehicles to test, and the other rater had two.

The two rating teams tested the 25 vehicles in approximately four hours. Generally, two vehicles were on the track simultaneously, separated by approximately 0.3 miles. No problems with vehicles impeding one another were encountered with this schedule.

B. Fueling and Warm-Up

After the rating teams finished testing a vehicle, they dropped it off at the fueling/defueling area. The gas cap was removed, and the remaining test fuel was drained from the vehicle fuel tank through the fuel rail system by activation of the fuel pump with the engine operating. The vehicle fuel systems were then flushed and fueled with the next day's test fuels. Three different flushing procedures were used: one procedure for the conventional vehicles, one procedure for the E85 vehicles flushing fuels with nearly constant ethanol content (e.g., E0 – E10 and E70 – E85), and one procedure for the E85 vehicle flushing from gasoline (E0 – E10) to high alcohol blends (E70 – E85) or vice versa. Separate dispensing pumps were used for the different fuels being pumped each day to prevent test fuel contamination. All vehicles were fueled with four gallons of test fuel.

An evaluation of the fuel flushing and refueling procedures was conducted to evaluate the efficiency of the procedures used in this program. The vehicles were sampled after completion of testing with a hydrocarbon-only fuel, which was immediately preceded with an ethanol blend. The analysis was performed by an outside contract laboratory, and the results are presented in Appendix E. The laboratory analyzed 23 vehicle samples and 8 drum or dispenser samples for ethanol. The drum and dispenser inspections are shown in Appendix E.

Upon completion of defueling, flushing, fueling, and sampling, all vehicles were preconditioned on the test track. In some instances, when vehicles were being flushed from one ethanol content to another, the first ten-mile drive was done on the auxiliary roads to prevent interference with testing, while allowing the fuel flushing to be accomplished at a continual flow of vehicles through the area. Staying on private property eliminated exposure of the vehicles to the public road system. The purpose of the first ten-mile drive when vehicles were being flushed from one ethanol content to another (i.e., E0 to E85 or vice versa) was to allow the vehicle computer to "learn" the new ethanol content of the fuel. The purpose of the final preconditioning was to allow for the test vehicle adaptive learning function to load data on the new fuel, and to clear the fuel system of the previous test fuel. Thirteen laps of the track (8.2 miles) were driven at a nominal 55 mph, followed by 0.65 mile at 45 mph, 0.65 mile at 35 mph, and operation on the return road for 0.25 mile at 25 mph, and 0.25 mile at 15 mph. The vehicles were then parked for overnight cold soak prior to the next day's testing.

C. Data Worksheets

The data from the vehicle driveability rating sheets were reviewed and summarized each day by the program manager and entered into an Excel spreadsheet for each test. Information included vehicle number, fuel code, rater, date time, overnight soak temperature, test run temperature, odometer reading, and the driveability ratings of the prescribed vehicle accelerations, decelerations, idles, and starts. Later, the data in the spreadsheet were confirmed on-site to ensure correct information would be used in the data analysis. A sample worksheet is shown in Appendix D. A summary of the complete data set is presented in Appendix F.

VIII. DISCUSSION OF RESULTS

A. Data Set Analysis

The final data set was analyzed using the SAS® System to calculate least square mean values for each vehicle and all vehicles, as well as for each fuel and all fuels. In this report, the term "significant" refers to a confidence level of greater than or equal to 95%. The term "marginally significant" refers to a confidence level of between 90% and 95%. The confidence level is defined as (1 minus the p-value) x 100.

The group of nineteen flex-fuel vehicles and the group of six selected conventional vehicles were analyzed separately. The initial analysis model included fuel, vehicle, fuel*vehicle interactions, run temperature, and vehicle*run temperature interactions. Rater was not a variable since the two raters did not test any common vehicles. As is common with driveability data, a natural log transformation was done on the total weighted demerits (TWD) values due to the wide range of vehicle/fuel TWDs (7 – 210.5, excluding the one "no-start" data point, for flex-fuel vehicles and 8 – 318.5 for conventional vehicles). Transforming the data leads to a data set that is approximately normally distributed and has approximately constant variance. The data were corrected using the run temperature variable, but not the interaction terms. The flex-fuel vehicle and conventional vehicle test fuel sets were tested twice in the program at the two target ambient temperature ranges (20 – 29°F and 30 – 40°F) except for one conventional vehicle which was only tested once at the higher target temperature. Single tests were conducted in many of the vehicles for most fuels at the unscheduled 45 – 50°F temperature range. Six selected flex-fuel vehicles were tested once using a special 8.6 psi E85 fuel (Fuel 9) in addition to the test program E85 fuels (Fuels 1 – 3) and gasoline (Fuels 7 and 8) to further assess the effect of E85 vapor pressure (DVPE). The individual vehicle temperature corrected data are shown in the tables in Appendix F. The individual vehicle plots showing the response to fuel vapor pressure and to run temperature are presented in Appendix G and Appendix H.

The results for the two vehicle groupings were corrected to 23°F, 33°F, and 47°F average group run temperatures. Table 3 presents the least-squares mean corrected Ln TWD and TWD values for each fuel across the respective vehicle fleets at each average temperature. Table 4 shows the corrected Ln TWD and TWD values for each vehicle across all fuel sets for each average temperature. The regression analyses are on file at the CRC offices and are available upon request.

The least-squares mean corrected TWD data from Table 4 averaged across all fuels and temperatures for each vehicle are shown graphically in Figure 1. Analysis of these data shows that the two older conventional vehicles, one equipped with a carburetor, had significantly ($p = <0.0001$) higher TWDs than the other vehicles in the program. Even without the two high-TWD vehicles, the conventional vehicles have higher TWDs than the flex-fuel vehicles ($p = 0.0017$). Figure 2 shows the plot of the mean corrected TWD for each fuel averaged across all temperatures and all the vehicles of each group. The conventional vehicles with their fuel set produced on average a higher level of TWDs than the flex-fuel vehicles on their fuel set ($p = <0.0001$).

B. <u>E85 Vapor Pressure Analysis</u>

Using the Ln TWD data from Table F-1 and vapor pressure data from Table 2, regression analyses were undertaken against the vapor pressure of E85 and gasoline. The Ln mean corrected TWD is plotted against vapor pressure for each fuel set in Figure 3. The regression lines are developed using all temperature data. The E85 slope is significantly different from zero (p = 0.012), while the slope of the gasoline line is not (p= 0.479).

Additional analysis was performed eliminating the 4.7-psi E85 fuel data in order to compare the TWDs of E85 and gasoline across similar vapor pressure ranges. At comparable vapor pressures (the range of 5.7 to 8.1 psi), E85 blends resulted in higher total weighted demerits than gasoline (p = 0.014). For this subset, average total weighted demerits for E85 blends and gasolines were 24 and 19, respectively.

Six flex-fuel vehicles were selected based on their response to DVPE and had their driveability evaluated using an 8.6-psi E85 (Fuel 9) to determine if driveability would be improved using a higher vapor pressure fuel. The testing temperature was corrected to 33°F since the lower temperatures were not available. The data for these six vehicles are plotted in Figure 4. The overall slope for these six vehicles performance on E85 was not significantly different from zero (p = 0.276). The difference in performance for E85 relative to gasoline was marginally significantly worse (p = 0.083).

C. E85 Temperature Analysis

The run temperatures were corrected to 23°F, 33°F, and 47°F. The Ln TWD data averaged across the vapor pressures are plotted as a function of temperature for the flex-fuel vehicles in Figure 5. The slopes for both the E85 and gasoline regression lines are not statistically different from zero (p = 0.625 and 0.135). Across the temperature range, however, E85 performed significantly worse than gasoline (p = 0.05).

Additional analysis was performed eliminating the 4.7-psi E85 fuel data in order to compare the effect of temperature on TWDs of E85 and gasoline across similar vapor pressure ranges. Across the temperature range and at comparable vapor pressures (the range of 5.7 to 8.1 psi), there was no statistically significant difference between the total weighted demerits for E85 blends and gasolines (24 versus 19).

D. E85 Multiple Variable Analysis

Regression analyses were undertaken investigating the variables of vapor pressure, run temperature, and fuel type (E85 or gasoline, E0). The regression results are shown in Table 5. Regressing against all three variables showed none were significant, although fuel type was marginally significant (p = 0.066). Using fuel type and vapor pressure as the variables did not change the results. A fuel type and run temperature regression showed only fuel type to be a significant term (p = 0.009). A vapor pressure and run temperature regression showed only vapor pressure to be significant (p = 0.016). Run temperature alone was not significant (p = 0.471). Both vapor pressure and fuel type alone are each significant (p = 0.014 and 0.008). When regressed together, vapor pressure is found to be not significant (p = 0.117), whereas fuel type is found to be marginally significant (p = 0.065). This is believed to be due to the high correlation between vapor pressure and fuel type in the fuel set.

E. Individual Vehicle Performance

The individual flex-fuel vehicle plots of Ln TWD versus vapor pressure are shown in Figures G1 through G19. Similar plots for Ln TWD versus temperature are shown in Figures H1 through H19.

There are no apparently obvious trends related to vehicle technology as measured by the effect of E85 vapor pressure on TWDs. Some vehicles responded to vapor pressure, while others did not, even within the same make and model. E85 driveability performance was more sensitive to vapor pressure than gasoline on most vehicles. There appeared to be vehicle-to-vehicle variability in driveability response, as has been seen in previous programs.

Figures H1 through H19 show that there is little or no sensitivity to ambient temperature within the range tested in this program, but they do show an overall difference between E85 and gasoline. The E85 blends have higher TWDs than gasoline on most vehicles. Average vapor pressure for the E85 blends is slightly lower than for the gasolines.

F. E15/E20 Vapor Pressure Analysis

Using the Ln TWD data from Table E-1 and vapor pressure data from Table 2, regression analyses were undertaken against E15/E20 and gasoline vapor pressure. The E15 and E20 data were combined in this analysis, because the limited E20 data were not shown to be different from the E15 data. The Ln mean corrected TWD is plotted against vapor pressure for each fuel set in Figure 6. The regression lines are developed using all temperature data. The E15/E20 slope and gasoline slope are not significantly different from zero (p = 0.599 and 0.369). The two regression lines are not different from each other (p = 0.19), indicating the two fuel types performed similarly.

G. E15/E20 Temperature Analysis

As was the case for E85, the run temperatures were corrected to 23°F, 33°F, and 47°F. The Ln TWD data averaged across the vapor pressures are plotted as a function of temperature for the conventional vehicles in Figure 7. The slope for E15/E20 fuel is marginally significant (p = 0.069) showing a decreasing trend with temperature. The gasoline regression line is not statistically different from zero (p = 0.263). Across the temperature range, E15/E20 had higher TWDs compared with gasoline, but the difference was not significant (p = 0.62).

H. E15/E20 Multiple Variable Analysis

Regression analyses were undertaken investigating the variables of vapor pressure, run temperature, and fuel type (E15/E20 or gasoline, E0). The regression results are shown in Table 6. Regressing against all three variables showed only run temperature was significant ($p = 0.002$). Fuel type was marginally significant ($p = 0.064$). Using fuel type and vapor pressure as the variables did not change the results. A fuel type and run temperature regression showed only run temperature to be a significant term ($p = 0.003$). A vapor pressure and run temperature regression showed only temperature to be significant ($p = 0.004$). Vapor pressure and fuel type alone were not significant ($p = 0.574$ and 0.323). Thus, the only significant variable is run temperature ($p = 0.003$). This is a higher level of significance than shown in Figure 7, but the data in Figure 7 are averaged across vapor pressure, whereas the regression data were not. The multiple variable regression analysis thus has more data and more degrees of freedom for calculating significance.

I. Individual Vehicle Performance

The individual conventional vehicle plots of Ln TWD versus vapor pressure are shown in Figures G20 through G25. Similar plots for Ln TWD versus temperature are shown in Figures H20 through H25.

On average, conventional vehicles had higher TWDs than comparable model-year E85 vehicles included in the test program. Furthermore, the older technology conventional vehicles had higher TWDs than the later-model conventional vehicles. There are no trends with vapor pressure, and no differences between E15/E20 and gasoline. It should be noted that there are only six vehicles in this sample.

The two oldest conventional vehicles showed an effect of temperature on driveability with noticeably higher TWDs. Ethanol content between E0 and E20 did not appear to make a difference.

J. Fuel Flushing Efficiency

To assess the flushing efficiency of the new flushing procedure used to change fuels, the ethanol content was determined for a gasoline (E0) sample following an E85 fuel for the flex-fuel fleet, and following an E15 test run for the conventional vehicle fleet. These data are shown in Table E-3. Figure 8 shows graphically for each vehicle the residual amount of ethanol found in the gasoline. The average amount across all flex-fuel vehicles was 2.27 volume percent ethanol, and ranged from 0.29 to 4.61 volume percent. For the conventional vehicles, the average amount of ethanol present was about 0.12

volume percent (ranged <0.1 to 0.152 vol % ethanol) which is better than in past programs. A carryover of 0.5 volume percent ethanol corresponds to about 5 volume percent dilution of the test fuel with the previous test fuel.

The new flushing procedure for flex-fuel vehicles does not allow pump suction to draw vapors; otherwise, the malfunction indicator light (MIL) will frequently trip. If the MIL trips, in many vehicles the tank has to be filled with gasoline before the MIL can properly be reset using a scan tool. Both flushing procedures for the E85 vehicles call for the vehicle engines to be turned off 30 seconds after the "low fuel" light illuminates. This is to prevent the vehicle from running out of fuel which will affect the ethanol content calibration; however, it also prevents a thorough drain of the fuel system in many cases. The residual volume of the previous fuel can significantly affect the flushing efficiency. It is recommended that the E85 flushing procedure be reviewed to determine what modifications should be made so there is less carryover of ethanol from the previous run.

K. On-Site Test Fuel Confirmation

To ensure that the test fuels on-site conformed to the target specifications, samples were taken from a drum of each test fuel batch. The analytical results are presented in Table E-2. This analysis confirmed that the on-site test fuels were on-specification.

L. Lessons Learned During This Program

Since the E85 technology is new to the CRC volatility research programs, this test program provided an opportunity to learn more about this technology. Some of the lessons learned include:

- During the flushing procedure, maintain rail pressure within 5 psi of nominal rail pressure. Some vehicles require tighter tolerances of rail pressure.

- Acquire OEM-specific scan tools to determine the vehicle's ethanol content and determine whether the vehicle has adapted to the new fuel. Solicit OEM input on what parameters to monitor. It is imperative to have OEM-specific scan tools and OEM assistance to monitor input variables and understand whether the vehicle is operating correctly.

- Determine from each OEM the amount of fuel addition necessary to trigger the vehicle's fuel-level monitor so the vehicles know that new fuel has been added and the vehicle needs to activate its learning process.

- The fuel flushing must be followed stringently by all participants during the entire program (e.g., "rocking" all vehicles for exactly 30 seconds at the beginning of each drain and "rocking" them all with the same intensity).

- During initial set-up for each vehicle:
    - Drain the tank until "low fuel" light illuminates.
    - Measure the time and fuel quantity from the illumination of the "low fuel" light until a pending MIL is set and then until the tank runs dry.
    - Record those times and fuel quantities, and from this information, determine the individual vehicle flushing requirements.
    - Determine if clearing the MIL code via the scan tool affects the vehicle's ability to learn ethanol content.

- If a MIL occurs, stop draining immediately. Check the activity of the learning system of the vehicle with a scan tool to determine if the MIL has affected the learning. If not, it is possible to continue with the draining.

- At the end of the flushing procedure, check each vehicle for any pending or active MILs and clear them prior to the preconditioning of the vehicle.

- During vehicle preconditioning, check the ethanol leaning function using a scan tool.

- Before the start of test, record the coolant temperature of the vehicles with a scan tool to determine the effective ambient soak temperature.

REFERENCES

1. ASTM International, ASTM D5798 Specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines, 2008 Annual Book of ASTM Standards.

TABLES

AND

FIGURES

Table 1
2008 CRC Driveability Program Test Vehicles

E85 Flex-Fuel Fleet

Year	Make	Model	Mileage	Displacement	VIN
2008[1]	Chevrolet	Impala	14493	3.5L	2G1WT55K289134060
2008	Chevrolet	Impala	16754	3.5L	2G1WT55K889133026
2006	Chevrolet	Silverado	100566	5.3L	3GCEC14Z76G255499
2008	Chevrolet	Silverado	9383	5.3L	3GCEK13368G100204
2008	Chevrolet	Suburban	10698	5.3L	3GNFK16328G105942
2008	Chevrolet	Suburban	14180	5.3L	3GNFK16348G105909
2008	Chevrolet	Tahoe	9272	5.3L	1GNFK130X8J101856
2008	Chevrolet	Tahoe	13081	5.3L	1GNFK13048J102288
2008	Chevrolet	Uplander	1005	3.9L	1GNDV23W18D124773
2008	Chevrolet	Uplander	1360	3.9L	1GNDV23WX8D124545
2008	Chrysler	Aspen	3319	4.7L	1A8HW58N98F107791
2008	Chrysler	Aspen	1853	4.7L	1A8HW58NX8F117648
2007	Dodge	Caravan	26632	3.3L	1D4GP25E37B209633
2007	Dodge	Caravan	19644	3.3L	1D4GP25E47B209589
2008	Dodge	Dakota	3834	4.7L	1D7HW48N78S507668
2008	Dodge	Dakota	1003	4.7L	1D7HW48N78S539617
2007	Ford	F150	11336	5.4 L	1FTPW14V97FB33534
2007	Ford	F150	10515	5.4 L	1FTPW14V57FB33532
2008	GMC	Yukon XL	2786	5.3L	1GKFK16348J136038
2008	GMC	Yukon	9467	5.3L	1GKFK13088J1166000

Conventional Fleet

Year	Make	Model	Mileage	Displacement	VIN
1981	Buick	Riviera	85105	5.0L[2]	1G4AZ57Y2BE409802
1997[1]	Buick	Skylark	77561	3.1L	1G4NJ52M7VC401157
1997[1]	Chevrolet	1500	109167	4.3L	1GCEC14W0VZ238225
2007	Chrysler	300	16245	3.5L	2C3KA53G77H888249
1995	GMC	Sierra	128783	5.0L	1GTEC14HX5Z560979
1999	Honda	Civic	48198	1.6L	1HGEJ6677XL043383
2007[1]	Mazda	6	18195	2.3L	1YVHP80C975M38563
2007	Nissan	Altima	26123	2.5L	1N4AL21E37N410795
2008[1]	Nissan	Frontier	6356	4.0L	1N6AD07W68C404690
1999	Toyota	Camry	83327	2.2L	4T1BG22K0XU897236
2007[1]	Toyota	Camry	14803	2.4L	4T1BE46K67U676932
1999[1]	Toyota	Corolla	72011	1.8L	2T1BR12E2XC139351

[1]Not used in final program
[2]The 1981 Buick Riviera was equipped with a closed-loop feedback control carburetor.

Table 2
CRC 2008 Volatility Program Fuel Inspections

Fuel Description			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Property	**Method**	**Units**	**E85-4.7**	**E85-5.7**	**E85-7.0**	**E20-7.1**	**E-15-7.1**	**E15-9.9**	**E0-5.9**	**E0-8.1**	**E85-8.5**
Gravity	ASTM D4052	°API	49.7	50.3	51.1	59.7	60.5	54.0	62.5	57.1	50.6
Relative Density		60/60°F	0.7807	0.7783	0.7748	0.7401	0.7371	0.7626	0.7295	0.7502	0.7770
Uncorrected Ethanol	ASTM D5501	wt %	84.2	84.7	85.7	-	-	-	-	-	84.13
Ethanol	ASTM D5501	vol %	82.4	82.4	82.9	-	-	-	-	-	81.09
Methanol	ASTM D5501	vol %	0.0	0.0	0.0	-	-	-	-	-	0.15
Ethanol	ASTM D4815	wt %	-	-	-	-	-	-	-	-	-
Ethanol	ASTM D4815	vol %	-	-	-	19.0	14.5	14.7	0.0	0.0	-
Water	ASTM E203	wt. %	0.546	0.531	0.544	-	-	-	-	-	0.68
Water	ASTM E203	vol %	0.430	0.427	0.439	0.103	0.079	0.078	0.034	0.007	0.53
Estimated Hydrocarbon		vol %	17.5	17.3	16.9	-	-	-	-	-	17.42
DVPE	ASTM D5191	psi	4.68	5.72	7.00	7.11	7.13	9.93	5.92	8.09	8.57
Distillation	ASTM D86										
Initial Boiling Point		°F	133.4	120.0	113.6	110.0	107.8	94.8	107.6	94.9	93.7
5% Evaporated		°F	156.4	144.5	142.5	131.1	129.3	116.6	138.3	120.1	126.6
10% Evaporated		°F	162.7	157.0	153.9	135.6	133.6	127.6	147.4	138.1	146.3
20% Evaporated		°F	167.9	166.5	164.5	141.8	140.1	143.5	159.6	161.4	166.1
30% Evaporated		°F	169.9	169.6	168.6	147.9	146.4	153.7	173.9	182.6	169.7
40% Evaporated		°F	170.9	170.9	170.4	154.3	152.4	160.4	190.3	201.6	170.7
50% Evaporated		°F	171.4	171.4	171.2	159.2	157.7	170.1	207.6	217.9	171.3
60% Evaporated		°F	171.7	171.7	171.6	164.2	204.7	224.4	226.4	231.7	171.5
70% Evaporated		°F	172.0	171.9	171.8	228.4	235.7	239.4	245.1	245.5	171.6
80% Evaporated		°F	172.3	172.2	171.9	255.8	260.0	256.6	268.3	265.6	171.8
90% Evaporated		°F	172.8	172.5	172.1	294.8	298.8	300.8	307.4	309.8	172.0
95% Evaporated		°F	173.9	173.1	172.5	328.0	331.8	341.4	319.5	347.7	172.4
End Point		°F	233.8	193.0	193.4	381.4	382.0	395.6	389.3	397.6	174.3
Recovery		vol %	98.4	97.9	98.3	97.8	98.1	97.2	98.5	97.3	98.0
Residue		vol %	1.1	0.7	0.3	1.1	1.1	1.1	0.8	0.7	1.0
Loss		vol %	0.5	1.4	1.5	1.2	0.8	1.7	0.7	2.0	1.0
Benzene	DHA	vol %	0.12	0.14	0.26	0.58	0.61	1.10	0.71	1.12	0.14
Ethanol	DHA	vol %	84.6	85.6	87.3	19.6	14.6	13.9	0.0	0.0	85.8
Methanol	DHA	vol %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrocarbon	DHA	vol %	15.4	14.4	12.7	80.4	85.4	86.1	100.0	100.0	14.18
Aromatics	DHA	vol %	3.5	2.4	1.2	17.8	6.6	36.1	21.6	35.8	2.4
Olefins	DHA	vol %	0.8	0.4	0.1	3.5	3.8	2.9	4.5	3.7	1.1
Saturates	DHA	vol %	11.1	11.6	11.4	59.1	63.0	47.0	73.9	60.6	10.68

Table 3
Least-Squares Mean Natural Log and Mean Corrected TWD Values
Fuel by Temperature Results

		Ln TWD LSMean			TWD LSMean		
Fuel	Vehicle	Run Temp 23˚F	Run Temp 33˚F	Run Temp 47˚F	Run Temp 23˚F	Run Temp 33˚F	Run Temp 47˚F
1	Flex-Fuel	3.50	3.65	3.61	33.0	38.6	37.0
2	Flex-Fuel	3.43	3.04	3.24	30.8	20.9	25.5
3	Flex-Fuel	3.01	2.96	3.34	20.4	19.3	28.2
4	Conventional	4.02	3.73	3.63	55.7	41.8	37.7
5	Conventional	4.14	3.84	3.48	62.9	46.4	32.6
6	Conventional	3.68	3.76	3.74	39.7	43.1	41.9
7	Flex-Fuel	2.83	3.00	2.87	16.9	20.0	17.7
7	Conventional	3.95	3.95	3.39	51.9	52.1	29.8
8	Flex-Fuel	2.86	2.92	3.19	17.4	18.5	24.3
8	Conventional	3.65	3.64	3.38	38.6	37.9	29.4
9	Flex-Fuel		3.20			24.6	

Table 4
Least-Squares Mean Natural Log and Mean Corrected TWD Values
Vehicle by Temperature Results

	Ln TWD LSMean			TWD LSMean		
Vehicle	Run Temp 23˚F	Run Temp 33˚F	Run Temp 47˚F	Run Temp 23˚F	Run Temp 33˚F	Run Temp 47˚F
1	2.78	2.91	2.99	16.2	18.4	20.0
2	3.14	2.81	3.25	23.1	16.6	25.9
3	3.24	3.43	3.22	25.6	30.7	25.0
4	2.55	2.57	2.56	12.7	13.0	13.0
5	3.20	3.30	3.53	24.5	27.1	34.1
6	3.29	3.31	3.21	27.0	27.4	24.8
7	2.52	2.64	2.52	12.4	14.0	12.4
8	3.27	3.20	2.97	26.2	24.5	19.5
9	3.48	3.13	3.18	32.4	22.8	24.1
10	2.66	2.80	3.00	14.3	16.4	20.1
11	3.17	3.10	3.68	23.8	22.1	39.5
12	3.39	3.17	3.62	29.7	23.7	37.4
13	3.40	3.41	3.39	29.9	30.1	29.6
14	3.55	3.33	3.70	34.8	27.9	40.4
16	3.62	3.55	3.62	37.4	34.8	37.4
17	3.05	3.32	3.03	21.2	27.6	20.8
18	2.99	3.27	3.30	19.9	26.4	27.1
19	3.10	3.01	2.72	22.2	20.3	15.2
20	2.98	2.99	2.62	19.6	19.8	13.7
21	3.44	3.48	3.48	31.1	32.3	32.5
23	3.39	3.46	3.23	29.7	31.9	25.4
26	4.91	4.62	3.99	135.7	101.9	54.1
28	5.15	4.54	4.27	172.5	93.3	71.6
29	3.33	3.36	3.30	27.9	28.7	27.1
32	3.23	3.25	2.96	25.2	25.7	19.3

Table 5
Flex-Fuel Vehicle E85 Regression Models

Regression Variables	R^2	RMSE	Constant	Vapor Pressure		Temperature		Fuel Type	
				Coef.	p-value	Coef.	p-value	Coef.	p-value
Vapor Pressure, Temperature, and Fuel Type (E85 or E0)	0.580	0.206	3.64	-0.0896	0.119	0.00558	0.324	-0.257	0.066
Vapor Pressure and Fuel Type	0.539	0.207	3.83	-0.0896	0.117	-	-	-0.257	0.065
Fuel Type and Temperature	0.471	0.222	3.12	-	-	0.0056	0.356	-0.365	0.009
Vapor Pressure and Temperature	0.422	0.232	3.88	-0.1443	0.016	0.0055	0.377	-	-
Temperature	0.041	0.287	2.97	-	-	0.0056	0.471	-	-
Vapor Pressure	0.381	0.230	4.07	-0.1443	0.014	-	-	-	-
Fuel Type	0.430	0.221	3.31	-	-	-	-	-0.365	0.008

Table 6
Conventional Vehicle E15/E20 Regression Models

Regression Variables	R^2	RMSE	Constant	Vapor Pressure		Temperature		Fuel Type	
				Coef.	p-value	Coef.	p-value	Coef.	p-value
Vapor Pressure, Temperature, and Fuel Type (E15/E20 or E0)	0.659	0.146	4.71	-0.0496	0.133	-0.0154	0.002	-0.172	0.064
Vapor Pressure and Fuel Type	0.157	0.22	4.18	-0.050	0.303	-	-	-0.172	0.065
Fuel Type and Temperature	0.577	0.156	4.31	-	-	-0.0154	0.003	-0.12	0.170
Vapor Pressure and Temperature	0.527	0.165	4.46	-0.025	0.441	-0.0154	0.004	-	-
Vapor Pressure	0.025	0.227	3.93	-0.025	0.574	-	-	-	-
Fuel Type	0.075	0.221	3.78	-	-	-	-	-0.120	0.323
Temperature	0.502	0.162	4.26	-	-	-0.0154	0.003	-	-

Figure 1
Mean Corrected TWD vs. Vehicle
Across All Fuels and Temperatures

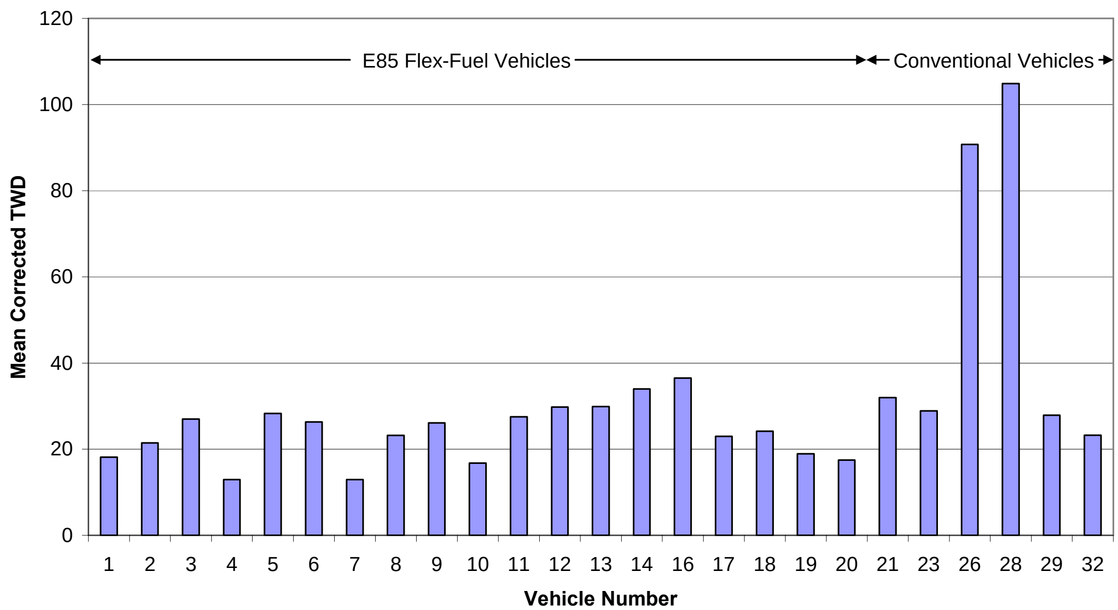


Figure 2
Mean Corrected TWD vs. Fuel
Across All Vehicles and Temperatures

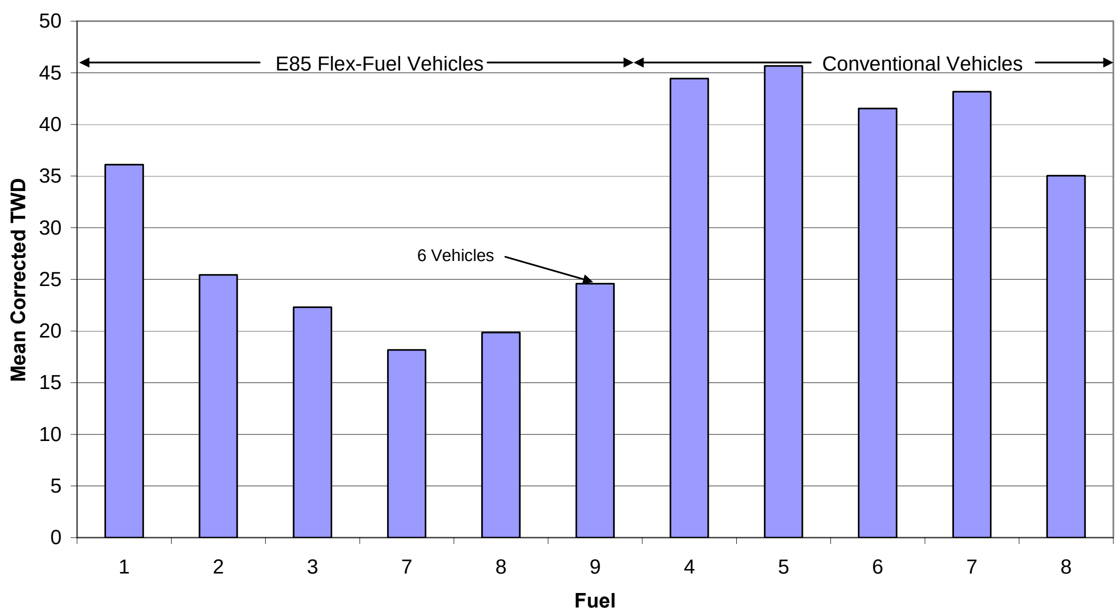


Figure 3
CRC E85 Cold-Start and Warm-Up Program
All Flex-Fuel Vehicles Effect of Vapor Pressure on Ln TWD

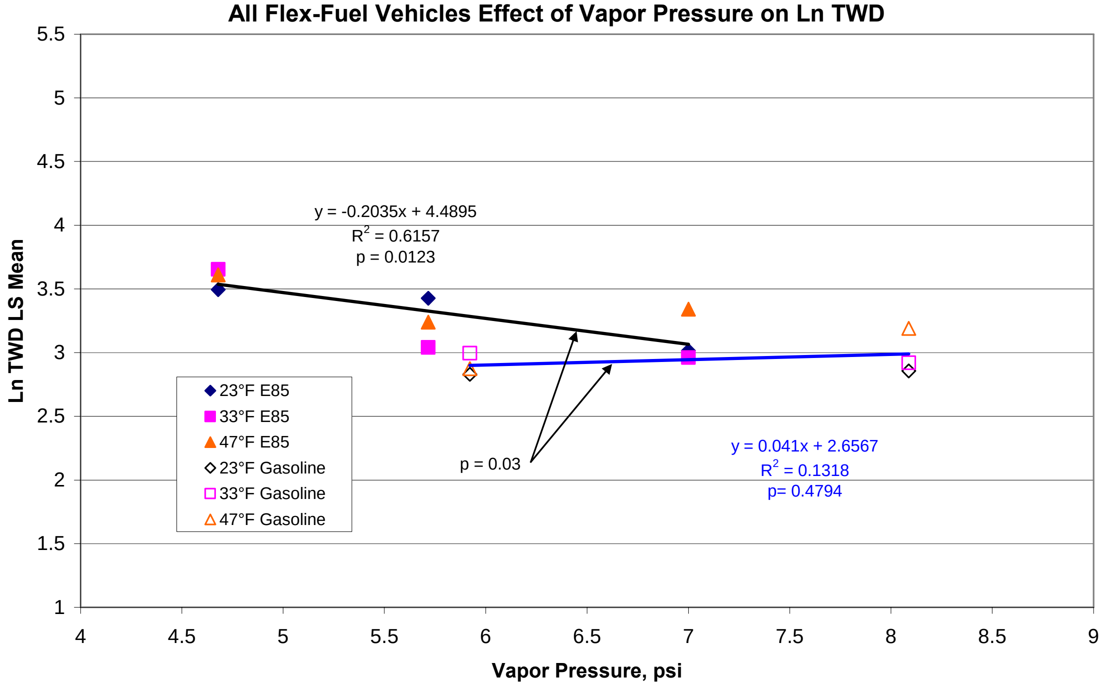


Figure 4
CRC E85 Cold-Start and Warm-Up Program
Assesment of High Vapor Pressure E85 in Six Flex-Fuel Vehicles

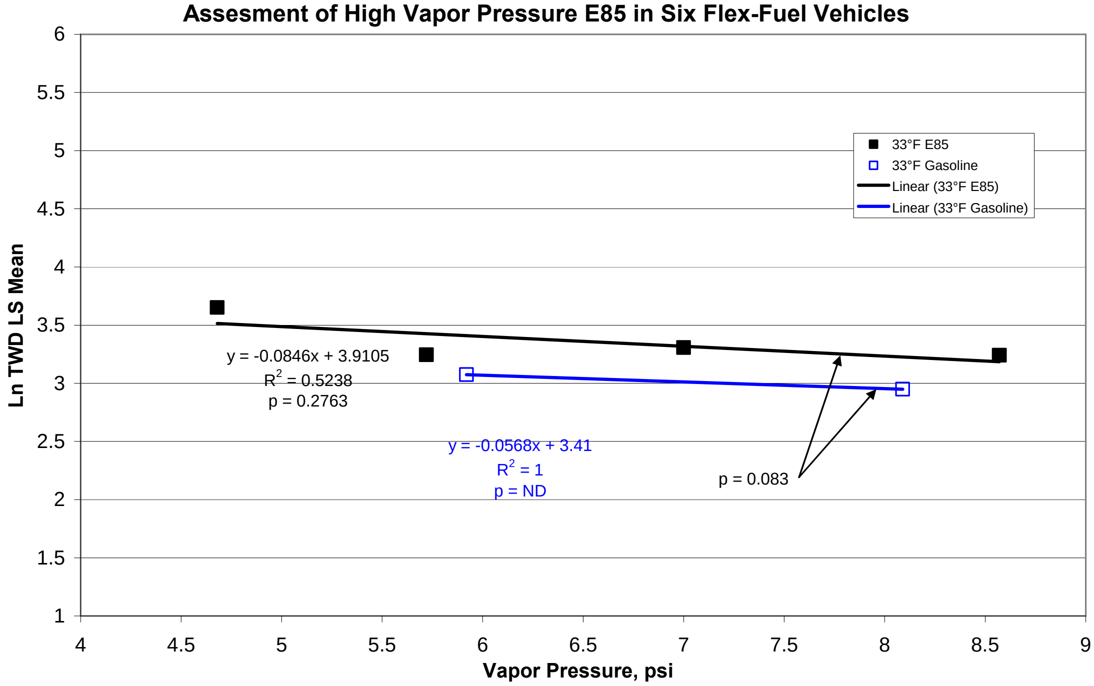


Figure 5
CRC E85 Cold-Start and Warm-Up Program
All Flex-Fuel Vehicles Effect of Temperature on Ln TWD

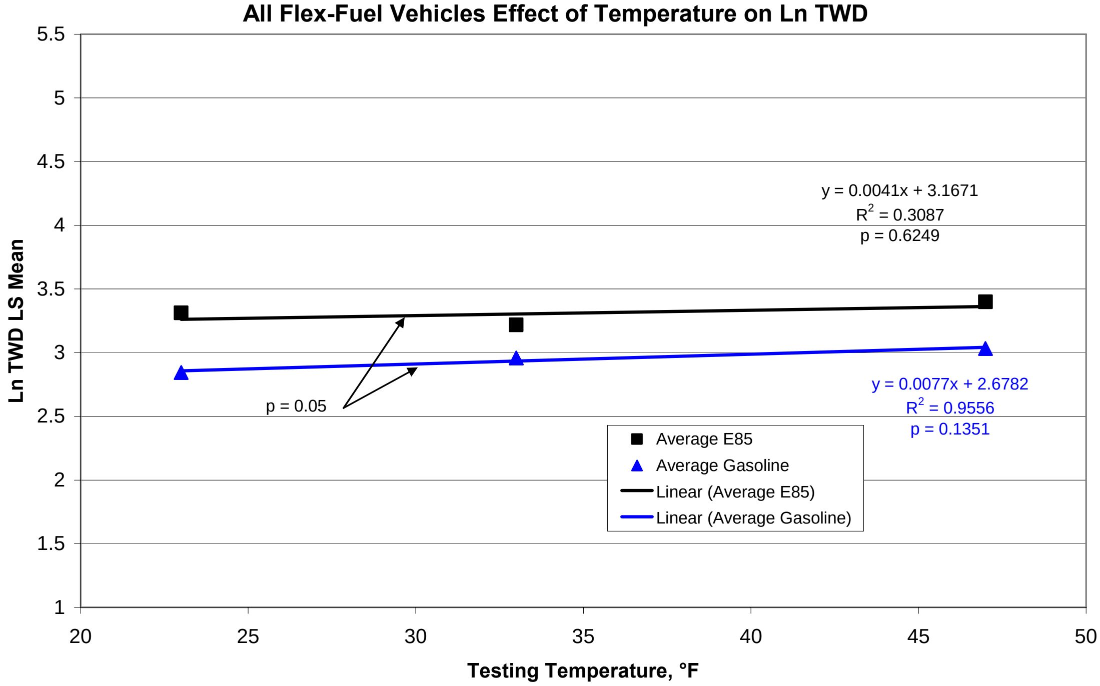


Figure 6
CRC E15/E20 Cold-Start and Warm-Up Program
All Conventional Vehicles Effect of Vapor Pressure on Ln TWD

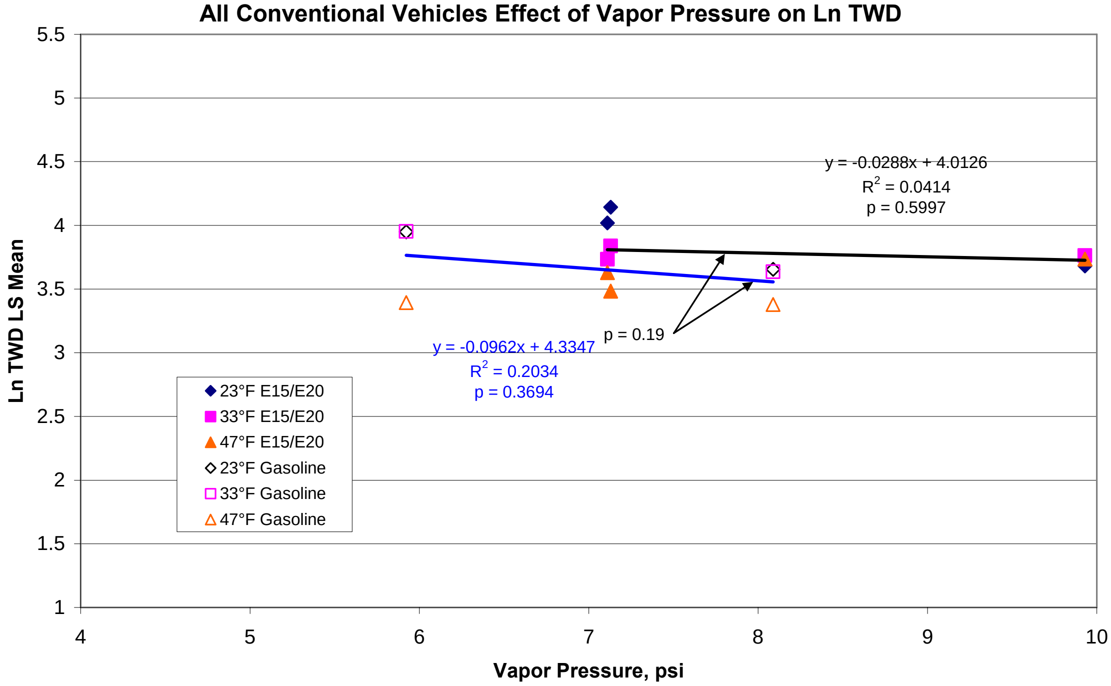


Figure 7
CRC E15/E20 Cold-Start and Warm-Up Program
All Conventional Vehicles Effect of Temperature on Ln TWD

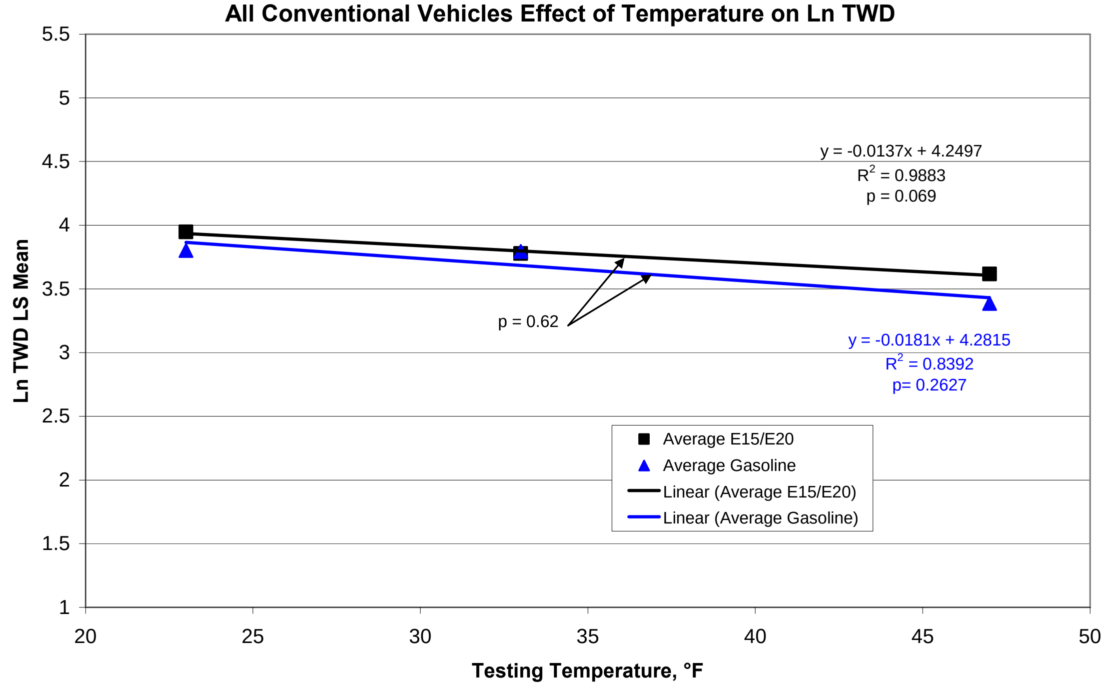
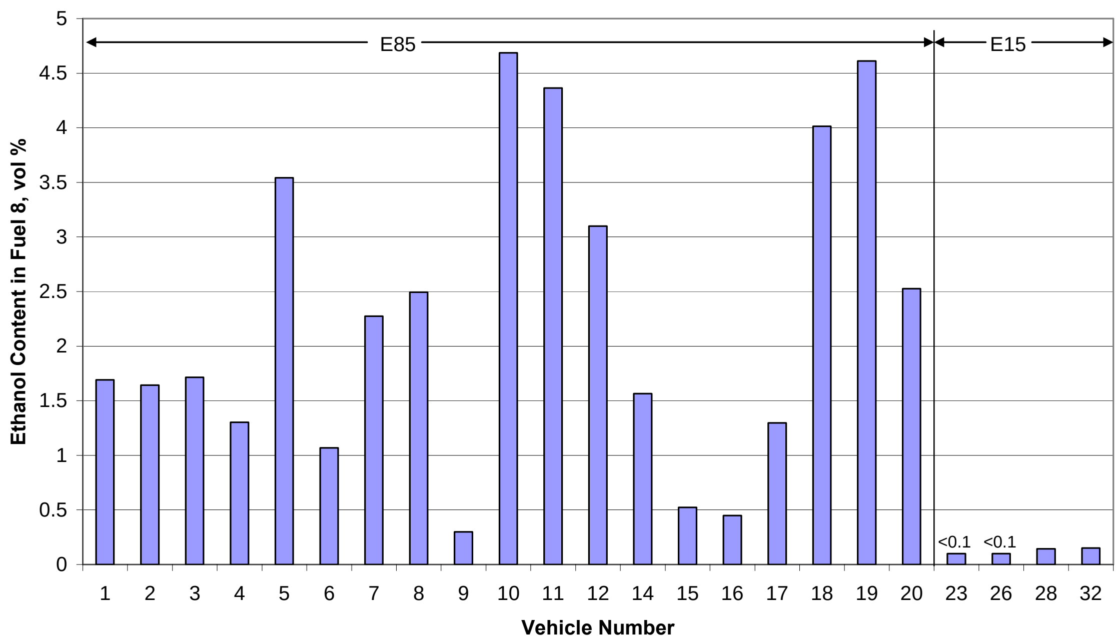


Figure 8
Ethanol Carry-Over After Flushing with Hydrocarbon-Only Fuel 8



APPENDIX A

MEMBERS OF THE

2008 CRC E85 AND E15/E20 DRIVEABILITY PROGRAM

DATA ANALYSIS PANEL

Appendix A

Members of the 2008 CRC E85 and E15/E20 Driveability Program Data Analysis Panel

Name	Affiliation
Lew Gibbs, Leader	Chevron Products Company
King Eng	Shell Global Solutions (US)
Beth Evans	Evans Research Consultants
Jeff Farenback-Brateman	ExxonMobil Research & Engineering
Pat Geng	General Motors Powertrain
Carl Jewitt	Renewable Fuels Association
Keith Knoll	National Renewable Energy Laboratory
Winnie Torres-Ordonez	BP Global Fuels Technology

APPENDIX B

ON-SITE PARTICIPANTS IN THE

2008 CRC E85 AND E15/E20 DRIVEABILITY PROGRAM

Appendix B

On-Site Participants in the 2008 CRC E85 and E15/E20 Driveability Program

Name	Affiliation
Harold "Archie" Archibald	Evans Research Consultants
Mike Babicki	Sunoco
Matt Borden	Honda R&D Americas
Bobby Bowden	Shell Global Solutions (US)
Maria Bruen	Honda R&D Americas
Andy Buczynsky	General Motors Powertrain
Shaleen Clark	General Motors Powertrain
Jim Coley	Shell Global Solutions (US)
Tim Cushing	General Motors Corporation
Beth Evans	Evans Research Consultants
Pat Geng	General Motors Powertrain
Heather Hamje	ExxonMobil Research & Engineering
Mark Hartman	BP Global Fuels Technology
Calvin James	The Lubrizol Corporation
Carl Jewitt	Renewable Fuels Association
Adrian Juergens	Shell Global Solutions (US)
Katie Kennedy	ExxonMobil Research & Engineering
Keith Knoll	National Renewable Energy Laboratory
Kristy Moore	Renewable Fuels Association
Bill Most	Fuels Technology Associates
Mike Neisen	Honda R&D Americas
Matt Nichols	Chevron Oronite Company
Bob Priester	VeraSun
Dave Sporleder	Shell Canada
Teresa Terrado	Chevron Products Company
Matt Thornton	National Renewable Energy Laboratory
George Tsigolis	BP Global Fuels Technology
Marie Valentine	Toyota Technical Center
Phil Van Acker	BP Global Fuels Technology
Shon Van Hulzen	POET Energy
Ken Wright	ConocoPhillips

APPENDIX C

2008 CRC COLD START AND WARM-UP

E85 AND E15/E20

DRIVEABILITY PROGRAM

2008 CRC COLD START AND WARM-UP E85 AND E15/E20 DRIVEABILITY PROGRAM

Objective

There are two parts to this volatility program. 1) Determine the effect of vapor pressure of E85 Fuel Ethanol on cold start and warm-up driveability performance under cool ambient conditions in a large group of late model flexible-fuel vehicles equipped with fuel injection systems, 2) Determine the effect of E15 and E20 on cold start and warm-up driveability performance under cool ambient conditions in a moderate size group of late model and older conventional vehicles.

Deliverables

The minimum vapor pressure required for the two warmer ambient conditions of the three volatility classes in ASTM Specification D5798 (Classes 1 and 2) for acceptable cold start and warm-up driveability will be determined. A follow-on program would be required to investigate E85 properties for the coldest Class 3 fuels. The cold-start and warm-up performance of E15 and E20 versus gasoline with similar vapor pressures will be determined.

Introduction

ASTM D 5798 Specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines specifies minimum vapor pressure limits for three volatility classes. The volatility classes are assigned based on the minimum ambient temperature expected for the month. For the warmer ambient temperature class, the amount of hydrocarbon is allowed to range from 17 to 21 vol % (includes denaturant). For the intermediate temperature class, the amount of hydrocarbon is allowed to range from 17 to 26 vol % (includes denaturant). For the coldest ambient temperature class, the amount of hydrocarbon is allowed to range from 17 to 30 vol % (includes the denaturant). The data base used to develop the volatility and compositional limits is over 12 years old. Now with the lower summertime federal and state vapor pressure limits for both conventional and reformulated gasoline, it is difficult to blend 15 vol % commercially available gasoline into denatured ethanol and meet the minimum vapor pressure limits in D 5798. Vehicle designs have changed since the early work was undertaken and today's design dates back about seven years.

Chevron working with the assistance of the Honda Raymond, OH laboratory, TRC, Beth Evans, and Arch Archibald conducted a pilot E85 cold-start and warm-up program using four 2006-2007 vehicles. The results from the pilot program were used to design the fuel set for this program.

The state of Minnesota has mandated the use of E20 starting in 2013 contingent on obtaining an EPA waiver by 2010. Others have suggested a more practical higher ethanol content blend would be E15 which would be more compatible with existing fuel system materials and with less change in stoichiometric fuel-air ratio than E20. NREL has been asked to conduct driveability tests on E15 and E20 blends and wish to join our CRC program. NREL has funding to cover the cost of joining with the CRC.

Test Program

Vehicle cold start and warm-up driveability performance will be determined using the test procedure from the 2003 CRC volatility test program. This program will be conducted in early 2008.

Test Fuels

The test fuel design will vary the vapor pressure allowed for E85 fuel ethanol in ASTM Specification D5798. To minimize blending costs, commercial gasolines without oxygenate and natural gasoline will be utilized as much as possible. A special batch of denatured ethanol with 2 vol % of a low vapor pressure denaturant will be used in this program and it must meet ASTM D4806 specification limits. This batch is needed to ensure the low vapor pressures needed for the test program. Estimated compositions have been developed, but will have to be adjusted when actual stocks are on hand. Two commercial hydrocarbon-only gasoline stocks will be obtained. One will be summertime California Reformulated Gasoline Blendstocks for Oxygenate Blending (CARBOB) with a nominal vapor pressure of 5.7 psi. Another will be conventional gasoline without oxygenate having a vapor pressure of 10 psi. A third hydrocarbon blend stock will be natural gasoline with a vapor pressure of around 12 psi (used by many ethanol producers as a denaturant and in the E85 that they are blending). The low vapor pressure fuel (Blend No. 1) will be a blend of 85 vol% denatured ethanol and 15 vol % of summertime CARBOB resulting in a vapor pressure of about 4.5 psi. The No. 2 blend will consist of 85 vol % denatured ethanol, 8 vol % CARBOB, and 7 vol % natural gasoline with a target vapor pressure of 5.5 psi. If the measured vapor pressure is too low, the amount of natural gasoline will need to be increased and the amount of CARBOB decreased so the total of the two remains 15 vol %. If the measured vapor pressure is too high, the ratio of CARBOB to natural gasoline will be increased. Blend No. 3 will consist of 85 vol % denatured ethanol, 15 vol % of natural gasoline with a target vapor pressure of 7.0 psi. If the resulting blend is too high in vapor pressure, part of the natural gasoline will be replaced by the 5.5 psi CARBOB. Blend No. 4 will consist of 20 vol % denatured ethanol and 80 vol % CARBOB with an estimated vapor pressure of 6.8.0 psi. Blend No. 5 will consist of 15 vol % denatured ethanol and 85 vol % of CARBOB with an estimated vapor pressure of 6.8 psi. Blend No. 6 will consist of 15 vol % denatured ethanol, 63 vol % 10 psi commercial gasoline, and 22 vol % CARBOB with a target vapor pressure of 10 psi. The ratio of the two hydrocarbons can be adjusted to obtain the target vapor pressure. Blend No. 7 is a full-boiling hydrocarbon-only gasoline with a low, 5.7 psi vapor pressure made from 100 vol % CARBOB, and is a low vapor pressure gasoline reference for Blend No. 1. Blend No. 8 is targeted to be a typical summer conventional gasoline with a vapor pressure of 7.8 psi and is included as a reference. It will consist of 51 vol % 10 psi commercial gasoline and 49 vol % CARBOB. The ratio of the two gasolines may require adjustment to meet the target vapor pressure. The two gasolines also are the reference fuels for the E15/E20 portion of the test program.

The compositions and specifications for the 8 test fuels are shown in Table 1. After reviewing hand blend data, the compositions are subject to adjustments to meet the required vapor pressures. A Fuel Blending and Analysis Task Force will be formed to assist in the analyses of the fuels.

Test Vehicles

Approximately 20 late model flexible-fuel vehicles will be used in the E85 portion of the test program to evaluate the cold start and warm-up driveability performance of the E85 and hydrocarbon-only gasoline test fuels. The selected flexible-fuel vehicles must represent several makes of compact, midsize, and large cars, pickup trucks, and sport utility vehicles listed in the 2006 and 2007 DOE/EPA Fuel Economy Guide. No more than two of the same make and models will be in the test fleet. The vehicles will nominally cover 2006-2007 model years and will have stabilized mileages at over 6,000 odometer miles, and be in good mechanical condition with functional air conditioning systems. These vehicles will be used to assess the performance of fuels Nos. 1, 2, 3, 7, and 8.

Approximately 12 late model and older conventional vehicles will be obtained for the E15/E20 portion of the program. They will initially be tested on the No. 4 E20 fuel. Those that show driveability malfunctions will then be tested on No. 8 gasoline to ensure the malfunctions are fuel and not mechanical related. The goal is to screen the 12 vehicles and select six sensitive vehicles for full blown testing using fuels No. 4 through No. 8.

Test Procedure

The Test Procedure used in the 2003 CRC volatility program (CRC Report No. 638) will be used in this 2007 or 2008 program. Duplicate tests will be conducted on each vehicle and fuel combination. Each vehicle will be flushed with test fuel following the latest attached flushing procedure and filled with four gallons of the next test fuel. The flushing procedure is a modification of recent flushing procedures and is based on information from the vehicle manufacturers to be compatible with the flexible-fuel technology.

Test Temperatures

The program plans are to cover the low end ambient test temperature of D5798 volatility Classes 1 and 2. This means testing would be required for Class 1 (30°F to 40°F) and for Class 2 (20°F to 30°F). It is hoped that the two temperature ranges can be covered during the selected test period of a single program. All fuels for both portions of the program will be tested under both temperature conditions.

Test Location

The test program will be conducted at the Renegade Raceways in Yakima, Washington, where the 2003 CRC program was conducted. The planned testing period will be January/February 2008. Set-up will be accomplished the week of January 7, 2008, and testing will begin on January 14, 2008 and the ending date will thus be February 23, 2008.

Timing

The timing will be as follows:

The first week – 2 to 3 people will be required on-site to receive delivery of equipment, repair equipment, set up vehicles, etc. and to screen the conventional vehicles.

The next six weeks – the core test program with the 26 selected vehicles and 8 test fuels will be conducted.

It is planned that the data analysis and report-writing activities can be completed within about nine-months following the completion of the testing portion of the program.

Personnel Requirements

The core 6-week program will require 13 people on-site for each testing week for a total of 78 person-weeks. Mechanics and set-up people will be required for the week prior to the start of testing.

October 2007

Revised 2007-2008 CRC Volatility Program Test Fuel Compositions and Properties

Blend No.		1	2	3	4	5	6	7	8
Composition, vol %									
Denatured Fuel EtOH*		85.0	85.0	85.0	20.0	15.0	15.0	0.0	0.0
CARBOB -- Summer		15.0	8.0	0.0	80.0	85.0	22.0	100.0	49.0
10 psi Conventional Hydrocarbon-Only		0.0	0.0	0.0	0.0	0.0	63.0	0.0	51.0
12 psi Natural Gasoline		0.0	7.0	15.0	0.0	0.0	0.0	0.0	0.0
Required Properties	Test Method								
Vapor Pressure, psi	D 5191	Report**	5.5 - 5.8	7.0 - 7.3	6.5 -6.8	6.5 -6.8	9.8 - 10.1	5.5 - 5.8	7.8 - 8.1
Distillation, °F	D 86	Report	Report	Report	Report	Report	Report	D 4814	D 4814
EtOH Content, vol %	D 4815/D 5501	81.0 - 83.0	81.0 - 83.0	81.0 - 83.0	18.0 - 20.0	13.5 - 15.0	13.5 - 15.0	0.0	0.0

*Denatured with 2 vol % CARBOB --- Summer
**Around 4.5 psi

APPENDIX D

CRC COLD START AND WARM-UP DRIVEABILITY TEST PROCEDURE AND FUEL SYSTEM DRAINING AND FLUSHING PROCEDURES

<u>REVISED CRC COLD-START AND WARMUP DRIVEABILITY PROCEDURE</u>

A. Record all necessary test information at the top of the data sheet.

B. Turn key on for 2 seconds before cranking to pressurize fuel system. Make sure defrost is on and fan is in "low" position. Start engine per Owner's Manual Procedure. Record start time.

C. There may be a total of three starting attempts recorded. If the engine fails to start within 5 seconds on any of these attempts, stop cranking at 5 seconds and record "NS" (no start) in the appropriate starting time box on the data sheet. After the first and second unsuccessful attempts to start, turn the key to the "off" position before attempting to restart per the Owners Manual procedure. If the engine fails to start after 5 seconds during the third attempt, record an "NS" in the Restart2 box, then start the engine any way possible and proceed as quickly as possible to Step D without recording any further start times.

Once the engine starts on any of the first three attempts, idle in park for 5 seconds and record the idle quality. If the engine stalls during this 5-second idle, record a stall in the Idle Park "Stls" box, then restart per the above paragraph, subject to a combined maximum (in any order) of three no-starts and Idle Park stalls. After all the start-time boxes are filled, no further starts should be recorded.

D. Apply brakes (right foot), shift to "Drive" ("Overdrive" if available) for 5-second idle, and record idle quality. If engine stalls, restart immediately. <u>Do not record restart time.</u> Record number of stalls.

A maximum of three Idle Drive stalls may be recorded; however, only one stall contributes to demerits. If the engine stalls a fourth time, restart and proceed to the next maneuver as quickly as possible. It is important to complete the start-up procedure as quickly as possible to prevent undue warmup before the driving maneuvers and to maintain vehicle spacing on the test track.

E. After idling 5 seconds (Step D), make a brief 0-15 mph light-throttle acceleration. Light-throttle accelerations will be made at a constant throttle opening beginning at a predetermined manifold vacuum. This and all subsequent accelerations throughout the procedure should be "snap" maneuvers: the throttle should be depressed immediately to the position that achieves the pre-set manifold vacuum, rather than easing into the acceleration. Once the throttle is depressed, no adjustment should be made, even if the pre-set vacuum is not achieved. Use moderate braking to stop. Idle for approximately 3 seconds without rating it. Make a brief 0-15 mph light-throttle acceleration. Both accelerations together should be made within 0.1-mile. If both accelerations are completed before the 0.1-mile marker, cruise at 15 mph to the 0.1-mile marker. Use moderate braking to stop; idle for approximately 3 seconds without rating it.

F. Make a 0-20 mph wide-open-throttle (WOT) acceleration beginning at the 0.1-mile marker. Use moderate braking to achieve 10 mph and hold 10 mph until the 0.2-mile marker (approximately 5 seconds). Use moderate braking to stop; idle for approximately 3 seconds without rating it.

G. At the 0.2-mile marker, make a brief 0-15 mph light-throttle acceleration. Use moderate braking to stop. Idle for approximately 3 seconds without rating it. Make a brief 0-15 mph light-throttle acceleration. If accelerations are completed before the 0-3-mile marker, cruise at 10 mph to the 0.3-mile marker.

H. At the 0.3-mile marker, make a light-throttle acceleration from 10-20 mph. Use moderate braking to make a complete stop at the 0.4-mile marker in anticipation of the next maneuver. Idle for approximately 3 seconds at the 0.4-mile marker without rating the idle.

I. Make a 0-20 mph moderate acceleration beginning at the 0.4-mile marker.

J. At the 0.5-mile marker, brake moderately and pull to the right side of the roadway. Idle in "Drive" for 5 seconds and record idle quality. Slowly make a U-turn.

K. Repeat Steps E through J. At the 0.0-mile marker, brake moderately and slowly make a U-turn.

NOTE: Items L-N may be useful only at colder temperatures.

L. Make a crowd acceleration (constant predetermined vacuum) from 0-45 mph. Four-tenths of a mile is provided for this maneuver. Decelerate from 45 to 25 mph before the 0.4-mile marker.

M. At the 0.4-mile marker, make a 25-35 mph detent position acceleration.

N. At the 0.5-mile marker, brake moderately. Idle for 30 seconds in "Drive," recording idle quality after 5 seconds and after 30 seconds, and record any stalls that occur. This ends the driving schedule. Proceed to the staging area.

Definitions of light-throttle, detent, and WOT accelerations are attached. During the above maneuvers, observe and record the severity of any of the following malfunctions (see attached definitions):

1. Hesitation
2. Stumble
3. Surge
4. Stall
5. Backfire

It is possible that during a maneuver, more than one malfunction may occur. Record all deficiencies observed. Do not record the number of occurrences. If no malfunctions occur during a maneuver, draw a horizontal line through all boxes for that maneuver. Also, in recording subjective ratings (T, M, or H), be sure the entry is legible. At times, M and H recordings cannot be distinguished from each other.

Record maneuvering stalls on the data sheet in the appropriate column: accelerating or decelerating. If the vehicle should stall before completing the maneuver, record the stall and restart the car as quickly as possible. Bring the vehicle up to the intended final speed of the maneuver. Any additional stalls observed will not add to the demerit total for the maneuver, and it is important to maintain the driving schedule as closely as possible.

DEFINITIONS AND EXPLANATIONS

Test Run

Operation of a car throughout the prescribed sequence of operating conditions and/or maneuvers for a single test fuel.

Maneuver

A specified single vehicle operation or change of operating conditions (such as idle, acceleration, or cruise) that constitutes one segment of the driveability driving schedule.

Cruise

Operation at a prescribed constant vehicle speed with a fixed throttle position on a level road.

Wide Open Throttle (WOT) Acceleration

"Floorboard" acceleration through the gears from prescribed starting speed. Rate at which throttle is depressed is to be as fast as possible without producing tire squeal or appreciable slippage.

Part-Throttle (PT) Acceleration

An acceleration made at any defined throttle position, or consistent change in throttle position, less than WOT. Several PT accelerations are used. They are:

1. Light Throttle (Lt. Th) - All light-throttle accelerations are begun by opening the throttle to an initial manifold vacuum and maintaining *constant throttle position* throughout the remainder of the acceleration. The vacuum selected is the vacuum setting necessary to reach 25 mph in 9 seconds. The vacuum setting should be determined when the vehicle is cold. The vacuum setting is posted in each vehicle.

2. Moderate Throttle (Md. Th) - Moderate-throttle accelerations are begun by immediately depressing the throttle to the position that gives the pre-specified vacuum and maintaining a *constant throttle position* throughout the acceleration. The moderate-throttle vacuum setting is determined by taking the mean of the vacuum observed during WOT acceleration and the vacuum prescribed for light-throttle acceleration. This setting is to be posted in the vehicle.

3. Crowd - An acceleration made at a constant intake manifold vacuum. To maintain *constant vacuum*, the throttle-opening must be continually increased with increasing engine speed. Crowd accelerations are performed at the same vacuum prescribed for the light-throttle acceleration.

4. Detent - All detent accelerations are begun by opening the throttle to just above the downshift position as indicated by transmission shift characteristic curves. Manifold vacuum corresponding to this point at 25 mph is posted in each vehicle. *Constant throttle position* is maintained to 35 mph in this maneuver.

Malfunctions

1. Stall

   Any occasion during a test when the engine stops with the ignition on. Three types of stall, indicated by location on the data sheet, are:

   a. Stall; idle - Any stall experienced when the vehicle is not in motion, or when a maneuver is not being attempted.

   b. Stall; maneuvering - Any stall which occurs during a prescribed maneuver or attempt to maneuver.

   c. Stall; decelerating - Any stall which occurs while decelerating between maneuvers.

2. Idle Roughness

   An evaluation of the idle quality or degree of smoothness while the engine is idling. Idle quality may be rated using any means available to the lay customer. The rating should be determined by the worst idle quality experienced during the idle period.

3. Backfire

   An explosion in the induction or exhaust system.

4. Hesitation

   A temporary lack of vehicle response to opening of the throttle.

5. Stumble

   A short, sharp reduction in acceleration after the vehicle is in motion.

6. Surge

   Cyclic power fluctuations.

Malfunction Severity Ratings

The number of stalls encountered during any maneuver are to be listed in the appropriate data sheet column. Each of the other malfunctions must be rated by severity and the letter designation entered on the data sheet. The following definitions of severity are to be applied in making such ratings.

1. Trace (T) - A level of malfunction severity that is just discernible to a test driver but not to most laymen.

2. Moderate (M) - A level of malfunction severity that is probably noticeable to the average laymen.

3. Heavy (H) - A level of malfunction severity that is pronounced and obvious to both test driver and layman.

4. Extreme (E) - A level of malfunction severity more severe than "Heavy" at which the lay driver would not have continued the maneuver, but taken some other action.

Enter a T, M, H, or E in the appropriate data block to indicate both the occurrence of the malfunction and its severity. More than one type of malfunction may be recorded on each line. If no malfunctions occur, enter a dash (-) to indicated that the maneuver was performed and operation was satisfactory during the maneuver.

DEMERIT CALCULATION SYSTEM

A numerical value for driveability during the CRC test is obtained by assigning demerits to operating malfunctions as shown. Depending upon the type of malfunction, demerits are assigned in various ways. Demerits for poor starting are obtained by subtracting one second from the measured starting time and multiplying by 5. The number of stalls which occur during idle as well as during driving maneuvers are counted separately and assigned demerits as shown. The multiplying x factors of 7, 28, 50, and 100 for idle and maneuvering stalls account for the fact that stalls are very undesirable, especially during car maneuvers. A maximum of three total Idle Park stalls and No-Starts are permitted.

Other malfunctions, such as hesitation, stumble, surge, idle roughness, and backfire, are rated subjectively by the driver on a scale of trace, moderate, heavy, or extreme. For these malfunctions, a certain number of demerits is assigned to each of the subjective ratings. Since all malfunctions are not of equal importance, however, the demerits are multiplied by the weighting factors shown to yield weighted demerits.

Finally, weighted demerits, demerits for stalls, and demerits for poor starting are summed to obtain total weighted demerits (TWD), which are used as an indication of driveability during the test. As driveability deteriorates, TWD increases.

A restriction is applied in the totaling of demerits to insure that a stall results in the highest possible number of demerits within a given maneuver. When more than one malfunction occurs during a maneuver, demerits are counted for only the malfunction which had the largest number of weighted demerits.

When all the factors are multiplied together the following chart of demerit levels is generated.

Demerit levels for: Hesitation/Stumble/Surge/Backfire/Stall

Maneuver	Stall	Extreme	Heavy	Medium	Trace	
		Clear				
Light Throttle	50	16	8	4	2	0
Medium Throttle	100	32	16	8	4	0
WOT	100	32	16	8	4	0
Detent	50	16	8	4	2	0
Crowd	50	16	8	4	2	0

For Idle Roughness

Extreme	Heavy	Medium	Trace	Clear
8	4	2	1	0

<u>For Idle Stalls</u>

Idle-in- Park | Starting-in-Drive | Other Idle (after moderate throttle or at end of test)

7 each | 28 | 7

For Starting

No Start | Slow Start|

25 each | t-1*5

The Start time, t, is in seconds.

Only the results (start, start + stall, no-start) of the first three starting attempts in park count toward demerits.

Only the first stall in drive prior to maneuvering counts toward demerits

Only the first stall in each maneuver, or in each idle subsequent to the start of the maneuver is counted toward demerits.

Only the highest weighted demerit score from each maneuver is counted.

CRC Driveability Data Sheet

Run No.	Car	Fuel	Rater	Date	Time	Temperatures Soak	Temperatures Run	Odometer

Starting time, Sec.

Initial	Restart 1	Restart 2	Idle Park Ruf Stls	Idle Drive Ruf Stls

0.0 0-15 LT TH	0-15 LT TH	0.1 0-20 WOT	0.2 0-15 LT TH	0-15 LT TH	0.3 10-20 LT TH	0.4 0-20 MD TH
HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C

0.5 Idle Dr.
Ruf Stls

0.5 0-15 LT TH	0-15 LT TH	0.6 0-20 WOT	0.7 0-15 LT TH	0-15 LT TH	0.8 10-20 LT TH	0.9 0-20 MD TH
HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C	HS B ET S K A D S M G F C C

0.0 Idle Dr.	0.0 0-45 Crowd	0.4 25-35 Detent	0.5 Idle Dr.	Idle Dr.
	HS B	HS B	5 sec.	30 sec.

Ruf Stls

E T S K A D
S M G F C C

E T S K A D
S M G F C C

Ruf Stls

Ruf Stls

FUELING AND DEFUELING PROCEDURE
Conventional Vehicles

VEHICLE PREPARATION

Used test fuel from the vehicle is drained just before the fuel rail. The fuel line is disconnected at the OEM quick-disconnect to the fuel rail, and a Hansen fitting with hose is inserted between the fuel line and the fuel rail. During defueling, a tee is inserted between the two fittings, with one end of the tee leading to the "slop" fuel drum.

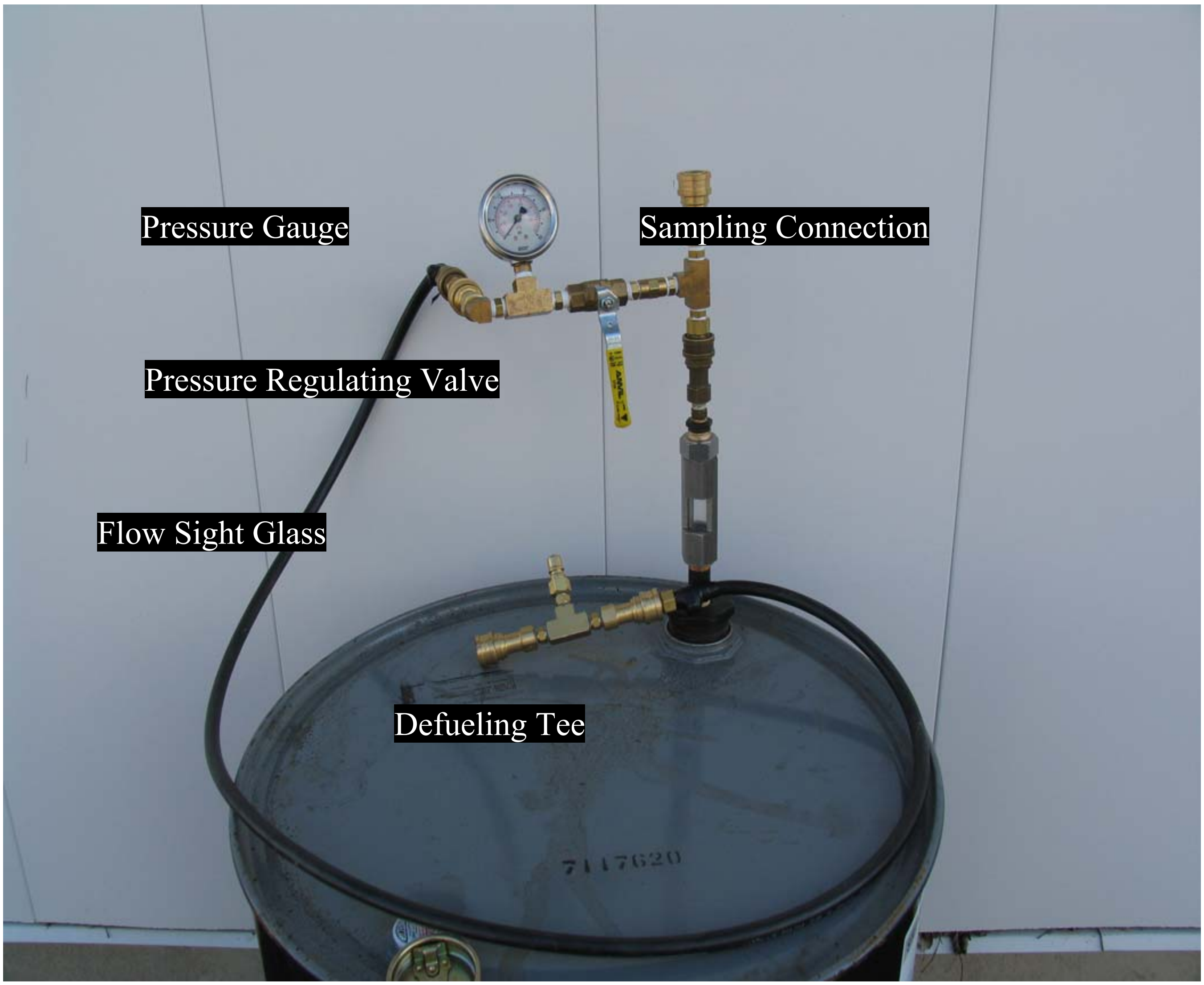
The next step in vehicle preparation is to install voltmeter leads to either the throttle-position-sensor (TPS) or the accelerator pedal, whichever is appropriate. The wires are routed into the passenger compartment of the vehicle to allow the rater to attach a voltmeter during testing. These wires should be long enough to allow either the rater or the observer to be able to read the voltmeter.

DEFUELING PROCEDURE

The fuel is drained into a "slop" drum. This draining system is a closed system, and requires the vehicle engine to be running during the draining procedure. The large bung of the "slop" drum is removed and replaced with a bung that has a two-foot stainless steel tube welded through it. The top of the tube has a Swedgelock fitting on it which attaches to a Hansen coupler. Atop the coupler is an apparatus which has a pressure gauge, a regulating valve, and a sight glass, along with an extra Hansen fitting to obtain fuel samples. During defueling, this apparatus is connected to the vehicle's fuel line via the tee inserted as described above.

The small bung of the drum is removed and replaced by a bung with a float arrangement fabricated to indicate when the drum is full. This float arrangement has corks mounted on a rod on the underside of the small bung and a flag mounted on the same rod on the top-side of the small bung. As the fuel level in the drum rises, it pushes the corks up, which in turn pushes the flag up. This notifies the defueling personnel that the drum is full and must be changed.

Following is the procedure for draining and flushing the fuel system:


Pressure Gauge
Sampling Connection
Pressure Regulating Valve
Flow Sight Glass
Defueling Tee

<u>FUEL TANK FLUSHING PROCEDURE – *Conventional Vehicles*</u>

Precautionary notes:

1. ***When draining the vehicle fuel tank, the vehicle engine is running, and the pressure to keep the engine running is regulated at the "slop" drum.***
2. ***Some vehicles require that the accelerator pedal be depressed to keep the engine running. An adjustable rod may be used to do this.***
3. ***Use a UL approved ground strap to ground defueling equipment to the fuel injector rail or fuel line fitting for all fuel draining.***

Flushing Procedure:

1. When a vehicle comes in from testing, the defueling apparatus is connected to the vehicle, and the engine is started so the fuel will flow. The flow to the "slop" drum is controlled by the regulating valve.

2. If a fuel sample is required, allow fuel to be drained for one minute through the draining apparatus on the "slop" drum before taking a fuel sample. Fuel from the vehicle should also be drained through the sampling line to ensure that the sample is not contaminated. A sample can then be taken from the sampling port on the draining apparatus.

3. Completely drain the vehicle's fuel tank, at which time the engine will shut down.

4. Remove the fill cap, add four gallons of the next test fuel to the vehicle fuel tank, and replace the fill cap.

5. Start and idle the vehicle for a total of 2 minutes.

6. Completely drain the fuel tank through the draining apparatus, at which time the engine will shut down.

7. Remove the fill cap, add four gallons of the next test fuel to the vehicle fuel tank, and replace the fill cap.

8. Start and idle the vehicle for a total of 2 minutes. From approximately 15 seconds into the idle for a period of 30 seconds, rock the rear end of the vehicle from side to side. This task will require one person on each side of the vehicle.

9. Completely drain the fuel tank through the draining apparatus, at which time the engine will shut down.

10. When the vehicle is ready, remove the fill cap, add four or five gallons as required of the test fuel to the vehicle fuel tank, and replace the fill cap.

FUELING PROCEDURE

The vehicles are fueled out of a 55-gallon drum of test fuel, using a portable dispensing pump. This dispensing pump has been fabricated by mounting the motor and gauge on a hand-truck. The dispensing pump is service station quality. The large bung of the drum is removed, and a steel pipe is inserted into the drum. The top of the pipe has the male side of the Hansen coupler on it and is connected to the female side of the coupler on the dispensing pump inlet hose. The small bung is loosened just enough to keep the drum from collapsing while fuel is being pumped out of it.

Ground straps are used throughout the fueling and defueling process to avoid static electricity.

FFV Fuel Tank Flushing Procedure for CRC Driveability Programs

Precautionary notes:

4. ***Use a UL approved ground strap to ground defueling equipment to the fuel injector rail or fuel line fitting for all fuel draining.***
5. ***This procedure should be used for driveability testing only; it is not appropriate for emissions testing.***

Flushing procedure for fuels with nearly constant ethanol content (E0 – E10 and E70 – E85):

1. Obtain a fuel sample (if needed) by hooking up the chilled sampling system and drawing the required fuel sample through the Schrader valve or adapter line fitting with the engine on. Once the sample has been obtained, shut off the engine.
2. Remove the sampling system and install the drain line. Clamp the drain line about halfway closed to keep adequate pressure in the fuel rail during draining. Remove the fill cap. Start the engine and drain the fuel tank through the Schrader valve or adapter line fitting. Once the low fuel light comes on, continue engine operation for 30 seconds, and then turn off the engine. Do not allow the vehicle to completely run out of fuel.
3. Add four gallons of the next test fuel to the vehicle fuel tank.
4. Start the engine and after 15 seconds, rock the vehicle from side to side for about 30 seconds while the fuel drains. Once the low fuel light comes on, continue engine operation for 30 seconds, and then turn off the engine. Do not allow the vehicle to completely run out of fuel.
5. Add another four gallons of fuel to the vehicle fuel tank.
6. Start the engine and after 15 seconds, rock the vehicle from side to side for about 30 seconds while the fuel drains. Once the low fuel light comes on, continue engine operation for 30 seconds, and then turn off the engine. Do not allow the vehicle to completely run out of fuel.
7. Remove the drain line, and replace the fill cap.
8. Start the engine and **DRIVE** the vehicle at least 10 meters.
9. Add another four gallons of fuel to the vehicle fuel tank, and replace the fill cap.
10. Start the engine and idle for 15 seconds. Drive the vehicle for 10 miles using the warm up cycle. Then park the vehicle for its overnight soak period.

<u>Flushing procedure when switching from gasoline (E0 – E10) to high alcohol blends (E70 – E85) or vice versa</u>

1. Obtain a fuel sample (if needed) by hooking up the chilled sampling system and drawing the required fuel sample through the Schrader valve or adapter line fitting with the engine running. Once the sample has been obtained, shut off the engine.
2. Remove the sampling system and install the drain line. Clamp the drain line about halfway closed to keep adequate pressure in the fuel rail during draining. Remove the fill cap. Start the engine and drain the fuel tank through the Schrader valve or adapter line fitting. Once the low fuel light comes on, continue engine operation for 30 seconds, and then turn off the engine. <u>Do not allow the vehicle to completely run out of fuel.</u>
3. Remove the drain line, and replace the fill cap.
4. Start the engine and **DRIVE** the vehicle at least 10 meters.
5. Add four gallons of the next test fuel to the vehicle fuel tank. Replace the fill cap.
6. Start the engine and idle for 15 seconds. Drive the vehicle for 10 miles using the warm up cycle. Return the vehicle to the de-fueling area, and shut off the engine.
7. Attach the drain line and remove the fill cap. Clamp the drain line about halfway closed to keep adequate pressure in the fuel rail during draining. Drain the fuel tank through the Schrader valve or adapter line fitting with the engine on. Once the low fuel light comes on, continue engine operation for 30 seconds, and then turn off the engine. <u>Do not allow the vehicle to completely run out of fuel.</u>
8. Add another four gallons of fuel to the vehicle fuel tank.
9. Start the engine and after 15 seconds, rock the vehicle from side to side for about 30 seconds while the fuel drains. Once the low fuel light comes on, continue engine operation for 30 seconds, and then turn off the engine. <u>Do not allow the vehicle to completely run out of fuel.</u>
10. Add another four gallons of fuel to the vehicle fuel tank.
11. Start the engine and after 15 seconds, rock the vehicle from side to side for about 30 seconds while the fuel drains. Once the low fuel light comes on, continue engine operation for 30 seconds, and then turn off the engine. <u>Do not allow the vehicle to completely run out of fuel.</u>
12. Remove the drain line, and replace the fill cap.
13. Start the engine and **DRIVE** the vehicle at least 10 meters.
14. Add another four gallons of fuel to the vehicle fuel tank. Replace the fill cap.
15. Start the engine and idle for 15 seconds. Drive the vehicle for 10 miles using the warm up cycle. Then park the vehicle for its overnight soak period.

APPENDIX E

INDIVIDUAL LABORATORY FUEL INSPECTIONS

AND ON-SITE SAMPLE INSPECTIONS

Table E-1
CRC 2008 Volatility Program Fuel Inspections

Fuel Description			1						2					
Property	**Method**	**Units**	E85-4.7						E85-5.7					
Laboratory			A	B	C	D	E	Average	A	B	C	D	E	Average
Gravity	ASTM D4052	°API	49.2	49.2	48.9	52.3	49.1	49.7	49.9	49.9	49.7	52.2	49.8	50.3
Relative Density		60/60°F	0.7830	0.7830	0.7844	0.7699	0.7835	0.7807	0.7800	0.7800	0.7809	0.7704	0.7805	0.7783
Uncorrected Ethanol	ASTM D5501	wt %			83.79	84.67		84.23			84.48	84.93		84.71
Ethanol	ASTM D5501	vol %	82.40	81.10	82.41	82.50	83.40	82.36	82.30	81.50	82.67	82.81	82.80	82.42
Methanol	ASTM D5501	vol %	0	0	0.00	0		0.0	0.00	0.00	0.00			0.0
Ethanol	ASTM D4815	wt %	-	-	-	-	-	-	-	-	-	-	-	-
Ethanol	ASTM D4815	vol %	-	-	-	-	-	-	-	-	-	-	-	-
Water	ASTM E203	wt. %		0.5222	0.5800	0.5280	0.5530	0.5458		0.5114	0.5800	0.5217	0.5120	0.5313
Water	ASTM E203	vol %	0.4500	0.4089	0.4550	0.4070		0.4302	0.4540	0.3989	0.4526	0.4020		0.4269
Estimated Hydrocarbon		vol %	17.15	18.49	17.13	17.09		17.47	17.25	18.10	16.88	16.79		17.25
DVPE	ASTM D5191	psi	4.61	4.66	4.61	4.89	4.63	4.68	5.74	5.70	5.70	5.80	5.64	5.72
Distillation	ASTM D86													
Initial Boiling Point		°F	134.6	126.3	139.4	132	134.8	133.4	124.0	113.9	124.8	115	122.2	120.0
5% Evaporated		°F	156.9	152.6	159.2	158.4	154.8	156.4	143.1	143.4	147.5	141.7	146.7	144.5
10% Evaporated		°F	162.9	160.5	164.4	163.5	162.0	162.7	156.4	155.3	158.9	157.2	157.3	157.0
20% Evaporated		°F	168.1	167.0	168.8	168.5	167.2	167.9	166.6	165.3	167.5	167	166.1	166.5
30% Evaporated		°F	170.1	169.3	170.6	170.5	169.2	169.9	169.7	168.9	170.2	170.1	169.2	169.6
40% Evaporated		°F	171.1	170.4	171.5	171.3	170.1	170.9	171.0	170.2	171.5	171.3	170.4	170.9
50% Evaporated		°F	171.5	171.1	171.8	171.8	170.6	171.4	171.5	170.7	172.0	171.8	171.0	171.4
60% Evaporated		°F	171.9	171.5	172.2	172.2	170.8	171.7	171.9	171.1	172.2	172.1	171.1	171.7
70% Evaporated		°F	172.2	171.6	172.4	172.5	171.1	172.0	172.0	171.5	172.4	172.3	171.5	171.9
80% Evaporated		°F	172.6	172.0	172.5	172.8	171.5	172.3	172.4	171.6	172.5	172.6	171.7	172.2
90% Evaporated		°F	173.1	172.5	173.1	173.4	172.0	172.8	172.8	172.0	172.9	173	172.0	172.5
95% Evaporated		°F	174.0	173.3	174	174.5	173.5	173.9	173.3	172.5	173.1	173.6	172.9	173.1
End Point		°F	206.0	177.0	175.4	294.4	316.0	233.8	207.5	176.3	174.2	176.6	230.4	193.0
Recovery		vol %	99.4	97.5	97.7	98.6	98.8	98.4	98.1	97.8	97.3	98.1	98.3	97.9
Residue		vol %	0.6	1.0	2	1	0.9	1.1	0.5	0.5	1.2	0.5	0.6	0.7
Loss		vol %	0.0	1.5	0.3	0.4	0.3	0.5	1.4	1.7	1.5	1.4	1.1	1.4
Benzene	DHA	vol %			0.12			0.12			0.14			0.14
Ethanol	DHA	vol %			84.55			84.55			85.59			85.59
Methanol	DHA	vol %			0			0.0			0			0.0
Hydrocarbon	DHA	vol %			15.43			15.43			14.39			14.39
Aromatics	DHA	vol %			3.54			3.54			2.39			2.39
Olefins	DHA	vol %			0.76			0.76			0.40			0.40
Saturates	DHA	vol %			11.14			11.1			11.60			11.6

Table E-1 Continued
CRC 2008 Volatility Program Fuel Inspections

Fuel Description			3						4					
Property	**Method**	**Units**	E85-7.0						E20-7.1					
Laboratory			**A**	**B**	**C**	**D**	**E**	**Average**	**A**	**B**	**C**	**D**	**E**	**Average**
Gravity	ASTM D4052	°API	50.6	50.7	50.4	53.4	50.6	51.1	59.4	59.3	59.1	61.4	59.3	59.7
Relative Density		60/60°F	0.7770	0.7765	0.7779	0.7655	0.7770	0.7748	0.7413	0.7418	0.7424	0.7334	0.7416	0.7401
Uncorrected Ethanol	ASTM D5501	wt %			85.57	85.86		85.7	-	-	-	-	-	-
Ethanol	ASTM D5501	vol %	82.30	81.70	83.35	83.18	83.8	82.9	-	-	-	-	-	-
Methanol	ASTM D5501	vol %	0.00	0.00	0.00	0.00		0.0	-	-	-	-	-	-
Ethanol	ASTM D4815	wt %	-	-	-	-	-	-			20.00	20.84		
Ethanol	ASTM D4815	vol %	-	-	-	-	-	-	19.00	18.95	18.70	19.35	19.24	19.0
Water	ASTM E203	wt. %		0.5168	0.6100	0.5260	0.5230	0.5440				0.1340	-	0.1340
Water	ASTM E203	vol %	0.4780	0.4013	0.4740	0.4030		0.4391	0.1070			0.0982		0.1026
Estimated Hydrocarbon		vol %	17.22	17.90	16.17	16.41		16.93						
DVPE	ASTM D5191	psi	7.05	7.04	6.90	7.09	6.92	7.00	7.10	7.08	7.09	7.25	7.05	7.11
Distillation	ASTM D86													
Initial Boiling Point		°F	113.0	116.0	114.0	113.9	111.0	113.6	112.5	100.9	117.1	109.5	110.1	110.0
5% Evaporated		°F	138.7	148.6	138.7	150.2	136.2	142.5	130.8	127.4	135.1	131.4	130.6	131.1
10% Evaporated		°F	152.6	154.7	152.9	158.6	150.8	153.9	134.6	134.0	139.6	135.9	134.1	135.6
20% Evaporated		°F	165.2	162.1	166.4	164.3	164.7	164.5	141.8	140.1	144.5	142.3	140.5	141.8
30% Evaporated		°F	169.3	167.1	170.0	167.7	169.0	168.6	148.5	146.8	148.4	148.8	147.2	147.9
40% Evaporated		°F	170.8	169.5	171.3	170.2	170.4	170.4	154.4	153.3	155.6	154.7	153.3	154.3
50% Evaporated		°F	171.3	170.7	171.8	171.3	171.0	171.2	159.8	158.5	159.9	159.5	158.2	159.2
60% Evaporated		°F	171.7	171.1	172.2	171.8	171.1	171.6	163.8	162.8	167.9	163.7	162.7	164.2
70% Evaporated		°F	171.9	171.3	172.2	172.1	171.3	171.8	230.5	224.2	225.5	230.3	231.4	228.4
80% Evaporated		°F	171.9	171.5	172.4	172.3	171.5	171.9	255.2	254.6	258.4	255.6	255.2	255.8
90% Evaporated		°F	172.2	171.8	172.5	172.5	171.7	172.1	297.0	290.6	297.3	295.7	293.2	294.8
95% Evaporated		°F	172.6	172.2	172.7	172.9	172.0	172.5	330.4	322.8	321.4	332.4	332.8	328.0
End Point		°F	186.1	215.9	181.4	187.9	195.8	193.4	379.9	378.3	382.8	380	386.1	381.4
Recovery		vol %	98.6	98.7	97.5	98.5	98.3	98.3	98.5	96.3	97.6	97.8	98.6	97.8
Residue		vol %	0.2	<0.1	0.5	0.2	0.2	0.3	1.1	0.8	1.4	1.2	0.8	1.1
Loss		vol %	1.2	1.3	2.0	1.3	1.5	1.5	0.4	2.9	1.0	1	0.6	1.2
Benzene	DHA	vol %			0.26			0.26			0.58			0.58
Ethanol	DHA	vol %			87.34			87.34			19.60			19.60
Methanol	DHA	vol %			0.00			0.0			0.00			0.0
Hydrocarbon	DHA	vol %			12.65			12.65			80.40			80.40
Aromatics	DHA	vol %			1.16			1.16			17.82			17.82
Olefins	DHA	vol %			0.14			0.14			3.53			3.53
Saturates	DHA	vol %			11.36			11.4			59.07			59.1

Table E-1 Continued
CRC 2008 Volatility Program Fuel Inspections

Fuel Description			5						6					
Property	Method	Units	E-15-7.1						E15-9.9					
Laboratory			A	B	C	D	E	Average	A	B	C	D	E	Average
Gravity	ASTM D4052	°API	60.2	60.0	59.9	62.2	60.1	60.5	53.8	53.6	53.3	55.8	53.7	54.0
Relative Density		60/60°F	0.7383	0.7389	0.7393	0.7304	0.7385	0.7371	0.7635	0.7644	0.7657	0.7555	0.7640	0.7626
Uncorrected Ethanol	ASTM D5501	wt %	-	-	-	-	-	-	-	-	-	-	-	-
Ethanol	ASTM D5501	vol %	-	-	-	-	-	-	-	-	-	-	-	-
Methanol	ASTM D5501	vol %	-	-	-	-	-	-	-	-	-	-	-	-
Ethanol	ASTM D4815	wt %			15.30	15.61					14.80	15.35		
Ethanol	ASTM D4815	vol %	14.3	15.38	14.25	14.43	14.18	14.5	14.7	15.39	14.27	14.68	14.29	14.7
Water	ASTM E203	wt. %				0.1031	-	0.1031				0.0984	-	0.0984
Water	ASTM E203	vol %	0.0830			0.0753		0.0792	0.0817			0.0743		0.0780
Estimated Hydrocarbon		vol %												
DVPE	ASTM D5191	psi	7.00	7.09	7.17	7.31	7.09	7.13	9.88	9.96	9.88	10.01	9.91	9.93
Distillation	ASTM D86													
Initial Boiling Point		°F	111.0	99.5	113.0	105.7	109.9	107.8	96.1	89.0	96.6	91.6	100.6	94.8
5% Evaporated		°F	130.3	127.0	130.1	130.1	129.2	129.3	113.9	111.3	120.3	120	117.5	116.6
10% Evaporated		°F	134.1	132.9	134.2	134.1	132.8	133.6	125.4	125.0	130.8	129.4	127.2	127.6
20% Evaporated		°F	140.9	138.7	140.5	141.3	139.3	140.1	142.3	141.6	145.5	145.2	142.7	143.5
30% Evaporated		°F	147.2	145.4	146.8	147.4	145.4	146.4	153.7	151.7	155.3	154.4	153.5	153.7
40% Evaporated		°F	153.0	151.3	153.1	153.2	151.5	152.4	160.5	158.7	161.4	160.8	160.7	160.4
50% Evaporated		°F	158.5	156.9	158.0	158.6	156.7	157.7	169.7	166.2	171.3	170.9	172.4	170.1
60% Evaporated		°F	208.0	198.1	204.6	206.8	206.2	204.7	222.4	221.1	228.2	224.2	225.9	224.4
70% Evaporated		°F	235.6	234.5	236.3	236.6	235.6	235.7	238.8	238.6	240.8	240	238.6	239.4
80% Evaporated		°F	259.3	257.1	261.8	262.2	259.5	260.0	255.2	254.3	258.9	256.5	257.9	256.6
90% Evaporated		°F	299.8	294.8	300.2	300	299.3	298.8	298.0	293.7	309.0	300.7	302.5	300.8
95% Evaporated		°F	332.4	324.3	334.4	333.3	334.4	331.8	338.2	332.2	350.4	341.4	344.7	341.4
End Point		°F	379.9	383.1	384.2	374.9	388.0	382.0	389.3	395.6	397.5	394.4	401.0	395.6
Recovery		vol %	98.8	98.2	97.4	97.8	98.1	98.1	96.9	96.4	97.6	98	97.2	97.2
Residue		vol %	1.0	1.0	1.4	1.3	0.8	1.1	1.0	0.9	1.4	1.2	1.0	1.1
Loss		vol %	0.2	0.8	1.2	0.9	1.1	0.8	2.1	2.7	1.0	0.8	1.8	1.7
Benzene	DHA	vol %			0.6100			0.6100			1.1000			1.1000
Ethanol	DHA	vol %			14.6300			14.6300			13.9400			13.9400
Methanol	DHA	vol %			0.00			0.0			0.00			0.0
Hydrocarbon	DHA	vol %			85.37			85.37			86.06			86.06
Aromatics	DHA	vol %			6.61			6.61			36.12			36.12
Olefins	DHA	vol %			3.79			3.79			2.94			2.94
Saturates	DHA	vol %			63.00			63.00			46.97			46.97

Table E-1 Continued
CRC 2008 Volatility Program Fuel Inspections

Fuel Description			7						8					
Property	**Method**	**Units**	E0-5.9						E0-8.1					
Laboratory			**A**	**B**	**C**	**D**	**E**	**Average**	**A**	**B**	**C**	**D**	**E**	**Average**
Gravity	ASTM D4052	°API	62.2	62.0	61.9	64.3	62.0	62.5	56.9	56.8	56.3	58.8	56.8	57.1
Relative Density		60/60°F	0.7306	0.7312	0.7316	0.7226	0.7313	0.7295	0.7511	0.7514	0.7535	0.7437	0.7515	0.7502
Uncorrected Ethanol	ASTM D5501	wt %	-	-	-	-	-	-	-	-	-	-	-	-
Ethanol	ASTM D5501	vol %	-	-	-	-	-	-	-	-	-	-	-	-
Methanol	ASTM D5501	vol %	-	-	-	-	-	-	-	-	-	-	-	-
Ethanol	ASTM D4815	wt %			0	0					0	0		
Ethanol	ASTM D4815	vol %	0	0	0	0	0	0.0	0	0	0	0	0	0.0
Water	ASTM E203	wt. %				0.0034	-	0.0034				0.0051	-	0.0051
Water	ASTM E203	vol %	0.0660			0.0025		0.0342	0.0101			0.0038		0.0069
Estimated Hydrocarbon		vol %												
DVPE	ASTM D5191	psi	5.74	5.79	5.91	5.99	6.18	5.92	8.00	8.09	8.06	8.14	8.15	8.09
Distillation	ASTM D86													
Initial Boiling Point		°F	111.7	100.2	108.6	108.8	108.9	107.6	95.9	89.7	95.7	94.7	98.6	94.9
5% Evaporated		°F	137.7	134.9	141.8	138.5	138.4	138.3	123.3	94.8	134.9	124.8	122.7	120.1
10% Evaporated		°F	145.4	145.7	150.6	148.8	146.7	147.4	137.5	128.3	147.7	139.6	137.3	138.1
20% Evaporated		°F	158.5	157.6	161.7	161.2	159.1	159.6	160.7	155.3	169.3	161.6	160.0	161.4
30% Evaporated		°F	173.1	171.6	176.7	175.4	172.6	173.9	182.3	177.2	189.5	182.8	181.2	182.6
40% Evaporated		°F	189.9	188.0	193.2	191.2	189.1	190.3	201.7	197.9	207.3	200.5	200.7	201.6
50% Evaporated		°F	208.4	205.8	208.7	208.2	207.1	207.6	217.8	215.6	221.9	217.1	217.0	217.9
60% Evaporated		°F	227.3	224.9	228.2	225.7	226.0	226.4	231.4	230.1	234.5	231.4	231.1	231.7
70% Evaporated		°F	245.7	244.0	247.1	243.8	245.1	245.1	244.9	243.8	248	245.3	245.3	245.5
80% Evaporated		°F	269.6	266.0	271.0	267.1	268.0	268.3	264.7	262.4	270.5	264.9	265.6	265.6
90% Evaporated		°F	308.3	303.2	311.5	306.4	307.8	307.4	309.6	302.7	318.3	309	309.2	309.8
95% Evaporated		°F	241.3	330.4	348.4	338.6	338.7	319.5	342.3		359	344.8	344.8	347.7
End Point		°F	387.0	391.6	395.4	381.9	390.6	389.3	400.1	397.9	392.7	393.5	403.7	397.6
Recovery		vol %	97.7	99.1	99.2	98.3	98.3	98.5	97.9	94.5	98.9	97.7	97.3	97.3
Residue		vol %	1.2	0.8	0.2	1.1	0.7	0.8	0.8	0.8	0	1.2	0.9	0.7
Loss		vol %	1.1	0.1	0.6	0.6	1.0	0.7	1.3	4.7	1.1	1.1	1.8	2.0
Benzene	DHA	vol %			0.71			0.71			1.12			1.12
Ethanol	DHA	vol %			0.00			0.00			0.00			0.00
Methanol	DHA	vol %			0.00			0.0			0.00			0.0
Hydrocarbon	DHA	vol %			100.00			100.00			100.00			100.00
Aromatics	DHA	vol %			21.56			21.56			35.80			35.80
Olefins	DHA	vol %			4.52			4.52			3.65			3.65
Saturates	DHA	vol %			73.92			73.92			60.55			60.55

Table E-2
Test Fuel Drum Inspections

Property	Test Method	Sample Date	798657 2/8/2008	798658 2/11/2008	798641 2/19/2008	798659 2/11/2008	798636 2/16/2008	798638 2/18/2008	798653 2/14/2008	798624 2/11/2008	798660 2/11/2008
Description			Fuel 1, E85-4.7	Fuel 2, E85-5.7	Fuel #3, E85-7.0	Fuel 4, E20-7.1	Fuel #5, E15 7.1	Fuel #6, E15-9.9	Fuel 7, E0-5.9	Fuel #8, E0-8.1	Fuel 9, E85-8.5
DVPE	D5191	in psi	4.92	5.74	7.06	7.08	7.09	9.85	6.48	8.05	8.63
API Gravity	D4052s	at 60°F	49.1	49.9	50.6	59.3	60.1	53.7	62.1	56.8	50.9
Relative Density		at 60°F	0.7835	0.7802	0.7769	0.7415	0.7386	0.7641	0.7309	0.7514	0.776
EtOH	D5501	wt%	84.7	85.11	85.15	-	-	-	-	-	83.91
MeOH		wt%	0	0	0	-	-	-	-	-	0
EtOH		vol%	83.58	83.63	83.32	-	-	-	-	-	82.01
MeOH		vol%	0	0	0	-	-	-	-	-	0
EtOH	D5599	Vol%	-	-	-	19.16	14.43	14.35	<0.1	<0.1	-
EtOH		Wt%	-	-	-	20.52	15.51	14.91	<0.1	<0.1	-
Water	D6304	Wt.%	0.5576	0.5655	0.5808	0.1583	0.1217	0.1151	0.0044	0.0061	0.7080
Distillation	D86										
IBP		deg F	-	-	-	108.4	108.2	94.1	108.4	88.3	-
Evap_5		degF	-	-	-	130.5	129.5	118.1	135.9	119.6	-
Evap_10		degF	-	-	-	135.3	134.7	128.9	146	135.9	-
Evap_15		degF	-	-	-	138.3	137.7	137.6	152.6	148.3	-
Evap_20		degF	-	-	-	141.8	141.3	144.7	158.7	159.9	-
Evap_30		degF	-	-	-	148.7	147.6	154.6	173.1	181.8	-
Evap_40		degF	-	-	-	154.7	153.7	161.4	190.1	202.3	-
Evap_50		degF	-	-	-	159.8	159.3	170	208.6	218.8	-
Evap_60		degF	-	-	-	164	204.8	226.4	227.5	233.1	-
Evap_70		degF	-	-	-	228.5	237.8	234.9	246.2	246.7	-
Evap_80		degF	-	-	-	253.4	259.6	257.6	269.7	265.5	-
Evap_90		degF	-	-	-	295.1	299.1	301	308.6	309.1	-
Evap_95		degF	-	-	-	328.9	332.2	340.6	339.7	343.7	-
FBP		degF	-	-	-	377.4	383.5	396.1	391.7	398.2	-
Recovered		%	-	-	-	98.3	97.3	97.5	97.9	97.6	-
Residue		%	-	-	-	0.9	1	0.9	0.9	0.9	-
Loss		%	-	-	-	0.8	1.7	1.6	1.2	1.5	-

Table E-3
Assessment of Flushing Procedure

Tests Sample Number	Date Sampled	Description	D5599 EtOH Vol%	D5599 EtOH Wt%
798634	2/14/2008	Car 1. Tk Drain, Fuel 8	1.69	1.785
798637	2/14/2008	Car 2, Tk Drain, Fuel 8	1.642	1.734
798651	2/14/2008	Car 3, Tk Drain, Fuel 8	1.714	1.81
798627	2/14/2008	Car 4, Tk Drain, Fuel 8	1.303	1.376
798650	2/14/2008	Car 5, Tk Drain, Fuel 8	3.542	3.738
798632	2/14/2008	Car 6, Tk Drain, Fuel 8	1.067	1.128
798655	2/14/2008	Car 7, Tk Drain, Fuel 8	2.274	2.402
798628	2/14/2008	Car 8, Tk Drain, Fuel 8	2.495	2.635
798652	2/14/2008	Car 9, Tk Drain, Fuel 8	0.299	0.316
798629	2/14/2008	Car 10, Tk Drain, Fuel 8	4.685	4.956
798656	2/14/2008	Car 11, Tk Drain, Fuel 8	4.364	4.608
798625	2/14/2008	Car 12, Tk Drain, Fuel 8	3.098	3.272
798649	2/14/2008	Car 14, Tk Drain, Fuel 8	1.564	1.653
798654	2/14/2008	Car 15, Tk Drain, Fuel 8	0.523	0.553
798626	2/14/2008	Car 16, Tk Drain, Fuel 8	0.449	0.475
798635	2/14/2008	Car 17, Tk Drain, Fuel 8	1.296	1.369
798633	2/14/2008	Car 18, Tk Drain, Fuel 8	4.013	4.235
798631	2/14/2008	Car 19, Tk Drain, Fuel 8	4.611	4.866
798630	2/14/2008	Car 20, Tk Drain, Fuel 8	2.526	2.667
798642	2/18/2007	Car 23, Tk Drain, Fuel 8	<0.1	<0.1
798643	2/18/2007	Car 26, Tk Drain, Fuel 8	<0.1	<0.1
798639	2/18/2008	Car 28, Tk Drain, Fuel 8	0.145	0.153
798640	2/18/2008	Car 32, Tk Drain, Fuel 8	0.152	0.161

APPENDIX F

VEHICLE TOTAL WEIGHTED DEMERIT SUMMARY

Table F-1
Vehicle Mean Corrected Total Weighted Demerit Summary

Average run temp = 23˚F

LnTWD LSMean	Fuel							
Car	1	2	3	4	5	6	7	8
1	2.45	3.19	2.71				2.51	3.06
2	3.22	3.17	3.16				2.94	3.20
3	3.49	3.41	3.17				3.18	2.96
4	2.83	2.57	2.31				2.56	2.45
5	4.06	3.40	2.97				3.07	2.50
6	3.39	3.66	3.34				3.23	2.85
7	2.84	2.60	2.25				2.61	2.29
8	3.46	3.90	3.35				3.03	2.61
9	4.58	3.78	3.30				2.73	3.00
10	2.80	2.88	2.62				2.43	2.56
11	4.03	3.60	3.56				2.38	2.29
12	3.97	3.72	3.24				3.61	2.42
13	3.72	4.18	3.19				2.80	3.10
14	3.45	4.08	3.25				3.21	3.76
16	5.48	4.31	3.14				2.10	3.08
17	2.80	3.34	3.08				2.90	3.14
18	3.17	2.95	2.74				2.95	3.13
19	2.93	3.44	2.86				2.81	3.46
20	3.66	3.01	2.94				2.78	2.49
21				3.43	3.88	3.22	3.73	2.93
23				3.21	3.52	3.28	3.67	3.28
26				4.77	4.83	5.03	4.89	5.03
28				5.73	5.32	4.77	5.19	4.74
29				3.22	3.48	3.40	3.22	3.32
32				3.73	3.83	2.95	2.97	2.66

Average run temp = 23˚F

TWD LSMean	Fuel							
Car	1	2	3	4	5	6	7	8
1	11.6	24.3	15.0				12.4	21.4
2	25.1	23.9	23.6				18.9	24.6
3	32.7	30.4	23.8				24.1	19.3
4	17.0	13.0	10.1				13.0	11.6
5	58.1	29.8	19.4				21.5	12.2
6	29.7	38.7	28.2				25.3	17.3
7	17.1	13.4	9.5				13.6	9.8
8	31.7	49.2	28.4				20.6	13.6
9	97.7	43.7	27.2				15.4	20.2
10	16.5	17.8	13.8				11.4	13.0
11	56.2	36.7	35.0				10.8	9.8
12	52.9	41.2	25.4				37.1	11.2
13	41.3	65.2	24.3				16.4	22.3
14	31.4	59.0	25.9				24.8	42.8
16	240.4	74.1	23.1				8.1	21.8
17	16.5	28.3	21.7				18.1	23.1
18	23.8	19.1	15.5				19.2	22.8
19	18.6	31.2	17.4				16.6	31.8
20	38.9	20.3	19.0				16.2	12.1
21				30.9	48.4	24.9	41.8	18.8
23				24.7	33.7	26.5	39.4	26.7
26				118.5	125.2	152.3	132.8	153.2
28				307.3	203.9	118.5	180.1	114.1
29				25.1	32.3	29.9	25.1	27.7
32				41.6	46.0	19.1	19.6	14.2

Table F-1 Continued
Vehicle Mean Corrected Total Weighted Demerit Summary

Average run temp = 33˚F

LnTWD LSMean	Fuel								
Car	1	2	3	4	5	6	7	8	9
1	3.41	2.55	2.84				2.88	2.89	
2	2.99	2.52	2.83				2.98	2.71	
3	3.74	3.48	3.46				2.96	3.49	
4	2.99	2.18	2.25				2.95	2.47	
5	3.92	3.02	3.20				3.16	3.20	
6	3.75	3.30	3.85				3.05	3.22	2.71
7	3.30	2.44	2.02				2.54	2.90	
8	3.59	3.41	3.13				3.15	2.72	3.19
9	3.64	2.90	2.86				2.97	2.88	3.51
10	3.91	2.67	2.56				2.36	2.49	
11	3.32	3.26	3.05				3.14	2.67	3.13
12	4.10	2.54	2.76				3.22	3.22	
13	3.73	3.47	3.52				3.15	3.07	3.49
14	3.89	3.15	3.42				2.97	3.14	3.42
16	4.57	3.69	3.35				3.10	3.04	
17	4.32	3.19	2.97				3.36	2.76	
18	3.49	3.66	2.73				3.44	3.05	
19	2.98	3.30	2.90				3.16	2.70	
20	3.53	3.27	2.74				2.77	2.62	
21				3.29	3.28	3.84	3.74	3.22	
23				3.33	3.37	3.26	3.80	3.55	
26				4.65	4.80	4.63	4.85	4.18	
28				4.76	4.76	4.14	4.74	4.28	
29				3.12	3.27	3.64	3.39	3.35	
32				3.04	3.42	3.41	3.18	3.19	

Average run temp = 33˚F

TWD LSMean	Fuel								
Car	1	2	3	4	5	6	7	8	9
1	30.3	12.8	17.0				17.9	17.9	
2	19.9	12.5	17.0				19.8	15.0	
3	42.0	32.5	31.9				19.2	32.8	
4	19.8	8.9	9.5				19.2	11.8	
5	50.5	20.6	24.4				23.6	24.6	
6	42.6	27.0	47.2				21.0	24.9	15.0
7	27.1	11.4	7.5				12.7	18.1	
8	36.2	30.2	22.9				23.3	15.2	24.4
9	38.2	18.1	17.5				19.5	17.8	33.4
10	49.9	14.4	12.9				10.6	12.0	
11	27.5	25.9	21.2				23.2	14.5	22.9
12	60.3	12.7	15.7				25.0	25.0	
13	41.5	32.1	33.9				23.4	21.5	32.8
14	48.8	23.2	30.4				19.6	23.1	30.5
16	96.6	40.1	28.6				22.1	20.8	
17	75.0	24.2	19.4				28.9	15.7	
18	32.7	38.8	15.3				31.1	21.1	
19	19.8	27.0	18.3				23.5	14.9	
20	34.1	26.2	15.4				16.0	13.8	
21				27.0	26.7	46.4	42.1	25.1	
23				27.9	29.2	26.1	44.7	34.9	
26				104.3	122.0	102.8	128.3	65.5	
28				116.4	117.2	62.5	114.4	72.5	
29				22.8	26.3	38.3	29.7	28.4	
32				20.8	30.5	30.2	24.1	24.3	

Table F-1 Continued
Vehicle Mean Corrected Total Weighted Demerit Summary

Average run temp = 47˚F

LnTWD LSMean	Fuel							
Car	1	2	3	4	5	6	7	8
1		2.67	3.57				2.74	
2		3.43	3.56				2.77	
3	3.47	2.44	3.97				2.89	3.33
4		2.30	2.44				2.94	
5	4.20	3.58	3.47				3.11	3.28
6	3.75	3.40	3.70				2.53	2.67
7		2.48	2.77				2.30	
8	2.71	3.51	2.86				2.67	3.09
9	3.18	3.45	3.61				2.35	3.31
10	3.30	3.40	2.80				2.89	2.60
11	3.99	3.82	4.32				2.56	3.69
12		3.58	3.82				3.47	
13	3.69	3.62	3.07				3.07	3.50
14	3.71	4.09	3.75				3.54	3.40
16	4.44	3.84	3.45				3.07	3.31
17	3.22	2.97	3.18				2.80	3.00
18	3.61	3.28	3.04				3.16	3.40
19		2.67	2.92				2.56	
20			2.67				2.56	
21				3.80	3.16	3.71	3.40	3.33
23				3.09	3.16	3.37	3.22	3.33
26				4.09	4.11	3.85	4.16	3.74
28				4.30	4.09	5.01	4.06	3.90
29				3.47		3.30	3.09	3.35
32				3.04	3.04	3.28	2.64	2.80

Average run temp = 47˚F

TWD LSMean	Fuel							
Car	1	2	3	4	5	6	7	8
1		14.5	35.5				15.5	
2		31.0	35.0				16.0	
3	32.0	11.5	53.0				18.0	28.0
4		10.0	11.5				19.0	
5	67.0	36.0	32.0				22.5	26.5
6	42.5	30.0	40.5				12.5	14.5
7		12.0	16.0				10.0	
8	15.0	33.5	17.5				14.5	22.0
9	24.0	31.5	37.0				10.5	27.5
10	27.0	30.0	16.5				18.0	13.5
11	54.0	45.5	75.5				13.0	40.0
12		36.0	45.5				32.0	
13	40.0	37.5	21.5				21.5	33.0
14	41.0	59.5	42.5				34.5	30.0
16	85.0	46.5	31.5				21.5	27.5
17	25.0	19.5	24.0				16.5	20.0
18	37.0	26.5	21.0				23.5	30.0
19		14.5	18.5				13.0	
20			14.5				13.0	
21				44.5	23.5	41.0	30.0	28.0
23				22.0	23.5	29.0	25.0	28.0
26				60.0	61.0	47.0	64.0	42.0
28				73.5	59.5	150.0	58.0	49.5
29				32.0		27.0	22.0	28.5
32				21.0	21.0	26.5	14.0	16.5

APPENDIX G

INDIVIDUAL VEHICLE VAPOR PRESSURE RESPONSE CHARTS

Figure G-1
CRC E85 Cold-Start and Warm-Up Program
Vehicle 1

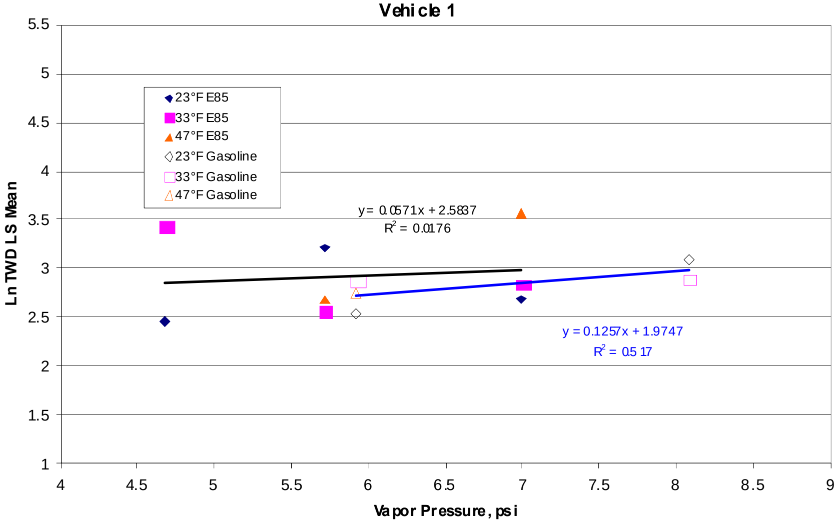


Figure G-2
CRC E85 Cold-Start and Warm-Up Program
Vehicle 2

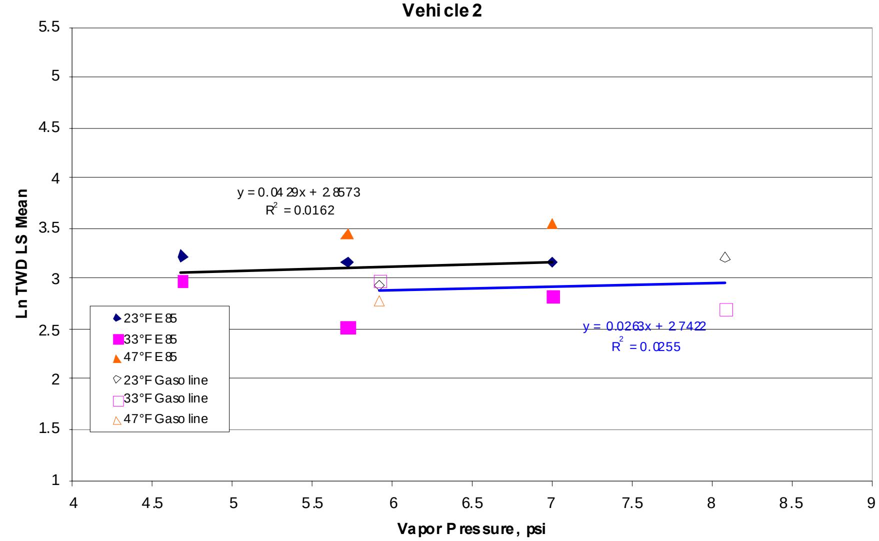


Figure G-3
CRC E85 Cold-Start and Warm-Up Program
Vehicle 3

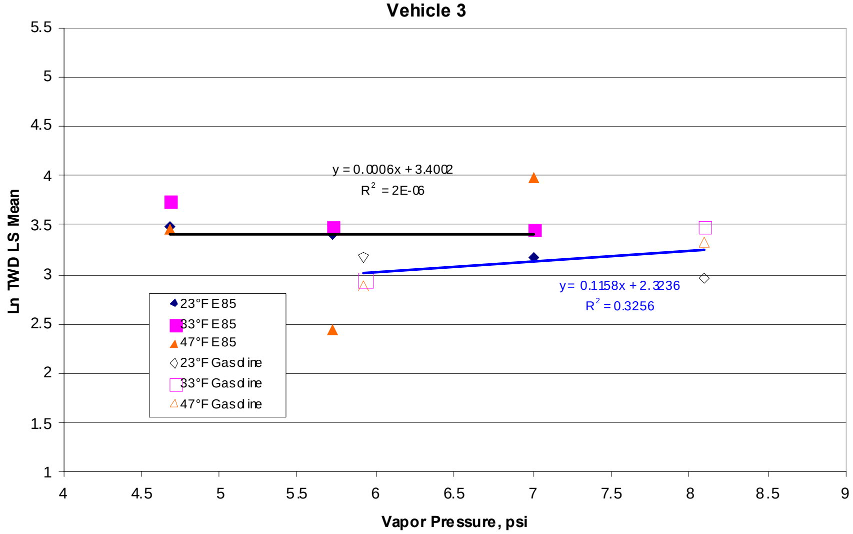


Figure G-4
CRC E85 Cold-Start and Warm-Up Program
Vehicle 4

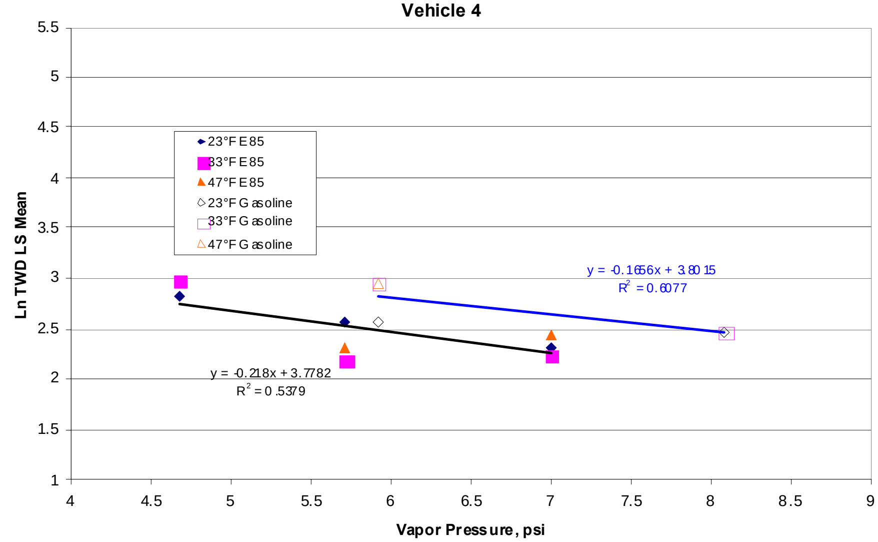


Figure G-5
CRC E85 Cold-Start and Warm-Up Program
Vehicle 5

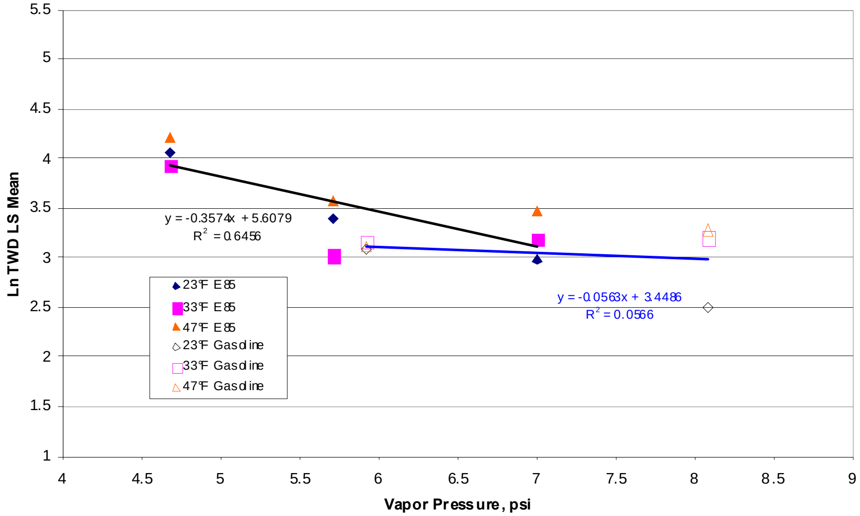


Figure G-6
CRC E85 Cold-Start and Warm-Up Program
Vehicle 6

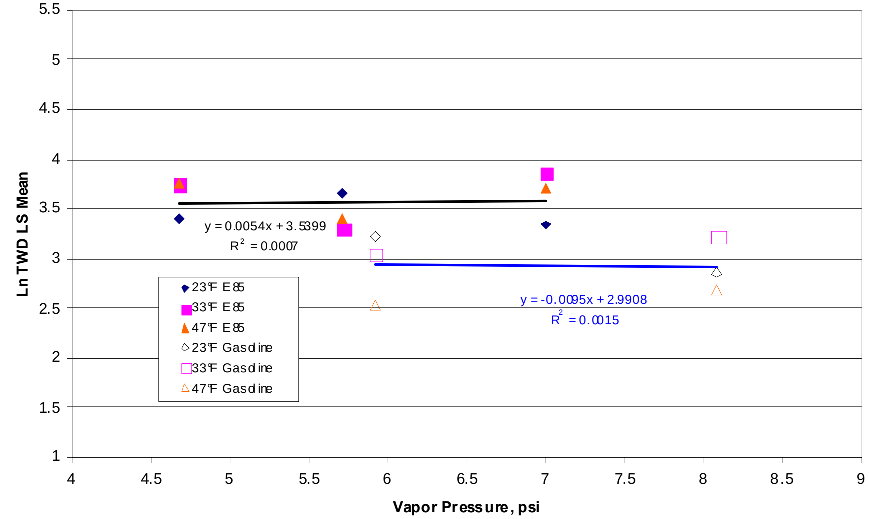


Figure G-7
CRC E85 Cold-Start and Warm-Up Program
Vehicle 7

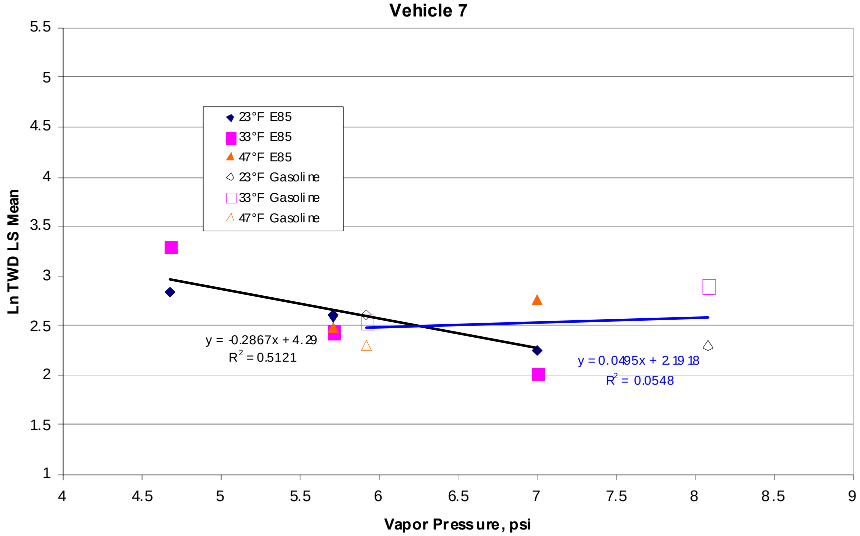


Figure G-8
CRC E85 Cold-Start and Warm-Up Program
Vehicle 8

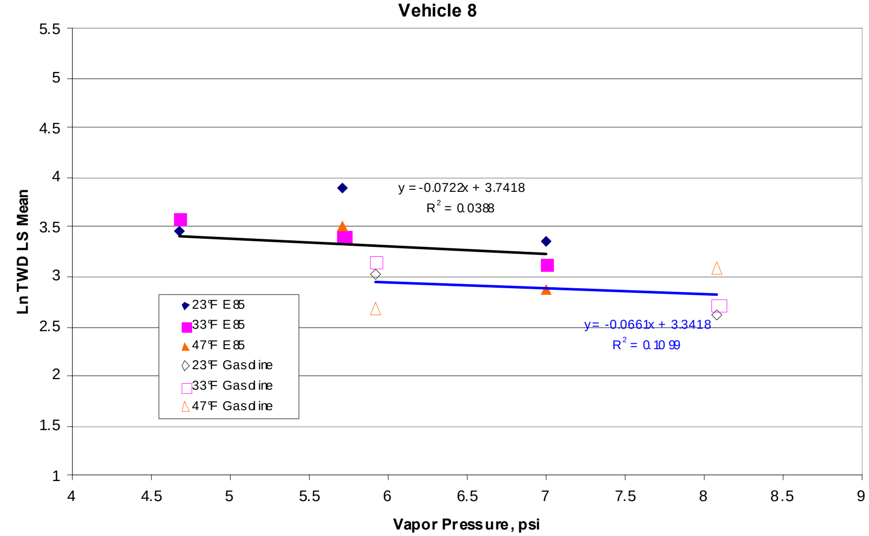


Figure G-9
CRC E85 Cold-Start and Warm-Up Program
Vehicle 9

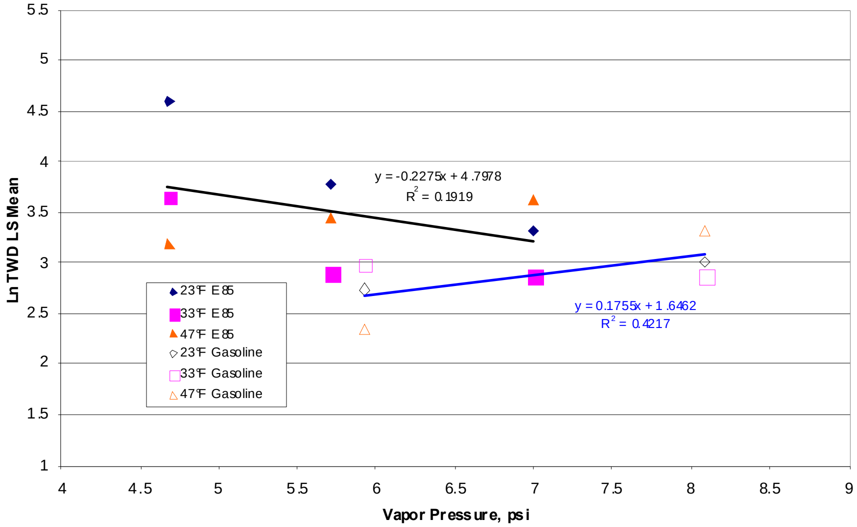


Figure G-10
CRC E85 Cold-Start and Warm-Up Program
Vehicle 10

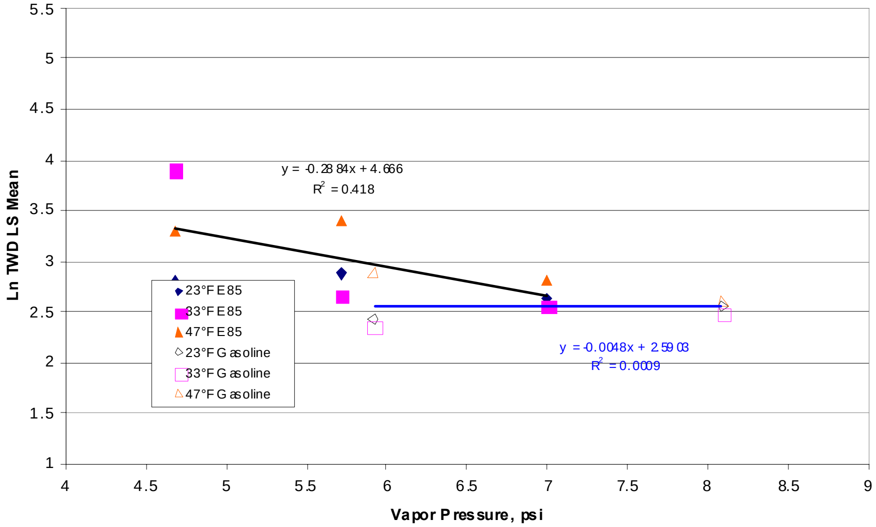


Figure G-11
CRC E85 Cold-Start and Warm-Up Program
Vehicle 11

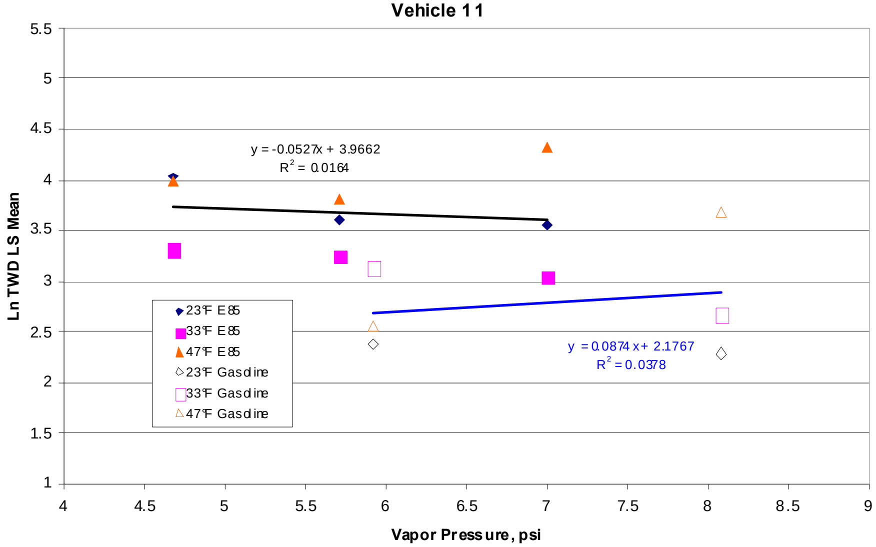


Figure G-12
CRC E85 Cold-Start and Warm-Up Program
Vehicle 12

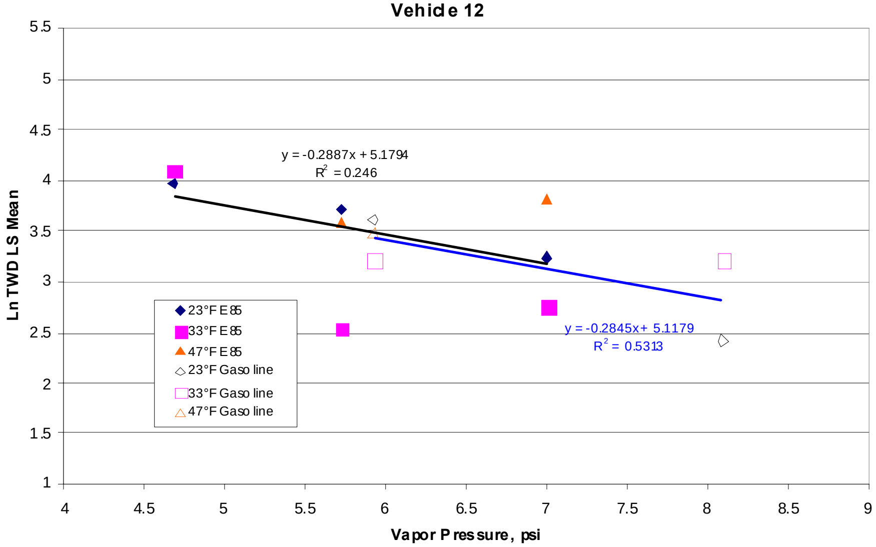


Figure G-13
CRC E85 Cold-Start and Warm-Up Program
Vehicle 13

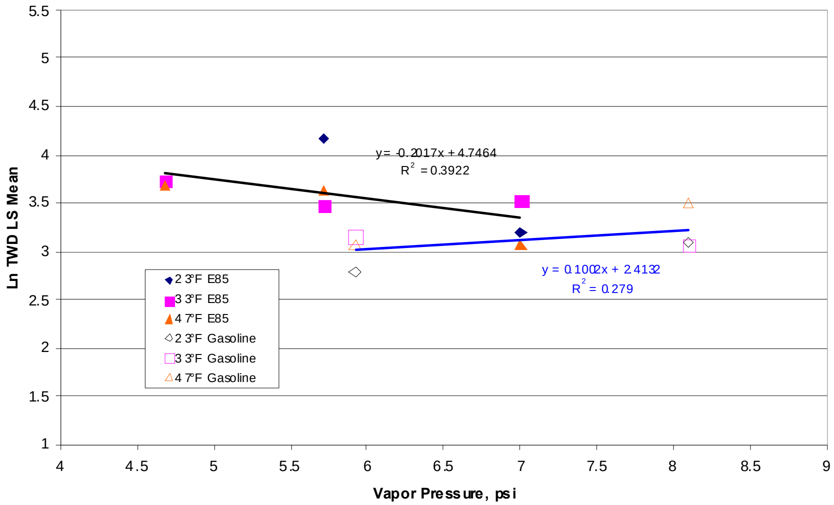


Figure G14
CRC E85 Cold-Start and Warm-Up Program
Vehicle 14

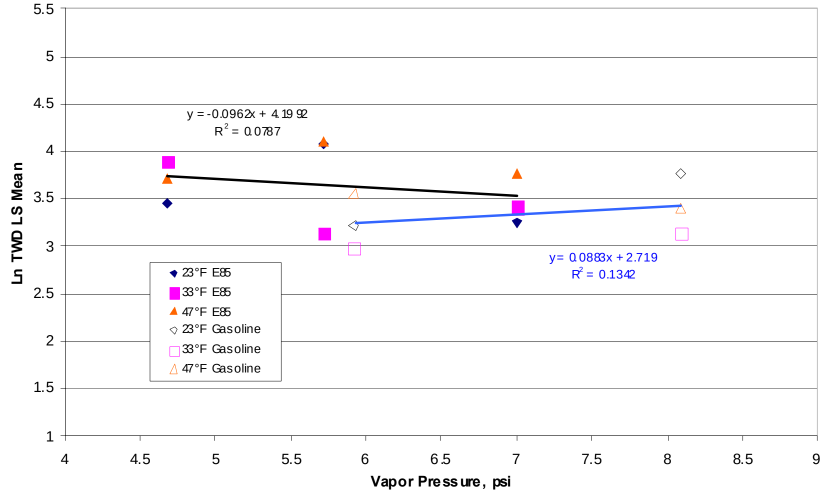


Figure G-15
CRC E85 Cold-Start and Warm-Up Program
Vehicle 16

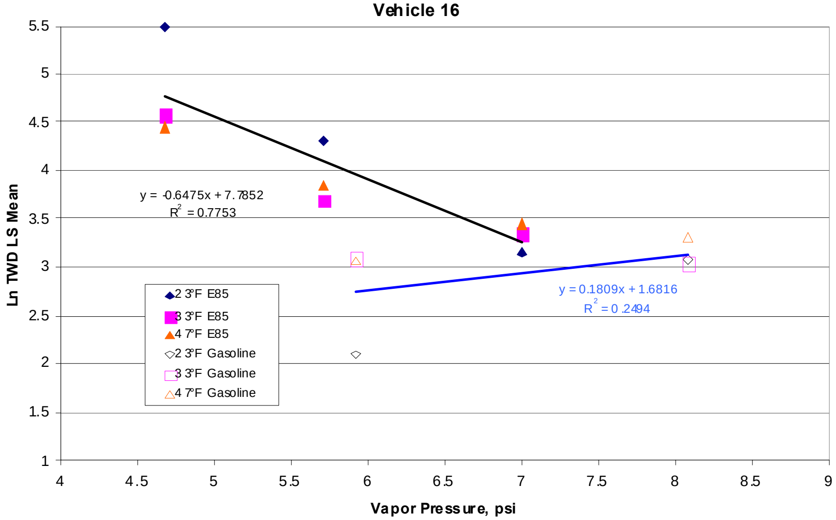


Figure G16
CRC E85 Cold-Start and Warm-Up Program
Vehicle 17

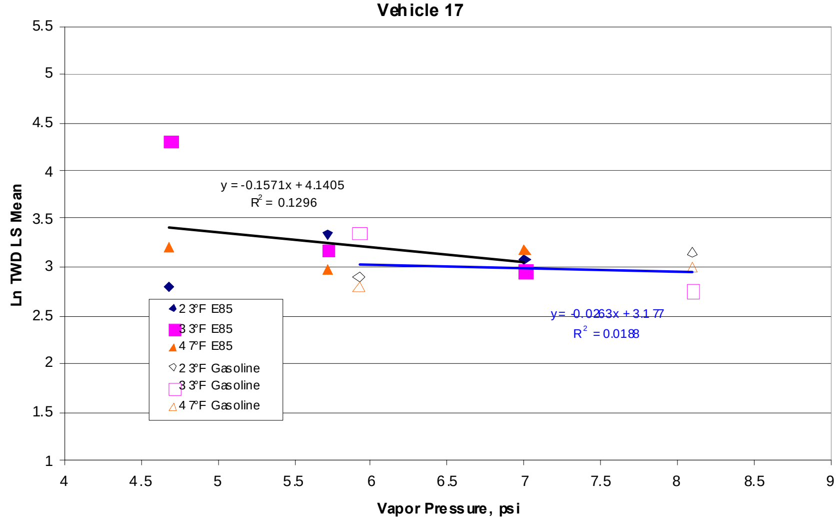


Figure G-17
CRC E85 Cold-Start and Warm-Up Program
Vehicle 18

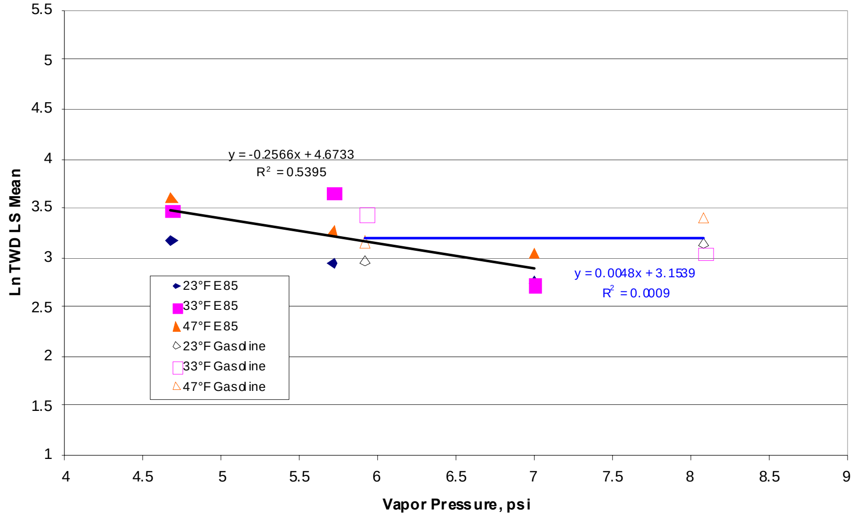


Figure G-18
CRC E85 Cold-Start and Warm-Up Program
Vehicle 19

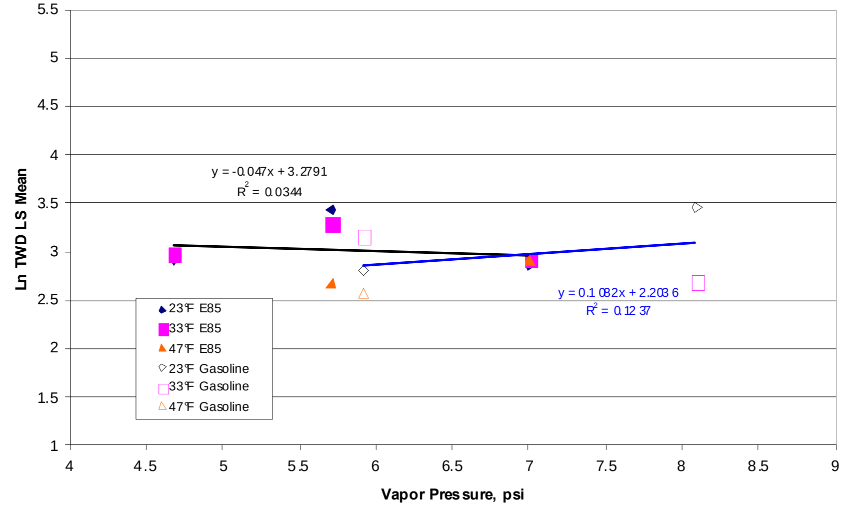


Figure G-19
CRC E85 Cold-Start and Warm-Up Program
Vehicle 20

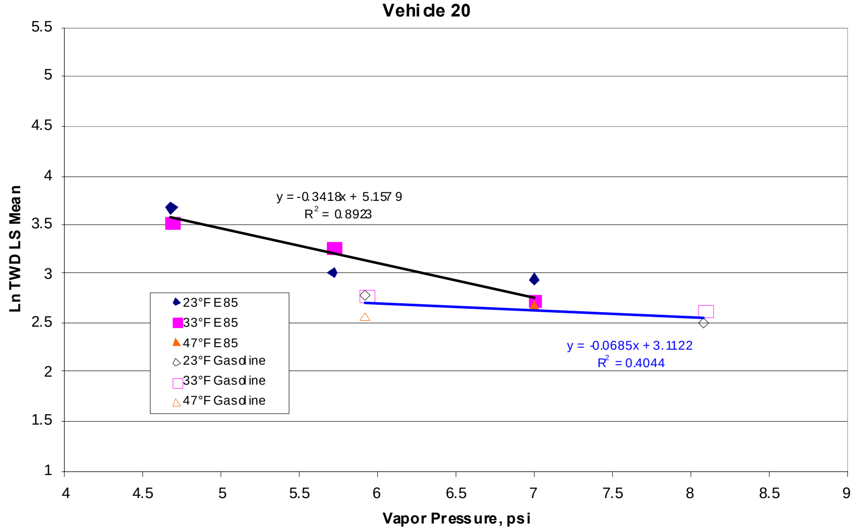


Figure G20
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 21

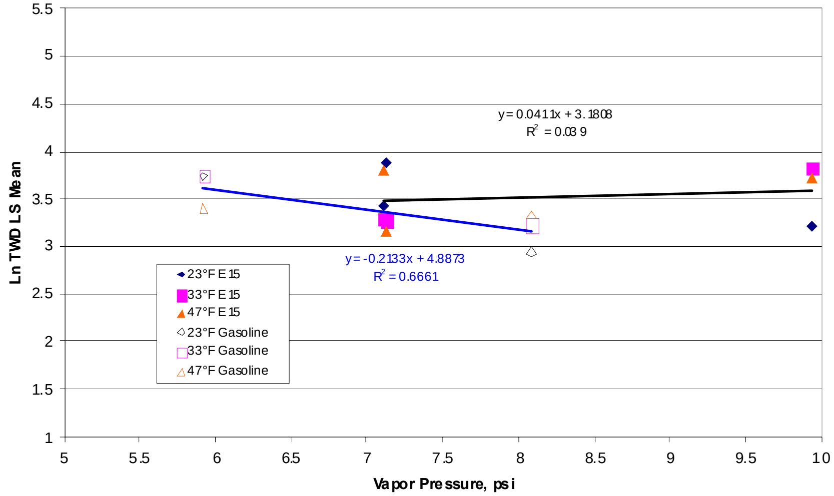


Figure G21
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 23

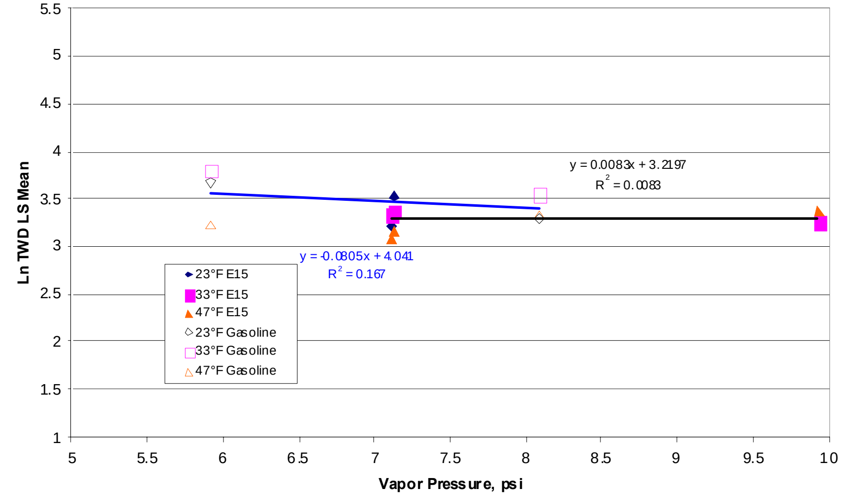


Figure G22
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 26

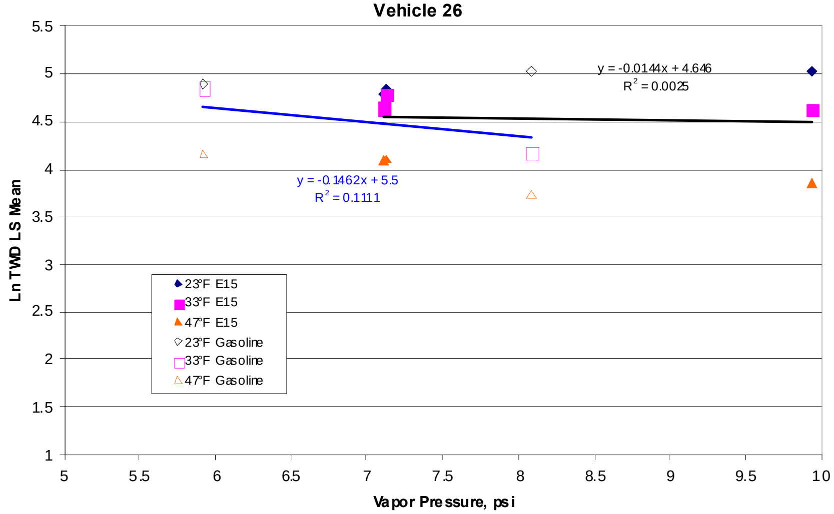
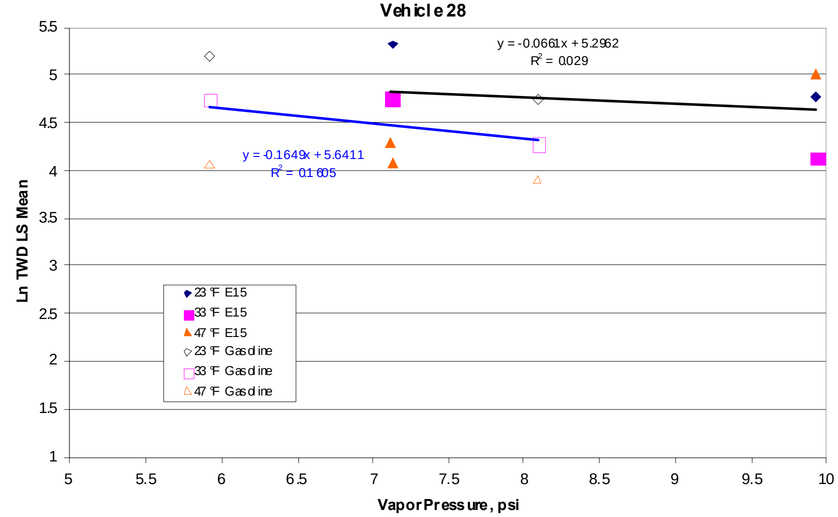


Figure G23
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 28



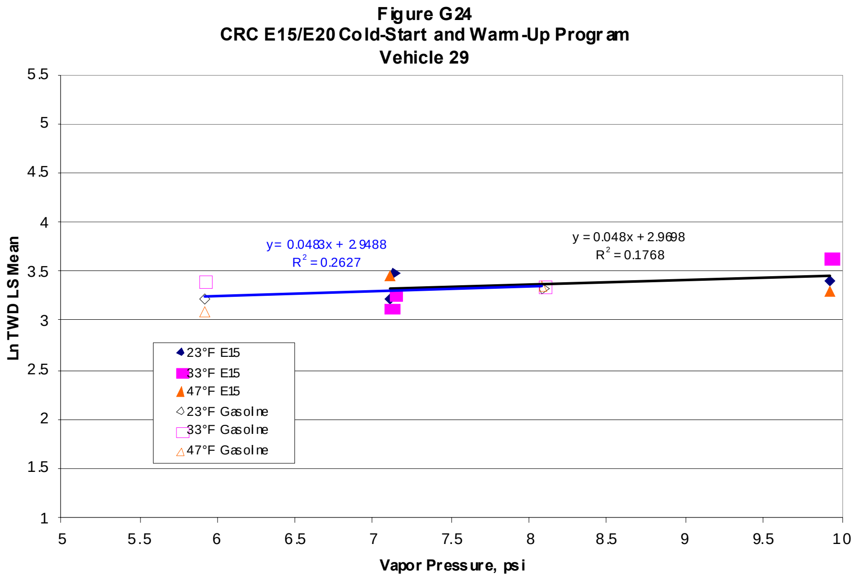


Figure G24
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 29
y= 0.0483x + 2.9488
R^2 = 0.2627
y = 0.048x + 2.9698
R^2 = 0.1768
23°F E15
33°F E15
47°F E15
23°F Gasoline
33°F Gasoline
47°F Gasoline
Ln TWD LS Mean
Vapor Pressure, psi

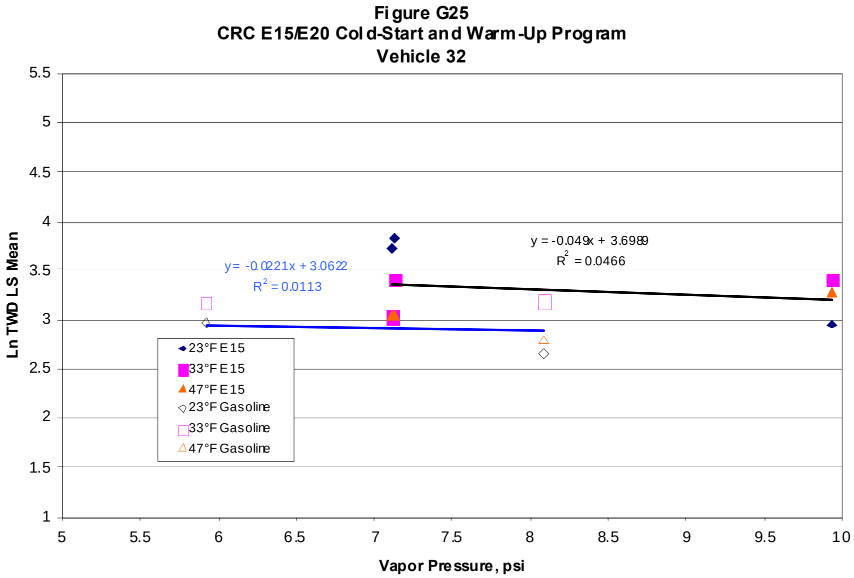


Figure G25
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 32
y = -0.049x + 3.6989
R^2 = 0.0466
y= -0.0221x + 3.0622
R^2 = 0.0113
23°F E15
33°F E15
47°F E15
23°F Gasoline
33°F Gasoline
47°F Gasoline
Ln TWD LS Mean
Vapor Pressure, psi

APPENDIX H

INDIVIDUAL VEHICLE TEMPERATURE RESPONSE CHARTS

Figure H-1
CRC E85 Cold-Start and Warm-Up Program
Vehicle 1

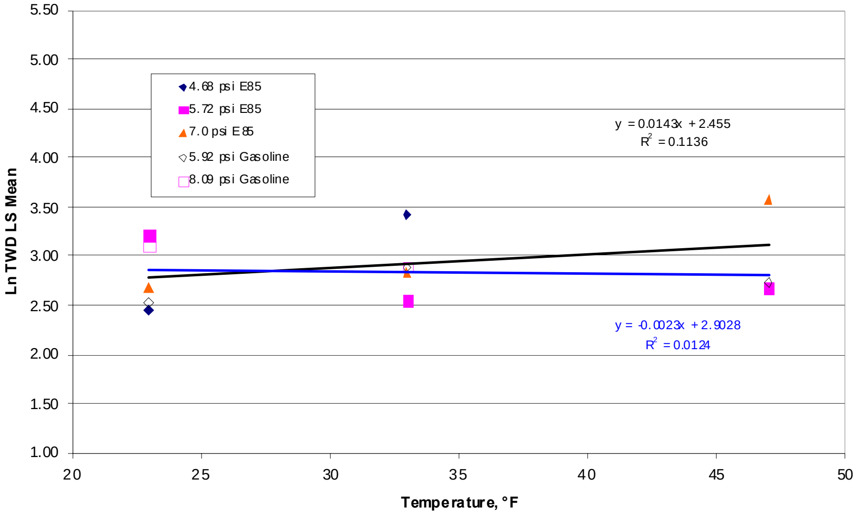


Figure H-2
CRC E85 Cold-Start and Warm-Up Program
Vehicle 2

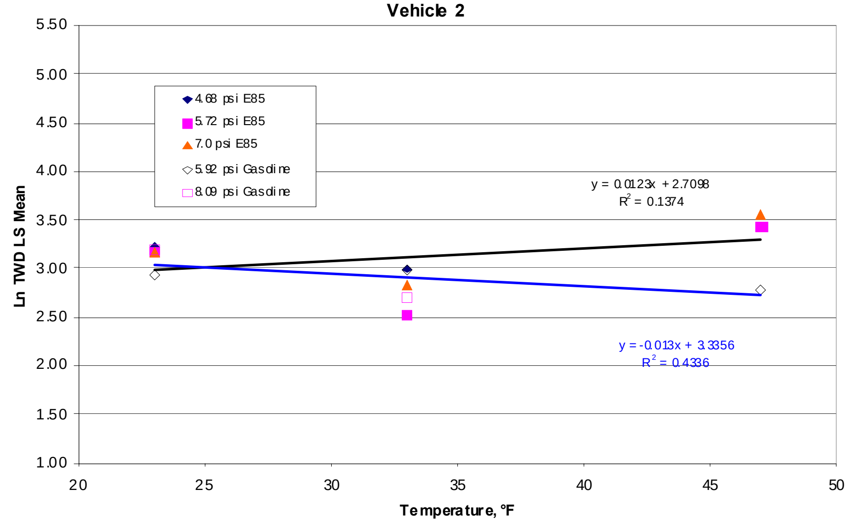


Figure H-3
CRC E85 Cold-Start and Warm-Up Program
Vehicle 3

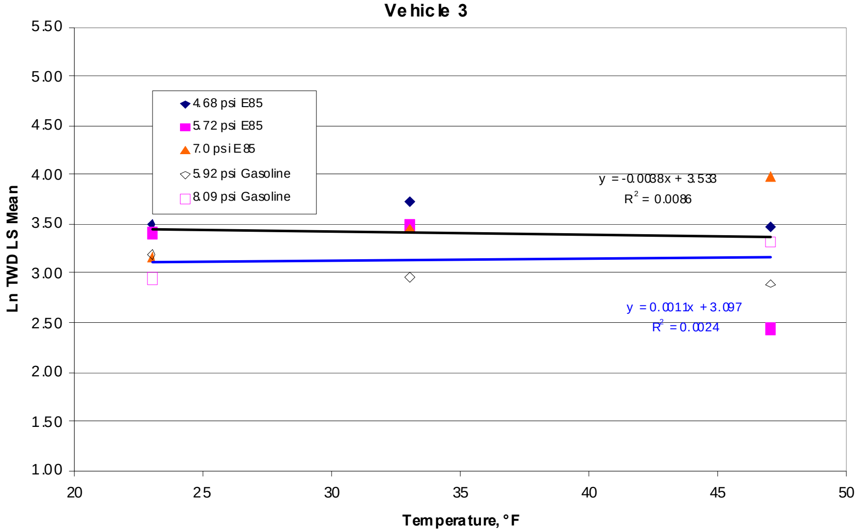
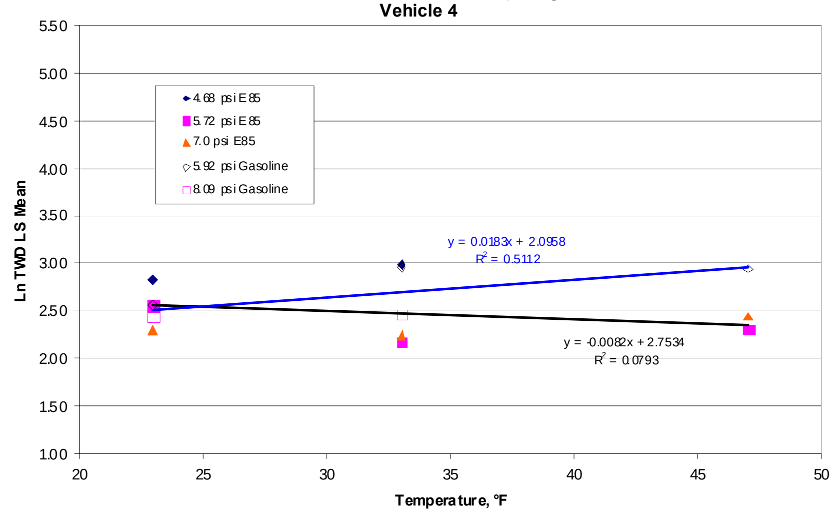


Figure H-4
CRC E85 Cold-Start and Warm-Up Program
Vehicle 4



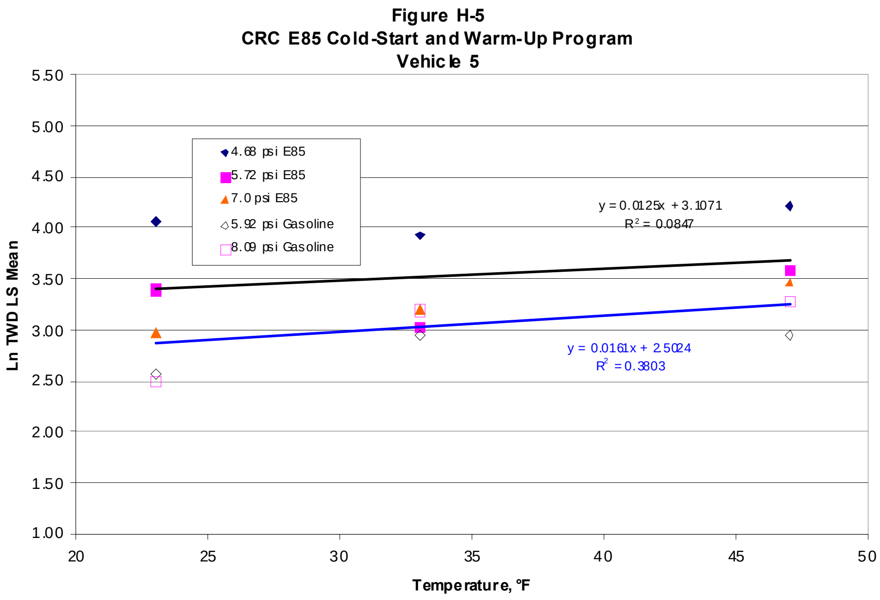


Figure H-5
CRC E85 Cold-Start and Warm-Up Program
Vehicle 5
4.68 psi E85
5.72 psi E85
7.0 psi E85
5.92 psi Gasoline
8.09 psi Gasoline
y = 0.0125x + 3.1071
R² = 0.0847
y = 0.0161x + 2.5024
R² = 0.3803
Ln TWD LS Mean
Temperature, °F

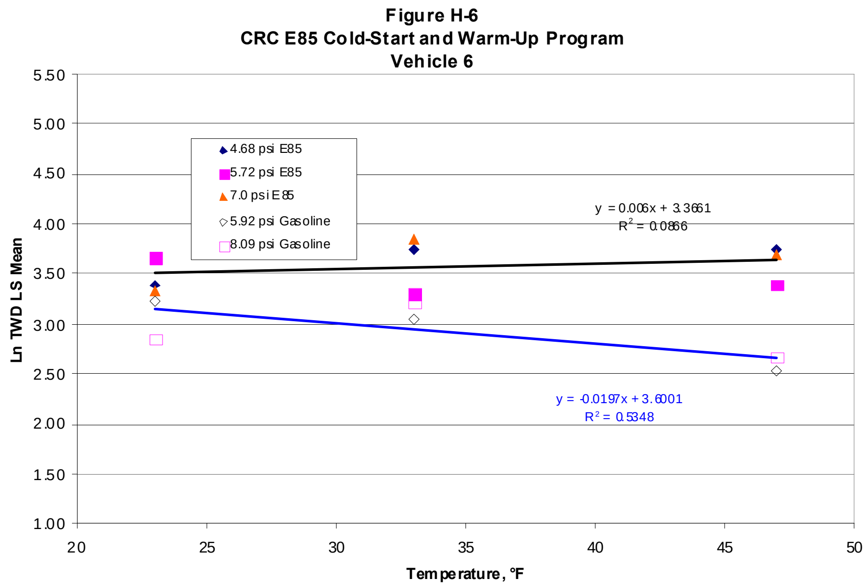


Figure H-6
CRC E85 Cold-Start and Warm-Up Program
Vehicle 6
4.68 psi E85
5.72 psi E85
7.0 psi E85
5.92 psi Gasoline
8.09 psi Gasoline
y = 0.006x + 3.3661
R² = 0.0866
y = -0.0197x + 3.6001
R² = 0.5348
Ln TWD LS Mean
Temperature, °F

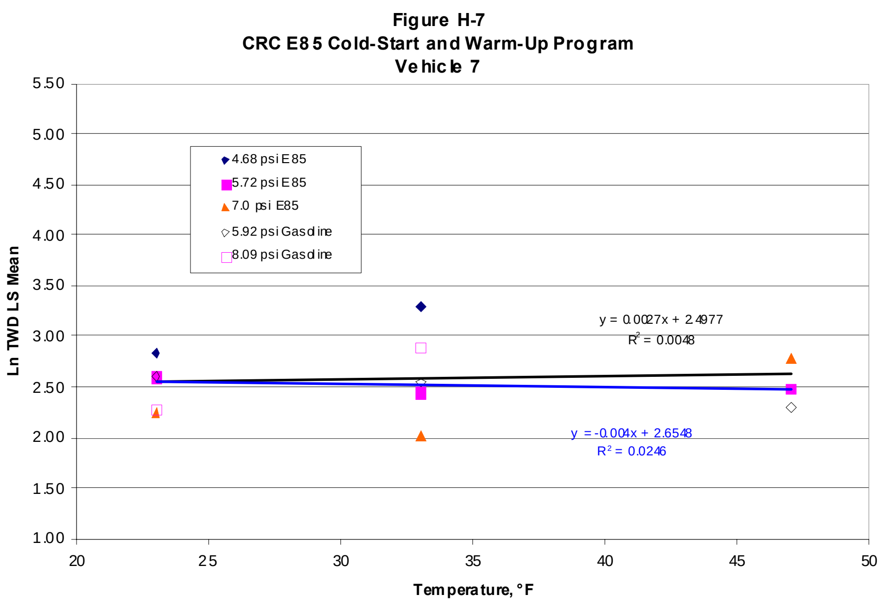


Figure H-7
CRC E85 Cold-Start and Warm-Up Program
Vehicle 7
4.68 psi E85
5.72 psi E85
7.0 psi E85
5.92 psi Gasoline
8.09 psi Gasoline
y = 0.0027x + 2.4977
R² = 0.0048
y = -0.004x + 2.6548
R² = 0.0246
Ln TWD LS Mean
Temperature, °F

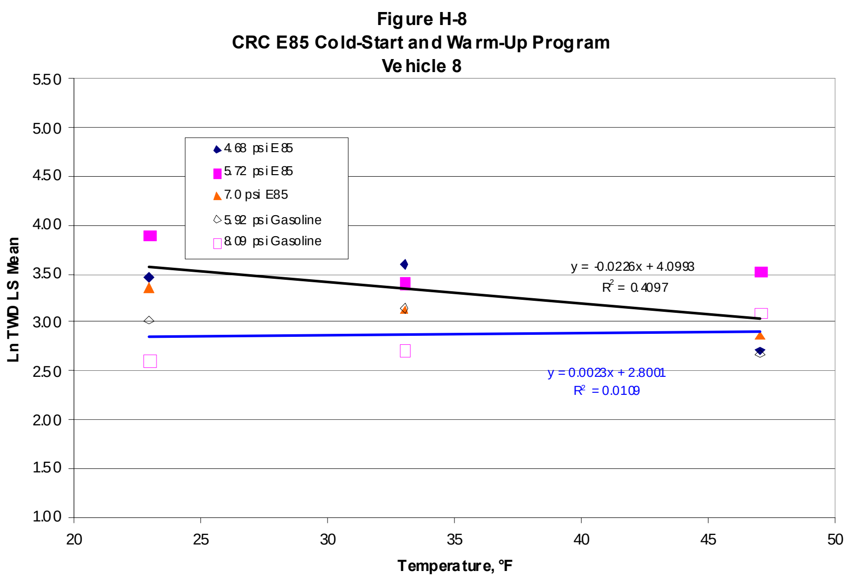


Figure H-8
CRC E85 Cold-Start and Warm-Up Program
Vehicle 8
4.68 psi E85
5.72 psi E85
7.0 psi E85
5.92 psi Gasoline
8.09 psi Gasoline
y = -0.0226x + 4.0993
R² = 0.4097
y = 0.0023x + 2.8001
R² = 0.0109
Ln TWD LS Mean
Temperature, °F

Figure H-9
CRC E85 Cold-Start and Warm-Up Program
Vehicle 9

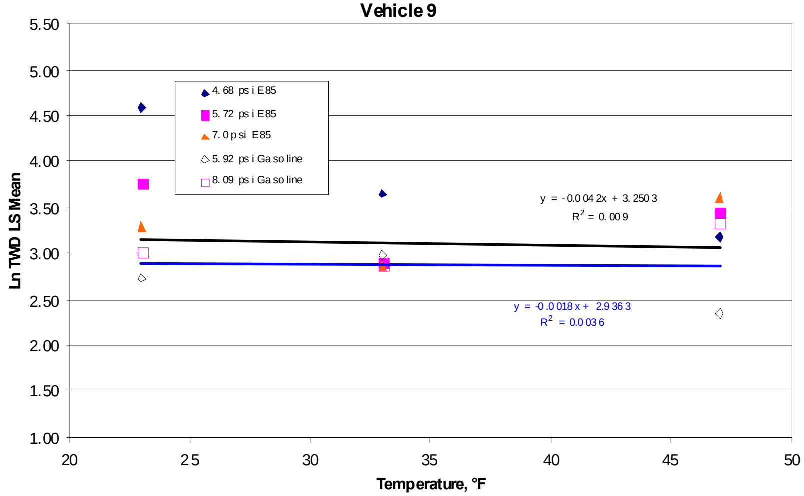


Figure H-10
CRC E85 Cold-Start and Warm-Up Program
Vehicle 10

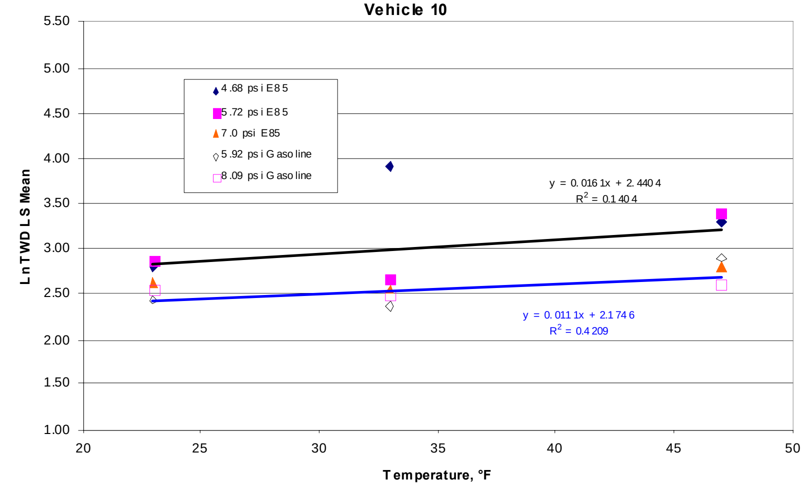


Figure H-11
CRC E85 Cold-Start and Warm-Up Program
Vehicle 11

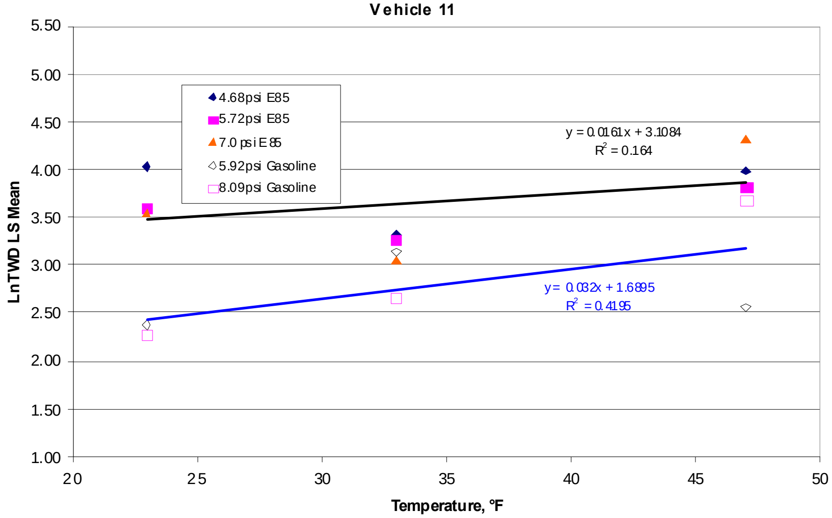


Figure H-12
CRC E85 Cold-Start and Warm-Up Program
Vehicle 12

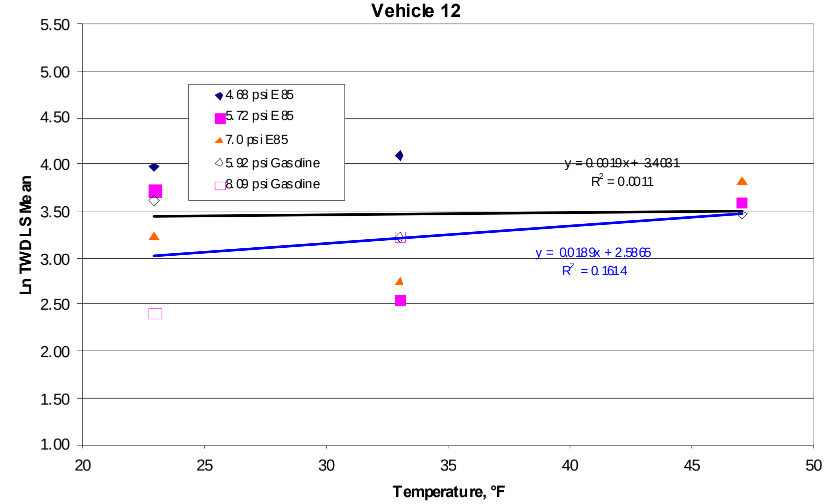


Figure H-13
CRC E85 Cold-Start and Warm-Up Program
Vehicle 13

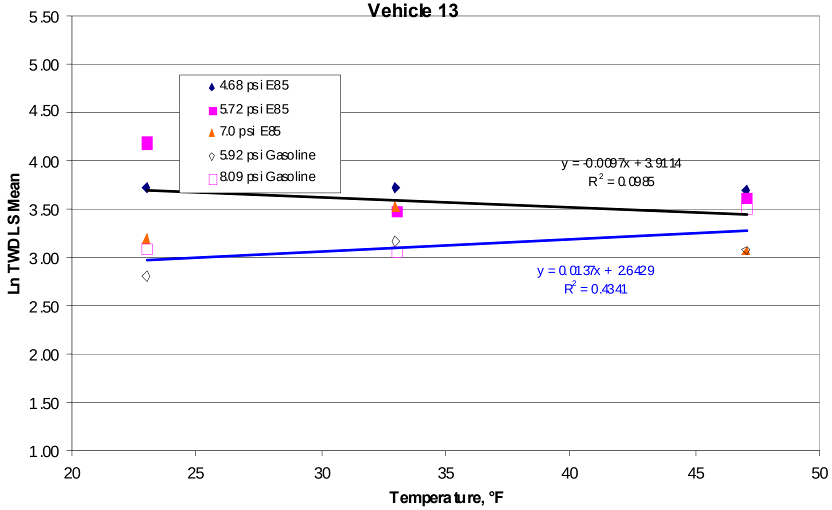


Figure H-14
CRC E85 Cold-Start and Warm-Up Program
Vehicle 14

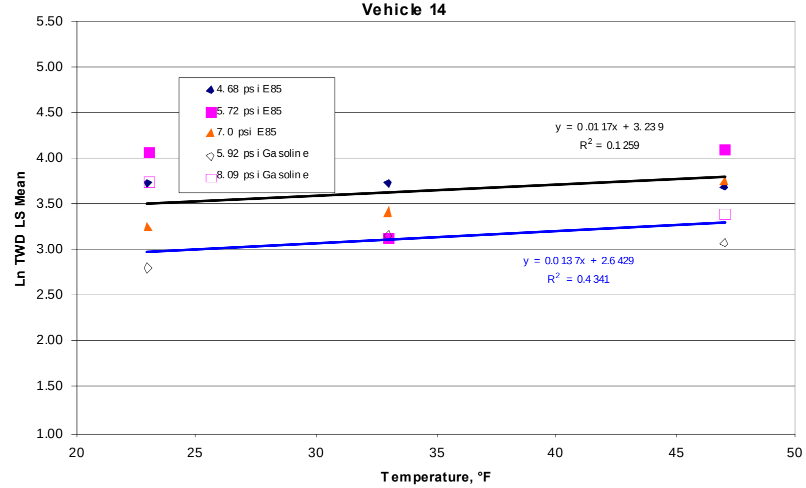


Figure H-15
CRC E85 Cold-Start and Warm-Up Program
Vehicle 16

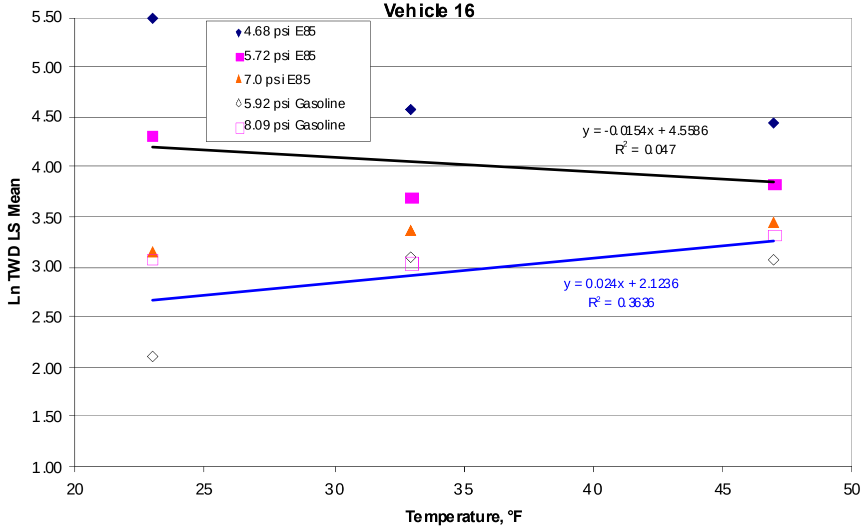


Figure H16
CRC E85 Cold-Start and Warm-Up Program
Vehicle 17

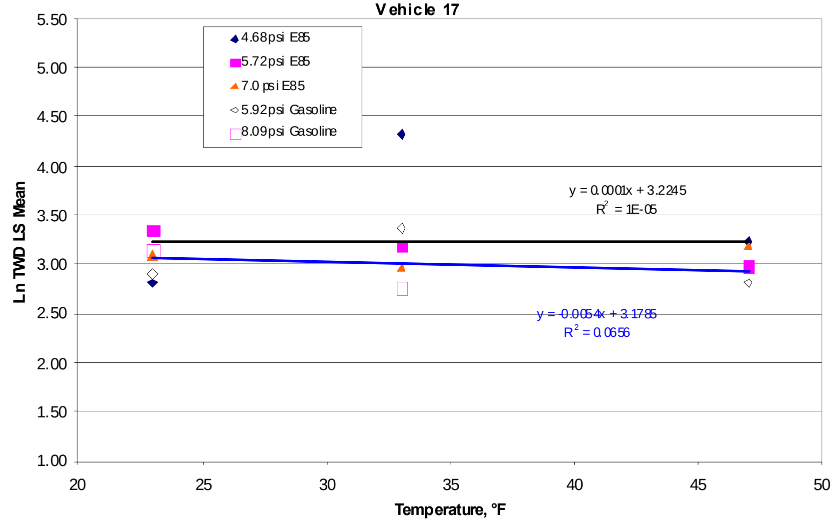


Figure H-17
CRC E85 Cold-Start and Warm-Up Program
Vehicle 18

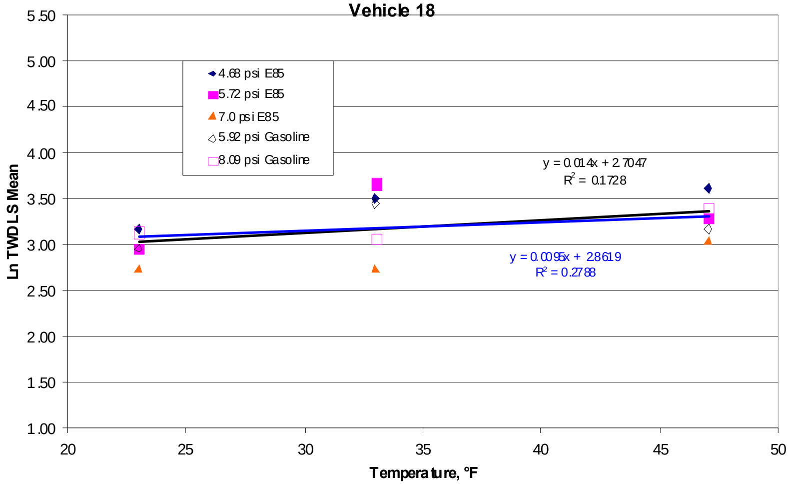


Figure H-18
CRC E85 Cold-Start and Warm-Up Program
Vehicle 19

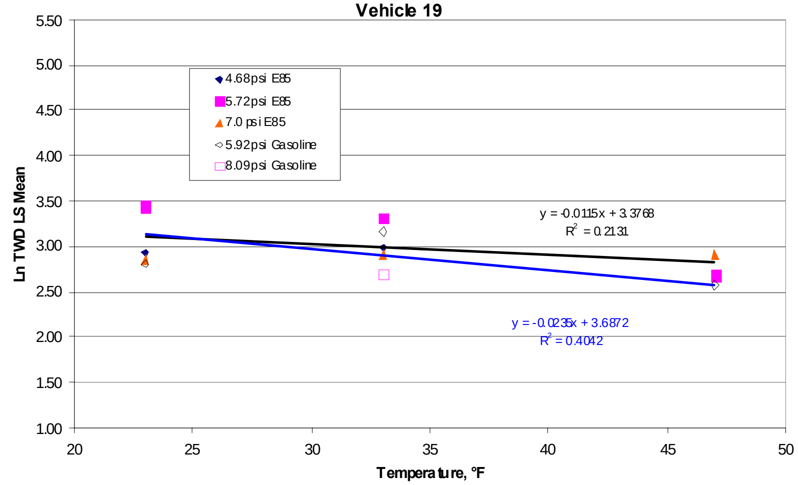


Figure H-19
CRC E85 Cold-Start and Warm-Up Program
Vehicle 20

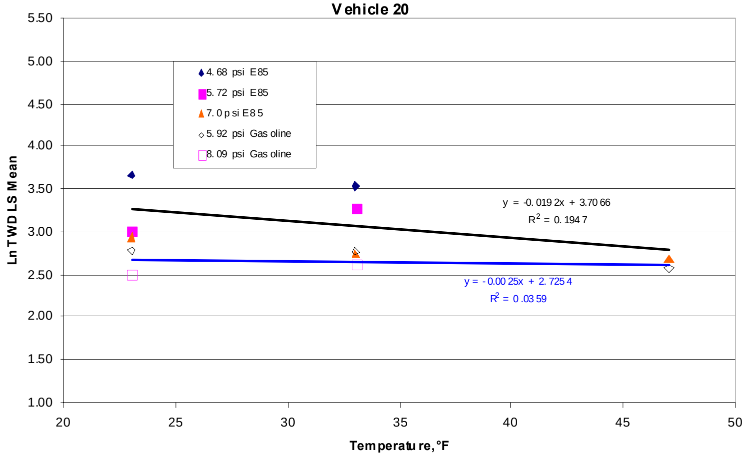


Figure H-20
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 21

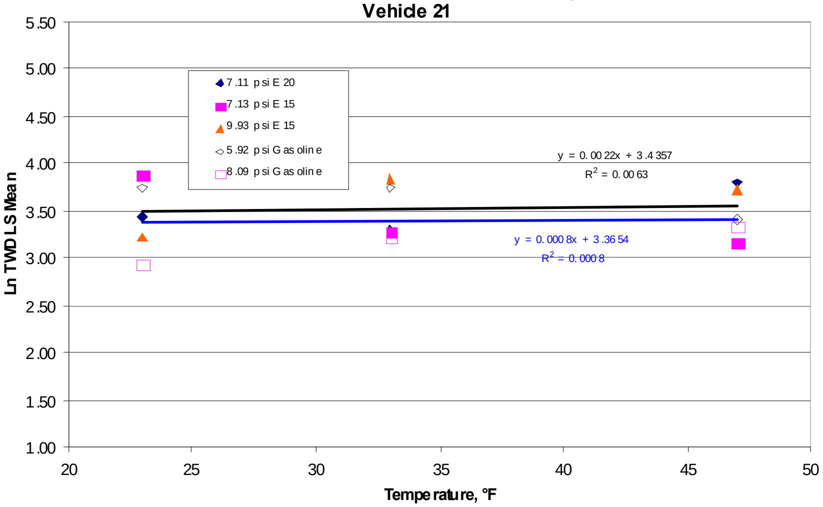


Figure H-21
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 23

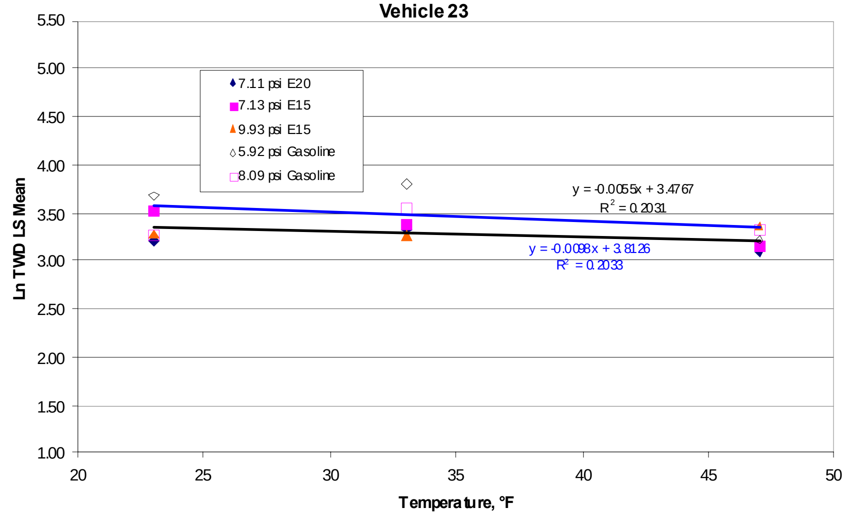


Figure H-22
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 26

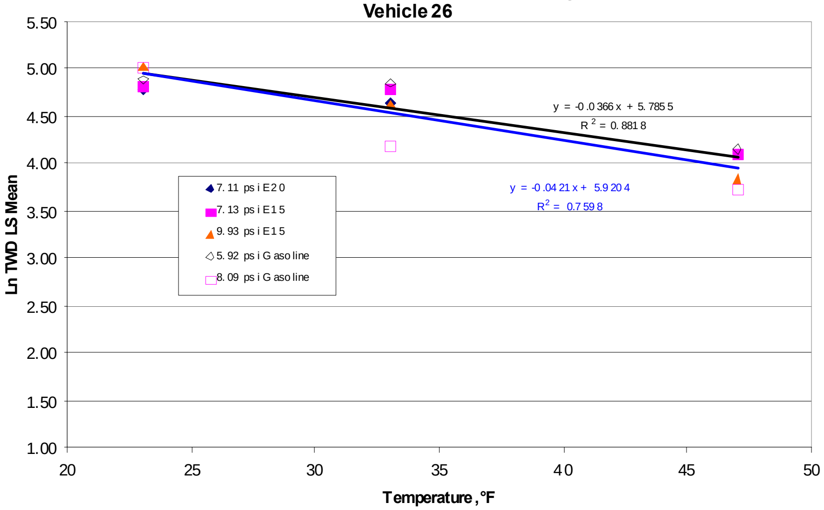


Figure H-23
CRC E15E20 Cold-Start and Warm-Up Program
Vehicle 28

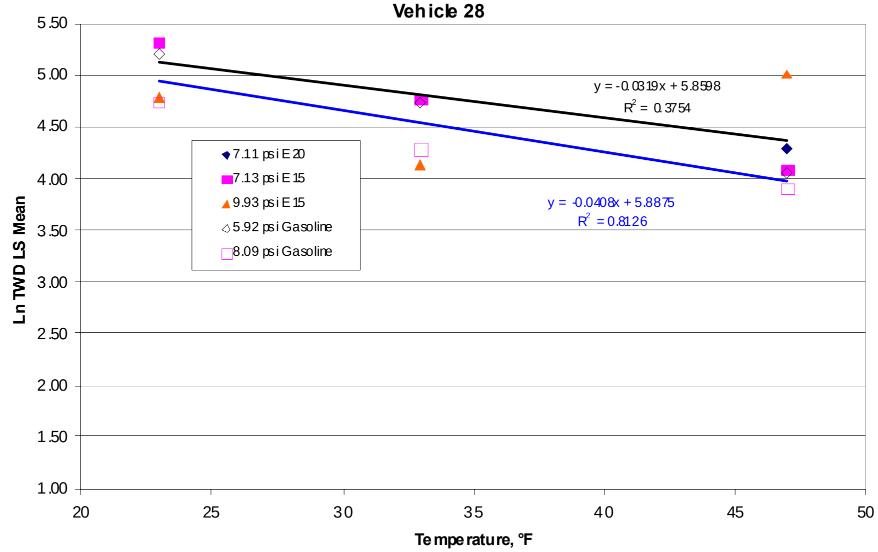


Figure H-24
CRC E15E20 Cold-Start and Warm-Up Program
Vehicle 29

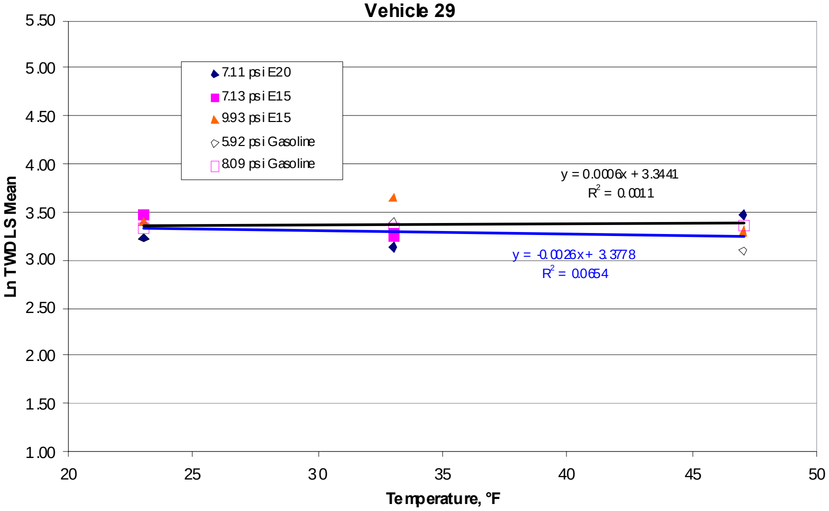


Figure H-25
CRC E15/E20 Cold-Start and Warm-Up Program
Vehicle 32