CRC Report: E-87-1

MID-LEVEL ETHANOL BLENDS CATALYST DURABILITY STUDY SCREENING

June 2009

COORDINATING RESEARCH COUNCIL, INC.
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CRC Project No. E-87-1

Mid-Level Ethanol Blends

Catalyst Durability Study Screening

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EXECUTIVE SUMMARY

The goal of the Coordinating Research Council (CRC) E-87-1 Mid-Level Ethanol Blends Catalyst Durability Screening Study was to identify vehicles which used learned fuel trims to correct open loop air-fuel ratios.

The Coordinating Research Council (CRC) E-87-1 Mid-Level Ethanol Blends Catalyst Durability Screening Study is the first phase of a two phase program to develop data on the durability effects of mid-level ethanol blends on emission control systems. The second phase consists of aging vehicles identified during this screening study to full useful life with mid-level ethanol blends to determine their durability effects.

Procedure

For this screening study TRC Inc. identified and acquired a fleet of 25 test vehicles based on criteria provided by the CRC. The target vehicle fleet consisted of models suggested by the US Department of Energy National Laboratories and by automakers. Twelve of the models represented high production vehicles manufactured since 2000. The thirteen remaining vehicles were identified as being unlikely to use adapted fuel trim and manufactured since 1990.

Each test vehicle was screened prior to acceptance into the program using a standard exhaust emissions FTP. None of the selected vehicles exceeded their full useful life emissions certification standards by more than 20% and each was accepted into the program. The vehicles were instrumented with a wide range universal exhaust gas oxygen (UEGO) sensor, thermocouples, and an Engine Control Module (ECM) data link. The wide range oxygen sensor was installed upstream of the front catalyst while the thermocouples were located upstream and downstream of the front catalyst and at the factory installed oxygen sensor.

Following instrumentation, each vehicle performed a matrix of four tests using fuels with four different ethanol levels. The test was a modified version of the European Programme for Emission, Fuels, and Engine Technologies (EPEFE) Sulfur Purge Cycle[1]. The ethanol content levels of the test fuels were 0%, 10%, 15%, and 20% by volume. The fuels were designated E0, E10, E15, and E20 respectively. The initial EPEFE test was performed using E0 fuel while the test order for the remaining three fuels was randomized for each vehicle.

The test cycle consists of two complete iterations of a vehicle warm-up phase followed by five successive wide-open throttle (WOT) accelerations from 0 to 84 mph each. Each WOT is separated by a brief cruise and idle period. Each EPEFE test includes a total of ten WOT

1 F. Palmer et. al., 1995, “Outcome of the European Programme on Emissions, Fuels, and Engine Technologies (EPEFE),” SAE SP1042

accelerations. During each EPEFE test, the UEGO, thermocouples, and ECM data were continuously recorded for post-test analysis. UEGO and thermocouple data were recorded at 10Hz while ECM data were collected at the maximum output rate of each test vehicle. TRC Inc. collected all available ECM data channels for each vehicle. These data ranged from 13 to 36 channels for the vehicle in the program. One test vehicle was not equipped with a Data Link Connector (DLC) and no ECM data were recorded.

Vehicle speed, oxygen sensor air-fuel-ratio (AFR), and catalyst temperature data from the tenth WOT event for each vehicle and fuel combination were analyzed to determine which vehicles used adaptive fuel trims during open loop control.

Results

Twenty-five vehicles were evaluated as to whether they adjusted their fueling with increased ethanol content to maintain a consistent fuel:air equivalence ratio (fuel:air actual / fuel:air stoichiometric) in open loop control. The assessment method for this study was the same as that used in the recently published Department of Energy screening test program: "Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1 – Updated"[2].

Thirteen of the twenty-five vehicles did not adjust open loop fueling to compensate for ethanol in the fuel. Eight of the twenty-five vehicles did adjust open loop fueling to compensate for ethanol in the fuel. Four of the twenty-five vehicles gave unclear results.

The thirteen vehicles (and potentially the four that could not be analyzed or gave ambiguous results) that do not adjust for ethanol in open loop control are likely to have their fuel enrichment operation compromised when operated on mid-level ethanol blends. As was documented in the Australian ethanol durability study[3], this can lead to catalyst performance degradation and increased harmful exhaust emissions. In addition, the durability of the engine and other systems may also be compromised. It is notable that one of the vehicles examined, the 2001 Hyundai Accent, demonstrated the same control behavior as a similar 2001 Hyundai Accent tested in Australia. During further durability testing in Australia, the 2001 Hyundai demonstrated catalyst performance degradation and an inability to meet the emissions standard after 50,000 mile aging on a mid-level ethanol blend.

2 NREL/TP-540-43543, ORNL/TM-2008/117, "Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1 – Updated," February 2009, http://feerc.ornl.gov/publications/Int_blends_Rpt1_Updated.pdf

3 Orbital Engine Company, "Market Barriers to the Uptake of Biofuels Study, A Testing Based Assessment to Determine Impacts of a 20% Ethanol Gasoline Fuel Blend on the Australian Passenger Vehicle Fleet Report to Environment Australia," March 2003

The twenty-five vehicles were ranked by six criteria developed jointly by CRC and US Department of Energy National Laboratories. This ranking was developed to identify vehicles for further testing in phase 2 of this program, aging to full useful life with mid-level ethanol blends to determine their durability effects.

The vehicles identified for further study are:

1. 2002 Nissan Frontier (4cyl)
2. 2000 Ford Focus
3. 1999 Ford Crown Victoria
4. 2001 Hyundai Accent
5. 2001 Mazda 626 (4cyl)
6. 2000 Honda Accord LX (4cyl)
7. 2006 Chevrolet Cobalt
8. 2002 Dodge Durango 4WD
9. 2003 Nissan Altima (4cyl)
10. 2006 Nissan Quest

INTRODUCTION

At both the federal and state levels, there has recently been legislation that mandates and/or encourages the use of alternative fuels, including ethanol. The Energy Independence and Security Act, passed in December 2007, mandates 36 billion gallons of renewable fuels usage by 2022. On-going and planned increases in ethanol production have made it likely that the supply of ethanol will exceed that required for nationwide 10% blending with gasoline. Although further production increases could expand the pool of E85 available, slow progress on installing E85 infrastructure has produced concerns that an ethanol "glut" could develop. In Minnesota, a law requires the use of E20, a blend of gasoline with 20% denatured ethanol by 2013. The Assistant Secretary of Energy for renewable energy called the use of E15 and E20 an "alternative approach to balance fuel production and use"[4]. One important aspect of E20 fuel usage is the durability of legacy and current production vehicles that were not designed for its use. Studies in Australia[5] have shown that the use of E20 can cause catalyst damage to some vehicles. Because no technical publications addresses US vehicle exhaust system durability with E10 – E20 fuels, CRC was motivated to conduct this test program.

The use of mid-level ethanol blends such as E20 results in a lean combustion mixture that will cause elevated oxygen concentrations in the exhaust gas impacting the oxygen sensor and catalyst. Lean combustion will also result in elevated in-cylinder engine, oxygen sensor, and catalyst temperatures. Modern closed loop engine control systems will prevent this from occurring by adjusting the fuel flow to ensure stoichiometric operation. However, most vehicles use switching type oxygen sensors and are in open loop control during periods of commanded enrichment such as heavy throttle operation. This is when the combustion mixture is enriched to cool the exhaust gases and thus the engine, catalyst and oxygen sensor. This is called "power enrichment", "engine protection mode", or "catalyst protection mode", depending on the immediate purpose. As was seen in the Australian studies[6], some vehicles do not use the learned fuel composition, adapted fuel trim, when calculating the amount of fuel required to operate in these modes. When the fuel contains ethanol, the use of a baseline (unlearned) fuel trim results in open loop operation that is leaner than anticipated. This enleanment is proportional to the

4 Testimony of Alexander Karsner Assistant Secretary for Energy Efficiency and Renewable Energy, Before the Committee on Energy and Natural Resources, United States Senate. Topic: Improving the Nation's Renewable Fuels Infrastructure, July 31, 2007

5 Orbital Engine Company, "Market Barriers to the Uptake of Biofuels Study Testing Gasoline Containing 20% Ethanol (E20)," Phase 2B Final Report to the Department of the Environment and Heritage, May 2004.

6 Orbital Engine Company, "Market Barriers to the Uptake of Biofuels Study, A Testing Based Assessment to Determine Impacts of a 20% Ethanol Gasoline Fuel Blend on the Australian Passenger Vehicle Fleet Report to Environment Australia March 2003

fuel's ethanol content so ethanol blends greater than E10 are more likely to cause damage. Sixty percent of the vehicles tested in Australia did not use an adapted fuel trim (one that compensated for the ethanol) during open loop control and all of these vehicles showed some level of catalyst performance deterioration after 50,000 miles of operation on E20.

A reduction in oxygen sensor or catalyst performance across large portions of the in-use fleet could have major implications for air quality. However, it was not known whether the same calibration strategies are used in US vehicles and whether, if used, they will have the same effect.

TEST BACKGROUND

There are two options for controlling the amount of fuel injected during open loop operation. Open loop operation is when there is no information from the oxygen sensor that enables the controller to use real time data to calculate the actual air-fuel ratio, thus the controller has no feedback and must control using pre-programmed parameters.

The first option is to use only the pre-programmed fuel values for the calculation of the air fuel ratio. These values contain no corrections for the actual build and aging of the particular vehicle being used nor for any variation in the fuel properties and will be the same value for all vehicles with a given calibration. The advantage is that potential errors from various sensors are not included in a calculation whose accuracy is critical for the protection of both the engine and the catalyst. This includes any changes in sensor accuracy when operating in the potentially different engine operating conditions characteristic of 'closed loop' and 'open loop' operation.

The second option is to calculate the air fuel ratio using the long term fuel trim that is frequently calculated and stored by the engine controller while in closed loop operation. The long term fuel trim corrects for variation from a range of sources including fuel oxygen content and helps ensure that the air and fuel volumes are exactly matched to minimize harmful exhaust emissions. The advantage of using the long term fuel trim during open loop control is that the vehicle to vehicle and part to part variation is accounted for in the air fuel ratio. In other words the air fuel equivalence ratio under a given set of conditions should be the same for all vehicles with a given set of software and calibration regardless of any part or fuel variations.

It is impossible to gather the details of the calibration for the thousands of types and model years of vehicles on US roads. The best way to determine whether a vehicle uses long term fuel trim during open loop operation is through experimentation. One way to run the experiment, a way particularly relevant to the ethanol blend question, is to reduce the heating value of the fuel, typically by increasing the oxygen content by adding ethanol. Observations of the air-fuel ratios in open loop control can be done by installing a wide range oxygen sensor and operating the vehicle at wide open throttle (WOT) with fuels of various compositions after a suitable exposure of the vehicle to the fuel that enables the vehicle to "learn" the fuel (develop new long term fuel trims that take the new fuel into account). A vehicle which adapts (by using the long term fuel trims in calculating air fuel ratios) to the fuel composition will use the same air fuel equivalence ratio under the same conditions regardless of the fuel composition. A vehicle that does not adapt will have the air fuel ratio become progressively leaner as more ethanol (oxygen) is added to the fuel. When the air fuel ratio is normalized and expressed as a lambda (the actual air-fuel ratio divided by the stoichiometric air fuel ratio) the oxygen content can be found by looking at the change in lambda. For example, a vehicle with a lambda of 0.80 on straight gasoline would have a lambda of 0.837 on E10 and 0.874 on E20 reflecting the 3.7% oxygen content in E10 and 7.4% oxygen content in E20.

Based on the experience in Australia, the decision as to which of the two approaches to use in determining the amount of fuel injected during open loop engine control is critical. All of the vehicles in the Orbital study that did not use long term fuel trims to determine the open loop air fuel ratio exhibited increases of over 100% in the emissions of hydrocarbons, carbon monoxide, and nitrogen oxides after 80,000 km durability testing using the European catalyst durability test cycle. Conversely none of the vehicles tested that used long term fuel trims for calculating open loop control exhibited a significant deterioration.

TEST PROGRAM

Approach

There are thousands of different makes and models of vehicle on the US road and it is impossible to perform durability tests on all of them. The approach taken in this investigation was to break the test program into two phases. The first was to determine by experimentation if the calibration strategies found to be responsible for the Australian catalyst deterioration were present in the US market (the screening test). The second phase is to perform durability testing on a selection of vehicles (if any) found to use the calibration strategy of interest to determine if this strategy will indeed result in emissions performance degradation of US vehicles.

The plan for phase two (durability testing) of the test program is to rank the vehicles in the test fleet by six criteria jointly developed by CRC and US Department of Energy National Laboratories. The vehicles with the highest pooled rankings will then be selected for the durability portion of the test program to determine if there is any effect of long term mid-level ethanol usage on catalyst performance.

Vehicles

A balanced approach was chosen to develop the screening fleet. Twelve of the 25 vehicles were selected by US Department of Energy National Laboratories based on volumes sales and manufacturer distribution. Thirteen of the 25 vehicles were selected by the CRC member automakers as being likely to use the calibration strategy found in Australia. Two of the vehicles selected by CRC were not manufactured by the CRC member automakers, but were selected based on data available in the literature. The Hyundai Accent was selected because it is a vehicle that displayed catalyst performance degradation on E20 in Australia that is also available in the US. The BMW 330 was selected based on internal CRC member company data. With one exception, all the screened vehicles were less than 9 years old at the beginning of the program and were younger than the median age of the US car fleet.

Plots of the test data are presented in the report's appendix. The raw data are available in MS Excel format from the Coordinating Research Council (CRC).

Procedure

The test procedure used here is essentially the same as used by the US Department of Energy in its recently published screening test program: "<u>Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1 – Updated</u>"[7]. The description of the test procedure of the Catalyst Durability Study Screening Program will highlight the following topics:

- Vehicle test sequence
- Step 1: Vehicle selection and procurement
- Step 2: Vehicle preconditioning and test fuels and specifications
- Step 3: FTP emissions testing and vehicle repair
- Step 4: Vehicle and laboratory instrumentation
- Step 5: EPEFE Sulfur Purge Cycle test matrix
- Data Collected and Analysis

Vehicle Test Sequence – The vehicle test sequence for this program was provided by CRC and is included as Figure 1. Each step of the seven-step sequence is discussed in detail within this report.

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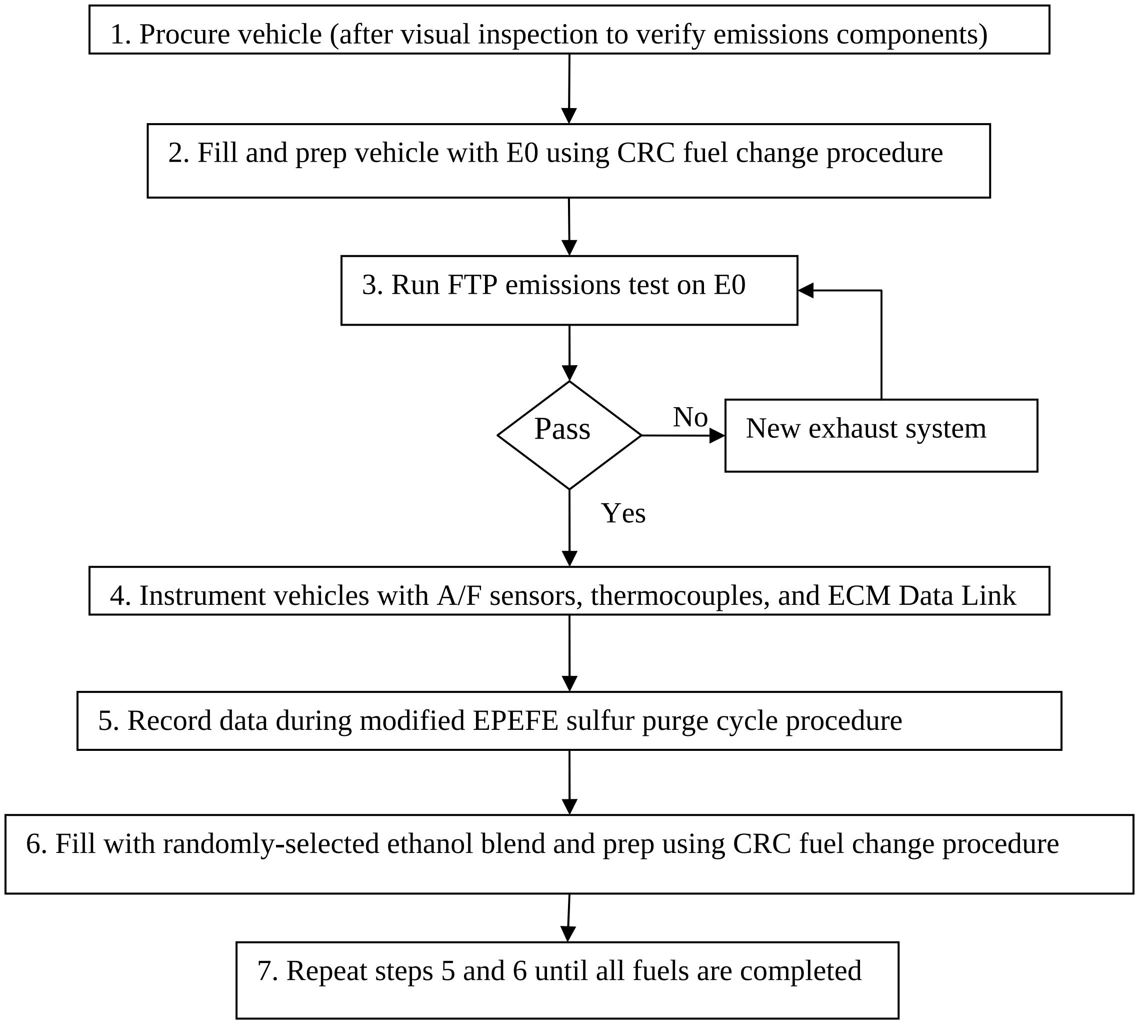
7 NREL/TP-540-43543, ORNL/TM-2008/117, "Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1 – Updated," February 2009, http://feerc.ornl.gov/publications/Int_blends_Rpt1_Updated.pdf

Figure 1. Vehicle Test Sequence for E-87-1 as provided by CRC



Step 1: Vehicle selection and procurement – The test fleet composition was based on the following guidelines:

- 13 vehicles suggested by automakers as being unlikely to use adapted fuel trim and being built since 1990
- 12 vehicles suggested by the DOE as representing high production vehicles built since 2000

The 25-vehicle list is included as Table 1 in this report. Table 1 also details the model year and incoming odometer reading for each vehicle procured for the program.

Table 1 Target Program Vehicle List and Actual Vehicle Information

CRC #	Manufacturer	Model Year(s)	Brand/Model	Engine/ Transmission	Actual Model Year Selected	Actual Odometer At Delivery
1	GM	2001-03	Chevrolet Tracker	2.0L Auto 4x4	2001	115,223
2	GM	2001	Chevrolet Metro	1.3L Auto	2001	81,790
3	Ford	1999	Crown Victoria	4.6L Auto	1999	73,057
4	Chrysler	2001	PT Cruiser	2.4L Auto	2001	76,637
5	Nissan	2003	Altima	QR25 I-4 2.5L Auto	2003	85,396
6	Nissan	2002	Frontier Truck	KA24 I-4 2.4L Auto	2002	70,210
7	Hyundai	2001	Accent	1.5L Auto	2001	79,382
8	BMW	2004	330i	3.0L Auto	2004	38,722
9	Mitsubishi	1999-2001	Mirage	1.5L Auto	1999	113,204
10	Mitsubishi	2001	Montero Sport	3.5L 4WD Auto	2001	85,871
11	Honda	1992-95	Civic DX, LX	1.5L Auto	1995	165,455
12	Chrysler	2007	Jeep Rubicon	3.8L 4WD Auto	2007	5,312
13	VW	2000-03	Jetta	1.8L Turbo Auto	2003	88,025
14	GM	2006	Chevrolet Cobalt 4 door	2.2L engine Auto	2006	12,423
15	GM	2006	Chevrolet Silverado Extended Cab	5.3L engine Not FFV Auto	2006	41,613
16	GM	2002	Chevrolet Suburban 4WD	5.3L engine Not FFV Auto	2002	83,036
17	Ford	2007	Focus	Federal Bin 4 Focus 2.0L Auto	2007	19,988
18	Ford	2000	Focus	SPI, 2.0L, Auto	2000	93,755
19	Ford	2003	Taurus	3.0L 2 valve not FFV Auto	2003	51,366

Table 1 Target Program Vehicle List and Actual Vehicle Information, Continued.

CRC #	Manufacturer	Model Year(s)	Brand/Model	Engine/ Transmission	Actual Model Year Selected	Actual Odometer At Delivery
20	Chrysler	2001-02	Dodge Durango 4WD	4.7L Auto	2002	75,191
21	Toyota	2000-02	Sienna	3.0L Auto	2000	81,880
22	Honda	2000	Accord LX	2.3L Auto	2000	97,291
23	Nissan	2006	Quest	3.5L Auto	2006	35,644
24	VW	2000-01	Jetta	2.0L, Auto, federal	2001	71,927
25	Mazda	2000-01	626	2.0L 16v Auto	2001	75,253

The following steps were taken to ensure each vehicle selected was correct and appropriate for this program.

- Each of the 25 vehicles was inspected prior to purchase to verify all emissions control components were in place and connected. Any vehicles with pending or existing Diagnostic Trouble Codes (DTC) were repaired by the seller prior to purchase and delivery.

- A maximum/minimum odometer range guideline was established for each vehicle based on the model years selected by the committee. Vehicles which had accumulated between 7,500 and 15,000 odometer miles per year since manufacture were selected. This odometer range was selected to assist with vehicle identification and location of any matching vehicles required for the then proposed future work related to this project.

23 of the 25 vehicles selected for the test program fell within the maximum/minimum odometer range guideline. The 2006 Chevrolet Cobalt (CRC #14) and 2007 Jeep Rubicon (CRC #12) selected for use in the program were slightly below the minimum mileage guideline target but were accepted as valid vehicles for the study. Their odometer mileages were determined to be close enough to typical that finding matching vehicles for any future work would be possible.

The 25 test vehicles for this program were procured and delivered to TRC Inc.'s East Liberty, Ohio facility between April 3, 2008 and June 26, 2008. Each vehicle received an incoming technical inspection to verify it was mechanically sound for chassis dynamometer operation. At that time only minor repairs were made to the vehicle exhaust systems prior to the initial FTP emissions test. The intent of the minimal repairs was to minimize any repair expenses for vehicles that could potentially fail the screening process and not enter the actual test program.

Step 2: Vehicle preconditioning and test fuels and specifications – Test fuels for this program were provided by CRC. The test fuels provided by CRC for the E-87-1 program are detailed in Tables 2, 3, and 4. Table 2 contains the averaged analysis results from four laboratories using standardized ASTM test methods. Table 3 contains the analysis results from the fuel blending laboratory. Table 4 contains the detailed hydrocarbon analysis results obtained by gas chromatography.

Table 2 E-87-1 Test Fuels: General Analysis Results (Average of Four Laboratories)

Designation	Units	E0	E10	E20
API Gravity	°API	63.3	58.8	57.0
Relative Density	60/60°F	0.7262	0.7435	0.7506
DVPE – D5191	psi	9.10	8.79	8.47
Oxygenates - D4815				
MTBE	vol %	0.00	0.00	0.00
ETBE	vol %	0.00	0.00	0.00
EtOH	vol %	0.00	9.42	20.38
O2	wt %	0.00	3.49	7.49
Hydrocarbon Composition - D1319				
Aromatics	vol %	23.4	23.6	21.2
Olefins	vol %	9.6	9.6	10.9
Saturates	vol %	67.1	57.5	47.4
D86 Distillation				
IBP	°F	88.8	97.2	103.3
5% Evaporated	°F	114.2	119.7	125.0
10% Evaporated	°F	122.4	125.1	131.2
20% Evaporated	°F	134.5	135.1	141.1
30% Evaporated	°F	148.2	143.6	148.5
40% Evaporated	°F	167.5	151.7	154.6
50% Evaporated	°F	191.0	189.8	159.6
60% Evaporated	°F	214.2	225.9	163.8
70% Evaporated	°F	236.6	246.9	227.9
80% Evaporated	°F	266.2	275.2	270.1
90% Evaporated	°F	316.5	319.0	313.7
95% Evaporated	°F	329.3	331.9	325.3
Designation	Units	E0	E10	E20
EP	°F	353.7	357.2	342.0
Recovery	Vol %	97.6	97.9	98.3
Residue	Vol %	1.6	1.1	1.1
Loss	Vol %	0.8	1.0	0.7
Driveability Index		1073.2	1075.9	989.1

Some fuel parameters were supplied by the fuel supplier (Table 3). The fuel supplier estimate (calculated) for the C/H ratio of the E0 fuel was used in the carbon balance calculations for emissions results to qualify the vehicles.

Table 3 E-87-1 Fuel Supplier Test Fuels Analysis Results

Designation	Units	E0	E10	E20
Sulfur Content	ppm	28	29	27
Estimated C/H Ratio		6.159	-	-
Benzene	Vol %	1.00	1.00	0.96
Research Octane Number		94.4	92.9	94.6
Motor Octane Number		84.5	84.1	83.4
(R+M)/2		89.5	88.5	89.0

A more accurate C/H ratio for the E0, E10, and E20 fuels was made available in the following Table 4, from the detailed hydrocarbon analysis (DHA) performed by one of the participating laboratories in the general fuel analysis. Note that the DHA yields results for many parameters already reported above, but the methods differ (and the general results are the average of four laboratory results). Despite the different methods, the results are in close agreement, and thus are shown here to confirm the earlier results.

Table 4 E-87-1 Test Fuels Detailed Hydrocarbon Analysis Results

Designation	Units	E0	E10	E20
Aromatics	Vol %	25.65	24.57	21.78
Olefins	Vol %	10.09	10.21	10.74
Saturates	Vol %	63.50	53.72	46.23
Unclassified	Vol %	0.76	1.75	0.15
Ethanol	Vol %	0.00	9.75	21.11
Benzene	Vol %	1.05	1.10	0.97
C/H Ratio		6.196	6.106	5.835
Oxygen	wt. %	0.00	3.61	7.73
Net Heat of Combustion	Btu/lb	18,733	17,973	17,160

The required E15 test fuel was not available from CRC. TRC Inc. splash blended E98 by volume with the existing E10 fuel to produce E15 for this program. Four drums of E10 were splash blended to create E15 for this program. Detailed analyses were not performed on the E15 test fuel blended at TRC Inc. The E15 fuel ethanol content was verified as 14.94 volume% using ASTM D4815 by a one of the laboratories participating in the project fuel analyses.

All test fuels for the E-87-1 program were provided, stored, and dispensed in drum quantities. All program fuel drums were maintained at 54° F in TRC Inc.'s Emissions Laboratory Fuel Storage Building throughout the program. Fuels were dispensed directly to the Emissions

Laboratory Refueling Bay via individual drum pumps using underground transport piping. To minimize the possibility of any potential fueling errors during the program each fuel change event included redundant vehicle/fuel checks between the technician performing the fuel change and a Project Engineer assigned to the Emissions Laboratory.

Prior to the initial vehicle preconditioning each vehicle was drained and filled to 40% tank capacity with the E0 test fuel. For this and each fuel change in the program the fuel change and preparation procedure provided by CRC and detailed in Table 5 was used.

Table 5 E-87-1 Fuel Change Procedure

Step	Action
1	Drain the fuel tank
2	Fill with new test fuel to 40% full
3	Run 3 cycles of the road LA-4 cycle

All test vehicle emissions, test weights and chassis dynamometer settings were taken from the US EPA Annual Certification Test Results and Data website (http://www.epa.gov/otaq/crttst.htm). All test vehicle fuel tank capacity data were collected from manufacturer information.

Step 3: FTP emissions testing and vehicle repair – A single exhaust emissions FTP test was employed to qualify the test vehicles for inclusion into the test program. If each of the emissions were less than 120% of the relevant emissions standards the vehicle was used for the screening tests. If any of the emissions were greater than 120% of standards the vehicle would either be serviced and retested or dropped from the program. Composite FTP emissions results for each of the twenty five vehicles in the program are included as Table 6. Details of TRC Inc's facilities and equipment are included as Appendix A.

Table 6 Composite FTP Emissions Results

CRC #	MY	Vehicle	Mileage	Composite FTP Result (g/mile)		
				NMHC	CO	NOx
1	2001	Chevrolet Tracker	115,223	0.081	1.5	0.15
2	2001	Chevrolet Metro	81,790	0.144	1.4	0.01
3	1999	Ford Crown Victoria	73,057	0.136	1.4	0.06
4	2001	Chrysler PT Cruiser	76,637	0.040	0.6	0.08
5	2003	Nissan Altima	85,396	0.033	1.0	0.12
6	2002	Nissan Frontier Truck	70,210	0.090	1.3	0.18
7	2001	Hyundai Accent	79,382	0.058	3.1	0.15
8	2004	BMW 330i	38,722	0.016	0.8	0.01
9	1999	Mitsubishi Mirage	113,204	0.368	4.5	0.41
10	2001	Mitsubishi Montero Sport	85,871	0.074	2.4	0.06
11	1995	Honda Civic DX, LX	165,455	0.208	2.6	0.37
12	2007	Jeep Rubicon	5,312	0.030	1.0	0.01
13	2003	Volkswagen Jetta	88,025	0.104	4.9	0.52
14	2006	Chevrolet Cobalt, 4 door	12,423	0.034	0.7	0.02
15	2006	Chevrolet Silverado Extended Cab	41,613	0.062	1.1	0.07
16	2002	Chevrolet Suburban 4WD	83,036	0.103	0.9	0.38
17	2007	Ford Focus	19,988	0.010	0.2	0.00
18	2000	Ford Focus	93,755	0.044	1.0	0.05
19	2003	Ford Taurus	51,366	0.116	2.9	0.02
20	2002	Dodge Durango 4WD	75,191	0.180	2.7	0.21
21	2000	Toyota Sienna	81,880	0.194	1.6	0.29
22	2000	Accord LX	97,291	0.068	1.9	0.06
23	2006	Nissan Quest	35,644	0.038	0.1	0.01
24	2001	Volkswagen Jetta	71,927	0.010	0.4	0.02
25	2001	Mazda 626	75,253	0.056	0.6	0.03

During the FTP testing, 23 of 25 vehicles were below their full useful life emission standards. No vehicles required any repairs, replacement, or retesting of the emissions system. The 1999 Mitsubishi Mirage (CRC #9) and the 2003 Volkswagen Jetta (CRC #13) exceeded their NMHC standard by 18% and 15% respectively. The Jetta also exceeded the CO standard by 15%. Neither of these vehicles exceeded their standards by 20% which would have required repair or replacement.

Seven vehicles received minor service prior to entering the test program. The vehicle service is detailed in Table 7. Four vehicles had exhaust system leaks which required new exhaust pipes. The 1995 Honda Civic (CRC #11) oxygen sensors were not functioning and were replaced prior to starting the test program.

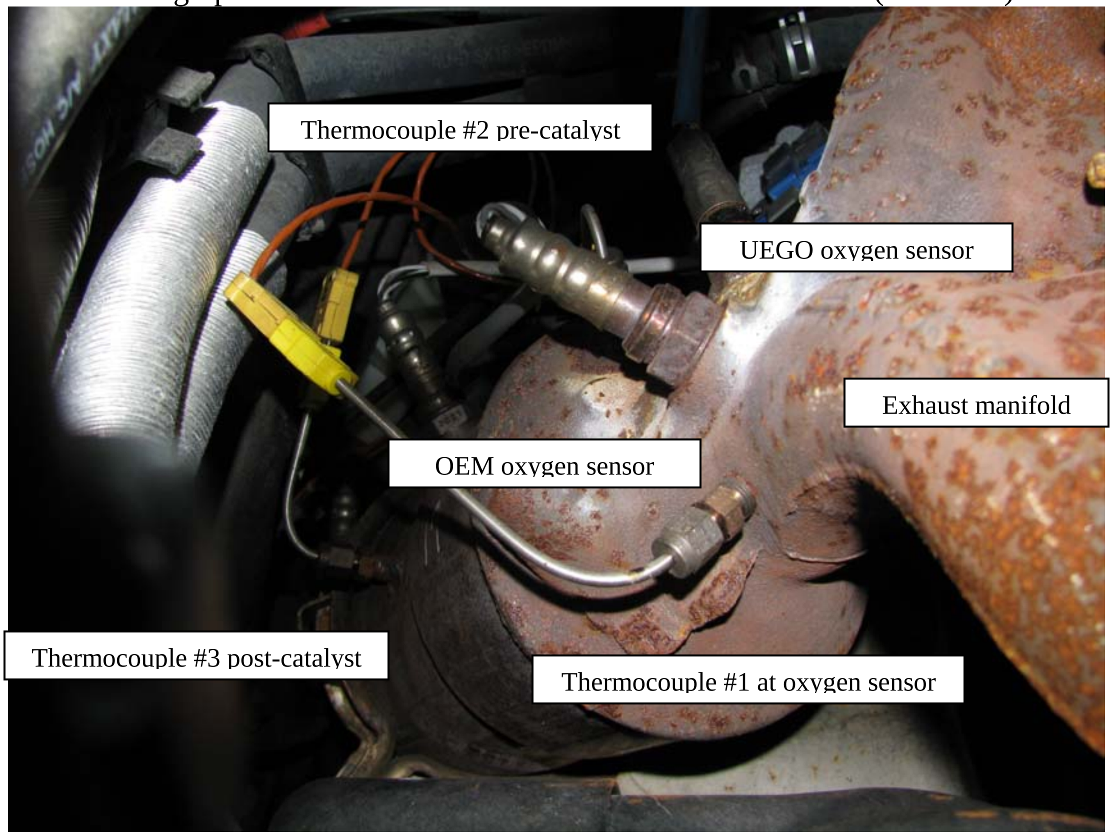
Table 7 Vehicle Service Detail

CRC #	Vehicle	Repair
1	2001 Chevrolet Tracker	Exhaust pipe from catalyst rearward including muffler
2	2001 Chevrolet Metro	Exhaust pipe from catalyst rearward including muffler
11	1995 Honda Civic	Upstream and downstream oxygen sensors
13	2003 VW Jetta	Upper radiator hose replacement, new coolant
19	2003 Ford Taurus	New battery
20	2002 Dodge Durango	Exhaust pipe from catalyst rearward including muffler
25	2001 Mazda 626	Exhaust system including muffler but excluding catalyst

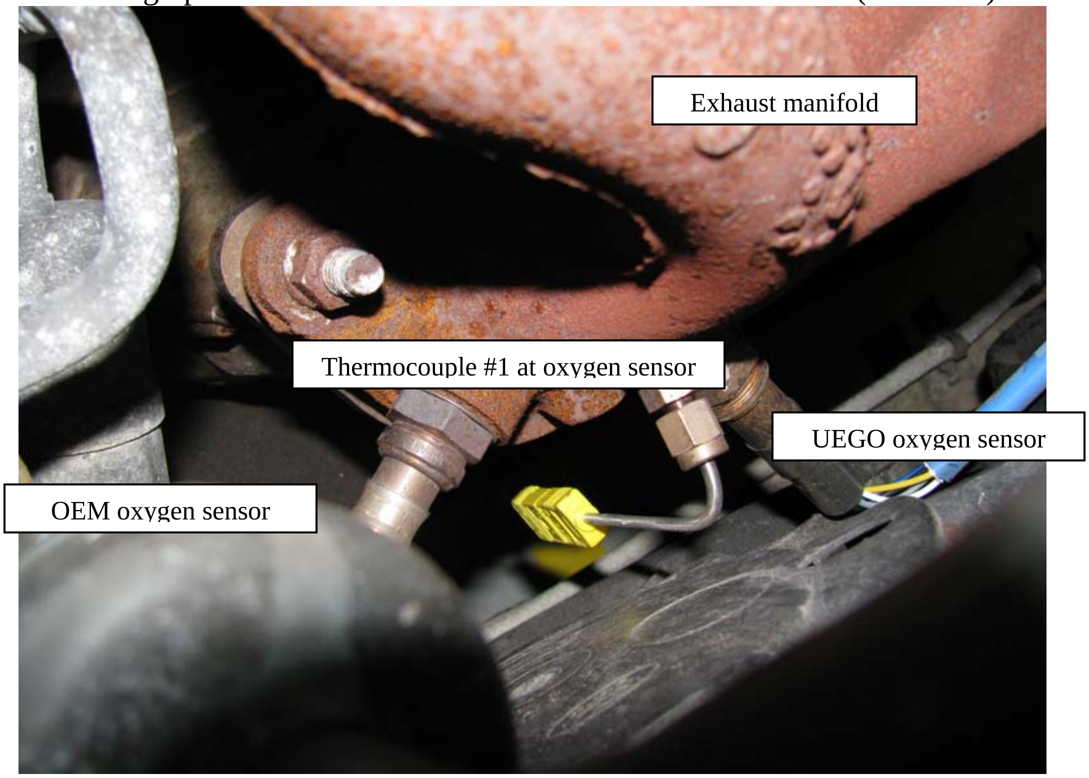
Step 4: Vehicle and laboratory instrumentation – All vehicles selected for the screening test were instrumented with a wide-range oxygen sensor just upstream of the front catalyst. Thermocouples were located just upstream and downstream of the front catalyst and at the oxygen sensor(s). The wide range oxygen sensor measures the air:fuel ratio even during periods of enrichment or enleanment. The thermocouples were installed to document changes in exhaust and catalytic converter temperature. For vehicles with two separate exhaust streams for each engine bank, only a single exhaust stream was instrumented. During vehicle instrumentation all exhaust gaskets and fasteners exposed during vehicle disassembly were replaced with new ones.

TRC Inc. attempted to place all thermocouples in the center of the exhaust stream 1” from the catalyst face. The thermocouples located at the factory oxygen sensor locations were placed in the center of the exhaust stream slightly upstream of the sensor. In some cases two thermocouples would have occupied approximately the same location. Typically this occurred with the oxygen sensor thermocouple and the catalyst inlet thermocouples. Photos 1 – 4 are included as typical instrumentation installation scenarios. TRC Inc. installed between two and four thermocouples in each of the 25 vehicles for this program; a detailed list of the thermocouple locations for each vehicle is included in Table 8.

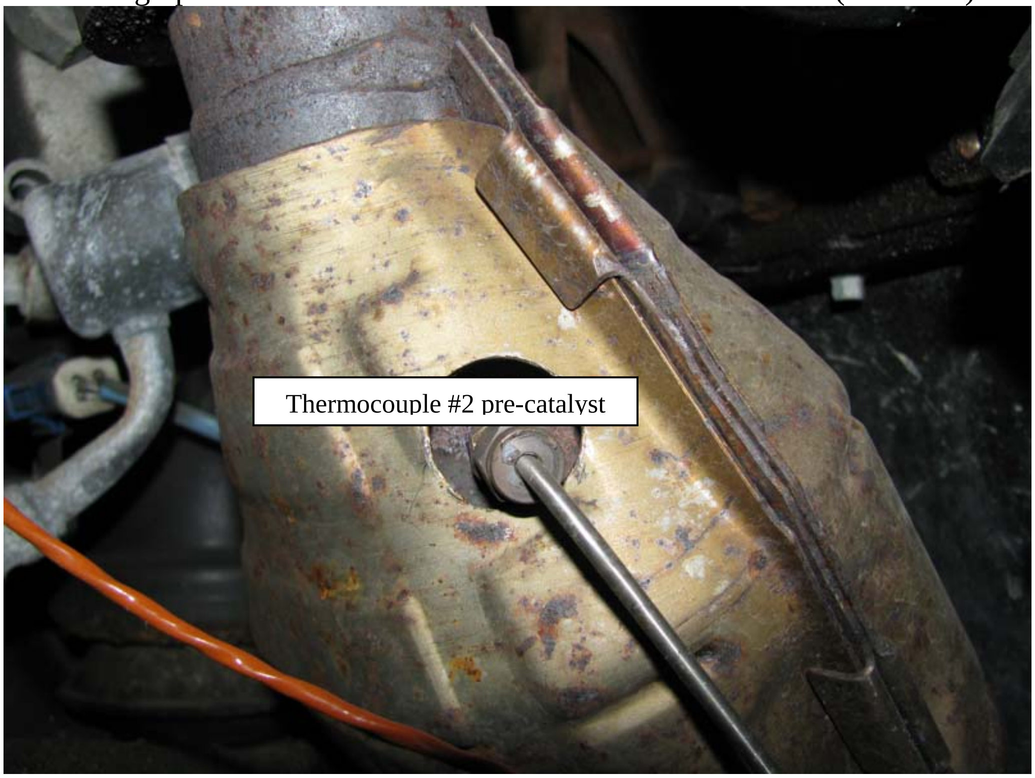
Photograph 1 Instrumentation Installation 2007 Ford Focus (CRC #17)



Photograph 2 Instrumentation Installation 2003 Ford Taurus (CRC #19)



Photograph 3 Instrumentation Installation 2003 Ford Focus (CRC #19)



Photograph 4 Instrumentation Installation 2003 Nissan Altima (CRC #5)

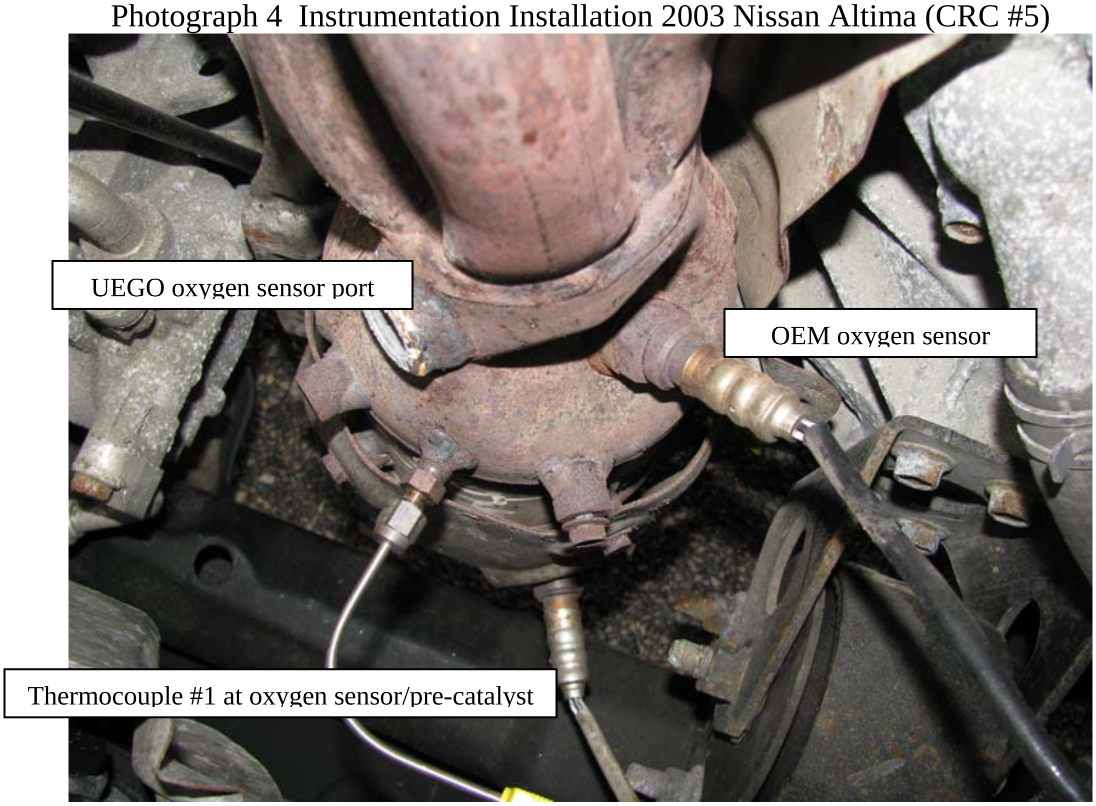


Table 8 Vehicle Thermocouple Locations

	Thermocouple			
CRC #	T #1	T #2	T #3	T #4
1	Oxygen Sensor; manifold	pre-catalyst; close coupled	post-catalyst	Oxygen Sensor downstream
2	Oxygen Sensor; manifold	pre-catalyst; underfloor	Post-catalyst	
3	Oxygen Sensor/Pre catalyst; drivers side not in manifold	Oxygen Sensor/Post-catalyst - close coupled		
4	Oxygen Sensor; manifold	Pre-catalyst ; underbody ~15"	Post-catalyst	
5	Oxygen Sensor/Pre catalyst #1; manifold	Post catalyst #1/Oxygen Sensor - close coupled	Pre catalyst #2	Post catalyst #2
6	Oxygen Sensor/Pre catalyst; manifold	Post-catalyst; close coupled	Oxygen Sensor #2	
7	Oxygen Sensor/Pre catalyst; manifold	Post-catalyst; close coupled		
8	Oxygen Sensor/Pre catalyst; manifold	Post-catalyst; close coupled	Oxygen Sensor #2	
9	Oxygen Sensor; manifold	pre-catalyst; under-floor	Post-catalyst	
10	Oxygen Sensor passenger side	pre-catalyst; under-floor	Post-catalyst	
11	Oxygen Sensor	Pre-catalyst	Post-catalyst	
12	Oxygen Sensor; manifold	pre-catalyst; under-floor	Post-catalyst	
13	Oxygen Sensor; underbody	Pre-catalyst	Post-catalyst	
14	Oxygen Sensor; manifold	Pre-catalyst ; underbody ~18"	Post-catalyst	
15	Oxygen Sensor/Pre catalyst; drivers side not in manifold	Pre-catalyst	Post-catalyst	Oxygen Sensor #2
16	Oxygen Sensor; underbody	Pre-catalyst	Post-catalyst	
17	Oxygen Sensor; manifold	pre-catalyst; close coupled	post-catalyst; 2nd Oxygen Sensor	
18	Oxygen Sensor; manifold	pre-catalyst; close coupled	Post-catalyst	
19	Oxygen Sensor; manifold	pre-catalyst; close coupled	Post-catalyst	

Table 8 Vehicle Thermocouple Locations, continued

CRC #	T #1	T #2	T #3	T #4
20	Oxygen Sensor; underbody	Pre-catalyst	Post-catalyst	Oxygen Sensor #2
21	Oxygen Sensor; manifold	pre-catalyst; under-floor	Post-catalyst	
22	Oxygen Sensor; manifold	pre-catalyst; under-floor	Post-catalyst	
23	Oxygen Sensor/Pre catalyst; manifold	Post-catalyst; close coupled	Oxygen Sensor #2	
24	Oxygen Sensor; manifold	pre-catalyst; under-floor	Post-catalyst	
25	Oxygen Sensor/Pre catalyst; manifold	Post-catalyst; close coupled; 2nd Oxygen Sensor	pre-catalyst #2 underbody	post-catalyst #2

All thermocouples installed in vehicles for this program were K-type and were installed into the vehicle exhaust system using a compression fitting welded or threaded into the pipe or exhaust manifold as appropriate. Twisted/shielded K-thermocouple wiring was used to connect the thermocouples to the TRC Inc. data acquisition equipment.

The wide-range oxygen sensor data for this program were collected using a universal exhaust gas oxygen (UEGO) sensor and Air Fuel Ratio Module. Several individual UEGO sensors were used for this program. Each vehicle completed the entire test program with the same sensor however, sensors were reused during the program and TRC Inc. did not track which sensors were used in each vehicle throughout the program.

Wide range UEGO and thermocouple data were collected using TRC Inc. data acquisition equipment supported by TRC Inc. data acquisition software operating at 10 Hz for this program.

Engine Control Module (ECM) data were recorded from each vehicle during the European Programme for Emission, Fuels, and Engine Technologies (EPEFE) Sulfur Purge test cycle (EPEFE test) via the Data Link connector (DLC). TRC Inc. elected to record each channel available via the vehicle's DLC during the program. The number of data channels recorded during the program varied based on vehicle make/model and ranged from 36 channels (2007 Jeep Rubicon) to 13 channels (2001 Chrysler PT Cruiser). Data were recorded at the maximum speed provided by the vehicle DLC (approximately 4 Hz). The 1995 Honda Civic (CRC #11) was not equipped with a DLC and no ECM data were recorded. Additional instrumentation was not added to the 1995 Honda Civic to collect data.

Step 5: European Programme for Emission, Fuels, and Engine Technologies (EPEFE) Sulfur Purge Test Cycle Matrix – The EPEFE sulfur purge cycle was chosen as the basis for the test procedure. This cycle was developed to heat the catalyst to a very high temperature in a rich environment. Its original purpose was to facilitate the purging of accumulated sulfur from the catalyst to enable more representative evaluation of catalyst efficiency. For the purposes of this test, the high catalyst temperatures induced by this procedure will ensure that the vehicle's control system will enrich the air-fuel ratio to cool the exhaust and protect the catalyst. Operation in the enriched (Lambda < 1) region ensures that the control system is not in closed loop control and is using calculated fuel volumes for control of the air-fuel ratio.

Each vehicle has its own map of Lambda versus engine speed, manifold pressure and other parameters. Although most vehicles frequently operate enriched (Lambda <1) it is important to have a repeatable procedure that ensures the engine is operating with an enriched air-fuel ratio. The EPEFE purge cycle does this and has the additional benefit of allowing the control system many opportunities to learn the various test fuel compositions.

The procedure was modified from its original cycle of 30 mph to 70 mph accelerations to 0 to 84 mph accelerations. This lengthening of the acceleration was done to lengthen the time the vehicle spends at WOT. Many vehicles have a timer or other device to initially inhibit enrichment at WOT. By lengthening the duration of the WOT period the vehicle is more likely to go into enrichment enabling the fuel effect to be discerned.

The EPEFE test was performed for each vehicle and fuel combination. A total of ten wide open throttle accelerations were performed while recording UEGO, thermocouple, and DLC data. The steps to perform the EPEFE test for this program are detailed in Table 9. During the program all test vehicles were stored in TRC Inc.'s emissions soak room between 68-86° F.

Table 9 CRC E-87-1 EPEFE Sulfur Purge Test Cycle Procedure - Modified

Step #	Procedure
1	Drive the vehicle from idle to 55 mph and hold speed for 5 minutes (to bring catalyst to full working temperature).
2	Reduce vehicle speed to 30 mph and hold speed for one minute.
3	Reduce speed to 0 mph and idle for 90 seconds.
4	Accelerate at WOT (wide-open throttle) for a minimum of 5 seconds, to achieve a speed in excess of 70 mph (84 mph). Continue WOT above 70 mph, if necessary to achieve 5-second acceleration duration (12 seconds or more is desirable). Hold the peak speed for 15 seconds and then decelerate to 30 mph.
5	Maintain 30 mph for one minute.
6	Reduce speed to 0 mph and idle for 90 seconds.
7	Repeat steps 4 through 6 to achieve 5 WOT excursions.
8	One sulfur removal cycle has been completed.
9	Repeat steps 1 to 7 for the second sulfur removal cycle.
10	The protocol is complete if the necessary parameters[8] have been achieved.

8 Successful completion of the protocol was defined as collection of data from ten WOT events meeting the conditions detailed in Step #4 of the procedure.

Each vehicle performed the EPEFE test using the E0, E10, E15, and E20 test fuels. The initial test fuel was always E0. Following the E0 EPEFE test, the sequence of the remaining EXX fuels was randomized for the entire vehicle fleet. The test fuel order for each vehicle is detailed in Table 10.

Table 10 CRC E-87-1 Fuel Test Matrix

CRC #	Vehicle	Test #1	Test #2	Test #3	Test #4
1	Chevrolet Tracker	E0	E10	E20	E15
2	Chevrolet Metro	E0	E15	E20	E10
3	Ford Crown Victoria	E0	E15	E10	E20
4	Chrysler PT Cruiser	E0	E20	E10	E15
5	Nissan Altima	E0	E20	E10	E15
6	Nissan Frontier Truck	E0	E10	E15	E20
7	Hyundai Accent	E0	E15	E20	E10
8	BMW 330i	E0	E20	E15	E10
9	Mitsubishi Mirage	E0	E15	E20	E10
10	Mitsubishi Montero Sport	E0	E10	E15	E20
11	Honda Civic DX, LX	E0	E20	E10	E15
12	Jeep Rubicon	E0	E15	E10	E20
13	Volkswagen Jetta	E0	E10	E20	E15
14	Chevrolet Cobalt, 4 door	E0	E20	E15	E10
15	Chevrolet Silverado Extended Cab*	E15*	E10	E20	E0*
16	Chevrolet Suburban 4WD	E0	E10	E15	E20
17	Ford Focus	E0	E15	E10	E20
18	Ford Focus	E0	E15	E10	E20
19	Ford Taurus	E0	E20	E10	E15
20	Dodge Durango 4WD	E0	E15	E20	E10
21	Toyota Sienna	E0	E10	E20	E15
22	Accord LX	E0	E10	E15	E20
23	Nissan Quest*	E20*	E15	E10	E0*
24	Volkswagen Jetta	E0	E20	E15	E10
25	Mazda 626	E0	E10	E20	E15

* The Chevrolet Silverado (CRC #15) and Nissan Quest (CRC #23) E0 test results were determined to be invalid post-test due to a failure of the data acquisition system. For those two vehicles the E0 test was repeated at the conclusion of the randomized test fuel sequence.

Step 6: Fuel Change Procedure – For each fuel change in the program, the CRC E-87-1 fuel change and preparation procedure was used. This included a drain of the fuel tank, a 40% tank capacity fill with new test fuel, and operating the vehicle though three consecutive LA-4 road cycles on a chassis dynamometer.

Data Collected and Analysis - Each vehicle performed four EPEFE Sulfur Purge Cycle Procedures during the program. The vehicle speed, oxygen sensor air-fuel-ratio (AFR), and catalyst temperature data from the tenth WOT event for each vehicle and fuel combination were used for analysis purposes to determine if each vehicle used adaptive fuel trims during open loop control. The 10^{th} WOT event was chosen to ensure that the vehicle was able to learn and apply the fuel trim in the WOT condition to assess if the control software used adaptive fuel trim.

The oxygen sensor AFR data were normalized for each vehicle using a 14.68 value. A chart was created for each vehicle visually displaying the normalized oxygen sensor lambda for each test fuel. If the individual fuel curves in this Lambda Chart overlay each other once the vehicle stabilizes, the vehicle is identified as using adaptive fuel trip during open loop control. For the purposes of this program, vehicle stability was identified as operating vehicle speeds above 40-50 mph. If the individual fuel curves in the Lambda Chart shadow each other separated by the oxygen content of the test fuel, the vehicle was identified as not employing adaptive fuel trim during open loop control. In these cases, the curves should be separated according to the oxygen content of the test fuel with the E0 curve being the lowest numeric lambda curve followed by E10 < E15 < E20.

Lambda Charts from a typical representative of using adaptive fuel trim and no adaptive fuel trim during open loop control are included as Figures 5 and 6 in this report. A complete set of Lambda Charts for the program is included as Appendix 2 of this report.

Figure 2 is the Lambda Chart for the 2006 Chevrolet Silverado (CRC #15). As noted on the chart, the fuel mixture is constant as ethanol content increases. This vehicle is adjusting for the ethanol content of the test fuel during open loop control. This vehicle and data are representative of an adjusting vehicle.

Figure 2 2006 Chevrolet Silverado (CRC #15) Lambda Chart

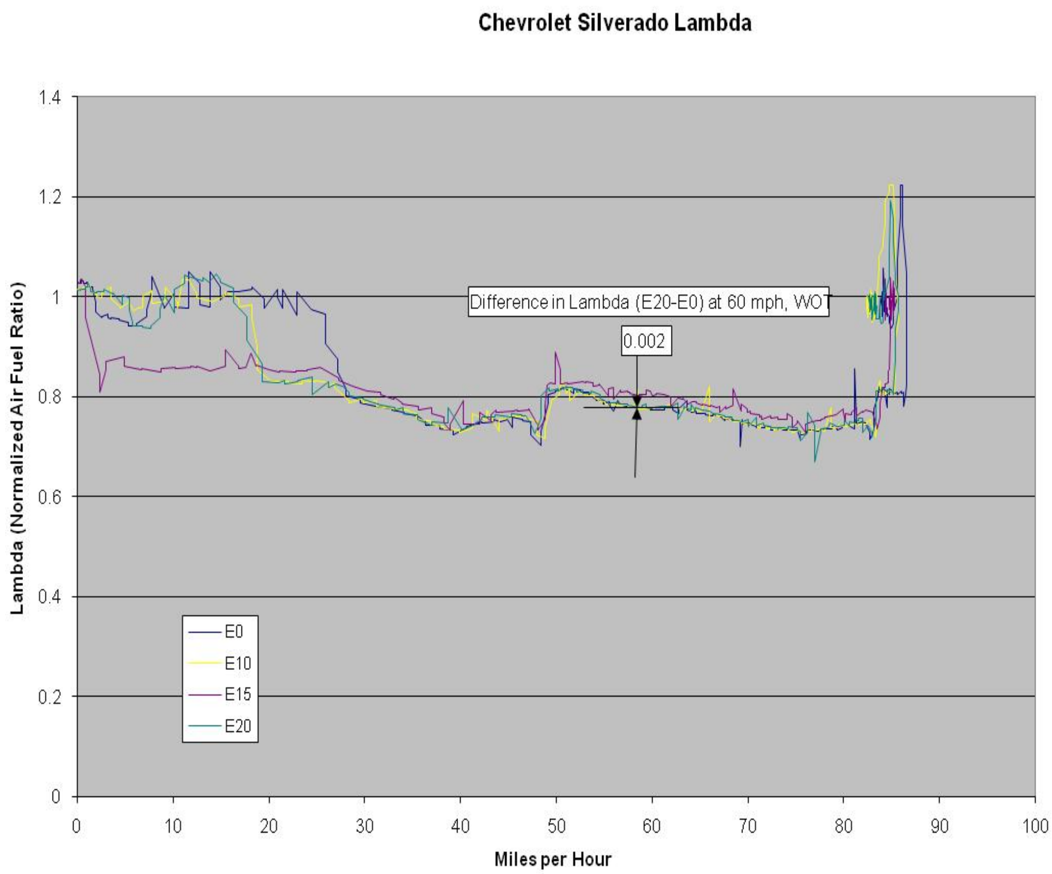
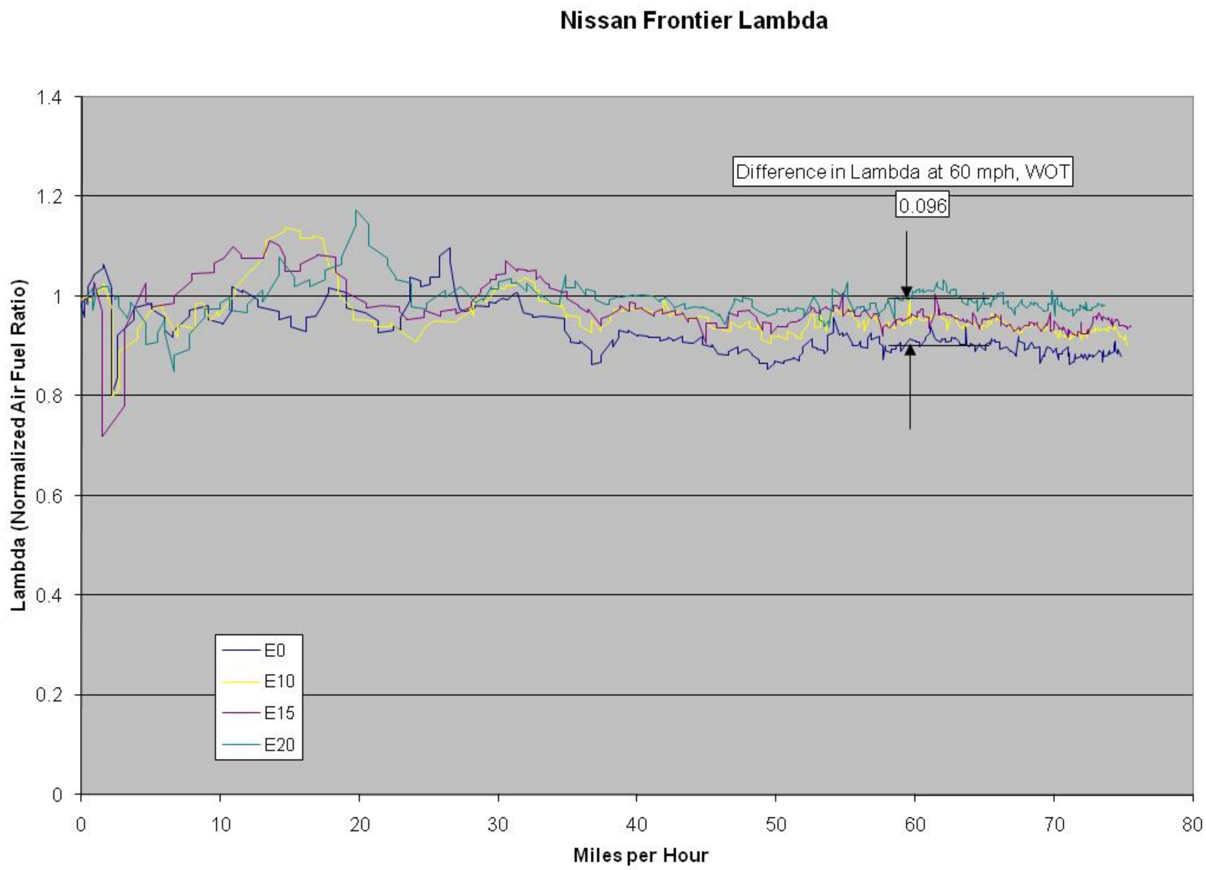


Figure 3 is the Lambda Chart for the 2002 Nissan Frontier (CRC #6). As noted on the chart the fuel mixture enleans as ethanol content increases from test to test. This vehicle is not adjusting for the ethanol content of the test fuel during open loop control. This vehicle and data are representative of a non-adjusting vehicle.

Figure 3 2002 Nissan Frontier (CRC #6) Lambda Chart



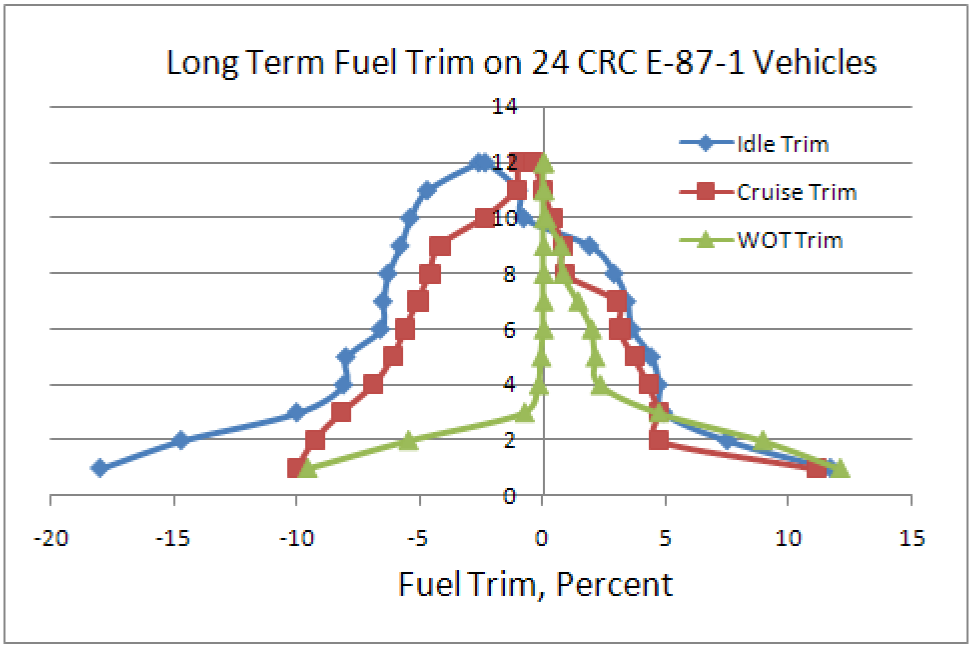
While testing the vehicles, data was taken from the data port and recorded. This data included the long term fuel trims throughout the test. The long term fuel trims vary depending on engine speed and manifold pressure because of the variation in fuel flows. Typically a vehicle has many values of long term fuel trim stored to account for fluctuations in its value as the engine speeds and loads change.

To compare the vehicles, samples were taken of these trims under three conditions that were relatively easy to replicate. In all cases, the data was taken from the E0 tests. The first was at idle where the vehicle speed was zero, the throttle opening was at a minimum, and engine was at idle speed. The second was at 55 mph cruise where the vehicle speed was approximately 55 mph, throttle opening was modest and stable and rpm was indicative of top gear with a locked or slip controlled torque converter. The third was wide open throttle (WOT) where the speed was high, the engine speed was over 4500 rpm except for a few high torque engines, and the throttle opening was at a maximum. The data are presented in Table 11 and Figure 4.

Table 11 Long Term Fuel Trims

		Long Term Fuel Trim		
CRC #	Vehicle	Idle	Cruise	WOT
1	Tracker	-8	-4.2	0
2	Metro	3.6	0.4	4.68
3	Crown Vic	4.9	4.3	0
4	PT Cruiser	-18	-9.3	0
5	Altima	-4.7	-6.1	-0.2
6	Frontier	4.4	-2.4	0.1
7	Accent	-0.78	-1	0
8	BMW	-2.6	-1.1	-0.1
9	Mirage	-5.4	3	2.3
10	Montero	-1	0.8	1.4
11	Civic	No Data	No Data	No Data
12	Rubicon	3.4	3.1	0
13	2003 Jetta	11.7	11.1	12.05
14	Cobalt	-14.7	-10	0.78
15	Silverado	4.7	3.7	2.1
16	Suburban	2.9	4.7	8.9
17	2007 Focus	-8.1	-4.6	-0.78
18	2000 Focus	1.9	-0.4	0
19	Taurus	-6.3	0.9	1.95
20	Durango	-6.6	-5.6	0
21	Sienna	-5.8	-6.9	-5.5
22	Accord	-10	-8.2	-9.6
23	Quest	7.5	4.7	0.7
24	2001 Jetta	-2.34	0	0
25	626	-6.5	-5.1	0
	Average	-2.33	-1.18	0.78
	St. Dev.	7.10	5.23	4.02

Figure 4 Distribution of Long Term Fuel Trims



As can be seen the average fuel trim at idle is -2.33 indicating a rich bias. This richness is probably due to canister purge activity. When the evaporative emissions canister is purging fuel vapors that were stored in the canister, the vapors are flushed into the intake manifold. This unmetered fuel vapor would make the vehicle appear "rich" to the engine controller prompting it to reduce the fuel trim hence the average negative value. Canister purge typically has a greater effect on fuel trim at idle because the overall fuel volumes are small. More interesting is the wide variation in conditions. This shows that there may be considerable variability in the response of individual vehicles to added fuel oxygen content. It is expected that vehicles with a negative long term fuel trim would be less likely to experience catalyst durability impacts with added oxygenate because these vehicles would tend to operate rich in the absence of long-term fuel trim.

Unfortunately, it is difficult to know the details of each vehicle's control strategy and we cannot know how the compensation for these effects work or even if it exists. For the purposes of doing additional experiments to determine if mid-level ethanol blends will have an effect, several vehicles of each type would be required to sample the fuel trim variation for that vehicle type. Alternatively, vehicles selected for additional testing could be screened and those with a built-in rich bias removed from the test sample on the assumption that they would be relatively insensitive to the effects of ethanol on the control system.

DATA ANALYSIS

The goal of data analysis was to identify vehicles which run lean and hot on E20. Several criteria were jointly determined by CRC and the US Department of Energy National Labs to be important to correctly identify these vehicles. The first stage of the data analysis was to identify the vehicles which did not use learned fuel trim (LFT) at WOT. This was decided by looking at Lambda changes relative to changes in fuel ethanol level.

Average lambda values from 60 to 63 mph and the data traces themselves were examined. Thirteen vehicles appear not to use learned fuel trim (LFT) at WOT. Eight vehicles appeared to use learned fuel trim (LFT) at WOT and one could not be analyzed. Three vehicles gave ambiguous results where there were differences in Lambda values for most fuels but the orders did not match the variation in oxygen content or not all Lambda values differed from one another. The results are summarized in Table 12 and Table 20, column 3.

Table 12 Assessment of Long Term Fuel Trim (LTF) Usage in Open Loop Control

CRC #	Vehicle	LFT @ WOT
1	2001 Chevrolet Tracker	No
2	2001 Chevrolet Metro	?
3	1999 Ford Crown Victoria	No
4	2001 Chrysler PT Cruiser	?
5	2003 Nissan Altima	No
6	2002 Nissan Frontier	No
7	2001 Hyundai Accent	No
8	2004 BMW 330i	Yes
9	1999 Mitsubishi Mirage	Yes
10	2001 Mitsubishi Montero Sport 4WD	Yes
11	1995 Honda Civic	No
12	2007 Chrysler Jeep Rubicon	No
13	2003 Volkswagen Jetta	NA
14	2006 Chevrolet Cobalt	No
15	2006 Chevrolet Silverado, Ext.	Yes
16	2002 Chevrolet Suburban, 4WD	Yes
17	2007 Ford Focus	?
18	2000 Ford Focus	No
19	2003 Ford Taurus	Yes
20	2002 Dodge Durango 4WD	No
21	2000 Toyota Sienna	Yes
22	2000 Honda Accord LX	No
23	2006 Nissan Quest	No
24	2001 Volkswagen Jetta	Yes
25	2001 Mazda 626	No

The twenty-five vehicles were then rank from 1 to 25 using the criteria detailed in Table 13. These criteria were equally weighted and summed. The detailed ranking for each category for all vehicles are included as Tables 13-19 while the summarized Final Rank Order results are included as Table 20. The supporting catalyst inlet temperature data collected during the program was included in Appendix 3 of this report.

Table 13 CRC E-87-1 LFT Identification Criteria

#	**Criteria**
1	Average Lambda E20, (50-70 mph), (highest to lowest)
2	Power to weight (lowest to highest)
3	Vehicle Registration, (2008 data), (highest to lowest)
4	Average inlet catalyst temperature, (50-70mph), (highest to lowest)
5	Delta lambda, (E20-E0), (60-63 mph), (highest to lowest)
6	Delta inlet catalyst temperature, (50-70mph), highest to lowest)

These six criteria were selected for the following reasons. Average Lambda E20 was selected because a vehicle with a high Lambda value at WOT should be more likely to approach stoichiometry (Lambda = 1) or even go lean in ordinary open loop operation. This near stoichiometric operation is most likely to be damaging to catalyst durability. Power to weight was selected because a vehicle with a low power to weight ratio is more likely to operate its engine at high loads and in open loop control. Number in service was deemed important because a vehicle with a catalyst durability issue is more important for air quality if there are a large number of vehicles in the in-use fleet. Average inlet catalyst temperature was chosen because a vehicle with an initially hot catalyst will be more sensitive to temperature increases. The difference in Lambda between E20 and E0 operation is indicative of whether and how well a vehicle is using adapted fuel trims to calculate open loop air fuel ratios. Similarly the difference in inlet catalyst temperatures between E20 and E0 operation is indicative of how well the control system is adapting to the ethanol in the fuel.

For criteria 1, 4, and 6 (tables 14, 17, and 19) the data traces were analyzed between 50 and 70 mph during the tenth WOT event for each vehicle. In cases where there was unstable data present, the unstable regions were excluded from the analysis. The typical cause of data instability was a gearshift. The vehicles which included unstable speed ranges and the actual speed range used to analyze the Lambda data are indicated in column 4 of each table. For criteria 1, 4, 5, and 6 (tables 14, 17, 18, and 19) The 2003 Volkswagen Jetta (CRC #13) data exhibited widely varying air-fuel ratios (Lambdas) throughout the 50-70 mph analysis range and were excluded from the rank order analysis.

Table 14 CRC E-87-1 Average Lambda E20 Rank Order Results

CRC #	Vehicle	E20 Lambda	Adjusted Analysis Range	Rank Order
6	2002 Nissan Frontier	0.99		1
20	2002 Dodge Durango 4WD	0.89		2
18	2000 Ford Focus	0.88*	50-66 mph	3
14	2006 Chevrolet Cobalt	0.87		4
23	2006 Nissan Quest	0.86		5
24	2001 Volkswagen Jetta	0.86		6
12	2007 Chrysler Jeep Rubicon	0.86*	56-70 mph	7
8	2004 BMW 330i	0.85		8
3	1999 Ford Crown Victoria	0.84		9
1	2001 Chevrolet Tracker	0.83		10
9	1999 Mitsubishi Mirage	0.81		11
19	2003 Ford Taurus	0.80		12
7	2001 Hyundai Accent	0.79		13
22	2000 Honda Accord LX	0.78		14
15	2006 Chevrolet Silverado, Ext.	0.78		15
2	2001 Chevrolet Metro	0.77		16
17	2007 Ford Focus	0.77		17
16	2002 Chevrolet Suburban, 4WD	0.75		18
10	2001 Mitsubishi Montero Sport 4WD	0.75*	50-68 mph	19
5	2003 Nissan Altima	0.73		20
11	1995 Honda Civic	0.725		21
21	2000 Toyota Sienna	0.72		22
25	2001 Mazda 626	0.72*	50-64 mph	23
4	2001 Chrysler PT Cruiser	0.7		24
13	2003 Volkswagen Jetta	NA		25

Table 15 CRC E-87-1 Power-to-Weight Ratio Rank Order Results

CRC #	Vehicle	Power (HP)	Weight (lbs)	P:W Ratio	Rank Order Results
6	2002 Nissan Frontier	143	3734	0.038	1
24	2001 Volkswagen Jetta	115	2886	0.040	2
2	2001 Chevrolet Metro	79	1958	0.040	3
10	2001 Mitsubishi Montero Sport 4WD	165	4085	0.040	4
7	2001 Hyundai Accent	92	2251	0.041	5
9	1999 Mitsubishi Mirage	92	2185	0.042	6
25	2001 Mazda 626	125	2864	0.044	7
1	2001 Chevrolet Tracker	127	2805	0.045	8
11	1995 Honda Civic	102	2226	0.046	9
19	2003 Ford Taurus	155	3335	0.046	10
4	2001 Chrysler PT Cruiser	150	3117	0.048	11
22	2000 Honda Accord LX	150	3020	0.050	12
21	2000 Toyota Sienna	194	3826	0.051	13
20	2002 Dodge Durango 4WD	235	4629	0.051	14
18	2000 Ford Focus	130	2545	0.051	15
3	1999 Ford Crown Victoria	200	3909	0.051	16
17	2007 Ford Focus	136	2636	.052	17
14	2006 Chevrolet Cobalt	145	2726	0.053	18
12	2007 Chrysler Jeep Rubicon	205	3762	0.054	19
5	2003 Nissan Altima	175	3043	0.058	20
16	2002 Chevrolet Suburban, 4WD	285	4914	0.058	21
13	2003 Volkswagen Jetta	180	3091	.058	22
23	2006 Nissan Quest	240	4086	0.059	23
15	2006 Chevrolet Silverado, Ext.	295	4627	0.064	24
8	2004 BMW 330i	225	3278	0.069	25

The Polk 2008 Vehicle Registration data included in Table 16 are model year specific for engine displacement only. The registration total for the 2003 Volkswagen Jetta (CRC #13) includes both turbo and non-turbo 4 cylinder engines. The twenty five vehicles selected for screening represent approximately 3.2 million of the vehicles registered in 2008.

Table 16 CRC E-87-1 Vehicle Registration Rank Order Results

CRC #	Vehicle	Registration (x1,000)	Rank Order
15	2006 Chevrolet Silverado, Ext.	414	1
22	2000 Honda Accord LX	256	2
18	2000 Ford Focus	248	3
11	1995 Honda Civic	237	4
19	2003 Ford Taurus	228	5
17	2007 Ford Focus	225	6
14	2006 Chevrolet Cobalt	218	7
3	1999 Ford Crown Victoria	178	8
5	2003 Nissan Altima	175	9
4	2001 Chrysler PT Cruiser	147	10
21	2000 Toyota Sienna	111	11
13	2003 Volkswagen Jetta*	108	12
24	2001 Volkswagen Jetta	98	13
20	2002 Dodge Durango 4WD	89	14
12	2007 Chrysler Jeep Rubicon	88	15
25	2001 Mazda 626	65	16
7	2001 Hyundai Accent	60	17
10	2001 Mitsubishi Montero Sport 4WD	39	18
16	2002 Chevrolet Suburban, 4WD	32	19
8	2004 BMW 330i	31	20
6	2002 Nissan Frontier	27	21
9	1999 Mitsubishi Mirage	27	22
23	2006 Nissan Quest	22	23
1	2001 Chevrolet Tracker	17	24
2	2001 Chevrolet Metro	14	25

Table 17 CRC E-87-1 Average E20 Catalyst Inlet Temperature Rank Order Results

CRC #	Vehicle	Average Catalyst Inlet Temperature, (deg C)	Adjusted Analysis Range	Rank Order
7	2001 Hyundai Accent	811		1
25	2001 Mazda 626	807*	50-64 mph	2
14	2006 Chevrolet Cobalt	795		3
5	2003 Nissan Altima	787		4
1	2001 Chevrolet Tracker	780		5
24	2001 Volkswagen Jetta	770		6
12	2007 Chrysler Jeep Rubicon	768*	56-70 mph	7
19	2003 Ford Taurus	756		8
23	2006 Nissan Quest	753		9
18	2000 Ford Focus	739*	50-66 mph	10
8	2004 BMW 330i	735		11
17	2007 Ford Focus	725		12
10	2001 Mitsubishi Montero Sport 4WD	717		13
3	1999 Ford Crown Victoria	715		14
6	2002 Nissan Frontier	715		15
15	2006 Chevrolet Silverado, Ext.	708		16
4	2001 Chrysler PT Cruiser	707		17
22	2000 Honda Accord LX	691		18
20	2002 Dodge Durango 4WD	653		19
11	1995 Honda Civic	641		20
13	2003 Volkswagen Jetta*	626		21
9	1999 Mitsubishi Mirage	603		22
16	2002 Chevrolet Suburban, 4WD	600		23
21	2000 Toyota Sienna	590		24
2	2001 Chevrolet Metro	579		25

The Delta Lambda E0-E20 values reported and ranked in Table 18 were recorded between 60 and 63 mph during the tenth WOT event for each vehicle. It is anticipated that the E0-E20 difference should be near zero for adapting vehicles and around 0.07 for non-adapting vehicles.

Table 18 CRC E-87-1 Delta Lambda E0-E20 Rank Order Results

CRC #	Vehicle	Delta Lambda E0-E20	Adjusted Analysis Range	Rank Order
23	2006 Nissan Quest	0.099		1
6	2002 Nissan Frontier	0.096		2
12	2007 Chrysler Jeep Rubicon	0.085		3
3	1999 Ford Crown Victoria	0.084		4
20	2002 Dodge Durango 4WD	0.071		5
7	2001 Hyundai Accent	0.068*	62-65 mph	6
25	2001 Mazda 626	0.062		7
22	2000 Honda Accord LX	0.061		8
18	2000 Ford Focus	0.059		9
14	2006 Chevrolet Cobalt	0.059		10
5	2003 Nissan Altima	0.052		11
11	1995 Honda Civic	0.050*	61-64 mph	12
1	2001 Chevrolet Tracker	0.046		13
2	2001 Chevrolet Metro	0.034		14
4	2001 Chrysler PT Cruiser	0.026*	58-61 mph	15
24	2001 Volkswagen Jetta	0.013		16
19	2003 Ford Taurus	0.01		17
9	1999 Mitsubishi Mirage	0.009		18
21	2000 Toyota Sienna	0.009		19
15	2006 Chevrolet Silverado, Ext.	0.002		20
16	2002 Chevrolet Suburban, 4WD	-0.001		21
8	2004 BMW 330i	-0.002		22
17	2007 Ford Focus	-0.008		23
10	2001 Mitsubishi Montero Sport 4WD	-0.019		24
13	2003 Volkswagen Jetta*			25

The Delta Inlet Catalyst Temperature E20-E0 values reported and ranked in Table 19. It is anticipated that the E20-E0 difference should be negative for adapting vehicles due to the cooling effect of ethanol and positive for non-adapting vehicles due to the enleanment effect of ethanol.

Table 19 CRC E-87-1 Delta Inlet Catalyst Temperature Lambda E20-E0 Rank Order Results

CRC #	Vehicle	Delta Catalyst Temperature E20-E0 (deg C)	Adjusted Analysis Range	Rank Order
25	2001 Mazda 626	33.2	50-64 mph	1
3	1999 Ford Crown Victoria	28.2		2
6	2002 Nissan Frontier	25.0		3
5	2003 Nissan Altima	23.3		4
22	2000 Honda Accord LX	20.1		5
11	1995 Honda Civic	19.5		6
23	2006 Nissan Quest	18.0		7
18	2000 Ford Focus	8.9	50-66 mph	8
1	2001 Chevrolet Tracker	8.3		9
19	2003 Ford Taurus	8.3		10
7	2001 Hyundai Accent	7.7		11
20	2002 Dodge Durango 4WD	6.9		12
2	2001 Chevrolet Metro	5.7		13
16	2002 Chevrolet Suburban, 4WD	5.1		14
24	2001 Volkswagen Jetta	2.9		15
17	2007 Ford Focus	1.6		16
4	2001 Chrysler PT Cruiser	-2.9		17
8	2004 BMW 330i	-3.2		18
21	2000 Toyota Sienna	-5.3		19
9	1999 Mitsubishi Mirage	-7.3		20
15	2006 Chevrolet Silverado, Ext.	-7.7		21
14	2006 Chevrolet Cobalt	-9.1		22
12	2007 Chrysler Jeep Rubicon	-10.6	56-70 mph	23
10	2001 Mitsubishi Montero Sport 4WD	-11.1		24
13	2003 Volkswagen Jetta	no data		25

The goal of the data analysis was to identify vehicles which run lean and hot on E20. Table 20 includes the ranking for each of the six analysis categories and the final rank order summary. Vehicles identified as non-adapting (those not using LFT at WOT) are listed at the top of the table in ascending order of rank order sum. The 2003 Volkswagen Jetta (CRC #13) was excluded from the final rank order table due to its unstable results throughout the data analysis ranges.

Table 20 CRC E-87-1 Final Rank Order Results

CRC #	Vehicle	LFT @ WOT	Average Lambda E20	Power to Weight Ratio	Registration Number	Average E20 Catalyst Inlet Temperature	Delta Lambda E0-E20	Delta Catalyst Inlet Temperature E0-E20	Final
6	2002 Nissan Frontier	No	1	1	21	15	2	3	43
18	2000 Ford Focus	No	3	15	3	10	9	8	48
3	1999 Ford Crown Victoria	No	9	16	8	14	4	2	53
7	2001 Hyundai Accent	No	13	5	17	1	6	11	53
25	2001 Mazda 626	No	23	7	16	2	7	1	56
24	2001 Volkswagen Jetta	Yes	6	2	13	6	16	15	58
22	2000 Honda Accord LX	No	14	12	2	18	8	5	59
19	2003 Ford Taurus	Yes	12	10	5	8	17	10	62
14	2006 Chevrolet Cobalt	No	4	18	7	3	10	22	64
20	2002 Dodge Durango 4WD	No	2	14	14	19	5	12	66
5	2003 Nissan Altima	No	20	20	9	4	11	4	68
23	2006 Nissan Quest	No	5	23	23	9	1	7	68
1	2001 Chevrolet Tracker	No	10	8	24	5	13	9	69
11	1995 Honda Civic	No	21	9	4	20	12	6	72
12	Rubicon	No	7	19	15	7	3	23	74
17	2007 Ford Focus	?	17	17	6	12	23	16	91
4	2001 Chrysler PT Cruiser	?	24	11	10	17	15	17	94
2	2001 Chevrolet Metro	?	16	3	25	25	14	13	96
15	2006 Chevrolet Silverado, Extended Cab	Yes	15	24	1	16	20	21	97
9	1999 Mitsubishi Mirage	Yes	11	6	22	22	18	20	99
10	2001 Mitsubishi Montero Sport 4WD	Yes	19	4	18	13	24	24	102
8	2004 BMW 330i	Yes	8	25	20	11	22	18	104
21	2000 Toyota Sienna	Yes	22	13	11	24	19	19	108
16	2002 Chevrolet Suburban, 4WD	Yes	18	21	19	23	21	14	116
13	2003 Volkswagen Jetta	NA	25	22	12	21	25	25	130

CONCLUSIONS

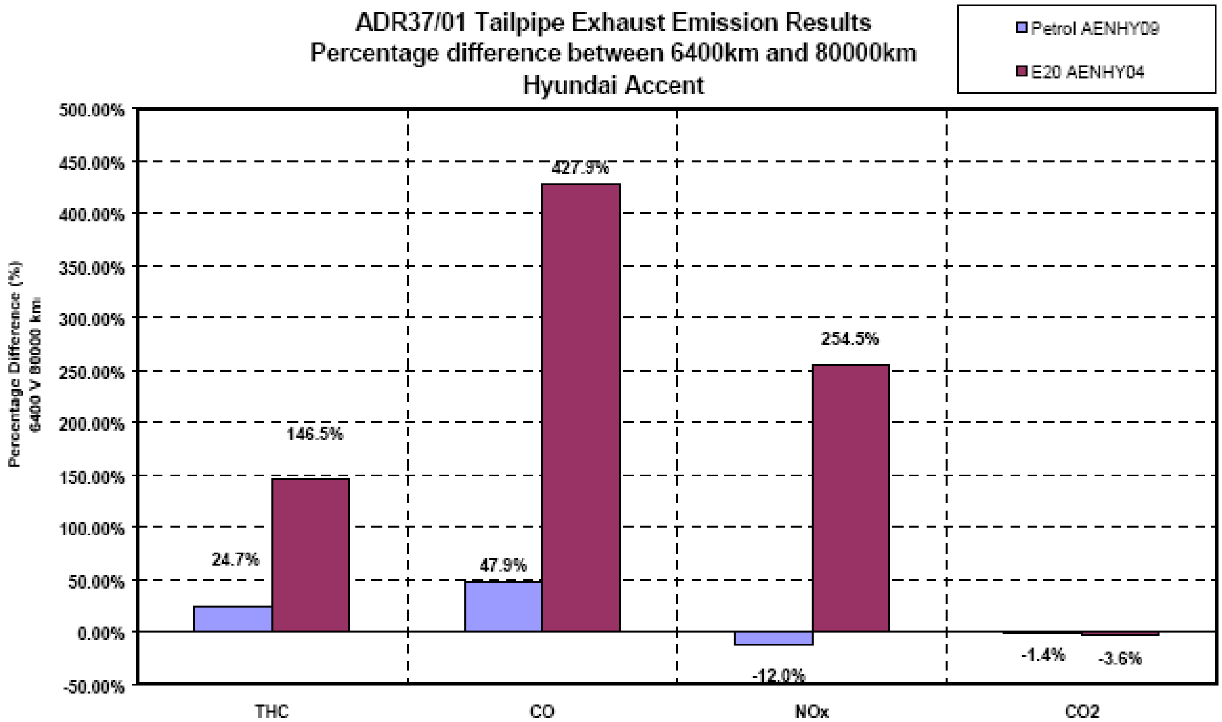
This preliminary screening study looked at 25 late model vehicles selected by CRC and the U.S. Department of Energy and sold in the US market. The vehicles were screened experimentally to determine which ones used learned fuel trims to correct the open loop air-fuel ratios. Of these twenty-five vehicles thirteen do not appear to use learned fuel trims, eight appear to use learned fuel trims and the results of four vehicles were unclear. Of the 3.2 million vehicle registrations represented by these vehicles, 53% do not appear to use learned fuel trims, 31% appear to use learned fuel trims, and 16% of the results were unclear.

The suitability of these vehicles for further testing was ranked based on six equally weighted criteria. The top ten vehicles were selected. Any vehicles that did use learned fuel trim were removed from the top ten resulting in these vehicles in order:

1. 2002 Nissan Frontier (4cyl)
2. 2000 Ford Focus
3. 1999 Ford Crown Victoria
4. 2001 Hyundai Accent
5. 2001 Mazda 626 (4cyl)
6. 2000 Honda Accord LX (4 cyl)
7. 2006 Chevrolet Cobalt
8. 2002 Dodge Durango 4WD
9. 2003 Nissan Altima (4cyl)
10. 2006 Nissan Quest

One of the vehicles screened was the 2001 Hyundai Accent. This is the only vehicle that demonstrated catalyst performance degradation in the Orbital study in Australia that is also available in the US. When it was evaluated by Orbital the Hyundai control system did not compensate for the extra oxygen introduced by the ethanol in the fuel. This was demonstrated by the enleanment of the open loop air-fuel mixture when operated on ethanol blended fuel and an increase in catalyst temperature. This vehicle was durability tested for 80,000 km on E0 and E20 using the AMA drive cycle as defined in European Council directive 98/69/EC. The emissions results are shown below.

Figure 5, Hyundai Accent Emissions Results Taken from the Orbital study[9]



The US Hyundai tested in this study also exhibited increases in catalyst temperature and reduced fuel enrichment when operated on E20. This demonstrated that the emissions issues found in Australia may also be found in the US if vehicles are operated for extended durations on mid-level ethanol blends.

This study has found that of the 25 vehicles tested, 13, including the Hyundai, have the potential to have their emissions control systems damaged by extended operation on mid-level ethanol blends. Eight of the vehicles tested appear not to have this potential problem and for four vehicles the results are unclear.

9 P128. Orbital Engine Company, "Market Barriers to the Uptake of Biofuels Study Testing Gasoline Containing 20% Ethanol (E20)," Phase 2B Final Report to the Department of the Environment and Heritage, May 2004.

APPENDIX A

TRC INC. FACILITIES AND EQUIPMENT

Chassis Dynamometer Laboratory Facility and Equipment:

Emissions Chassis Dynamometer:

AVL 48” Roll Dual Axle 2WD/4WD Dynamometer
Maximum Inertia Simulation: 12,000 lbs. in AWD
8,000 lbs. in 2WD mode
Maximum Vehicle Speed: 125 MPH
Repeat Tolerance of Inertia and Road Simulation: ≤ 1%
4WD wheelbase adjustment range: 82 -185 in (2100-4700 mm)
Maximum vehicle wheel width: 107 in (2725mm)
Maximum vehicle Axle Weight: 10,000 lbs. per axle

Emissions Dynamometer Test Chamber:

Maximum Temperature: 125°F
Minimum Temperature (during driving): 20°F
Nominal Temperature with Humidity Control: 75°F
Humidity Control: 35% to 75% RH ±5%RH
Chamber Ceiling Clearance Height: 9 Feet
Chamber Depth: 40 Feet
Chamber Width: 28 Feet
Vehicle Cooling Fan Max Airspeed at vehicle: 32mph at 0.5 m^2 discharge

Emissions Constant Volume Sampler (CVS):

Manufacturer: Rosemount Analytical
Dilution Tunnel: 12” Diameter
Cyclonic Separator: No
Nominal Flow Rate: 600 SCFM
Calibration Method: Laminar Flow Element (LFE)
Sample System: Continuous Dilute or Tedlar Bag Method

Analyzer Bench (Dilute/Bag):

Analyzers: Horiba 200 series
AIA-220 Non-Disperse Infrared Analyzer CO_2: 0-2 & 4 %
AIA-220 Non-Disperse Infrared Analyzer CO (Low): 0-25, 50, 250 ppm
AIA-220 Non-Disperse Infrared Analyzer CO (High): 0-1000, 3000, 10000 ppm
CLA-220 Chemiluminescent NOx Analyzer: 0-25, 50, 100 ppm
FIA-220 Flame Ionization Detector (THC): 0-10, 30, 100, 300, 1000 ppmC
GFA-220 CH4 Gas Chromatography Analyzer: 0-25 ppm

Additional Support Equipment

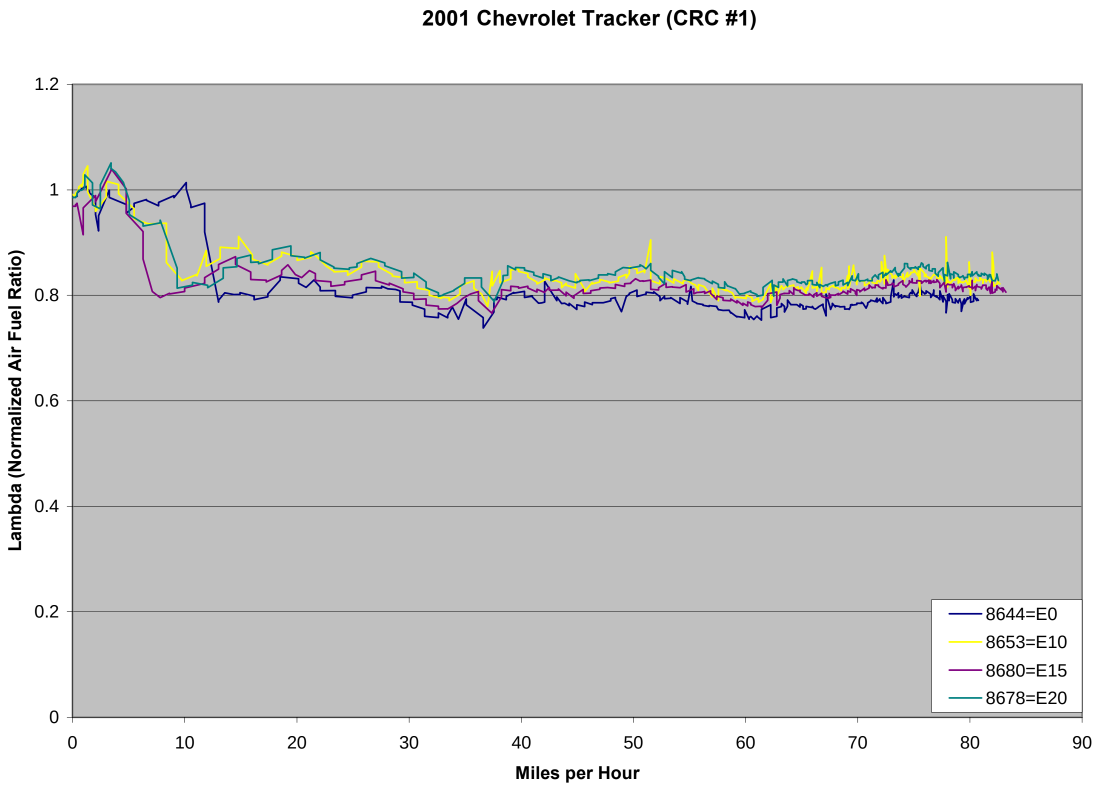
Lambda data for this program were collected using UEGO sensors and an AFR-1000 Air Fuel Ratio Module from ECM Motorsports.

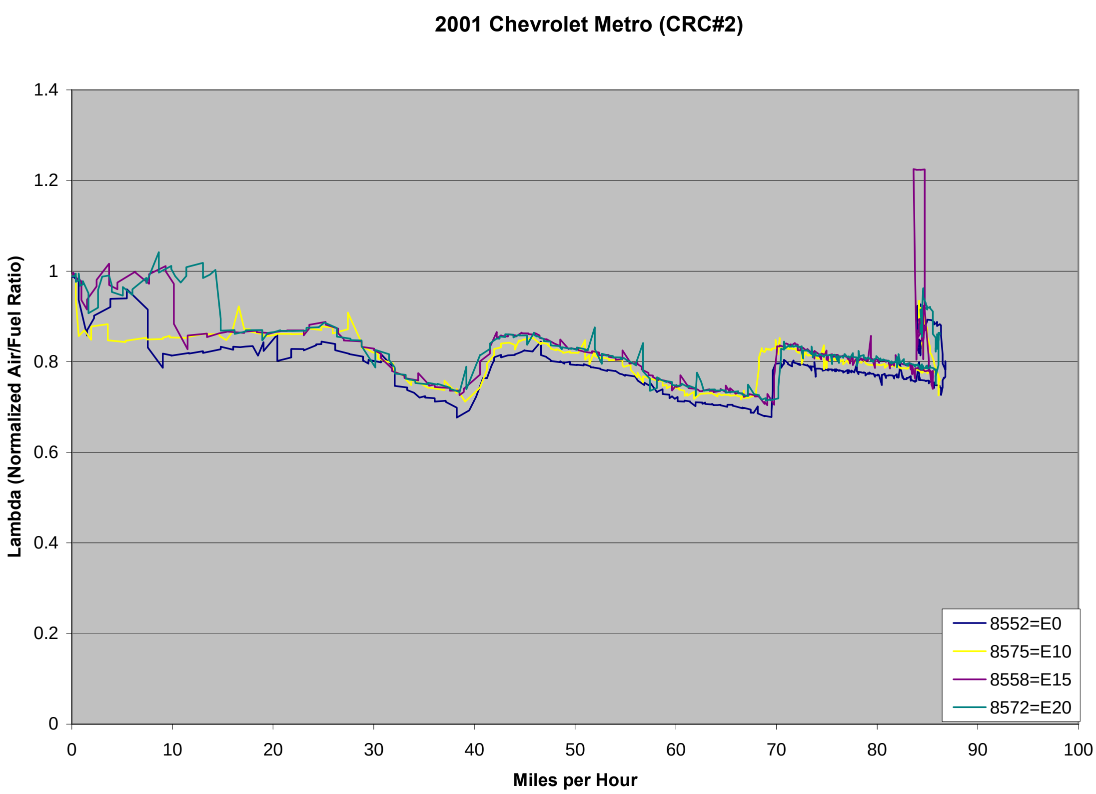
TRC Inc. collected DLC data using an Auto Enginuity Enhanced ODB-II scan tool. This tool is capable of collecting data from all vehicle makes and models offered for sale in the United States via the OBD-II port.

All test fuel was stored and dispensed from TRC Inc.'s temperature controlled drum storage building during the program. This building is located adjacent to the TRC Inc. Emissions Laboratory and includes small volume blending and weighing equipment, fuel transfer pumps and hazardous materials storage. Two of the 10 pumps and dispensing lines are designed for transfer and dispensing of high concentration alcohol fuels.

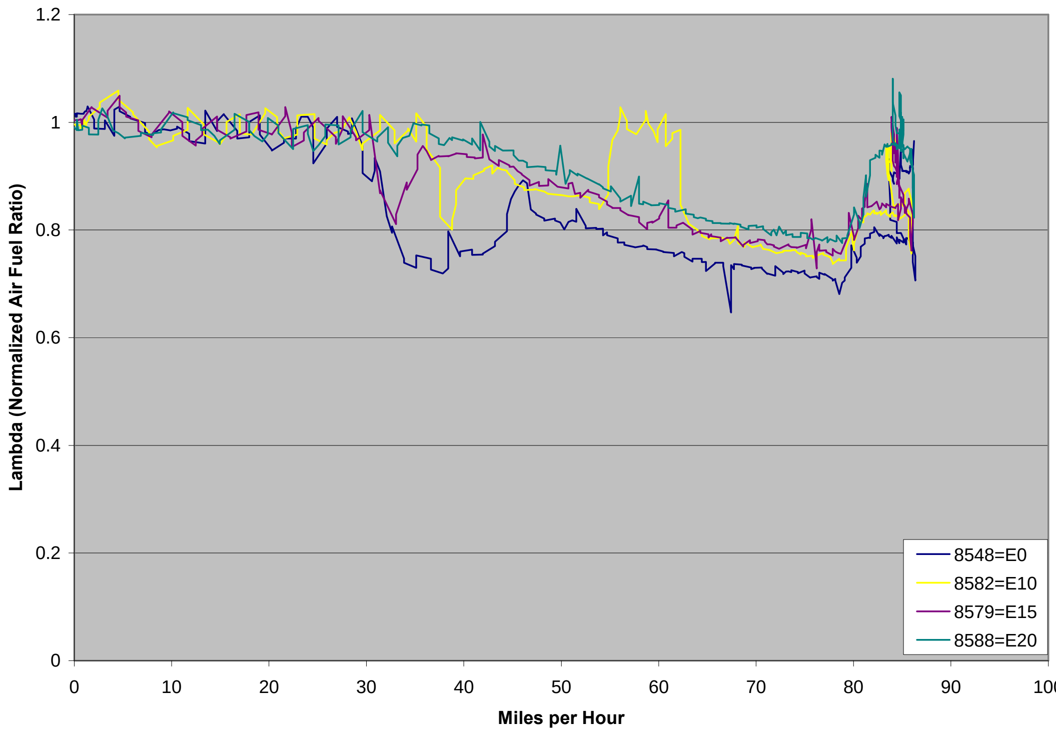
APPENDIX B

AIR/FUEL RATIO DATA

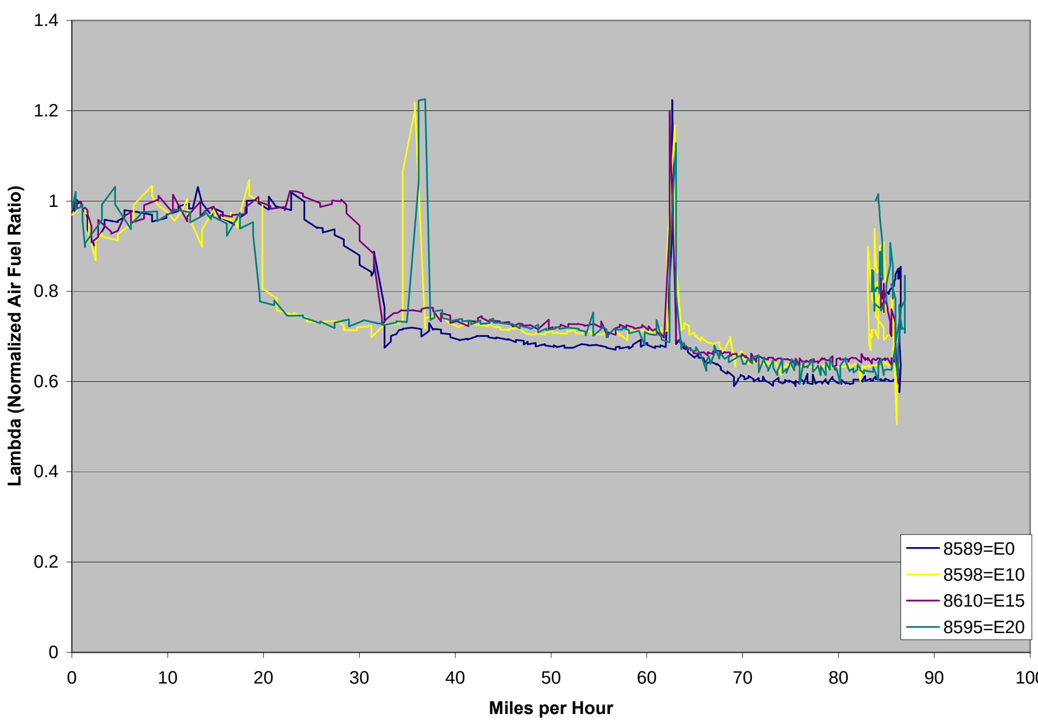

2001 Chevrolet Tracker (CRC #1)
Lambda (Normalized Air Fuel Ratio)
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
Miles per Hour
8644=E0
8653=E10
8680=E15
8678=E20


2001 Chevrolet Metro (CRC#2)
Lambda (Normalized Air/Fuel Ratio)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8552=E0
8575=E10
8558=E15
8572=E20

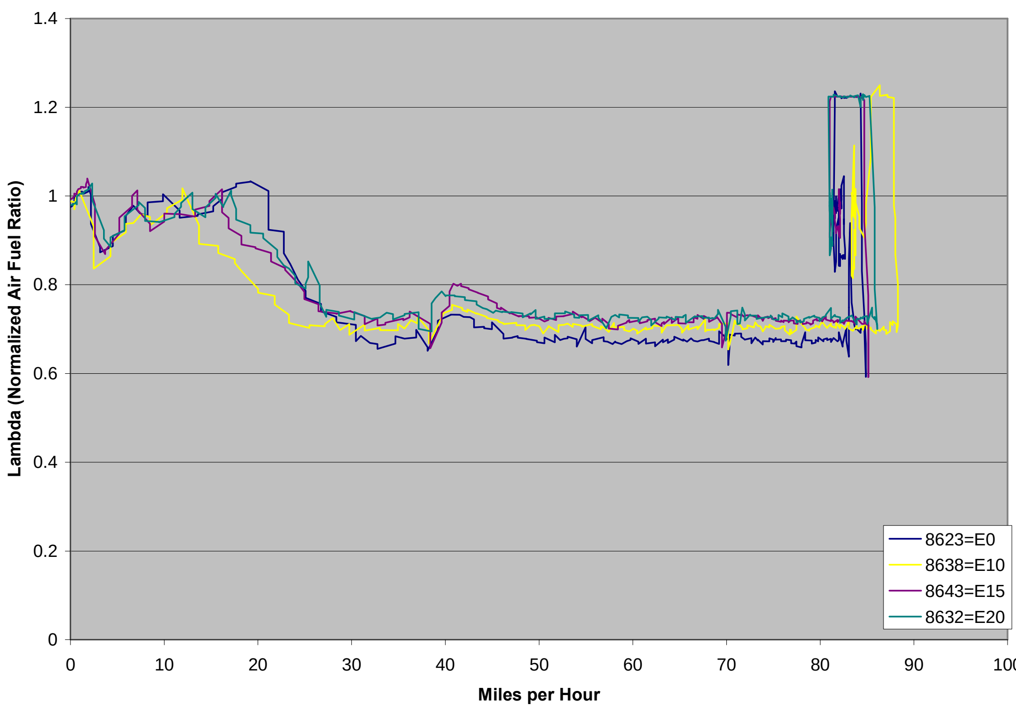
1999 Ford Crown Victoria (CRC#3)



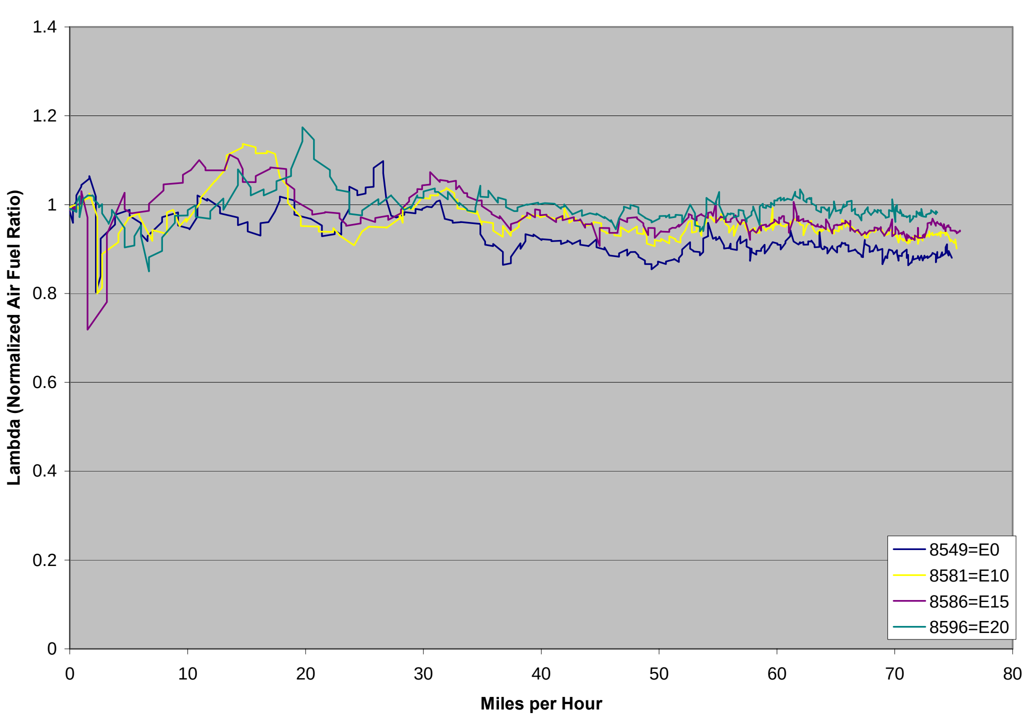
2001 Chrysler PT Cruiser (CRC#4)



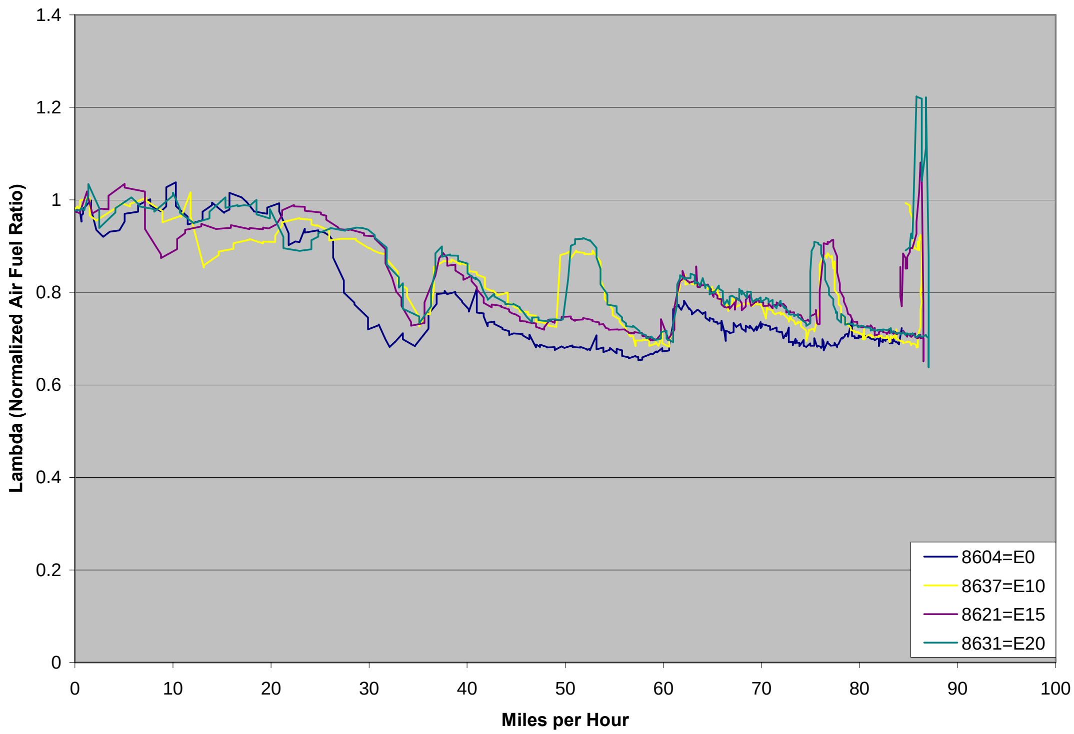
2003 Nissan Altima (CRC#5)



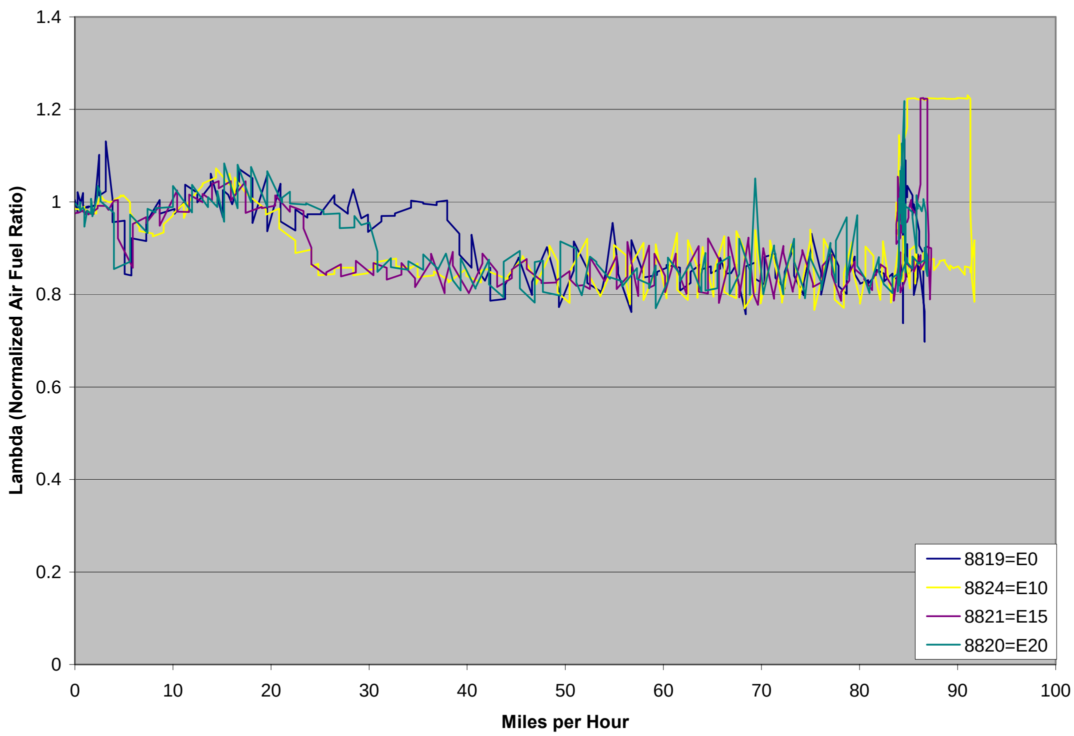
2002 Nissan Frontier Truck (CRC#6)



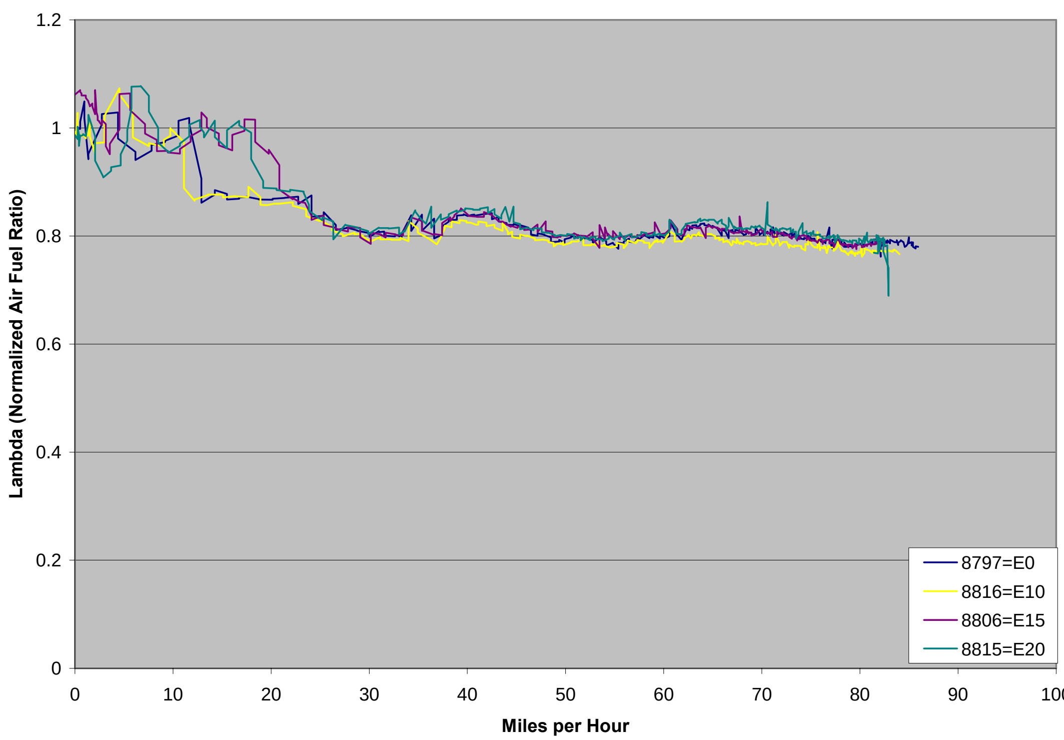
2001 Hyundai Accent (CRC#7)



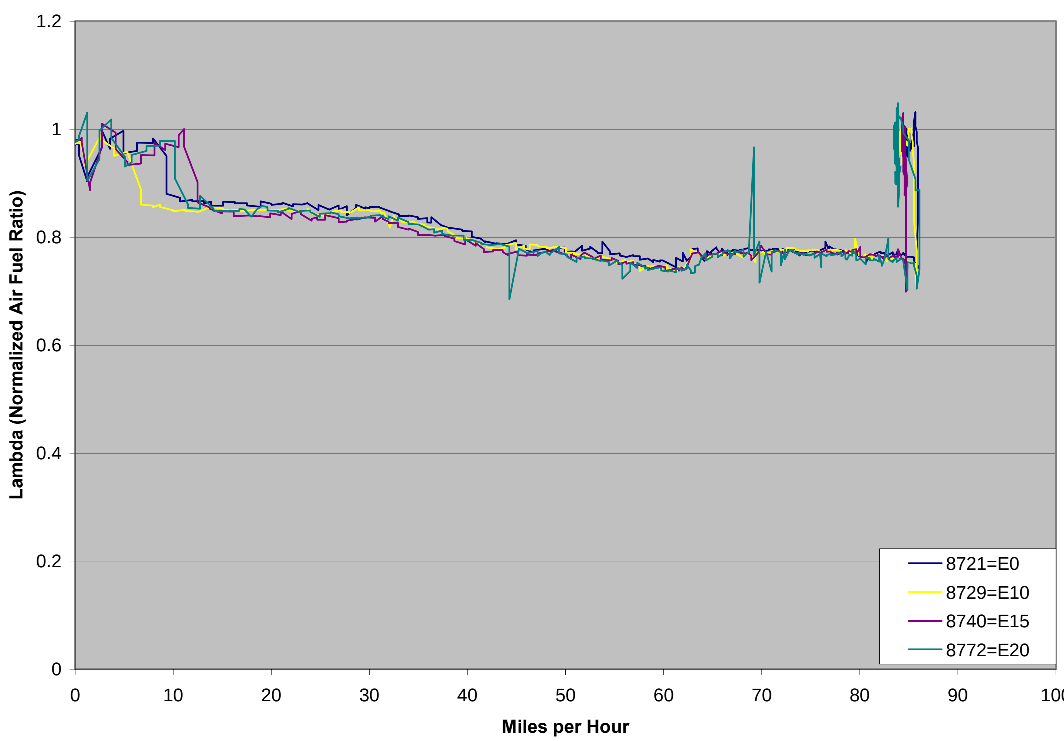
2004 BMW 330i (CRC#8)



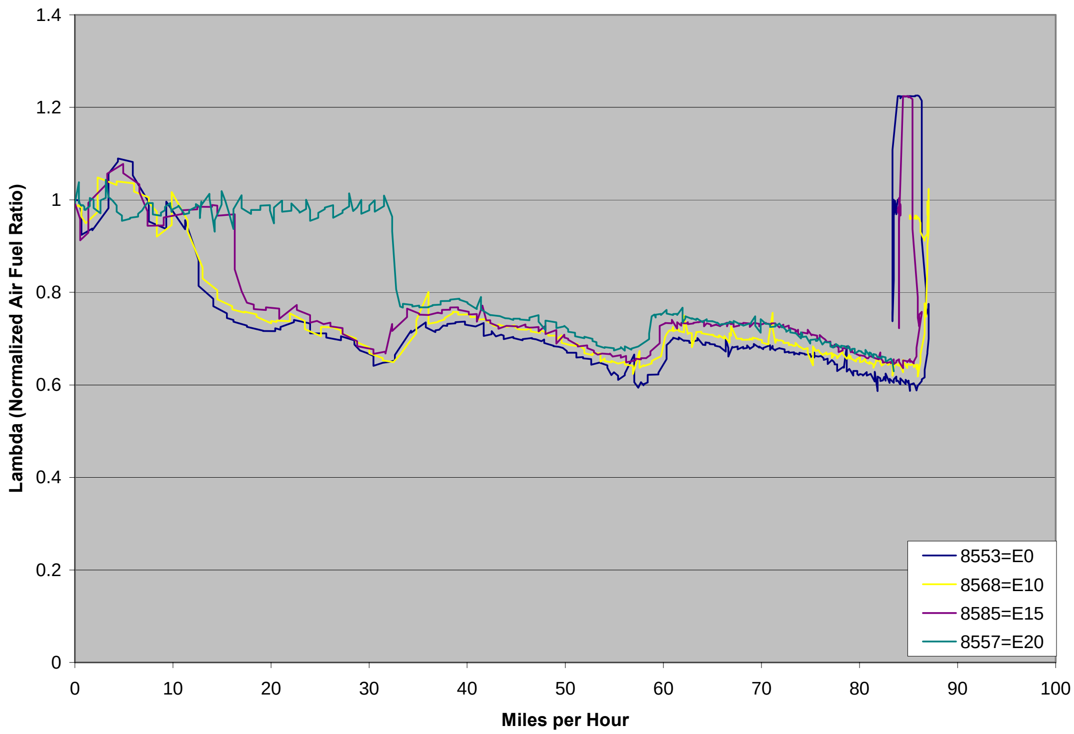
1999 Mitsubishi Mirage (CRC#9)



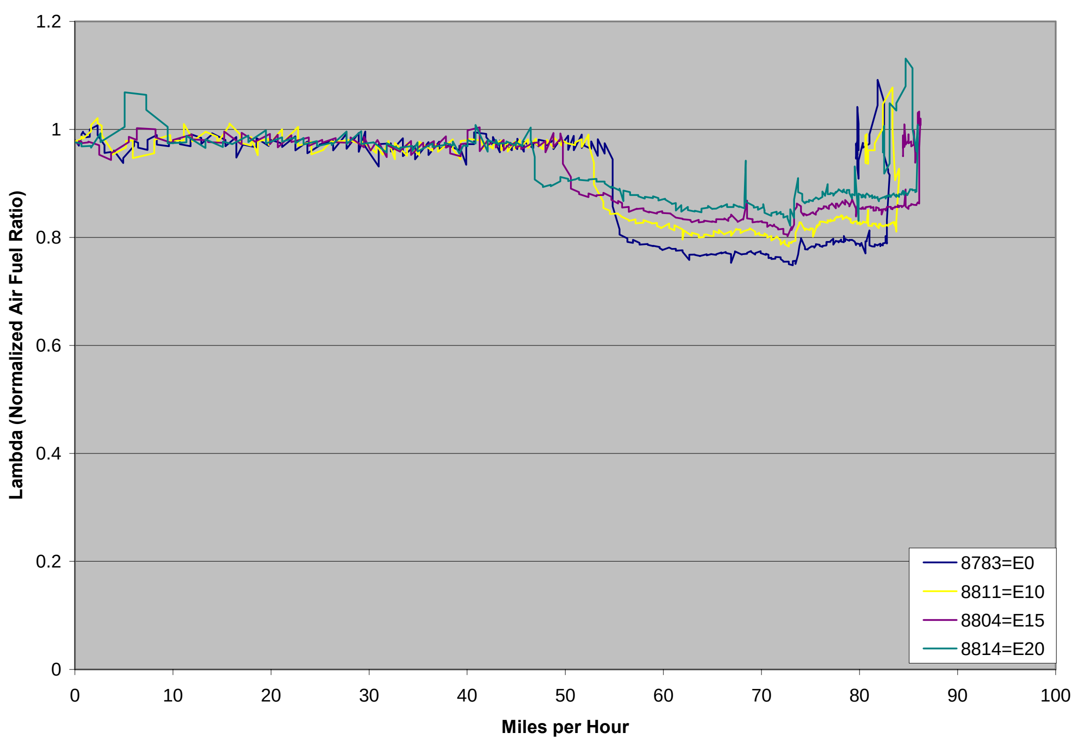
2001 Mitsubishi Montero Sport (CRC#10)



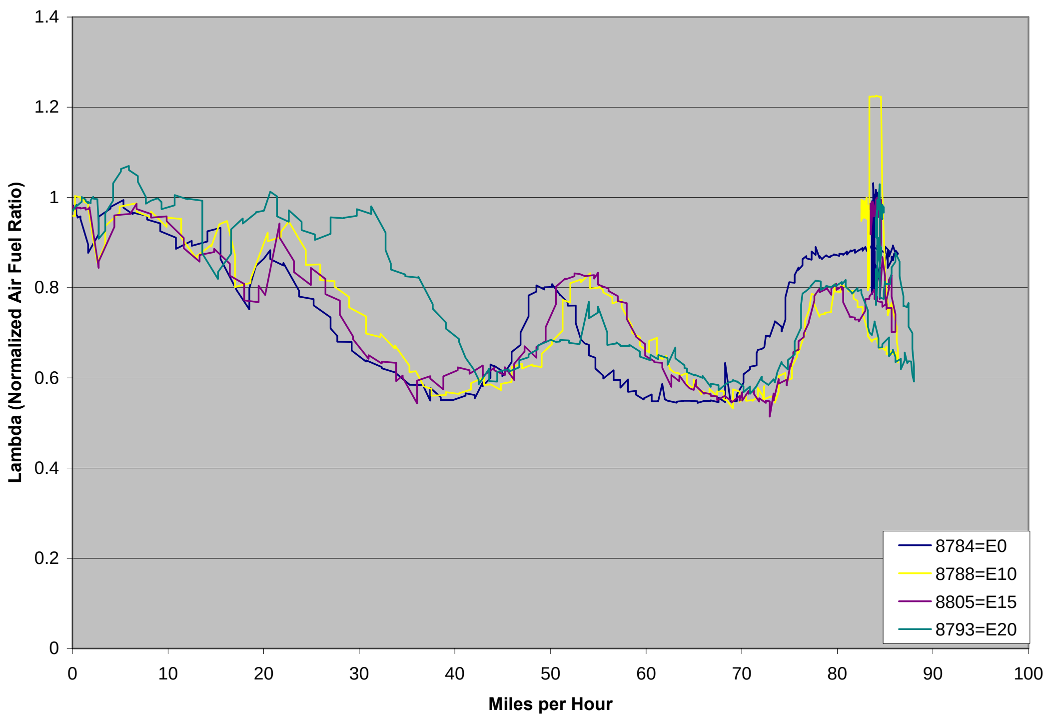
1995 Honda Civic DX, LX (CRC#11)



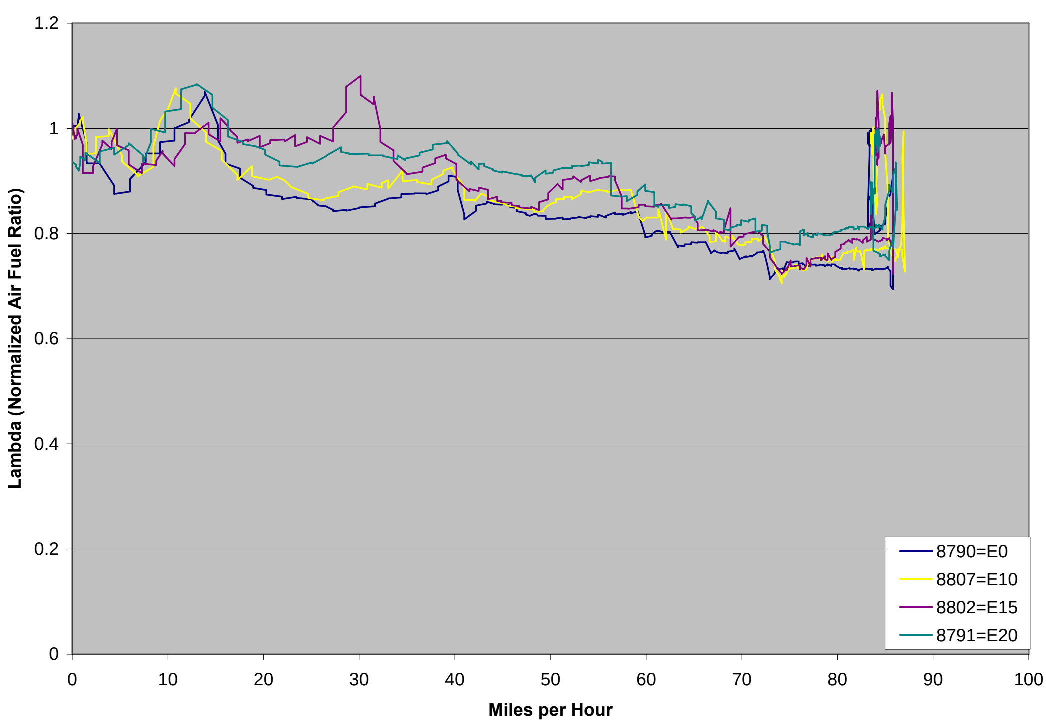
2007 Jeep Rubicon (CRC#12)



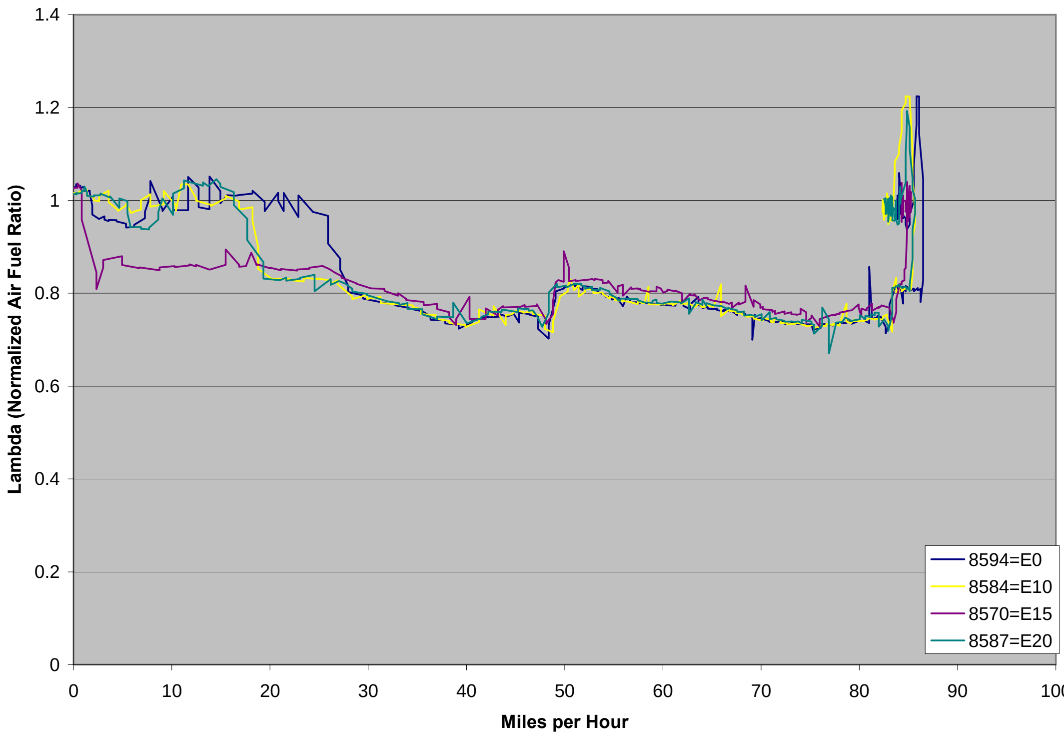
2003 Volkswagen Jetta (CRC#13)



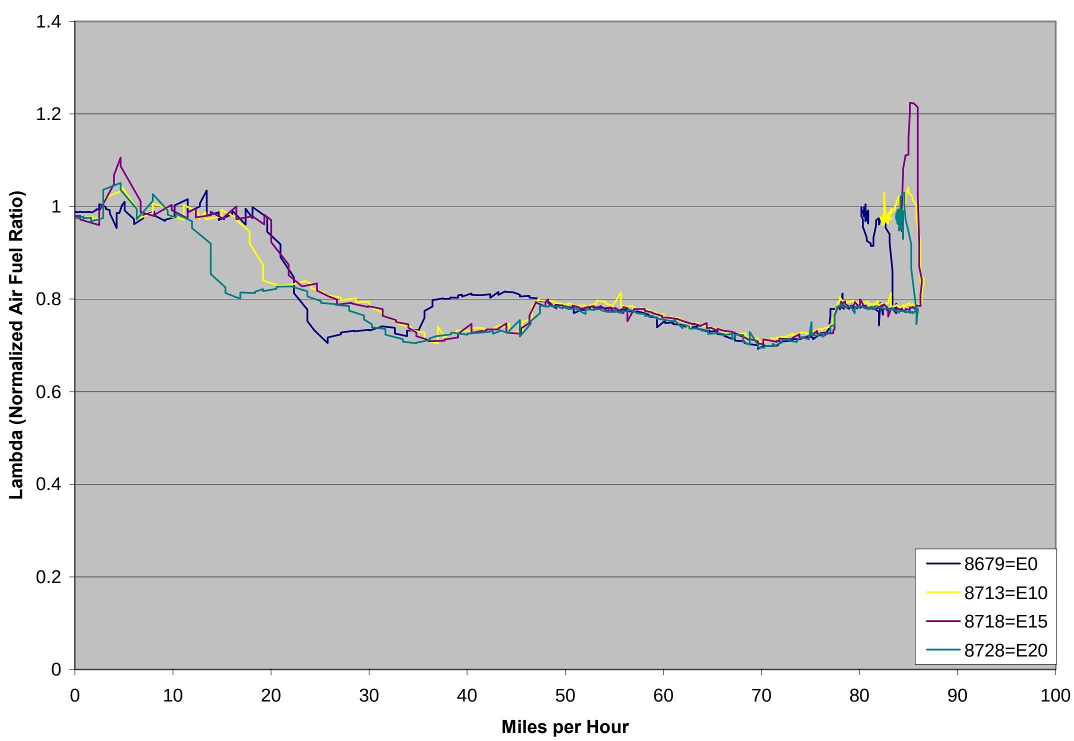
2006 Chevrolet Cobalt, 4 Door (CRC#14)

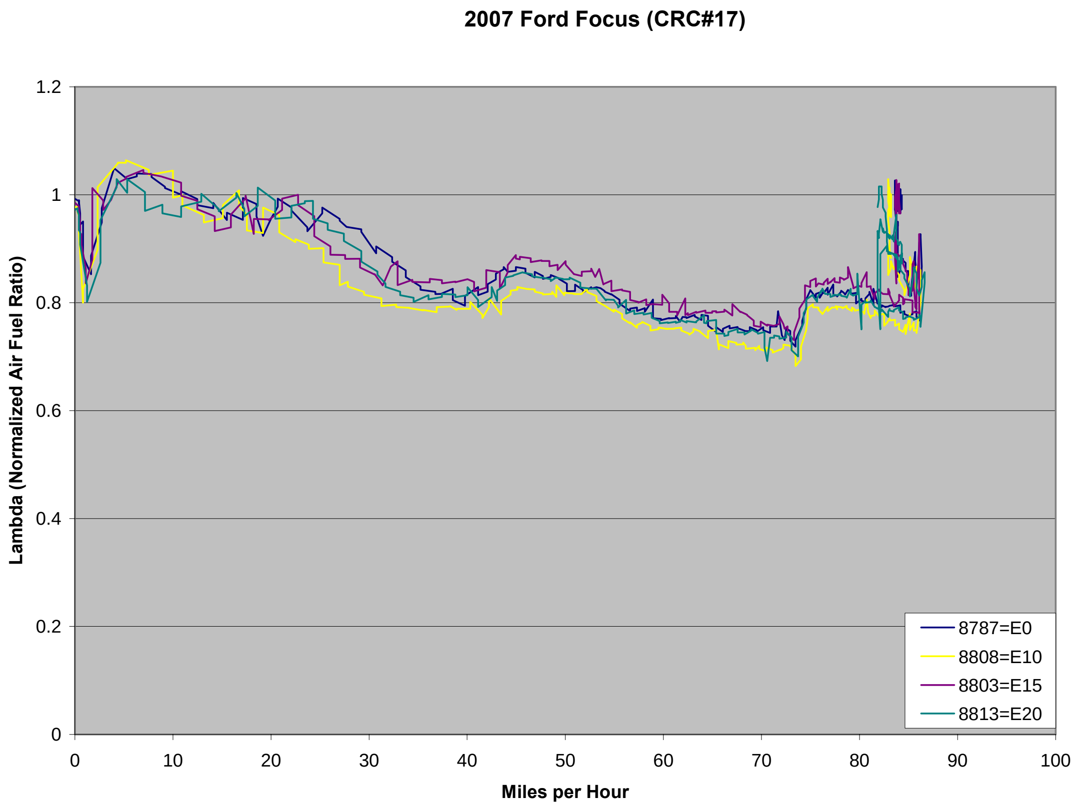


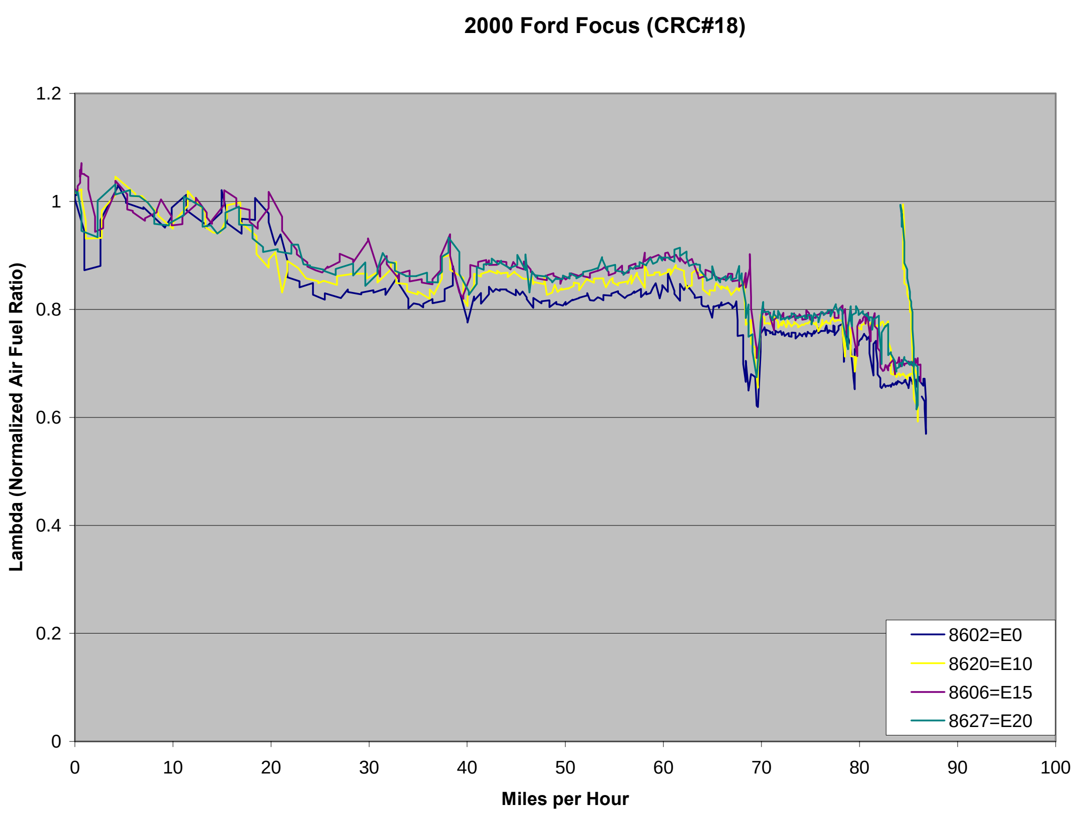
2006 Chevrolet Silverado Extended Cab, (CRC#15)



2002 Chevrolet Suburban 4WD, (CRC#16)




2007 Ford Focus (CRC#17)
Lambda (Normalized Air Fuel Ratio)
Miles per Hour
8787=E0
8808=E10
8803=E15
8813=E20


2000 Ford Focus (CRC#18)
Lambda (Normalized Air Fuel Ratio)
Miles per Hour
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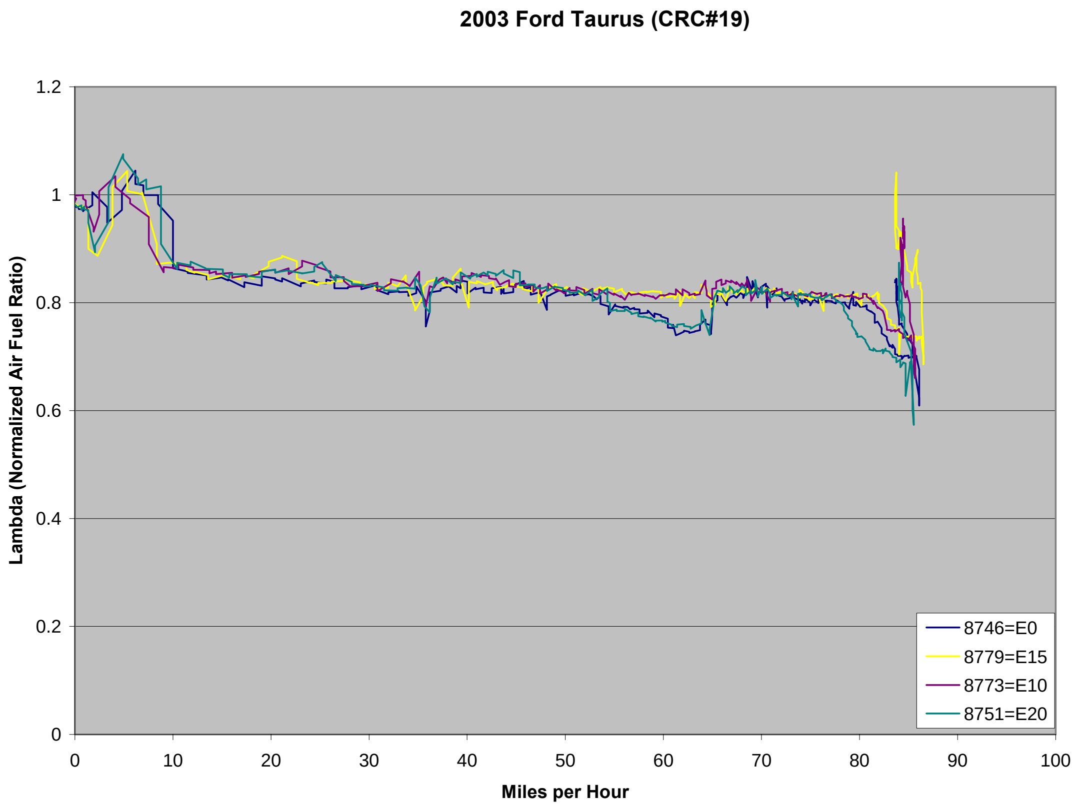
8620=E10
8606=E15
8627=E20


2003 Ford Taurus (CRC#19)
Lambda (Normalized Air Fuel Ratio)
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
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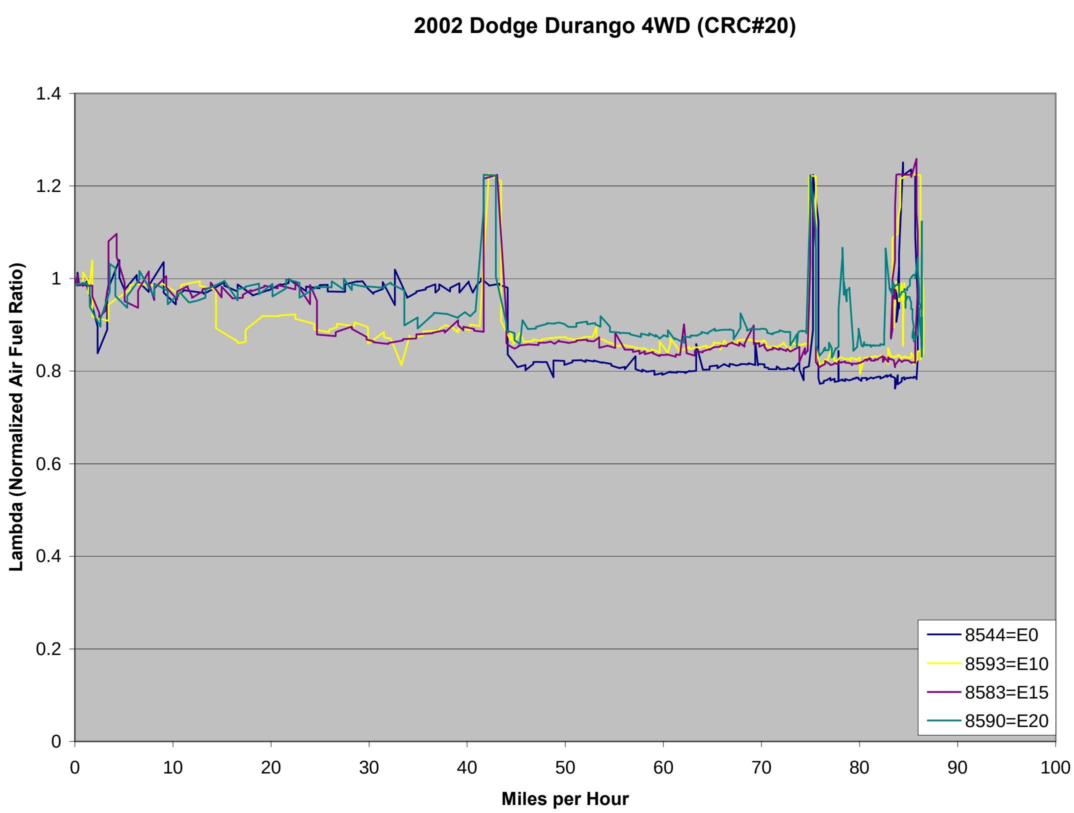
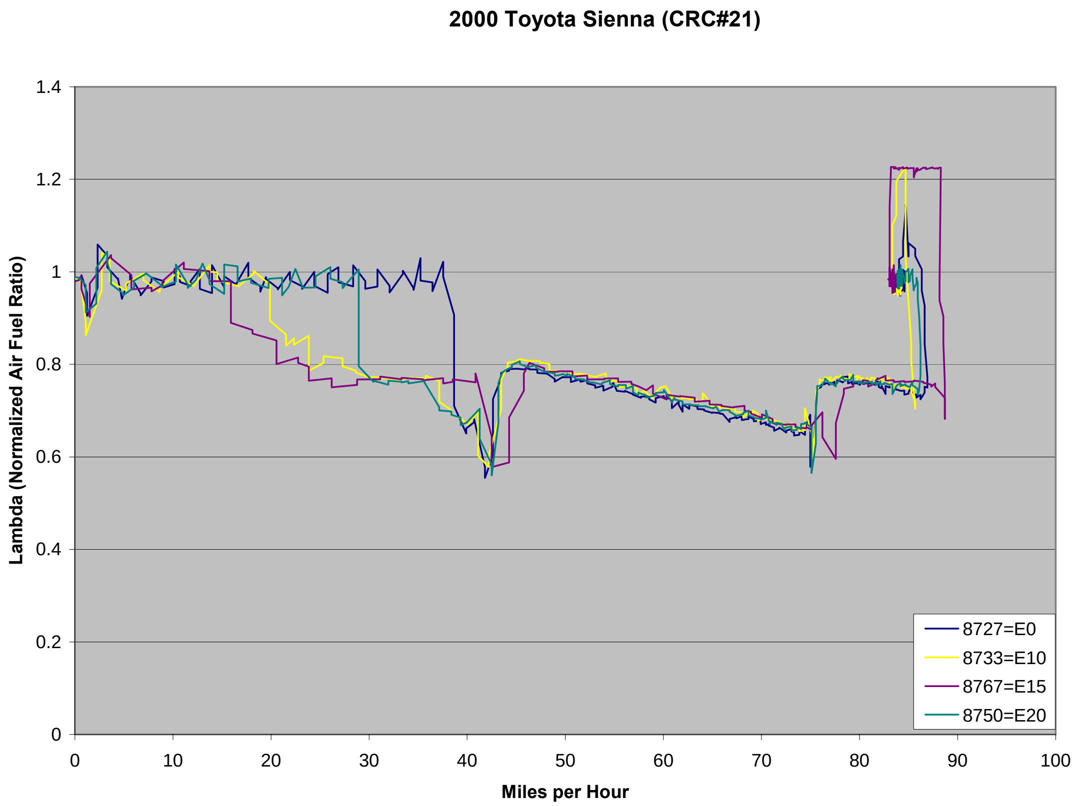
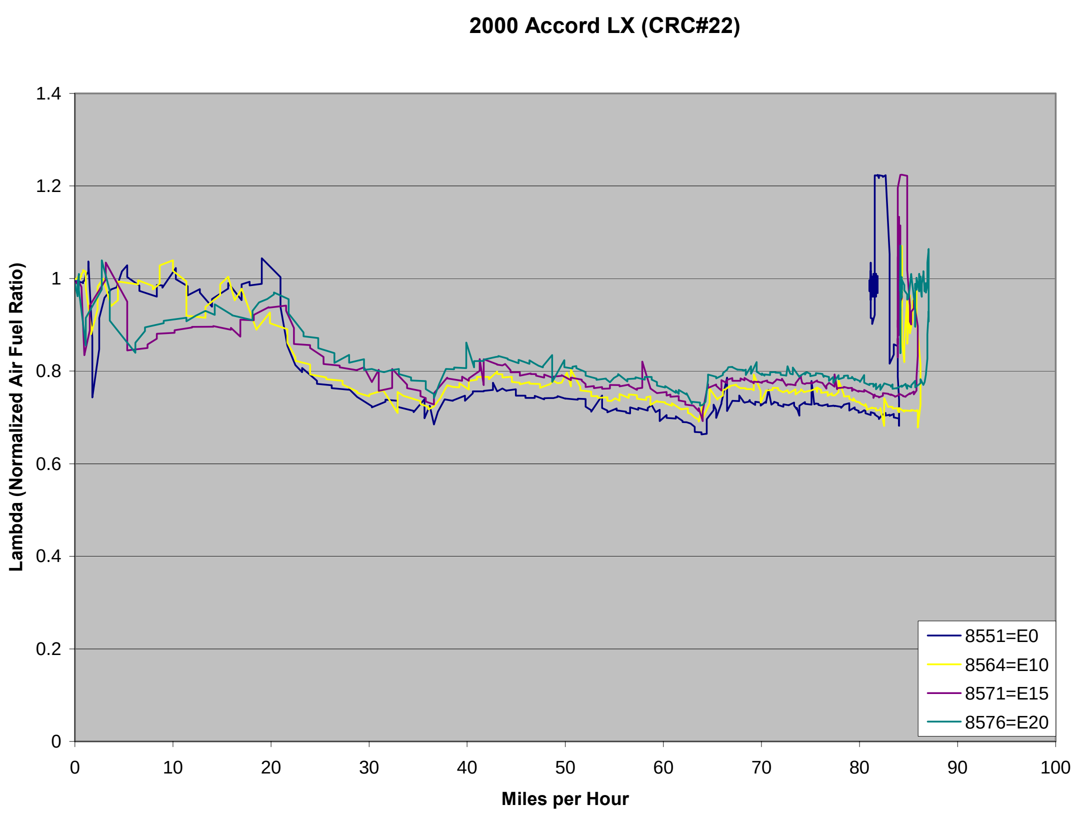
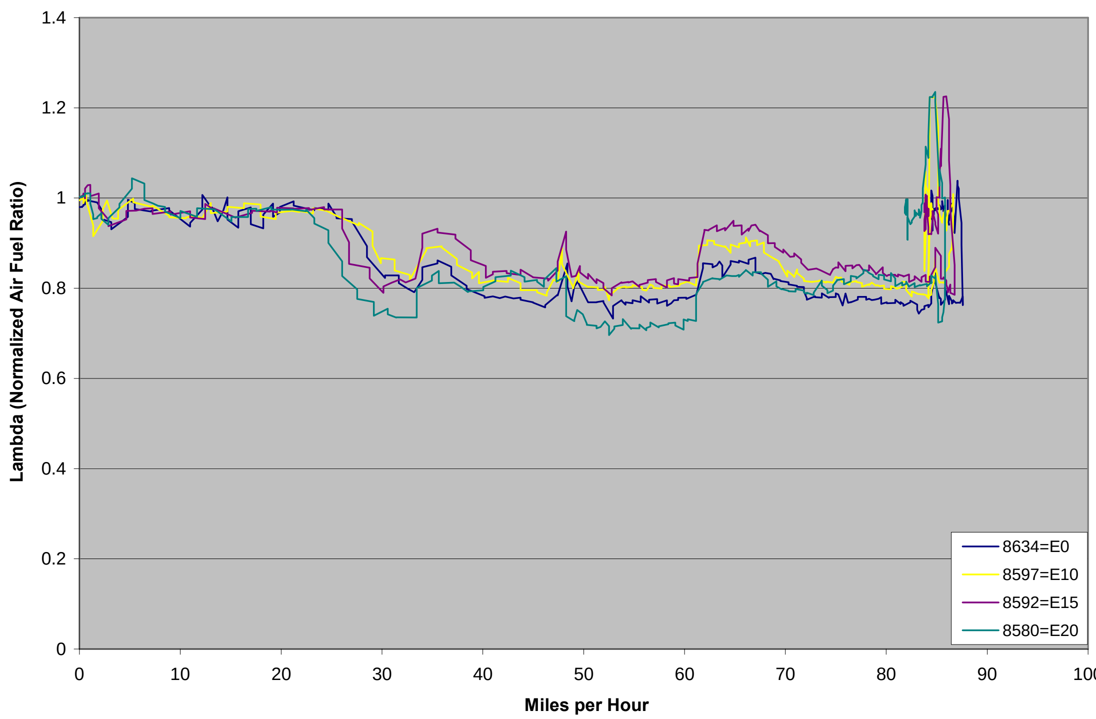
8773=E10
8751=E20


2002 Dodge Durango 4WD (CRC#20)
Lambda (Normalized Air Fuel Ratio)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8544=E0
8593=E10
8583=E15
8590=E20

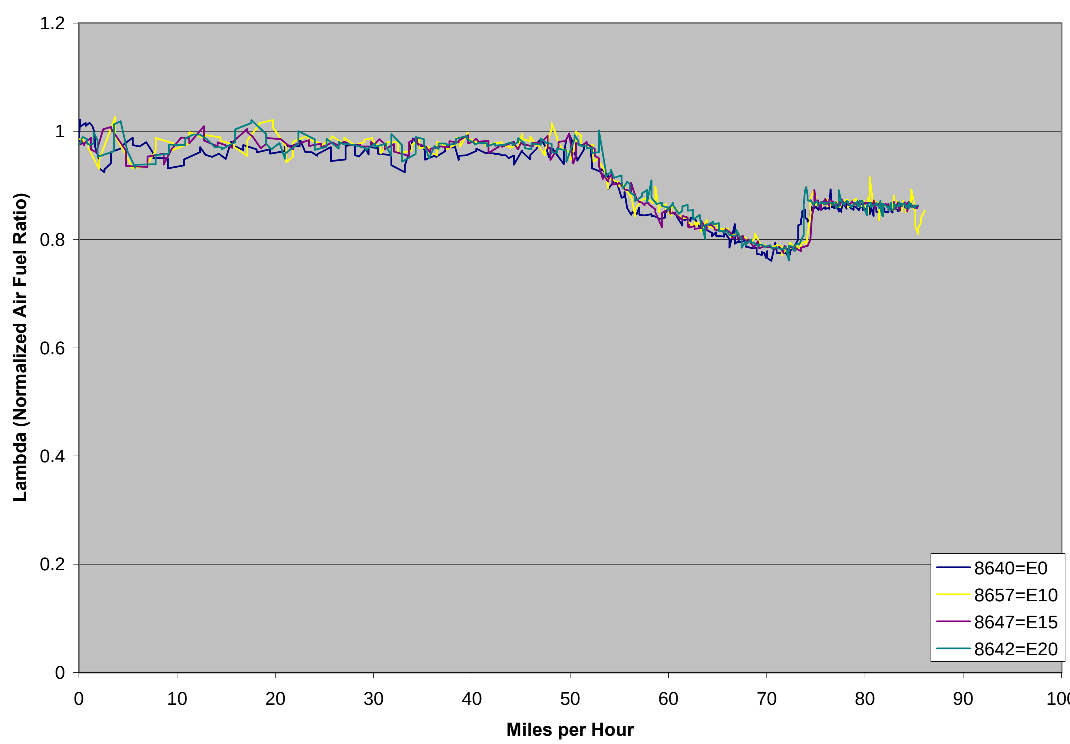

2000 Toyota Sienna (CRC#21)
Lambda (Normalized Air Fuel Ratio)
Miles per Hour
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
10
20
30
40
50
60
70
80
90
100
8727=E0
8733=E10
8767=E15
8750=E20

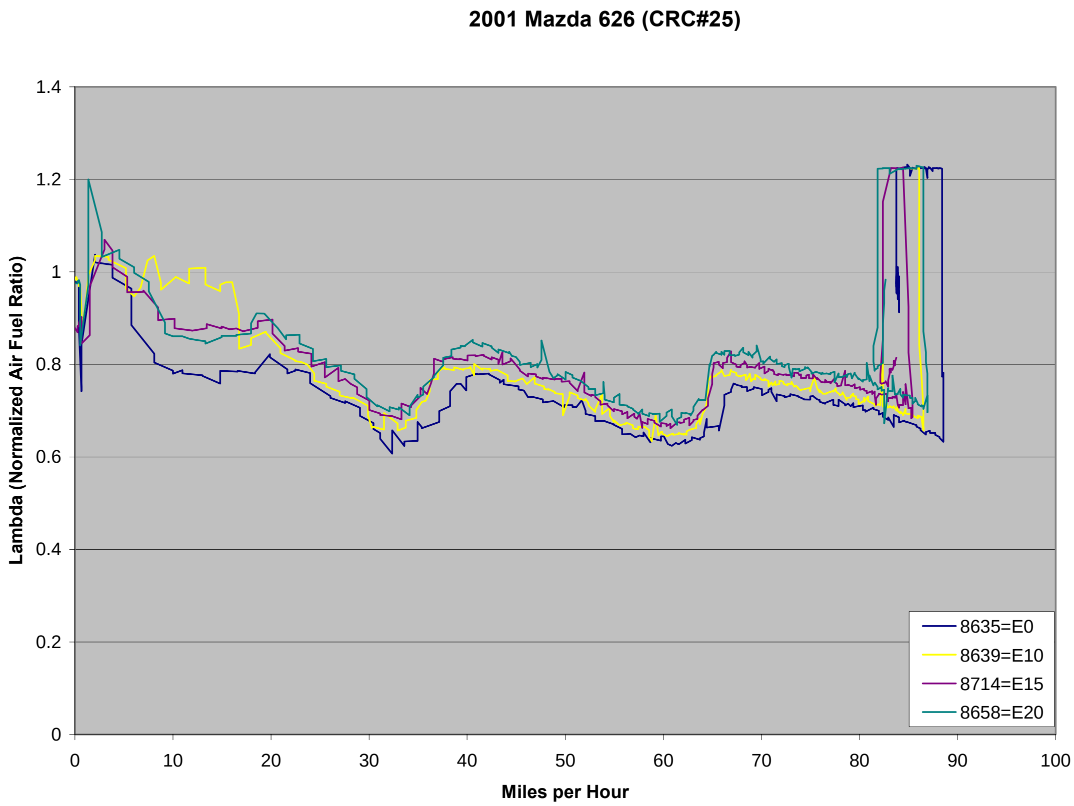

2000 Accord LX (CRC#22)
Lambda (Normalized Air Fuel Ratio)
Miles per Hour
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
10
20
30
40
50
60
70
80
90
100
8551=E0
8564=E10
8571=E15
8576=E20

2006 Nissan Quest (CRC#23)



2001 Volkswagen Jetta (CRC#24)

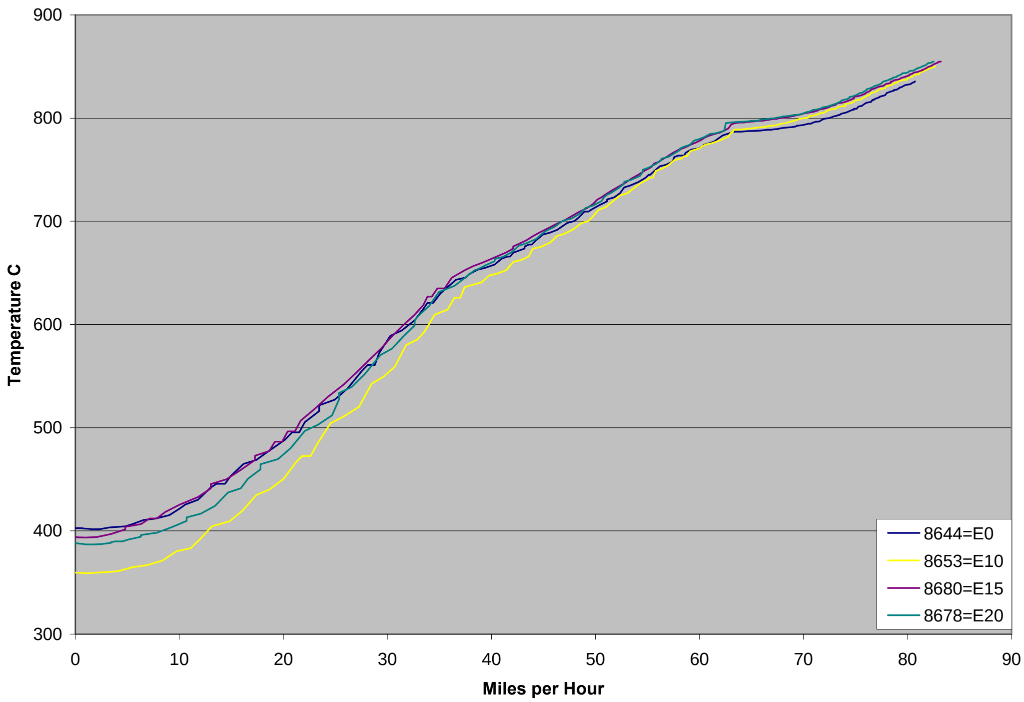



2001 Mazda 626 (CRC#25)
Lambda (Normalized Air Fuel Ratio)
Miles per Hour
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
10
20
30
40
50
60
70
80
90
100
8635=E0
8639=E10
8714=E15
8658=E20

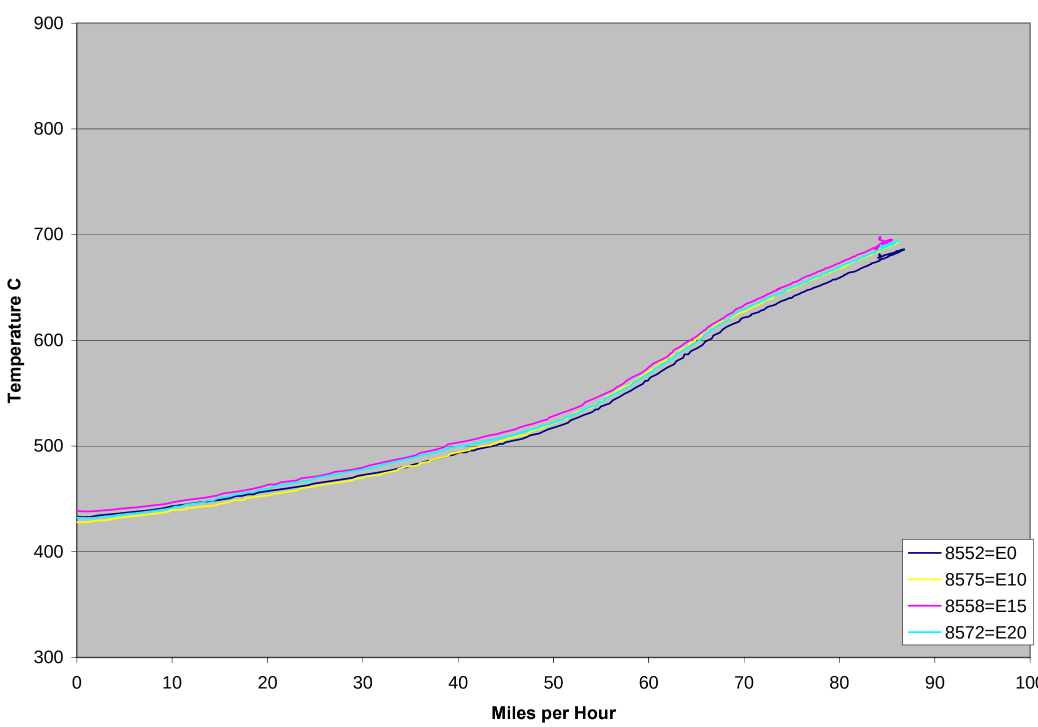
APPENDIX C

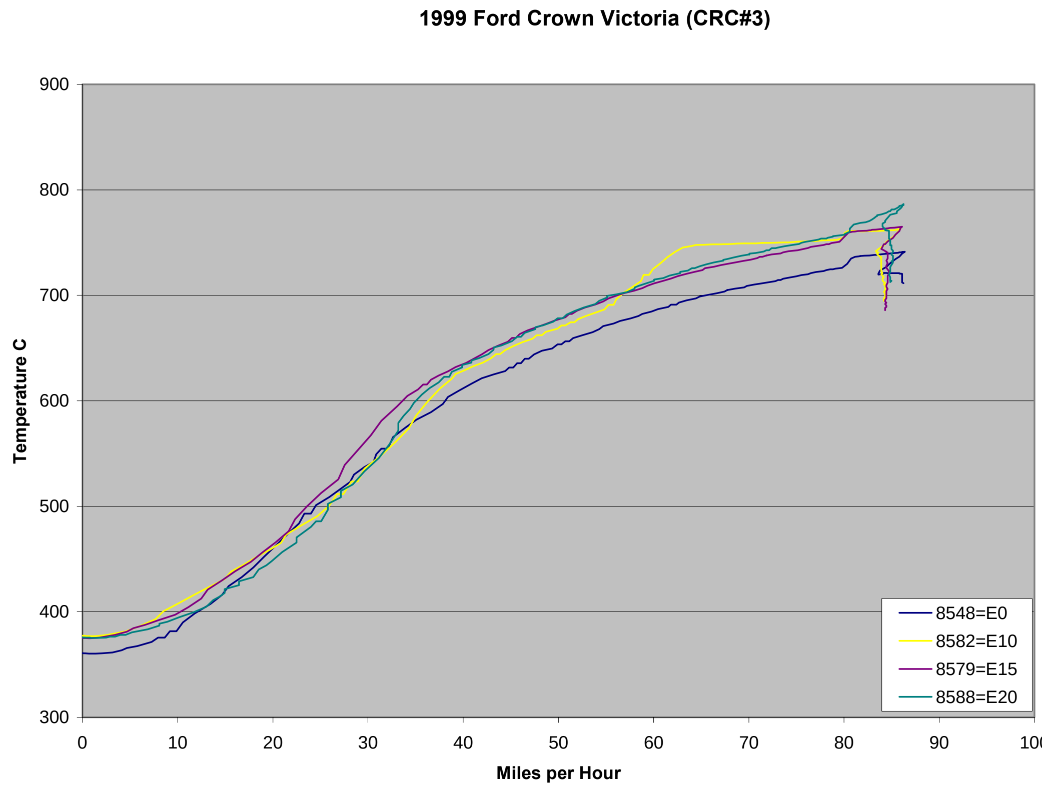
TEMPERATURE DATA

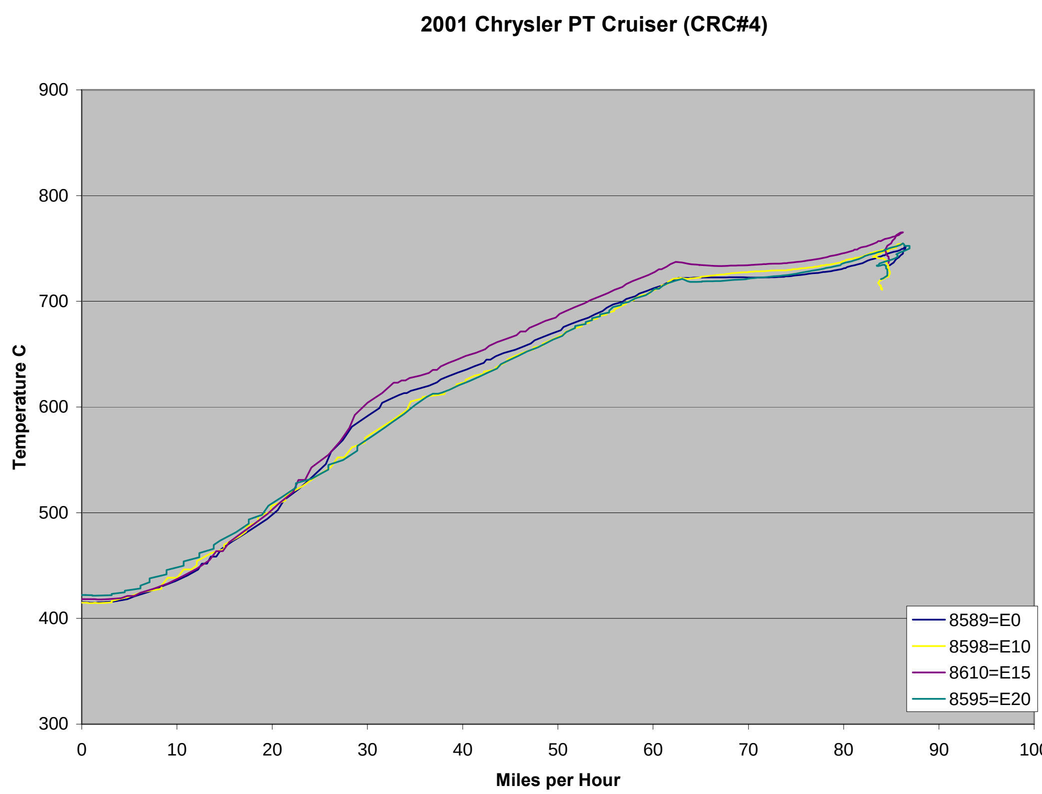
2001 Chevrolet Tracker (CRC#1)

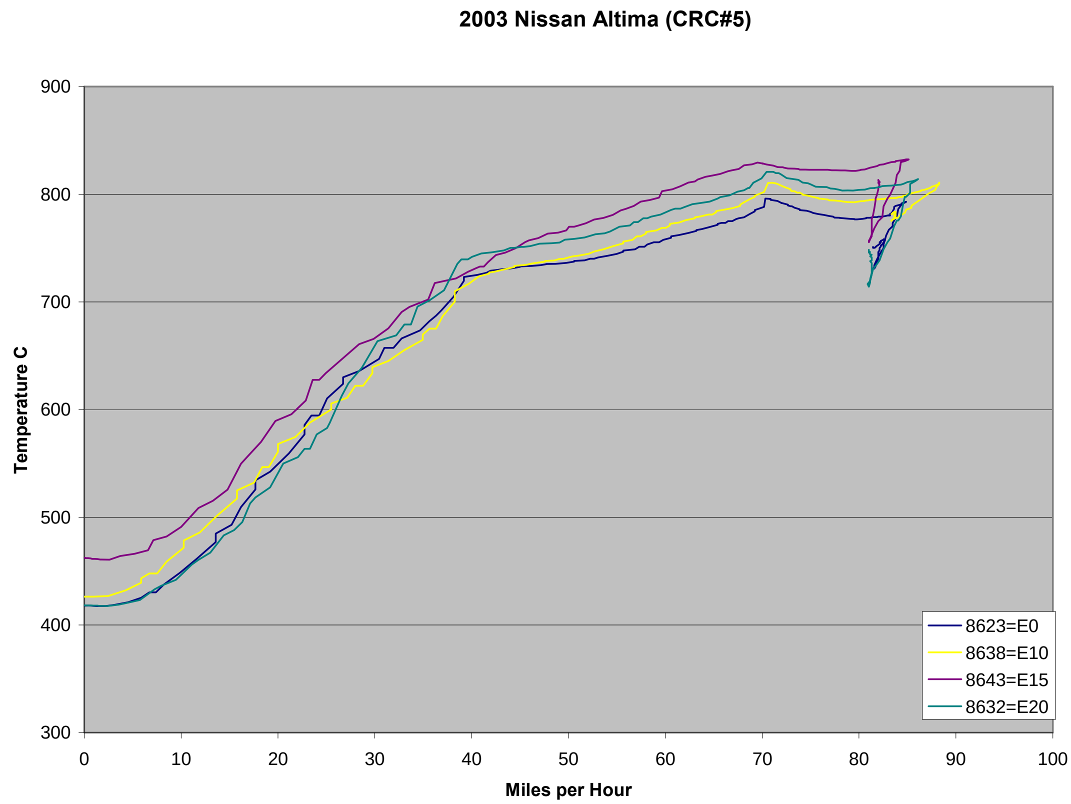


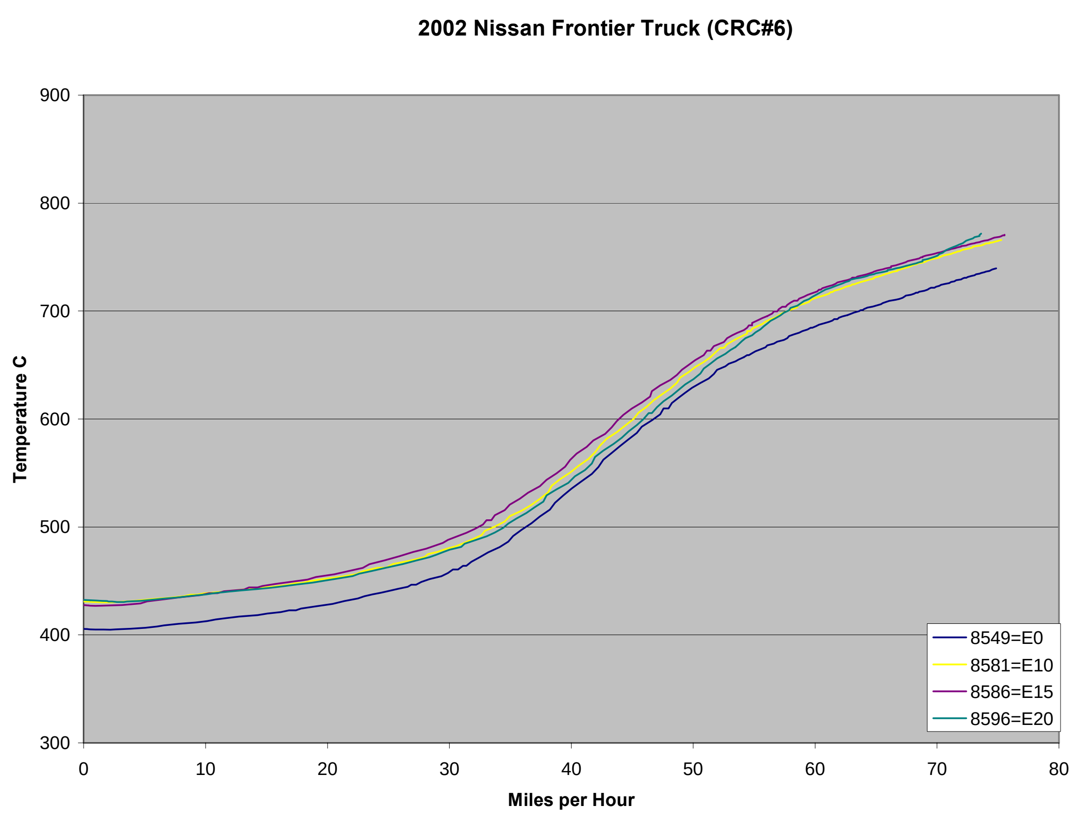
2001 Chevrolet Metro (CRC#2)

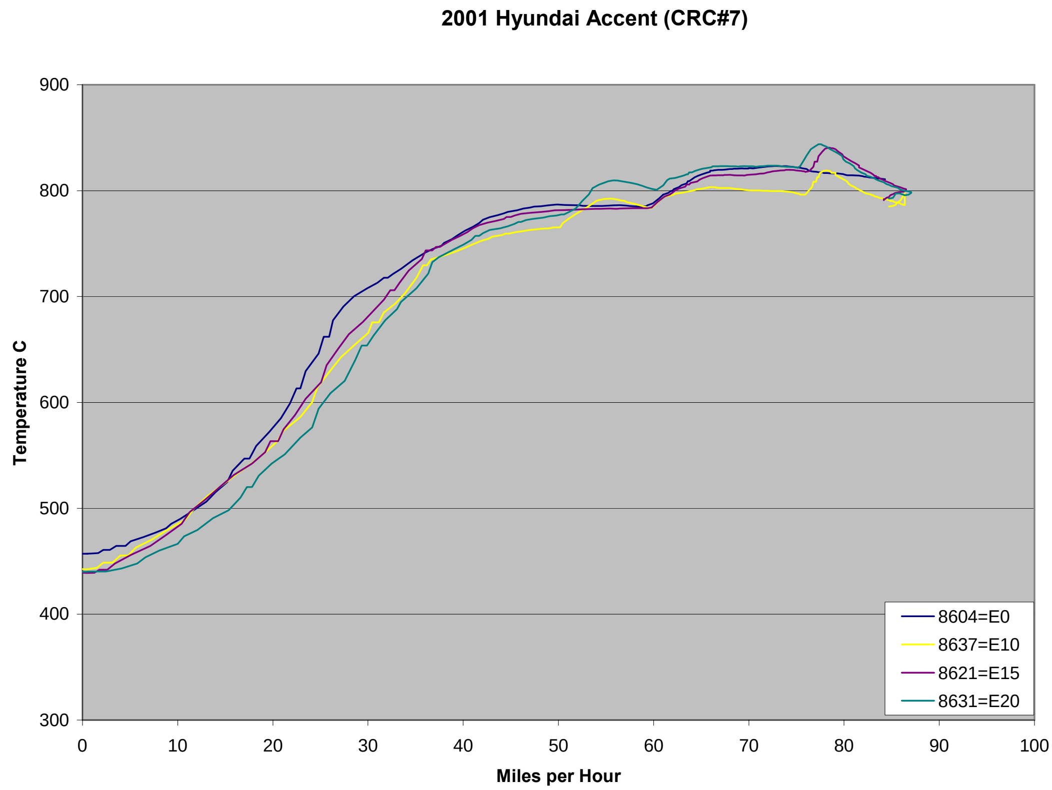


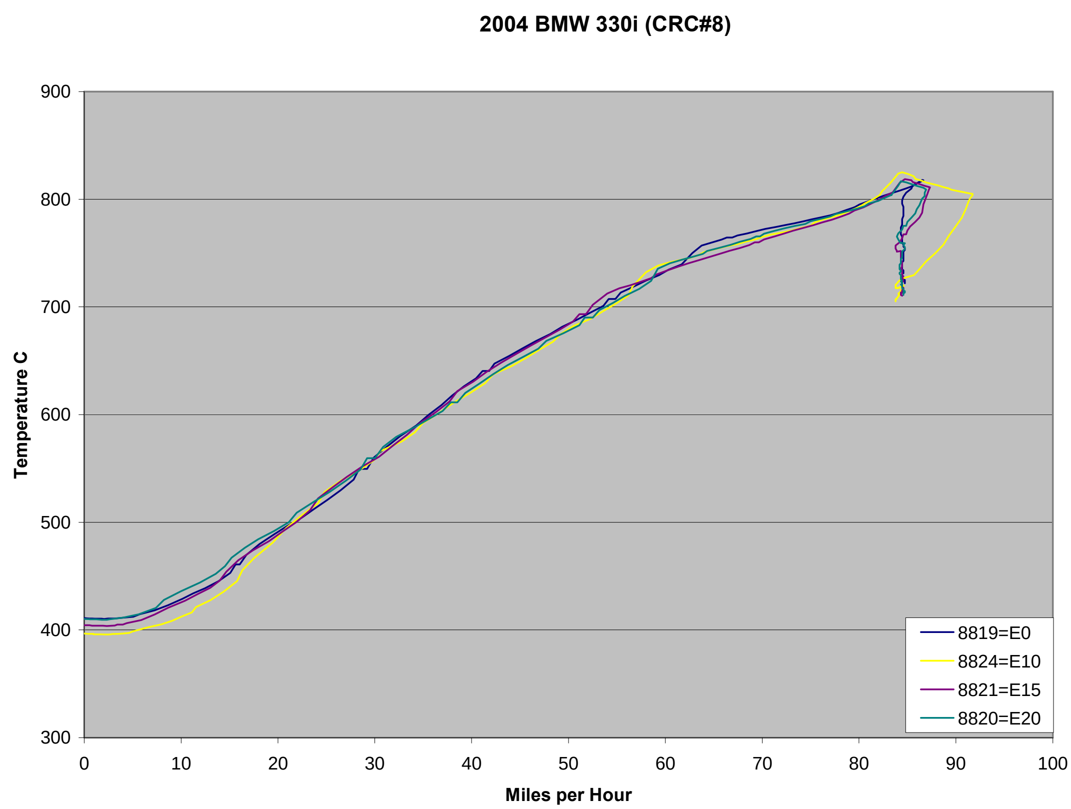

1999 Ford Crown Victoria (CRC#3)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8548=E0
8582=E10
8579=E15
8588=E20

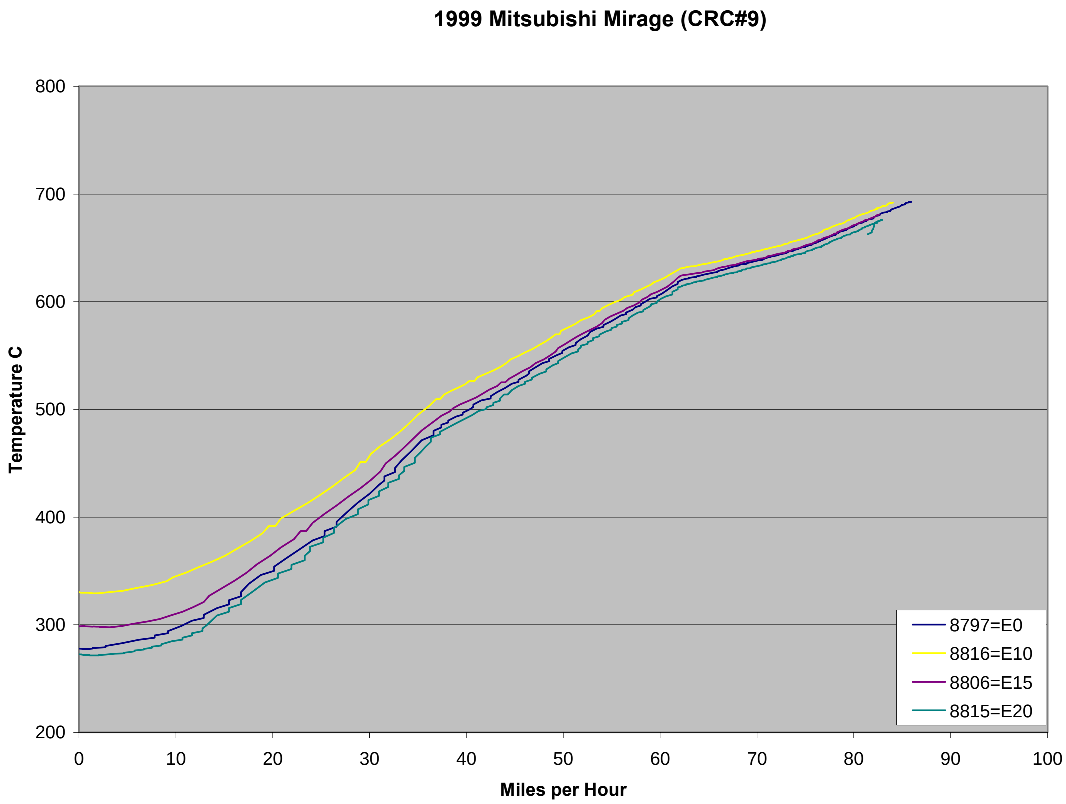

2001 Chrysler PT Cruiser (CRC#4)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8589=E0
8598=E10
8610=E15
8595=E20

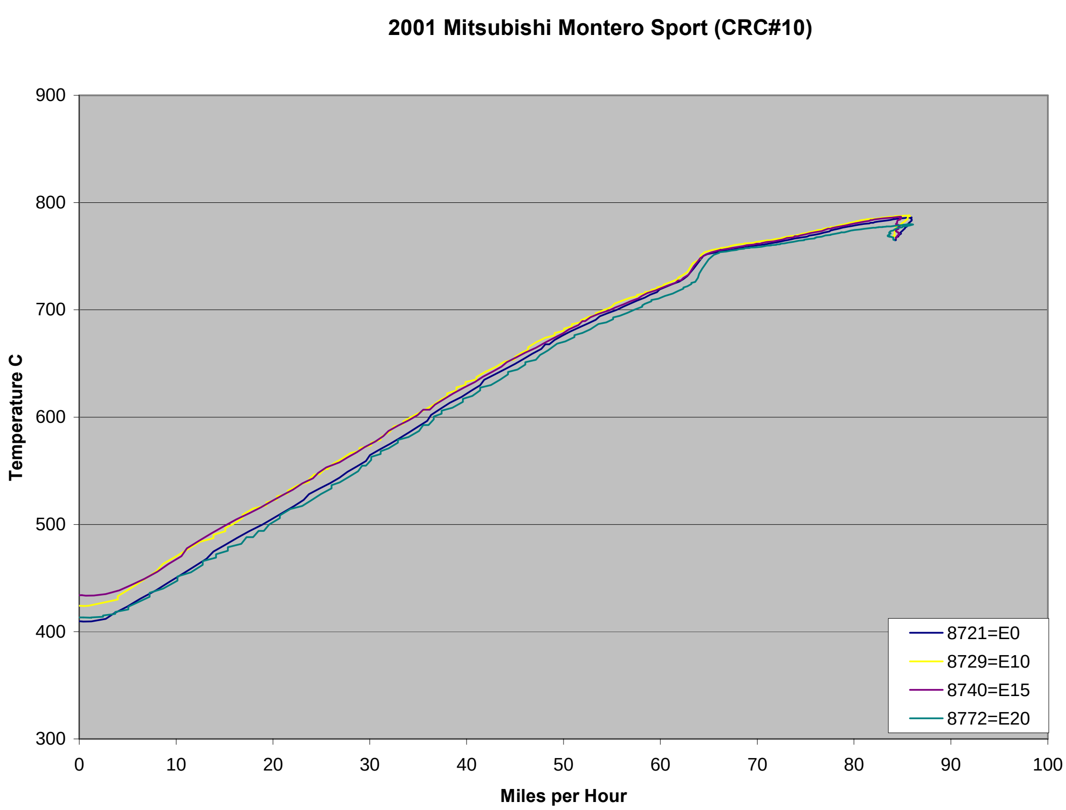

2003 Nissan Altima (CRC#5)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8623=E0
8638=E10
8643=E15
8632=E20

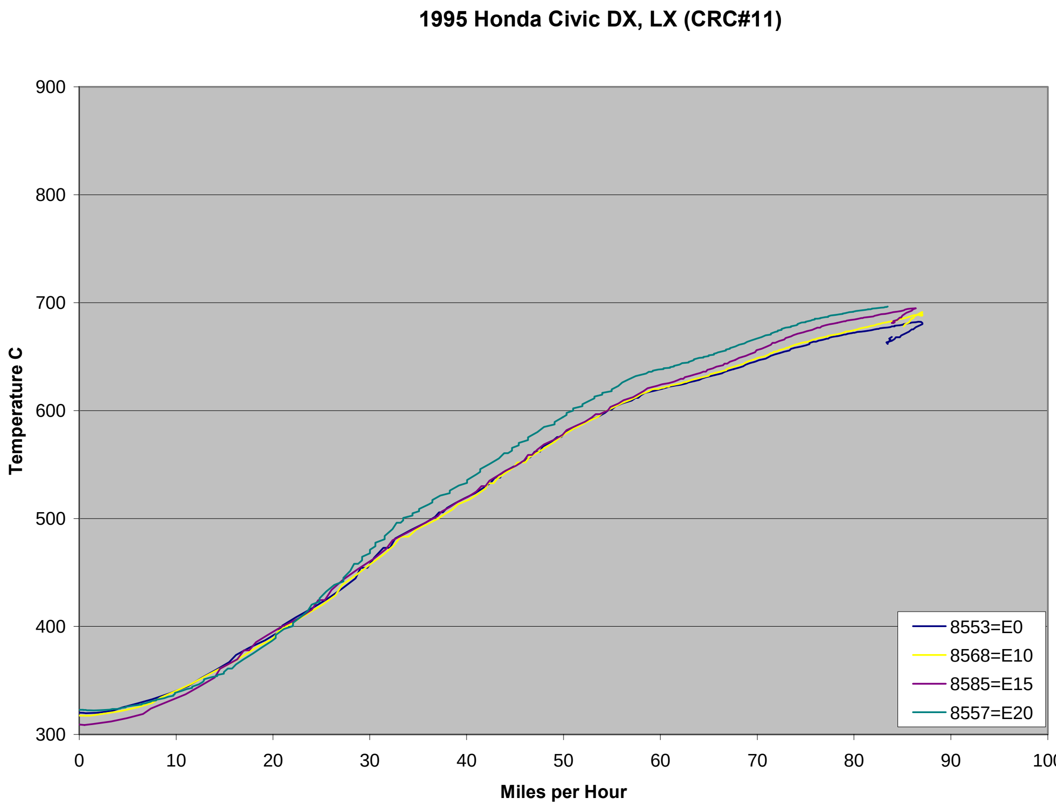

2002 Nissan Frontier Truck (CRC#6)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
Miles per Hour
8549=E0
8581=E10
8586=E15
8596=E20

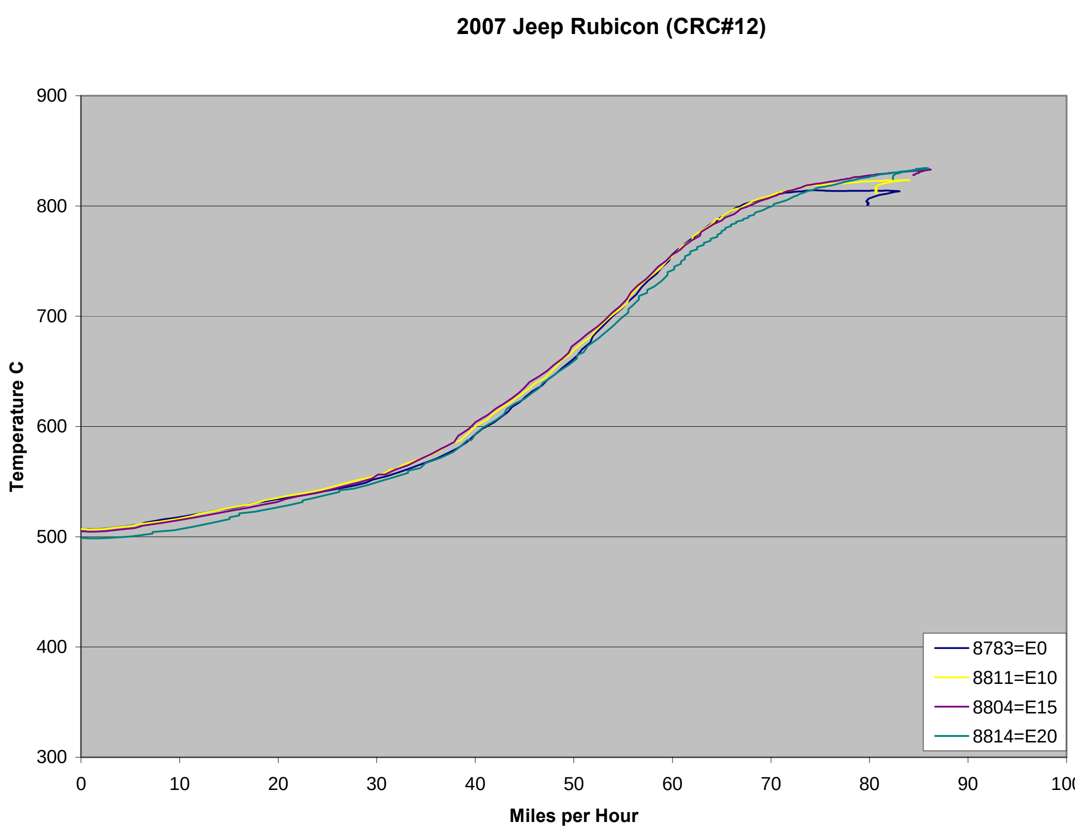

2001 Hyundai Accent (CRC#7)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8604=E0
8637=E10
8621=E15
8631=E20

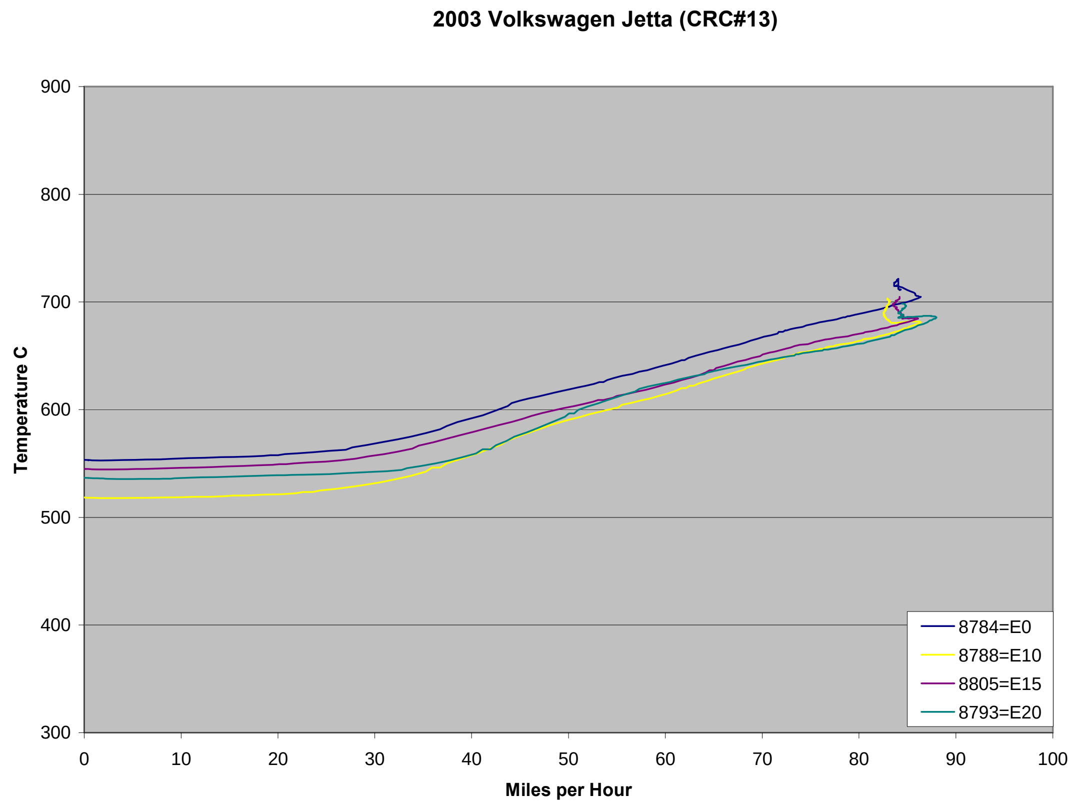

2004 BMW 330i (CRC#8)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8819=E0
8824=E10
8821=E15
8820=E20

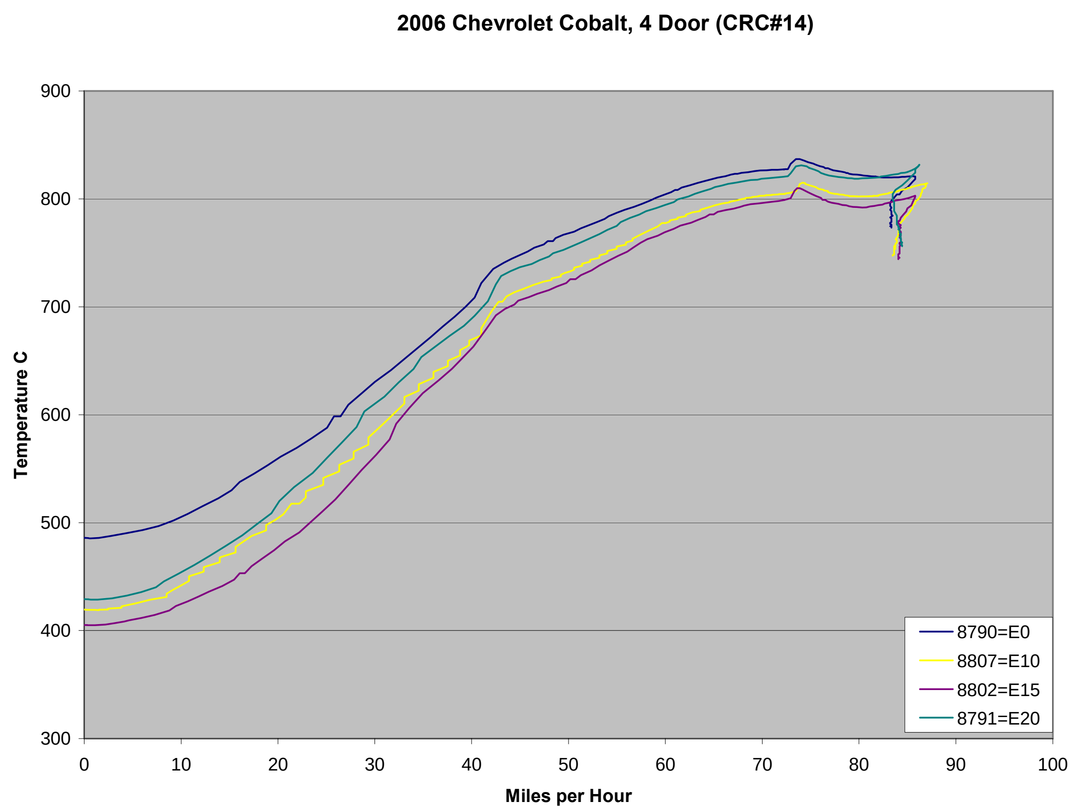

1999 Mitsubishi Mirage (CRC#9)
Temperature C
Miles per Hour
8797=E0
8816=E10
8806=E15
8815=E20

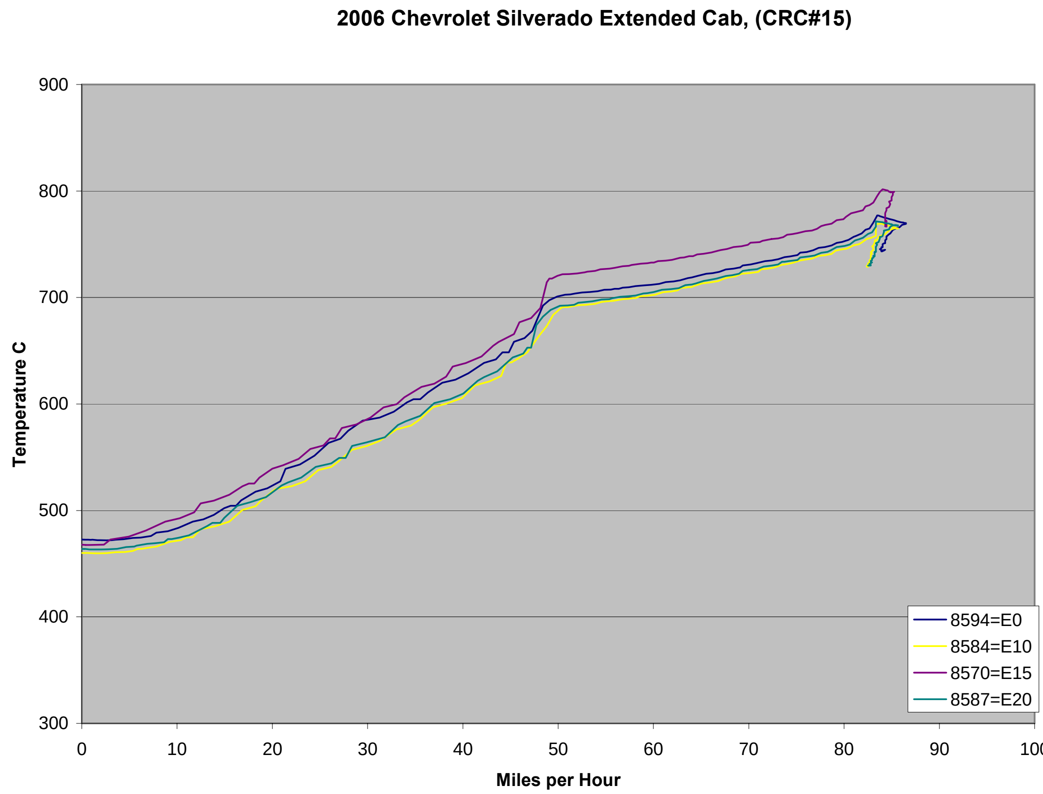

2001 Mitsubishi Montero Sport (CRC#10)
Temperature C
Miles per Hour
8721=E0
8729=E10
8740=E15
8772=E20

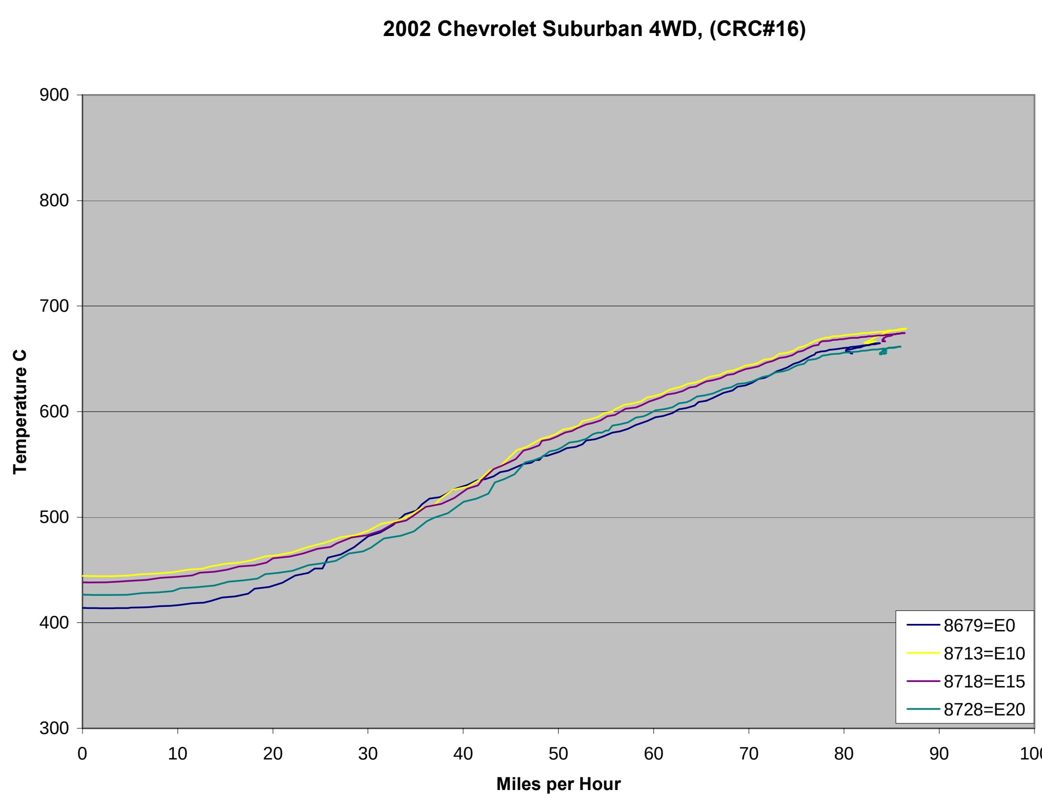

1995 Honda Civic DX, LX (CRC#11)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8553=E0
8568=E10
8585=E15
8557=E20

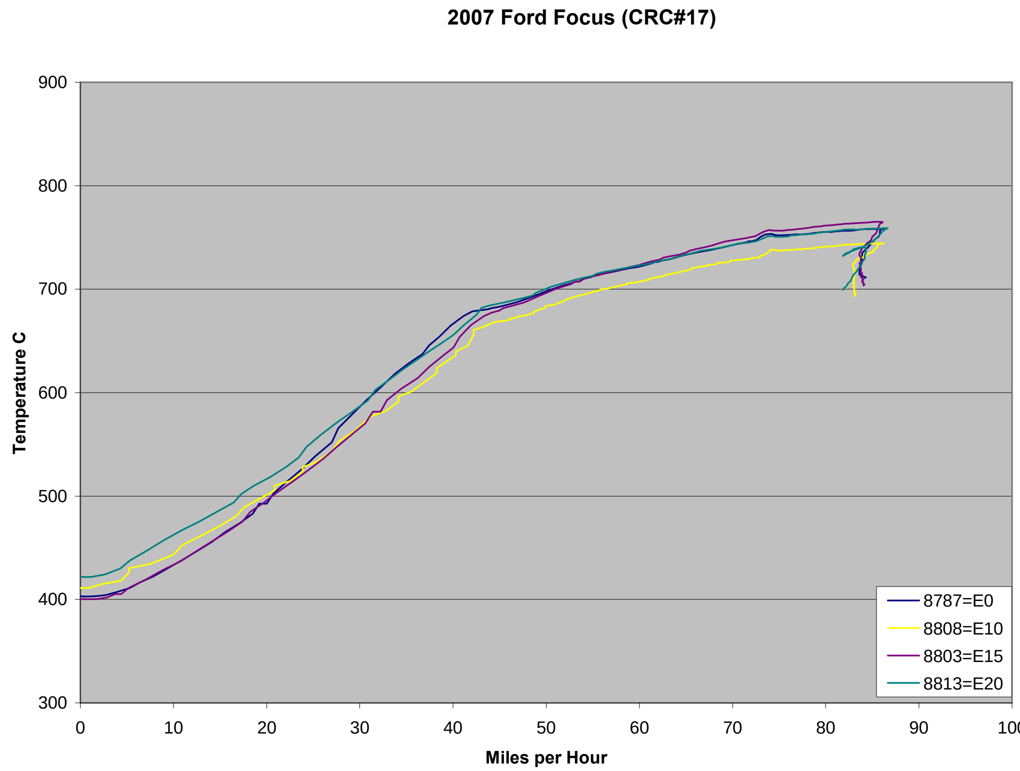

2007 Jeep Rubicon (CRC#12)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8783=E0
8811=E10
8804=E15
8814=E20

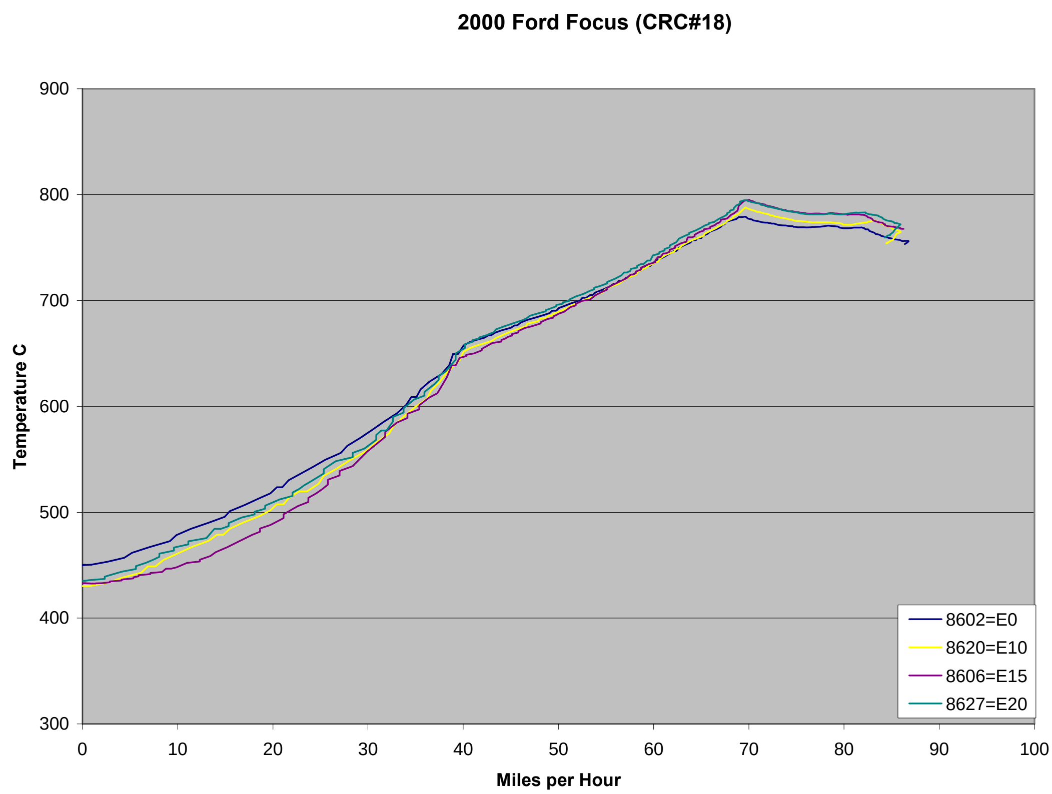

2003 Volkswagen Jetta (CRC#13)
Temperature C
900
800
700
600
500
400
300
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8784=E0
8788=E10
8805=E15
8793=E20

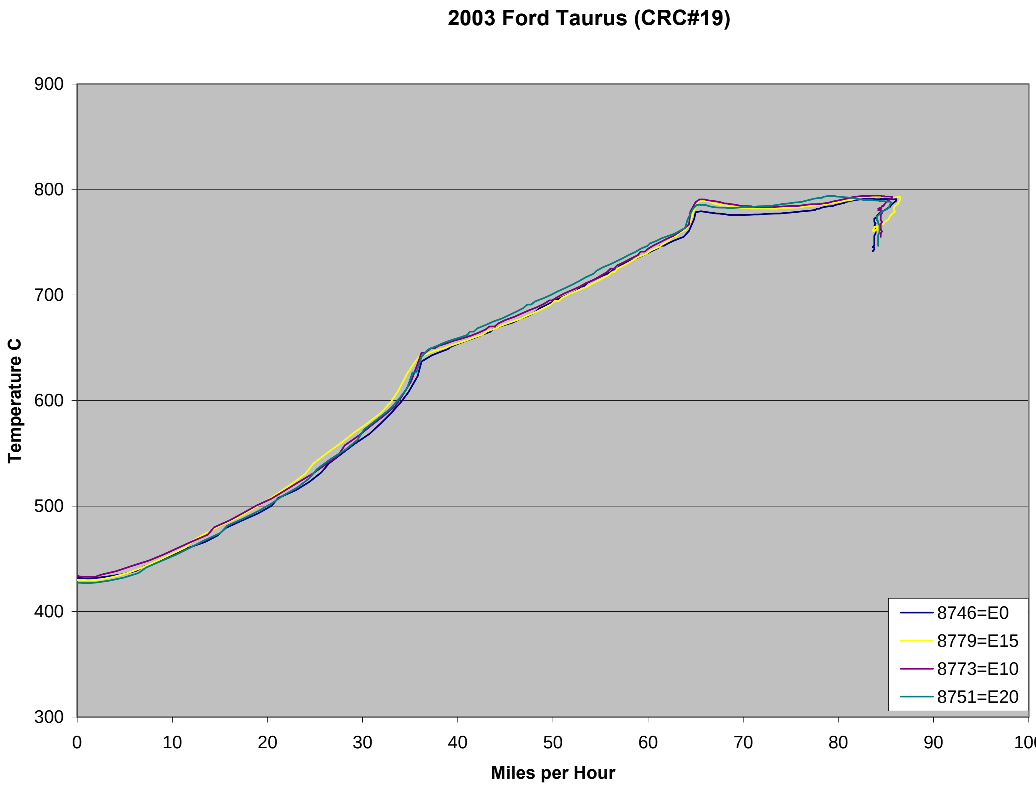

2006 Chevrolet Cobalt, 4 Door (CRC#14)
Temperature C
900
800
700
600
500
400
300
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8790=E0
8807=E10
8802=E15
8791=E20


2006 Chevrolet Silverado Extended Cab, (CRC#15)
Temperature C
900
800
700
600
500
400
300
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8594=E0
8584=E10
8570=E15
8587=E20

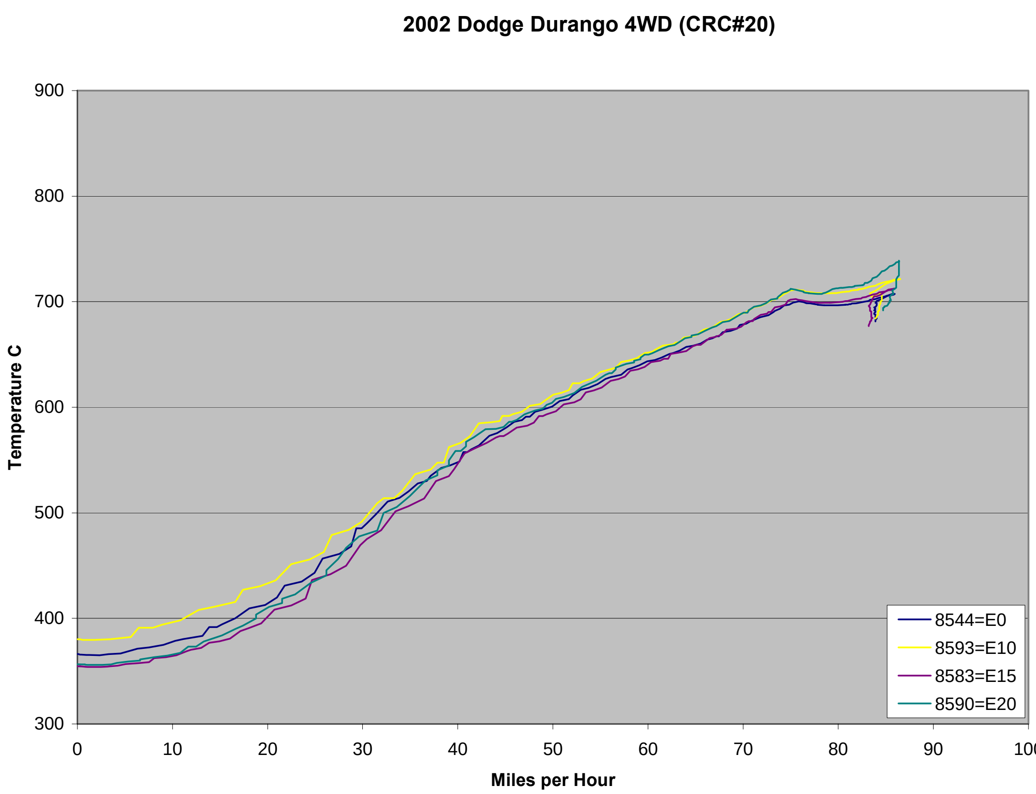

2002 Chevrolet Suburban 4WD, (CRC#16)
Temperature C
900
800
700
600
500
400
300
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8679=E0
8713=E10
8718=E15
8728=E20


2007 Ford Focus (CRC#17)
900
800
700
600
500
400
300
0
10
20
30
40
50
60
70
80
90
100
Temperature C
Miles per Hour
8787=E0
8808=E10
8803=E15
8813=E20


2000 Ford Focus (CRC#18)
900
800
700
600
500
400
300
0
10
20
30
40
50
60
70
80
90
100
Temperature C
Miles per Hour
8602=E0
8620=E10
8606=E15
8627=E20

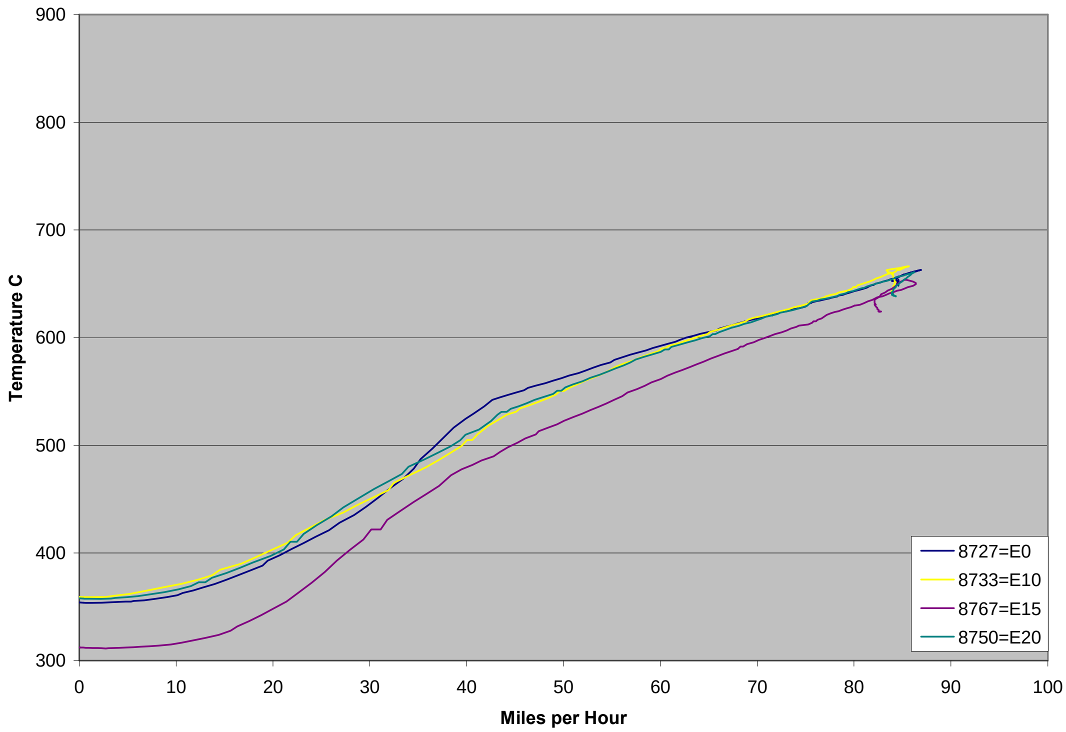


2003 Ford Taurus (CRC#19)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8746=E0
8779=E15
8773=E10
8751=E20

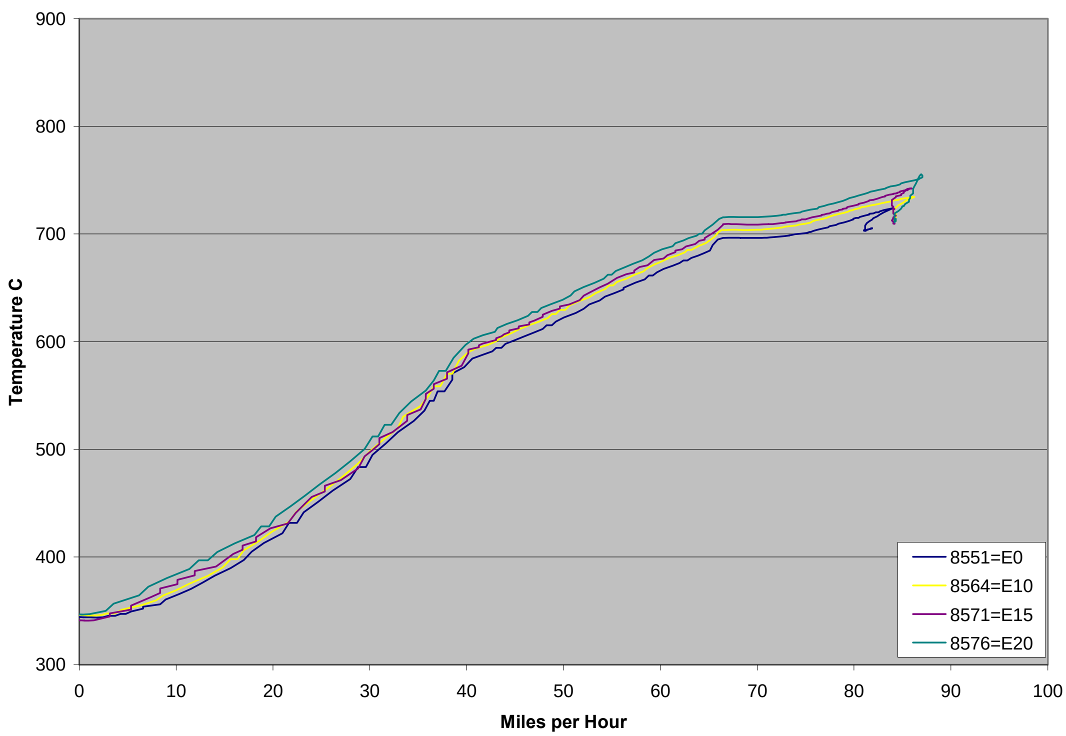


2002 Dodge Durango 4WD (CRC#20)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8544=E0
8593=E10
8583=E15
8590=E20

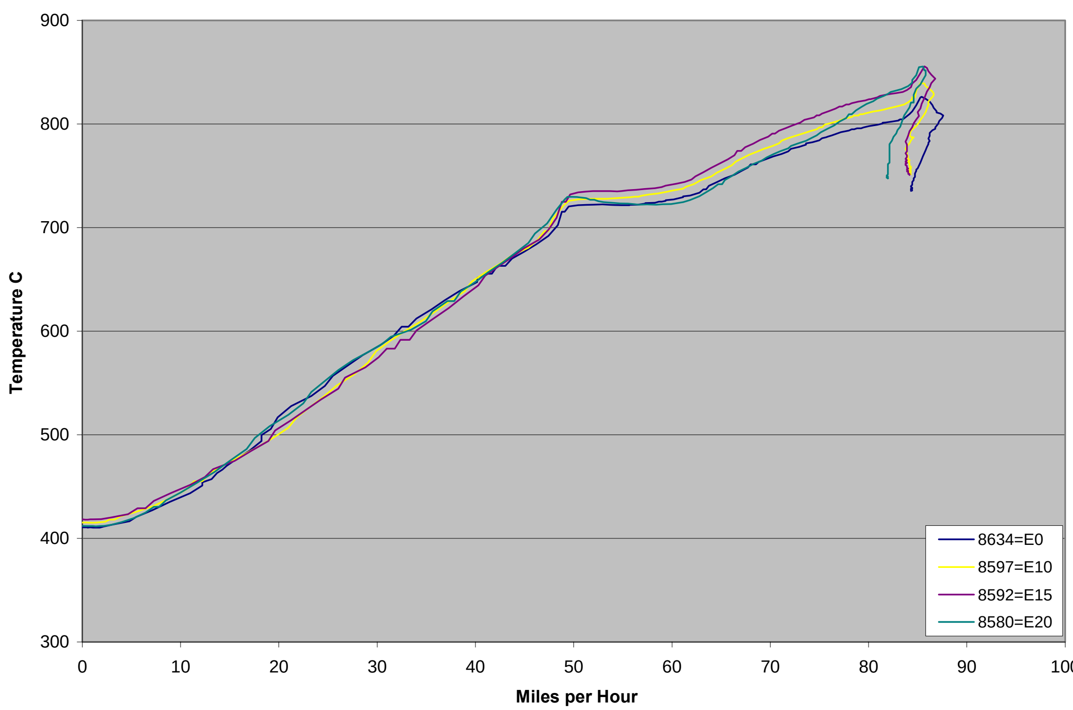
2000 Toyota Sienna (CRC#21)



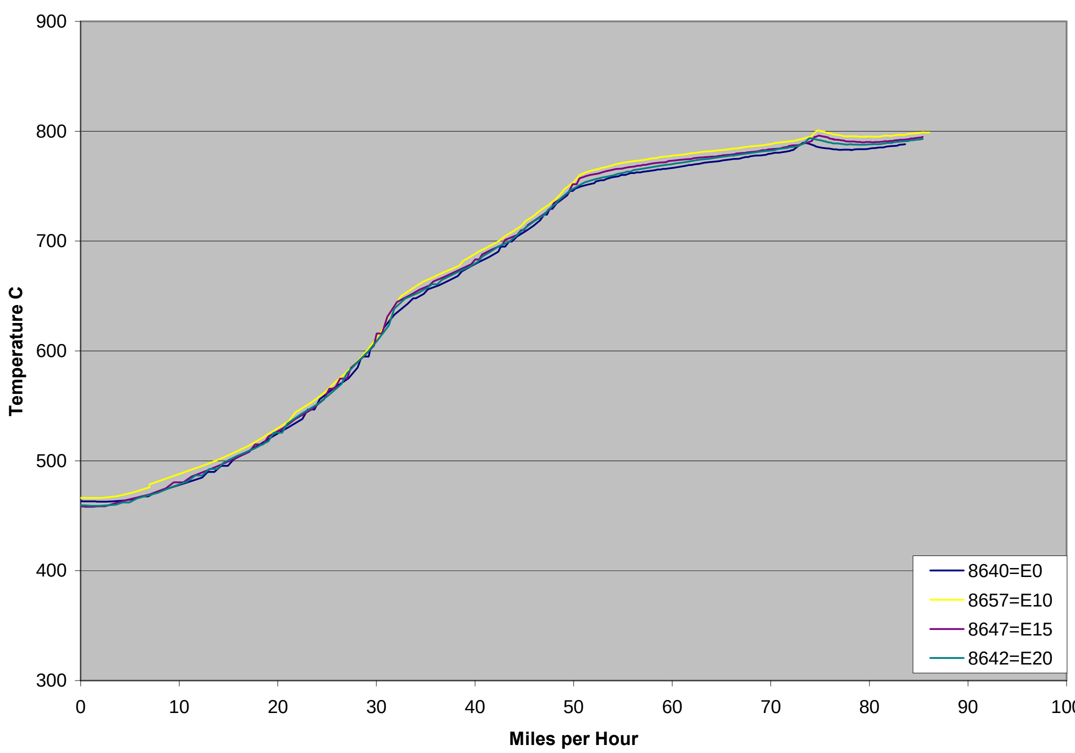
2000 Accord LX (CRC#22)

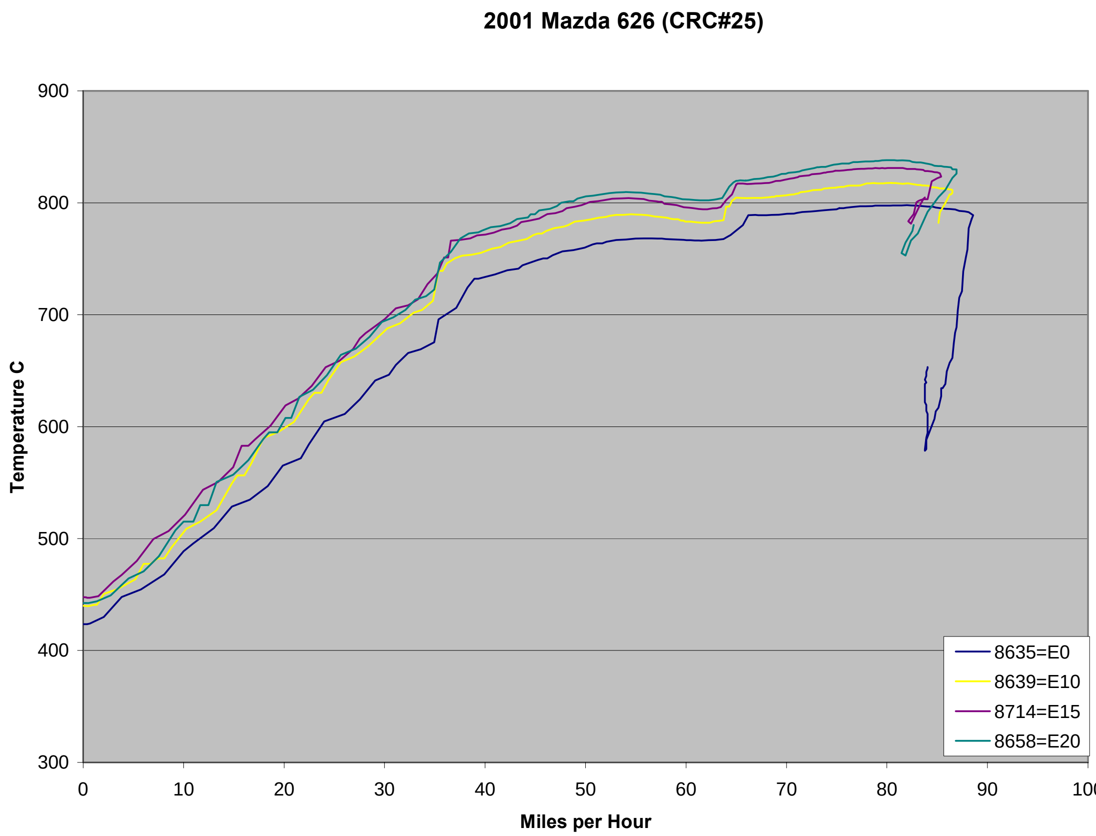


2006 Nissan Quest (CRC#23)



2001 Volkswagen Jetta (CRC#24)





2001 Mazda 626 (CRC#25)
900
800
700
600
500
400
300
Temperature C
0
10
20
30
40
50
60
70
80
90
100
Miles per Hour
8635=E0
8639=E10
8714=E15
8658=E20