CRC Report No. E-77-2

ENHANCED EVAPORATIVE EMISSION VEHICLES

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COORDINATING RESEARCH COUNCIL, INC.
3650 MANSELL ROAD · SUITE 140 · ALPHARETTA, GA 30022

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Final Report

ENHANCED EVAPORATIVE EMISSION VEHICLES
(CRC E-77-2)

Submitted to
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Acronyms

ATL................Automotive Testing Laboratories, Inc.
CFR …………Code of Federal Regulations
CRC…………Coordinating Research Council, Inc.
FID ....Flame Ionization Detector
FTTP ....Fuel Tank Temperature Profile
HC ....Hydrocarbon
HH&A............Harold Haskew & Associates
ID……………Internal Diameter
LA-92.............Unified Driving Cycle
MTBE ....Methyl Tertiary Butyl Ether
NBR ....Nitrile Rubber or Acrylonitrile Butadiene Rubber
ORVR ....On-Board Refueling Vapor Recovery
PFI..................Port Fuel Injection
psi …………..Pounds per square inch
RL SHED.......Running Loss Sealed Housing for Evaporative Determination
RVP................Reid Vapor Pressure
SHED ....Sealed Housing for Evaporative Determination
TEFVO...........Temporary Emissions Following Vehicle Operation
THC................Total Hydrocarbon
VT SHED.......Variable Temperature Sealed Housing for Evaporative Determination

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Executive Summary

This report describes an on-going investigation into the evaporative emission performance of light-duty vehicles as they exist in the United States population. Evaporative emissions are, in this context, the fuel-related emissions that escape from the vehicle at rest and during vehicle operation (omitting those that come from the tailpipe). The CRC E-77-2 Evaporative Emission Test Program, the subject of this report, evolved from the CRC E-77 Pilot Study (available at www.crcao.org, listed under "Publications: Emissions") and used test procedures and insight borrowed from other CRC test programs, including E-65, Fuel Permeation from Automotive Systems. Automotive Testing Laboratories, Inc. (ATL), located in Mesa, AZ, conducted the tests for all these programs, including those that are the subject of this report. ATL has the unique experience and facilities to perform evaporative emission programs of this nature.

For the follow-up study E-77-2, the sponsor selected eight vehicles for evaluation on five gasoline fuel blends, including three levels of ethanol (zero, 10, and 20 volume percent). In addition, two of the vehicles were given a limited evaluation with implanted small leaks in the evaporative system. The selected vehicles were prepared for test, preconditioned for a minimum of four weeks on the test fuel when the ethanol level was changed, and then subjected to the test sequence.

The test fleet included one pre-enhanced evaporative system vehicle (1996 model year), five "Enhanced Evaporative" system vehicles (model years 1999 to 2001), and two "Tier 2" (Near Zero) vehicles from model year 2004 or later. The pre-enhanced vehicle was certified to a single day's diurnal control. The enhanced control vehicles were subjected to a much more severe certification performance test, including a three day diurnal, a high temperature hot soak, and a measured running loss test. The certification test requirements for Tier 2 vehicles were similar to those for the enhanced vehicles, but at a standard of about one-fourth of the level for the enhanced vehicles. With the exception of the 1996 pre-enhanced vehicle, all were certified to the On-Board Refueling Vapor Recovery (ORVR) emission requirements. CRC owned all the vehicles, having previously purchased them for CRC Project E-74b (CO vs. RVP).

Static permeation rate increased with an increase in ethanol level. Three of the five enhanced emission vehicles did not show an increase in permeation rate when tested with the 9 psi E0 compared to the 7 psi E0.

The dynamic permeation rate (measured during vehicle operation) was higher with the E10 fuel compared to E0 for the enhanced vehicles. The E20 permeation rate was higher than E0 and the E10 fuel. The small sample size and limited data precludes us from making statements about statistical confidence, but this may indicate a trend. The near zero vehicle average increased as the ethanol level increased. Trends with volatility were mixed, or inconclusive.

There was a large increase in the hot soak value with the E10 fuel compared to the E0. The hot soak value with the E20 fuel was comparable to the E0 results, but lower than the E10.

The Near Zero vehicles (2) had zero hot soak emissions when tested on the 10 psi E10 fuel (Figure 16). With only two vehicles and the very low levels attained, no statistically significant conclusions can be drawn from the data available.

The average Day 1 diurnal permeation for the five Enhanced Vehicles tended to increase as ethanol content increased (with the exception of the E20 fuel). Again, statistical conclusions are not appropriate given the small sample size and limited data.

This study included an evaluation of two vehicles with implanted vapor system leaks. This interest followed the information gathered in the Pilot Study where tests were run with a specially modified fuel cap containing a 0.02" diameter hole. The newer vehicles evaluated in this phase of the study were configured and certified to the Onboard Refueling Vapor Regulations (ORVR). These are capable of containing 95% or more control of the refueling vapors at up to 10 gallons per minute fueling rate. Where the Chevrolet Cavalier had a small (0.055" diameter) orifice and a long vapor tube venting the tank's vapor space to the carbon canister (and then to the atmosphere), the ORVR compliant vehicles have a large (0.625"internal diameter), short vent hose to a low flow restriction carbon canister. The emission results measured with the ORVR vehicles were significantly lower than measured in previous studies with the pre-enhanced evaporative emission control systems.

Summary of Findings and Results

The E-77-2 test program was a continuation of the previously published E-77 test project, and added eight vehicles tested on five fuels to the knowledge base. The permeation trends previously shown were present for the most part. The small sample size and limited number of tests preclude making statements about trends in emissions with statistical confidence, but in general:

- The newer vehicle groups had lower emission levels.
- Adding ethanol to the fuel increased permeation over the non-oxygenated levels.
- Increased volatility increased permeation levels on average, but produced mixed results on the individual vehicles. The effect of volatility needs additional study.
- SHED emission rates must be corrected for the ethanol error in the Flame Ionization Detector (FID), and the non-fuel methanol and refrigerant in the measurement.

ENHANCED EVAPORATIVE EMISSION VEHICLES

CRC E-77-2

INTRODUCTION

Background - The Coordinating Research Council (CRC)[1] has sponsored studies on evaporative emissions of vehicles for over two decades. Whereas the exhaust (or tailpipe) emissions have been extensively studied as a source of air pollution, and through the development of advanced control systems, reduced to very low levels in properly maintained and functioning vehicles, the non-tailpipe emissions levels are not as well understood or documented.

This report describes an on-going investigation into the evaporative emission performance of light-duty vehicles as they exist in the American population. Evaporative emissions are, in this context, the fuel-related emissions that escape from the vehicle at rest, and during vehicle operation (omitting those that come from the tailpipe). The CRC E-77-2 Evaporative Emission Test Program, the subject of this report, evolved from the CRC E-77 Pilot Study and used test procedures and insight borrowed from other CRC test programs, including E-65, Fuel Permeation from Automotive Systems. All of these programs, including the subject of this report, were conducted at the Automotive Testing Laboratories, Inc. (ATL) in Mesa, AZ[2], which provides unique experience and facilities to perform evaporative emission programs of this nature.

For the follow-up study E-77-2, the sponsor selected eight vehicles for evaluation on five gasoline fuel blends, including three levels of ethanol (zero, 10, and 20 volume percent). In addition, two of the vehicles were given a limited evaluation with implanted small leaks in the evaporative system. The selected vehicles were prepared for test, preconditioned for a minimum of four weeks on the test fuel when the ethanol level was changed, and then subjected to the test sequence. The evaporative emission test sequence consisted of the following four parts:

1. Static Permeation Rate Measurement at 86°F (Includes leak checks)
2. Dynamic (Running Loss) Permeation and Canister Loss Measurement at 86°F
3. Hot Soak (“True” or Net Value) following the Dynamic Test at 86°F
4. Two Day Diurnal (65°F to 105°F) Permeation and Canister Loss Measurement

While one objective of this project was to measure the evaporative emission performance of the selected vehicles, a second objective was to develop and refine the test procedures and analysis methods. We have included documentation of these test procedures beginning on page 10.

Each vehicle started the evaluation with a 4-week preconditioning on 10 psi E10 fuel, and then ran the 10 psi E10 evaporative emission test sequence (static, running loss, hot soak, and

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[1] Coordinating Research Council, Inc., 3650 Mansell Road, Suite 140, Alpharetta, GA 30022, (678) 795-0506, www.crcao.org

[2] ATL, 263 S. Mulberry Street, Mesa, AZ, (480) 649 7906, www.ATL-AZ.com, Greg Barton, President

diurnal). Based on the previous experience with CRC E-65, it was thought that the four week period was appropriate for the permeation rate to re-stabilize following the fuel change. After validation and committee approval of the data, the fuel was changed to a lower volatility (7 psi) E10 fuel, allowed to re-stabilize for up to one week, and then re-evaluated on the emission test sequence. The shorter stabilization period was thought appropriate to allow the system to respond to a volatility change of a similar ethanol content fuel.

Once the test results were approved, the vehicle was refueled with 9 psi E0 fuel, and again subjected to a 4-week minimum re-stabilization. The evaporative performance test sequence was then repeated, and repeated again with a 7 psi E0 fuel after a one week stabilization period. The final test fuel was the 9 psi E20 mixture, again after a 4-week stabilization.

Contract History – Members of the CRC Real World Vehicle Emissions and Emissions Modeling Group, together with technical representatives from EPA and the California Air Resources Board, met at EPA's Ann Arbor office on December 14, 2006, and outlined the scope and content of the study. A follow-on to the CRC E-77 Pilot Study, it included evaporative emission performance testing of eight recent model light duty vehicles using three ethanol levels (E0, E10, and E20) at various RVP levels. The vehicles were not the same as those used in the Pilot Study.

The original contract included eight vehicles tested on four fuels (7 psi E0, 9 psi E0, 7 psi E10, and 10 psi E10). A later contract modification added limited testing on two vehicles with implanted leaks, added testing on 9 psi E20 Fuel, and included monies to pay for retesting and repairs of a problem vehicle.

Period of Performance – Vehicle preconditioning was first reported in the Volume 3, Number 1 progress report dated April 22, 2007, and continued through Volume 3, Number 83 dated November 16, 2008. Figure 1 depicts the actual program testing activity. The colored bars indicate both the preconditioning and the vehicle performance testing period. Analysis and comments were contained in the progress reports through November.

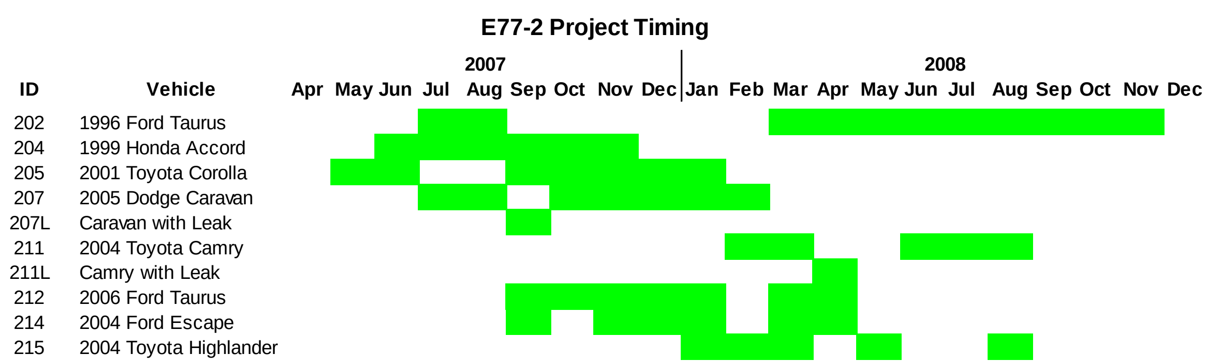

Figure 1 – Testing Activity

TEST PROGRAM OVERVIEW

Vehicle Selection

The sponsors chose to evaluate eight vehicles on five fuel blends. The vehicles were defined to be one pre-enhanced evaporative system vehicle (1996 model year), five "Enhanced Evaporative" system vehicles (model years 1999 to 2001), and two "Tier 2" (Near Zero) vehicles that were 2004 model year vehicles or later. The pre-enhanced vehicle was certified to a single day's diurnal control. The enhanced control vehicles were subject to a much more severe performance test, including a three-day diurnal, a high temperature hot soak, and a measured running loss test. The Tier 2 vehicles' test requirements were similar to the enhanced vehicles, but at a standard of about one-fourth of the enhanced vehicles level. All but the 1996 pre-enhanced vehicle were certified to the On-Board Refueling Vapor Recovery (ORVR) emission requirements. All the vehicles were the property of CRC, having been bought, along with other vehicles, for CRC Project E-74b (CO vs. RVP). The vehicles were originally purchased for the E-74b project from local retail sources in the Phoenix, AZ area.

Each candidate vehicle was checked at the start of the test program to make sure that there were no system leaks, to verify system purge was present, and to generally establish that it was safe to operate.

Vehicle Fleet

Table 1 below lists and describes the eight vehicles studied in this program. A more complete file containing the vehicle road load coefficients and dynamometer settings is included in the "E-77-2 Companion Files.xls" (Microsoft EXCEL™) file available on the CRC website, www.crcao.org.

Table 1

E77-2 Vehicle Fleet

Vehicle Number	Model Year	Make	Model	Odometer Miles	Evap Standards	Evap Family	Fuel Tank Plastic/ Metal
202	1996	Ford	Taurus	86,538	Pre-Enhanced	TFM1115AYMEB	Metal
204	1999	Honda	Accord	100,418	Enhanced/ORVR	XHNXR0130AAA	Metal
205	2001	Toyota	Corolla	92,047	Enhanced/ORVR	1TYXR0115AK1	Metal
207	2001	Dodge	Caravan	92,740	Enhanced/ORVR	1CRXR0165XAA	Plastic
214	2004	Ford	Escape	40,188	Enhanced/ORVR	4FMXR0110BBE	Plastic
215	2004	Toyota	Highlander	88,000	Enhanced/ORVR	4TYXR0165PZ1	Plastic
211	2004	Toyota	Camry	42,592	Near Zero/ORVR	4TYXR0130A11	Plastic
212	2006	Ford	Taurus	28,354	Near Zero/ORVR	6FMXR0185GAK	Metal

Test Fuels

The fuel comparisons selected for this project were three levels of ethanol content with volatility varied as listed in Table 2, below.

Table 2

Test Fuel Target Values

	7 psi	9 psi	10 psi
E0	**X**	**X**	
E10	**X**		**X**
E20		**X**	

CRC had fuels remaining from Project E-74 in quantities sufficient to conduct this program, e.g., 7 psi E0 and E10, and 9 psi E20[3]. Inspection records of the base fuels are repeated in the Appendix, using their E-74b identifications, fuels 6, 7 and 4, respectively. The nominal 7 psi fuels, both E0 and E10, were locally blended with commercial butane to make the higher volatility 9 psi E0, and the 10 psi E10. The blends were done in drum batches, approximately 50 gallons at a time, by adding small amounts of butane, circulating for a brief period, then sampling and determining the new volatility with a "Grabner[4]" instrument, using test procedures described in ASTM D 5191. The higher (10 instead of 9) volatility of the E10 fuel was specified because many localities permit "splash blending" of ethanol to gasoline and allow a 1 psi volatility exemption for their vapor pressure limits.

Adaption Period for Test Fuel Change

Many areas of the United States were required[5] to use an oxygenated fuel to improve vehicle emissions, especially during the summer season. While MTBE was the most common oxygenate, ethanol was also used. CRC Project E-65 demonstrated that the permeation of vehicle fuel systems increased with the use of fuels containing ethanol, compared to fuels with MTBE, or no oxygenate. CRC Project E-65 also demonstrated that if ethanol had been previously used, and the fuel replaced with a non-ethanol blend, it could take two to four weeks for the ethanol increase to dissipate.

The protocols adopted for this test program were to require a minimum of four weeks of vehicle exposure to a new fuel when first introducing 10 or 20 volume percent ethanol to the vehicle, and the same period of time when moving to an ethanol-free (E0) fuel. Note, when changing RVP only, a one week exposure has been demonstrated as sufficient.

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3 While the E20 target was 9 psi, the average inspection value (5 labs) was 8.5 psi. The sponsor chose to continue the test at this level.

4 www.grabner-instruments.com, MINIVAP VPS / VPSH Vapor Pressure Tester, The portable MINIVAP VPS and VPSH vapor pressure testers are the worldwide accepted standard instruments for determination of the vapor pressure of gasoline according to ASTM D 5191, ASTM D 6377, ASTM D 6378 and EN 13016 1+2.

5 The requirement for oxygen content in RFG fuels was removed by EPA in May of 2005, as directed by the Energy Policy Act of 2005. The Renewable Fuels Standard, requiring renewable fuels (e.g., ethanol) in increasing amounts over the years, replaces the mandate.

The Test Concept: Measuring Leaks, Permeation and Diurnal Vapor Losses

Mass emissions are measured in a VT SHED or Variable Temperature Sealed Housing for Evaporative Determination. The SHED test method combines all three emission mechanisms (leaks, diurnal venting, and permeation) into a single test result.

The SHED technique involves placing the vehicle in a sealed enclosure (Figure 2), and calculating the mass in the enclosure from the volume, density, and concentration in the enclosure at the start and end of a time period. The difference between the mass at the start and end of test is the emission rate, e.g., grams per unit time.

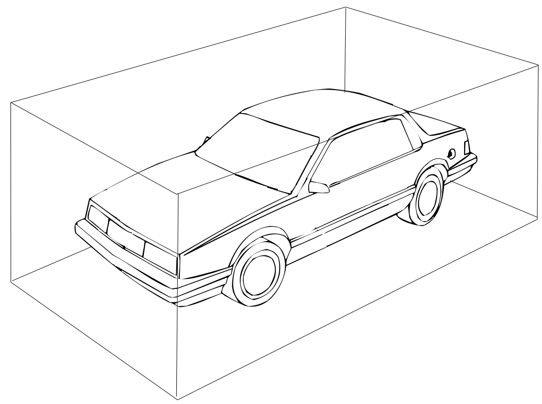

Figure 2 – Sealed Housing for Evaporative Determination

CRC's E-77 emission test programs have developed (and strive to continually improve) new methodologies for understanding and quantifying vehicle evaporative emission rates. The concept partitions and assigns the vehicle's contribution to the evaporative emission inventory into three mechanisms:

1. Permeation
2. Tank vapor venting
3. Leaks (with two subsets - Liquid and Vapor)

Permeation is the migration of HC through the various elastomers (polymers) in a vehicle fuel system[6]. Previous testing has shown that permeation rate is strongly affected by the material's temperature, doubling for each 10ºC (18ºF) increase in the range of normal summer temperatures. It is also strongly affected by gasoline composition, especially with ethanol-containing fuels.

[6] "Fuel Permeation from Automotive Systems: Final Report CRC Project E-65," Haskew, Liberty and McClement, September 2004, available on the CRC and California Air Resources Board websites.

Tank vapor venting emissions are controlled by fitting a carbon canister to the atmospheric tank vent. Figure 3 is a schematic of a typical early control system. During a daily heating period, the temperature of the vehicle's fuel tank increases, forcing HC vapors from the tank. Excess emissions, exceeding the carbon canister's capacity, are vented to the atmosphere.

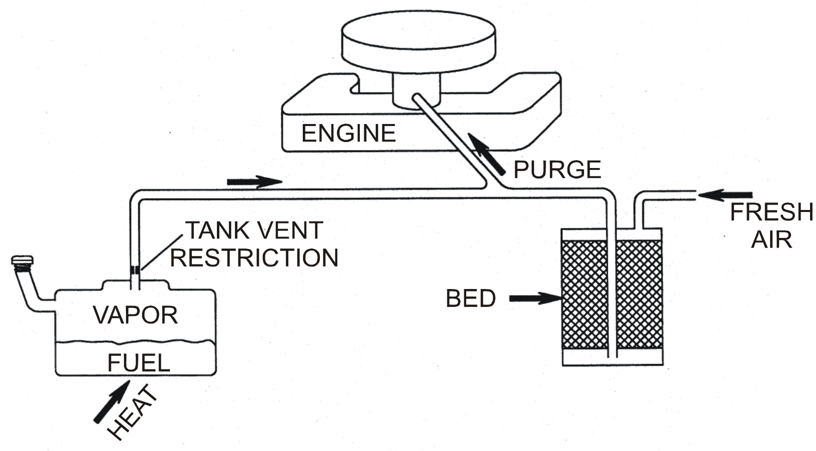

Figure 3 - Control System Schematic

Leaks can be liquid or vapor. Permeation and tank venting losses are strongly driven by fuel composition, ambient temperature, and ambient temperature change. Liquid leaks are not strongly affected by normal summer temperatures, and are thought to have two components:

1. Static leaks occurring while the engine is turned off and the vehicle is stationary
2. Increase in leak rate caused by the system pressure increase during engine operation.

A Test Method for Separating Permeation from Tank Venting and Leaks – In a previous CRC Project (E-65), the canister loss was separated from the permeation measurement by venting the losses from the carbon canister outside the SHED. For Project E-77, the canister vent losses were collected and measured in a separate "trap canister" on a scale outside the SHED, as shown in Figure 4. This vent line was capped off (i.e., sealed during the Static Test) but connected as shown in the figure for the Dynamic and the Diurnal Test. The ambient temperature in the SHED was constant during the static test, and there was no vapor created at constant temperature.

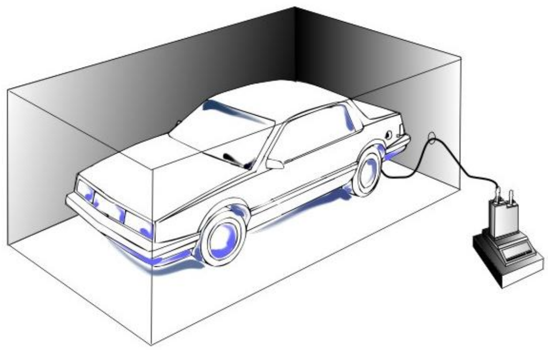

Figure 4 - Trap Canister

This vent was closed to pressurize the system for the leak evaluations. The resulting SHED increase in HC mass was permeation[7]. The last mechanism that needed to be evaluated was leaks. Leaks can be both vapor and liquid. A liquid leak can have significant mass, currently undetected by the vehicle's on-board diagnostic system. Considerable thought and effort have gone into the creation of a simple and effective liquid leak detection methodology, without success. The techniques used in this project required the use of a SHED for measurements. The techniques were not simple, but they proved effective.

Based on experience, a vehicle's permeation rate is expected to be between the range of 4 to 90 mg/hour at the 86°F test temperature. The presence of a static liquid leak is expected to overwhelm this value; such a leak would (or could) be apparent by inspection. Leaks from the vehicles were quantified in a three-step test process. The first step was to measure the static permeation rate of the vehicle at 86ºF. The vehicle was allowed to stabilize overnight at 86ºF in the SHED, and the permeation rate was calculated from the mass increase in the SHED during a one-hour measurement period. The second part of the test, looking for pressure driven leaks in the vapor system, was performed by pressurizing the vehicle's tank to 5" H_2O through a special fuel cap and tubing from outside the SHED (Figure 5). The special fuel cap, the hose, and the pressurization apparatus were installed before the start of the sequence. The HC concentration in the SHED was monitored, and the increase in the mass of HC in the SHED during the 30-minute pressurization period compared to the static permeation rate. If there was no (or insignificant) rate of increase, it was deduced that no vapor leak was present.

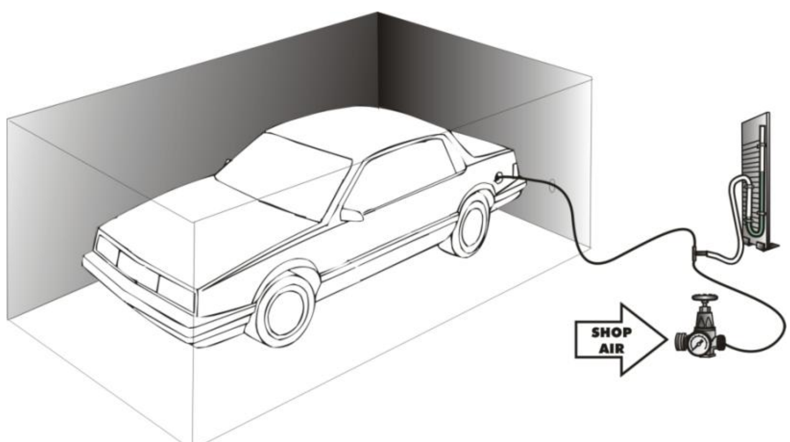

Figure 5 - Static Test – Tank Pressurization

The third and final part of the test was to energize the vehicle's fuel pump and pressurize the system up to and including the injectors (Figure 6). If there were a pressure leak in the liquid system, an increase in the SHED mass over the 30-minute measurement period would be seen, i.e., the leak would be additive to the permeation rate.

[6] This is a simplification. There are other HC sources present that are not fuel permeation. These include tire, paint, adhesives and vinyl emissions, and the possibility of fuel leaks from the fuel injectors. We believe these to be a minor component of the emissions measured in this study.

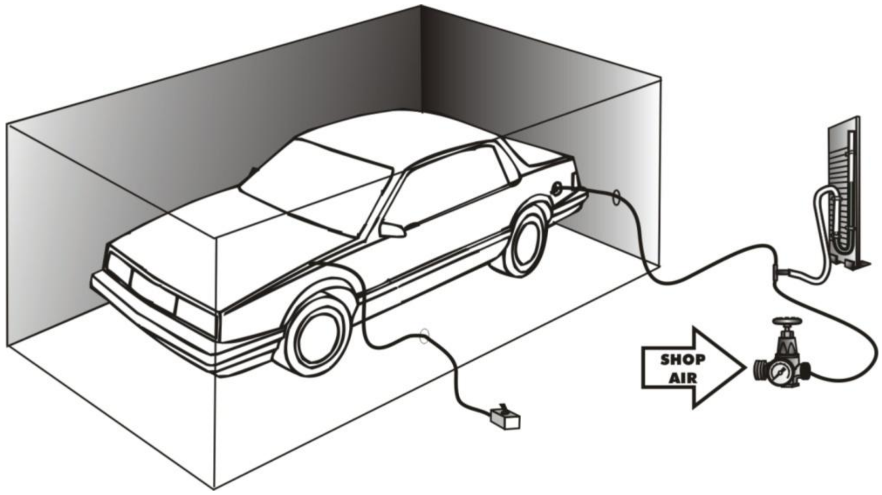

Figure 6 – Static Test – Fuel Pump Energized

Other Tests (Dynamic, Hot Soak, and Diurnal) - A similar configuration is used to isolate the tank venting losses from the permeation measurements determined by other test procedures. The vehicle's canister vent is connected with a low permeation hose (Teflon™) to a bulk-head fitting in the SHED wall and then to a separate "trap canister" on a top-loading scale. Any HC emissions that escape from the vehicle's canister are captured in the trap canister and measured at a 0.01 g (10 milligram) precision. The trap canister (a 1 Liter Ford model) is purged before each test and maintained at a "dry" condition so that it captures all of the vehicle's escaping emissions. This assumption is probably violated during the high volatility tests where there are 30 grams of daily emissions, but this is not a concern at this time.

Test Elements for E-77-2 - The following flow chart (Figure 7) displays the various elements utilized during the testing of the various vehicles and fuels during this program. Details of each of the four basic tests follow the flow chart.

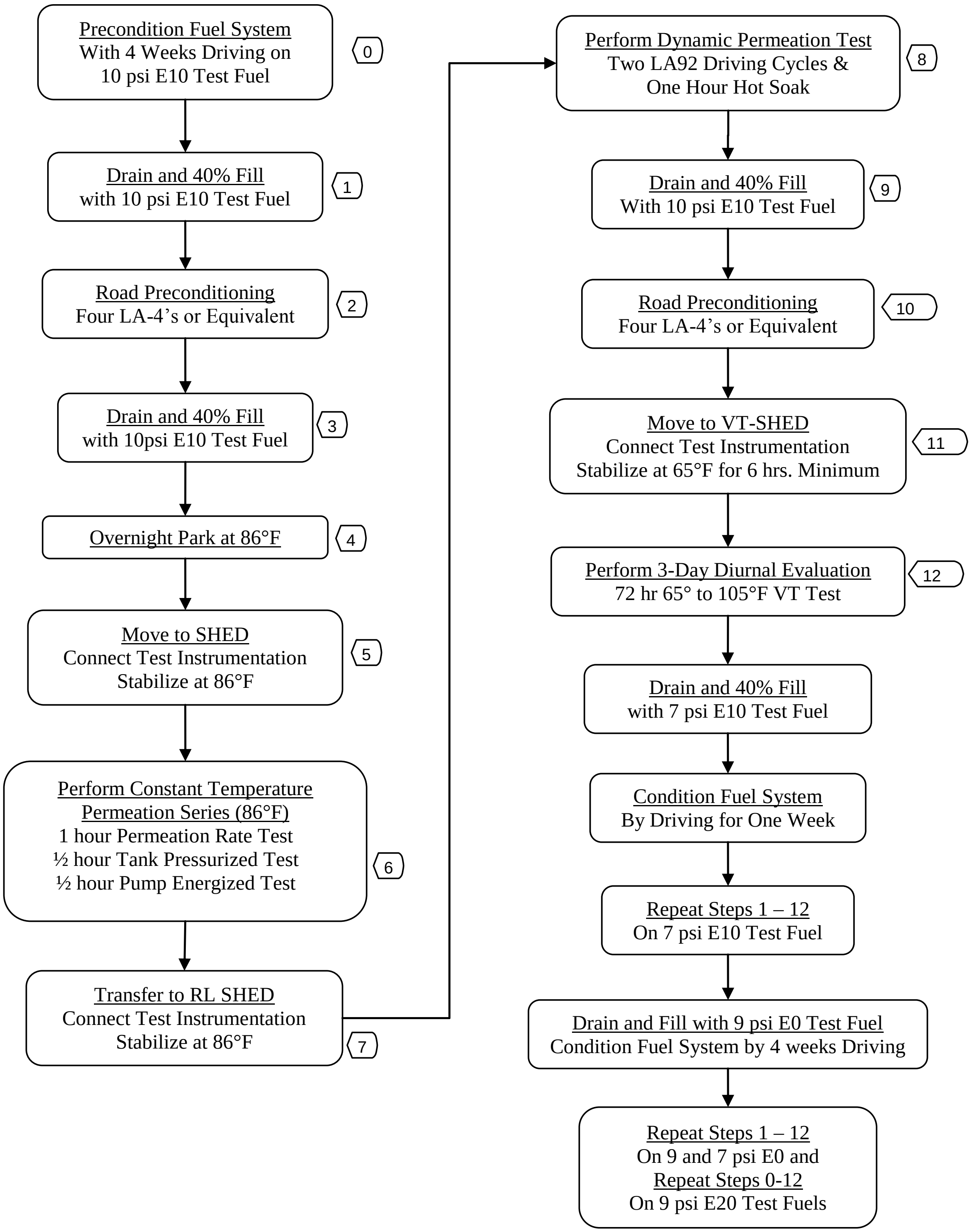

Figure 7 – Testing Flow Chart

Test Procedures – There are four basic tests in the E-77-2 test protocol:

1. Static Permeation Rate (includes checks for vapor and liquid leaks)
2. Running Emissions (Dynamic Test)
3. Hot Soak
4. Diurnal

Each is described in detail below.

1. Static Permeation Rate Testing

The constant temperature (static) permeation rate is measured in a traditional SHED (Constant temperature) in the following manner.

A. The fuel tank is drained and filled to 40% tank capacity with the test fuel.
B. The day before testing, the vehicle is driven over four road trips of 7.5 miles each to precondition the canister.[8] (These drives are similar to the LA-4.)
C. Upon return from the road pre-conditioning, the fuel tank is drained and filled to 40% tank capacity with the test fuel.[9]
D. Vehicle is parked for 18-22 hours in a controlled temperature environment at test temperature (86ºF).
E. The vehicle is then moved (without starting) into the test (86ºF) SHED.
F. The canister vent is connected to the SHED bulkhead fitting which routes the vapor to the trap canister outside the SHED.
G. The tank system pressurization hose is connected.
H. The fuel pump electrical connection is connected.
I. The SHED is sealed, the inside temperature is allowed to stabilize and the test is started. Continuous THC measurements are made using a FID. Ethanol, methanol and R134a concentrations are measured using an INNOVA analyzer. All measurements are made at least every minute for one hour to determine the stabilized permeation rate.
J. At the end of the static test (60 minutes), the vehicle's vapor system is pressurized to 5 inches of water for thirty minutes. Measurements are made to quantify vapor leaks as determined by a change in the THC in the SHED.
K. The fuel pump is then energized for 30 minutes while maintaining the 5 inches of water on the vapor system. Liquid leaks are quantified as determined by a change in the concentration of THC in the SHED.

The purpose of steps J and K above is to validate that the permeation rate measurement was made without the presence of any leak – either liquid or vapor. A detailed discussion follows, starting at page 12.

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[8] This conditioning can be done in the laboratory on a chassis dynamometer if proper attention is paid to underbody cooling, and unrepresentative fuel tank temperatures are avoided.
[9] Vehicles with ORVR systems will add the refueling vapors to the canister. This is OK.

2. Running Loss Test (Dynamic Test)

A. The vehicle is placed in the RL-SHED and prepared for test. (The fuel level and condition for the dynamic test is the fuel remaining after completion of the static test – 40% fresh fill of the appropriate test fuel.)
B. Outside air source for the engine is connected.
C. Vehicle exhaust is connected.
D. Fuel tank thermocouple is connected.
E. Canister vent is connected to the SHED bulkhead fitting which routes the vapor to the trap canister outside the SHED.
F. Vehicle is allowed to stabilize in the RL-SHED at test temperature (86°F) for a minimum of 12 hours – preferably overnight.
G. Two cycles of the Unified Cycle (LA-92) driving schedule (48 mins.) are driven while measuring the mass emissions in the SHED. Vehicle is allowed to idle (in drive) for 30 seconds between the two cycles. Ambient air temperature is maintained (to the extent possible) at 86°F. Fuel tank surface temperature is monitored during vehicle operation. It should increase during the drive from 10 to 18°F to simulate expected on-road temperature increase. Measured mass emissions are corrected using the INNOVA data for the ethanol, methanol, and refrigerant emissions.

3. Hot Soak[10]

This procedure is executed immediately following the Running Loss Test procedure described above.

A. Engine is turned off, transmission selector is placed in park, and driver exits the enclosure, using the double door air lock, taking care to minimize any air exchange between the laboratory and the SHED. This starts the one hour "hot soak" period.
B. Measurements of mass emissions in the SHED are continued for another 60 minutes (until time = 108 minutes), correcting for the ethanol, methanol, and refrigerant mass using the INNOVA instrument data. This ends the hot soak. Hot soak emissions are calculated as the net difference for the one hour hot soak ($CorrMass_{108}$ – $CorrMass_{48}$ minus the 86°F static hourly rate, all mass rates in mg/hour).

4. Diurnal Test

A. The fuel tank is drained and filled to 40% tank capacity with the test fuel.
B. The day before testing, the vehicle is driven over four road trips of 7.5 miles each to precondition the vehicle and the canister.
C. Upon return from the road pre-conditioning, the fuel tank is drained and filled to 40% tank capacity with the test fuel.
D. The vehicle is parked for 18-22 hours in a controlled temperature environment at the initial diurnal test temperature (65ºF).
E. The SHED is sealed, allowed to stabilize at the 65°F temperature and the 3-day California Diurnal Test is started.

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[10] We define the "hot soak" to be the temporary increase in emission rate caused by the immediately preceding operation of the vehicle. It is the increase in the SHED mass (corrected for EtOH, MeOH and R-134a) over the one hour period minus the previously established "static" permeation rate.

F. “Continuous” (every 30 seconds) THC measurements are made using a FID. Ethanol, methanol, and R134a (refrigerant) concentrations are measured using an INNOVA analyzer, at least every 10 minutes for the duration of the test (72 hours).

Static Permeation Test – Leak Validation

If a leak is detected during either the vapor system pressure portion (Step J) or the pump energized portion (Step K) of the Static Permeation Test procedure, it calls into question whether the permeation rate measurement accurately reflects fuel system permeation or if instead a combination of permeation and the implied leak was measured. If a leak is confirmed, the permeation rate measurement is called into question, and an investigation, possible remedy, and retest is indicated.

The permeation rate measurement must be corrected for the FID’s ethanol misrepresentation, and the presence of non-fuel hydrocarbons (methanol and refrigerant). The leak check, however, is made using the change in mass increase in the SHED using the uncorrected FID mass calculation as the determinate. It was found that the corrections for ethanol, methanol, and refrigerant were introducing “noise” into the trace and that these were being misinterpreted as leaks.

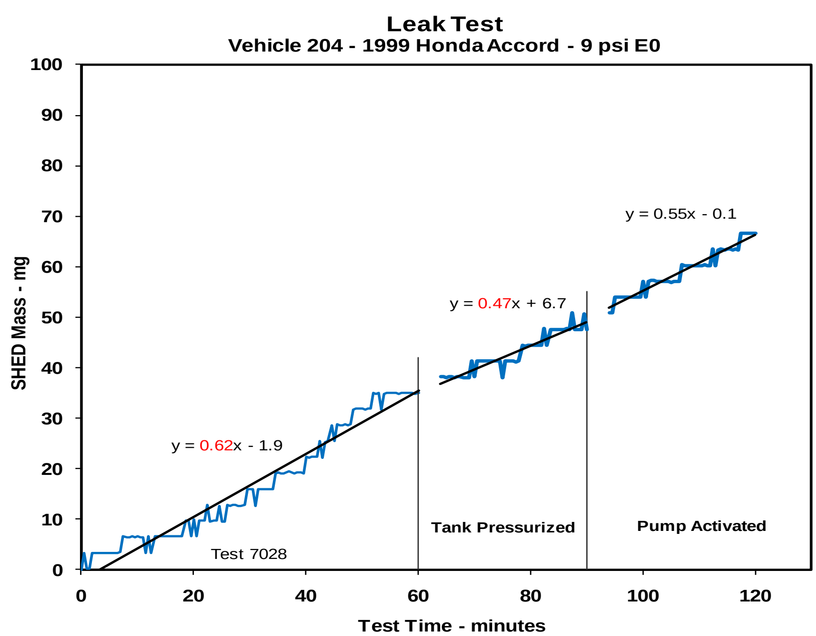

Figure 8 – Leak Test

Figure 8 above represents the calculations made during the inspection of data from a successful test. EXCEL’s™ “SLOPE” function is used to calculate the linear regression values based on the FID calculation for mass for: Time 0 to 60 minutes, Time 64 to 90 minutes, and Time 94 to 120 minutes. A 4-minute gap was included between each sequence to establish the new mass emission rate during the “pressure on,” (T_{60} to T_{90}), and the “pump energized” periods.

The slope of 0.47 for the “Tank Pressurized” period in the example above is compared to the slope of 0.62 calculated for the permeation rate (or hot soak) period. Since the “Tank

Pressurized" slope is not more than 10% higher than the hot soak permeation rate, we assume that there is no leak present. A similar comparison is made for the slope determined during the "pump on" period. The choice of a 10% allowance is arbitrary and is used here to allow for normal and unavoidable test variation.

For tests in which the above procedure determines that no leak is present, a value of zero is reported in the test summary for the leak results. If a positive value is reported, it calls that test into question, and an investigation, possible repair, and retest is indicated.

Static Permeation Rate Determination

The static permeation rate is determined based on a linear regression through the individual SHED mass data points (data measured each 30 seconds) of the corrected fuel results (corrected for the FID error, and subtracting the methanol and refrigerant) from the first 60 minutes of testing as illustrated in Figure 9 below.

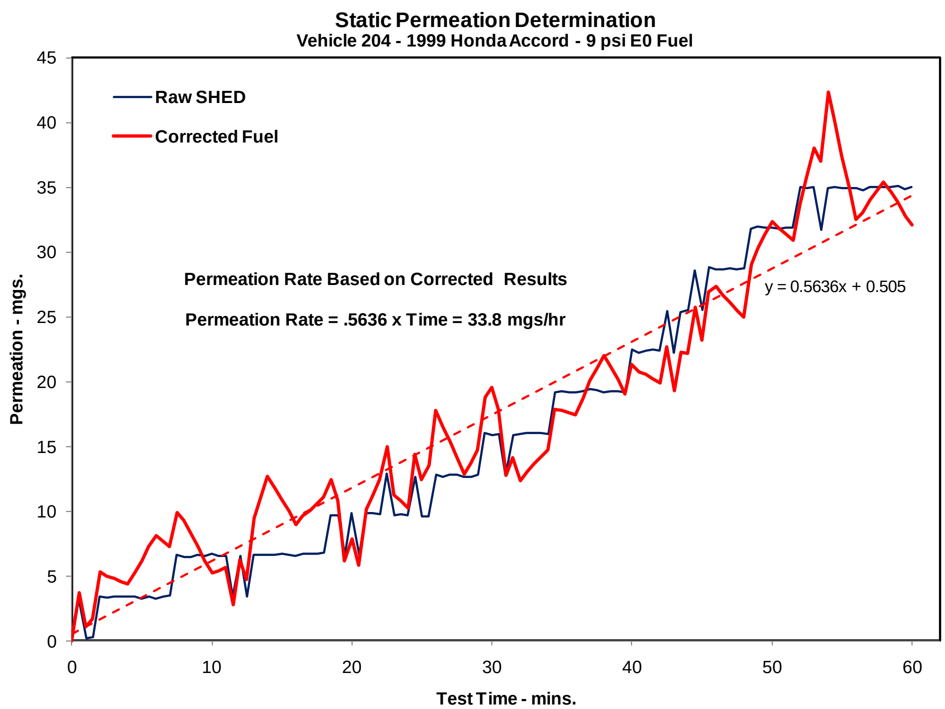

Figure 9 – Static Permeation Determination

In this example, the static permeation rate is 33.8 mg/hr.

Dynamic (Running Loss) and Hot Soak Test

The preceding section addressed the concepts of separating the permeation emissions from the tank venting emissions, and establishing the presence or absence of leaks. The second part of this study includes a dynamic test to measure the permeation and tank venting emissions during vehicle operation ("running losses") and the temporary condition following vehicle operation known as the "hot soak."

This is considered a "dynamic" test because the vehicle is driven and the fuel and vapor system temperatures rise during the test. The ambient temperature in the Running Loss SHED during the test was held constant at 86°F, while the vehicle's fuel system temperature rose during the test. Two 1435 second (23.9-minute) LA-92 driving cycles were performed consecutively during the running loss measurements with a 30-second idle in-between. During this test, tank fuel temperature was expected to rise by an average approximately 18°F above the initial ambient temperature. The running loss air handling system included a proportional speed under-car blower operated as a slave to dynamometer speed. This apparatus was used during running loss testing with minor tuning for specific vehicles. Without additional input, it is capable of reasonable fuel tank temperature control. Each vehicle was fitted with a surface-mount thermocouple at the front of the fuel tank, located at approximately the 1/8th fill level to measure the fuel liquid temperature. No attempt was made to follow a predefined fuel tank temperature profile (FTTP) in this program. Fuel temperatures were recorded, and results are available in the real-time records.

Figure 10 - Running Loss SHED

Vehicle running loss emissions are measured in a special version of a SHED known as a Running Loss SHED (RL-SHED), shown in Figure 10. Special features of the RL-SHED include a sealed chassis dynamometer for simulating vehicle driving loads, a sealed outside air supply for engine intake, a sealed exhaust conduit for engine exhaust, and an under-chassis fan for simulating underbody air flow as described above. A vehicle is operated inside the RL-SHED over a chosen driving cycle. The increase in HC emissions inside the enclosure are measured and calculated as mass emissions per 40 CFR §86.163-96.

Vehicle testing in an RL-SHED is complicated by several factors, including:

1. Engine must be supplied with external induction air.
2. Exhaust must be conducted externally without any leaks.
3. Load supplied to the vehicle through the chassis dynamometer must not create or allow external leaks.
4. Internal SHED temperature must be maintained while sizable heat is rejected to the ambient by the running engine and exhaust.
5. Cooling air supplied to the radiator must be modulated to represent the vehicle's road speed.
6. Underbody (and especially the fuel system) temperature should represent the rate of rise experienced by a real road-drive.

Canister vent losses were isolated from permeation emissions using the technique previously described. The vehicle's carbon canister fresh air vent was connected to the outside of the RL-SHED using a leak-tight PTFE® hose (3/8" OD commercial tubing, US Plastics #58055 PTFE or equivalent) connected to a small carbon "trap" canister located on a top-loading precision scale. The scale precision was 0.01 grams (10 milligrams) and it was purged prior to each test. There were no tank venting emissions measured on any of the running loss test measurements. All of the vehicles appeared to be actively "purging" their respective control canisters and drawing fresh air during the test. If there were any emissions from the vehicle's control canister, as might have occurred if there were no vehicle purge or if very high volatility fuels with excessive vapor generation were used, they would have been measured.

The Running Loss Driving Cycle consisted of two cycles of the "Unified Driving Cycle," otherwise known as the LA-92. A velocity versus time plot for one cycle is shown in Figure 11.

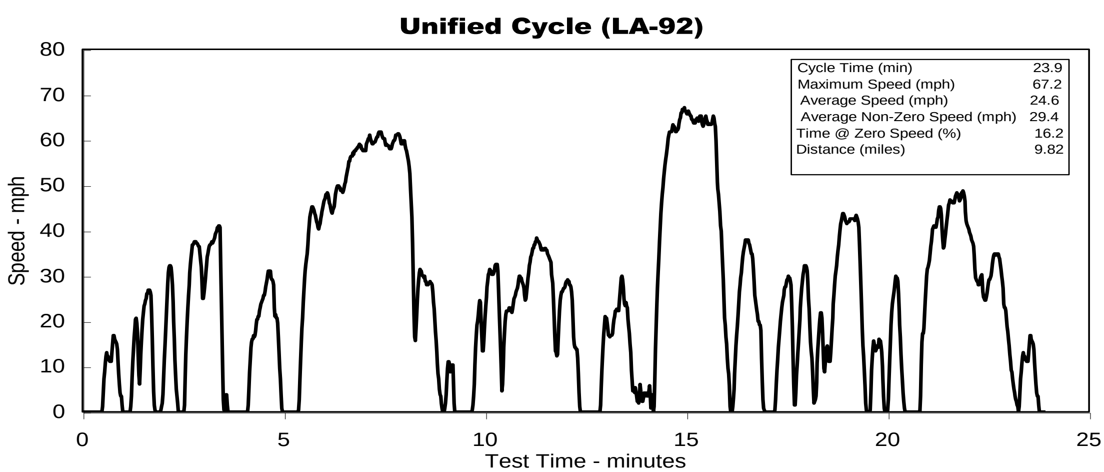

Figure 11 – Running Loss Driving Cycle

The LA-92 cycle takes 24 minutes to complete, and covers 9.8 miles, with many speed changes. Two back-to-back cycles were driven, the first as a "cold start," and the second following a 30-second vehicle idle. The "cold start" condition was created by soaking the vehicle for a minimum of 18 hours at 86°F, moving it to the stabilized 86°F RL-SHED, making the test connections, and then waiting a minimum of one hour before the initial start and run.

The SHED emissions were measured during 48 minutes of engine operation, and then continuously for one hour after the engine was turned off. This one hour, engine-off duration was the "hot soak" period. The total test time is 1 hour and 48 minutes.

Figure 12 shows results from the 9 psi E0 fuel test on Vehicle 204. The horizontal axis is test time in minutes, and the vertical axis is the HC mass measured in the RL-SHED during the test period.

The engine was shut off at the end of the second LA92 drive cycle (~48 minutes), and the analysis system continued to measure the HC emissions in the SHED for the next 60 minutes. This represented the "hot soak" portion of the test.

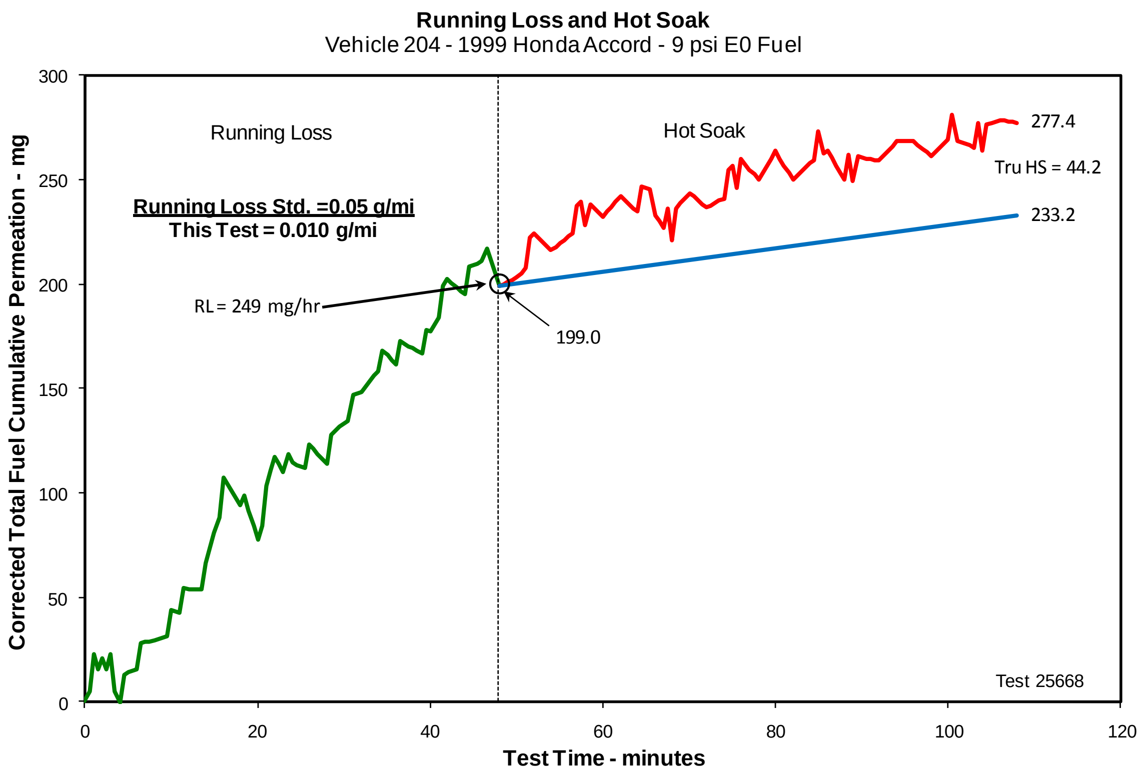

Figure 12 – Running Loss Test Results

The "True" Hot Soak

The traditional hot soak is determined from the increase in SHED emissions as measured for one hour following a prescribed drive to heat up the vehicle (2 LA-92 cycles during the Running Loss Test). Hot soak emissions, however, have two components; that caused by the elevated temperature resulting from the drive, and that resulting from one hour of static permeation.

To separate these two components and determine the "true" hot soak emissions, the following procedure was used. "Traditional" hot soak emissions were first calculated by subtracting the "start of hot soak" cumulative SHED hydrocarbon value (i.e., 199 mg @ t = 48 minutes) from the final cumulative SHED hydrocarbon value (i.e., 277.4 mg @ t = 108 min.). This resulted in a cumulative SHED hydrocarbon value of 78 mg for the 1 hour hot soak. The previously determined static permeation value (i.e., 33.8 mg for a 1 hour hot soak test- see Figure 9) was then subtracted to arrive at the "true" hot soak value of 44.2 mg. The increase in the permeation rate (the "hot soak effect") caused by the increase in the system temperature is accounted for by subtracting the "stabilized permeation rate" at 86°F.

In Figure 12, the static permeation rate is superimposed as a solid blue line on the plot from the starting point of the hot soak until its end (one hour). While the "traditional" hot soak would be calculated as 78 mg (277 mg – 199 mg), the "true" hot soak is determined as 44.2 mg (277.4 mg – 233.2 mg). True hot soak values reported here were determined in this manner.

Diurnal Test

Diurnal permeation was determined by subjecting the vehicle to a three-day period in a temperature controlled SHED while continuously recording the total hydrocarbon every 30 seconds. The SHED environmental temperature was varied from 65°F to 105°F per the California Diurnal Test protocol. Canister vent losses were isolated from permeation emissions using the technique previously described. The vehicle's carbon canister fresh air vent was connected to the outside of the RL-SHED using a leak-tight PTFE® hose connected to a small carbon "trap" canister located on a top-loading precision scale. The scale precision was 0.01 grams (10 milligrams), and it was purged before each test.

DISCUSSION OF TEST RESULTS

Results

Emission results are presented below by "mechanism[11]," with the data averaged for the five "enhanced" and the two "near zero" vehicles. The lone "pre-enhanced" vehicle, the 1996 Ford Taurus (202), was a special case and will be discussed in a separate section. Two of the vehicles, the 2001 Dodge Caravan (207), and the 2004 Toyota Camry (211) were also subjected to limited testing with an "implanted leak" (a 0.020" dia. hole in a special tank gas cap) to investigate the magnitude of a known leak. These results ("Leakers") follow the discussion on the Taurus.

Static Permeation Rate (Constant Temperature (86°F)) - Average permeation rate compared by fuel specification for two vehicle groups; "enhanced" and the "near zero" evaporative emissions.

[11] The "mechanisms" are; 1 Permeation, 2 Tank Venting (Daily Temperature Rise), and 3 Leaks.

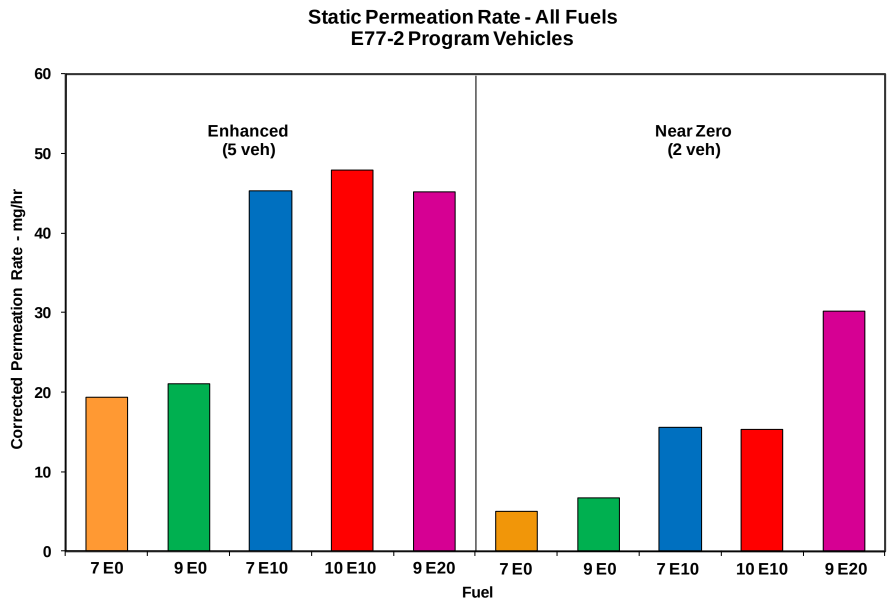

Figure 13 – Static Permeation Rate Comparison

Figure 13 presents the static permeation rate performance for the average of the 5 "enhanced" and 2 "near zero" vehicles on the five fuels included in the test program. Each group is ordered from left to right by ethanol level. The vertical scale is the average permeation rate in mg/hour for the static (86°F constant temperature) test.

Previous studies[12,13] had shown that vehicles operated on the fuel containing 10 vol-% ethanol would have higher permeation rates compared to those resulting from operation on a non-ethanol (E0) fuel of similar properties. We also expected that vehicles using higher vapor pressure fuel would exhibit increased permeation levels at similar ethanol levels. Other studies had reported mixed results when comparing E20 permeation rates against E10 measurements – some were higher and some were lower. The difference may have been within the repeatability of the measurements, and probably suffered from a limited number of observations. These mixed results are present in this testing of the enhanced vehicles however, the E20 (violet bar) is higher on average for static permeation rate for the Near Zero group. The data that were used to construct the averages in Figure 13 are listed in Table 3 below. There is significant variability in the test results, and the limited sample size precludes making conclusive statements with statistical confidence.

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12 CRC E-65.3, Fuel Permeation from Automotive Systems: E0, E6, E10, E20 and E85, December 2006

13 CRC E-77, Vehicle Evaporative Emission Mechanisms: A Pilot Study, June 2008.

Table 3

CRC E-77-2 Program - Static Permeation Results

		Static Permeation Rate - mg/hr				
Vehicle ID	Technology	7psi E0	9 psi E0	7 psi E10	10 psi E10	9 psi E20
204 1999 Honda Accord	Enhanced	12.9	33.8	66.4	84.3	55.3
205 2001 Toyota Corolla	Enhanced	9.9	19.5	59.6	41.6	46.2
207 2001 Dodge Caravan	Enhanced	40.1	32.5	64.4	78.7	88.2
214 2004 Ford Escape	Enhanced	25.2	10.7	23.9	24.4	16.8
215 2004 Toyota Highlander	Enhanced	8.7	8.5	12.2	10.4	19.3
Enhanced Averages		19.4	21.0	45.3	47.9	45.2
211 2004 Toyota Camry XLE	Near Zero	9.1	10.1	9.4	19.9	55.8
212 2006 Ford Taurus	Near Zero	0.9	3.2	21.8	10.6	4.7
Near Zero Averages		5.0	6.7	15.6	15.3	30.3

Summary – Static permeation rate increased with increase in ethanol level. Three of the 5 enhanced emission vehicles did not show an increase in permeation rate when tested with the 9 psi E0 compared to the 7 psi E0.

Dynamic (Running Loss) Permeation - In a similar presentation, Figure 14 shows the average "Running Loss" permeation rate for the vehicle types and the fuels tested. "Running Loss" permeation as described here is the permeation measured during a "cold start" 48 minute drive in a Running-Loss SHED (RL-SHED) at 86°F.

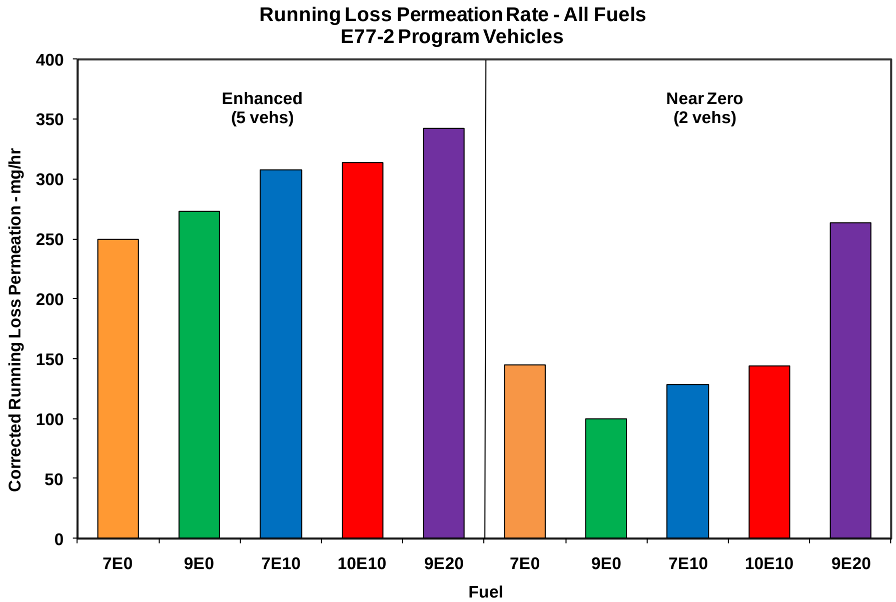

Figure 14 – Running Loss Permeation Comparison

The dynamic permeation rates for the enhanced vehicles (left panel) followed a similar pattern as the static permeation. The average of the E20 fuel was the highest of the average values observed on both the enhanced and the near-zero vehicles (left and right panels, respectively). Table 4 below shows the data used to generate the averages used in Figure 14.

Table 4

CRC E-77-2 Program - Running Loss Permeation Results

		Running Loss Permeation Rate - mg/hr				
Vehicle ID	Technology	7psi E0	9 psi E0	7 psi E10	10 psi E10	9 psi E20
204 1999 Honda Accord	Enhanced	222.6	249.2	287.9	316.4	272.0
205 2001 Toyota Corolla	Enhanced	67.1	103.1	232.8	191.6	169.7
207 2001 Dodge Caravan	Enhanced	842.5	833.9	812.2	858.1	1028.2
214 2004 Ford Escape	Enhanced	36.3	96.7	105.7	133.1	139.4
215 2005 Toyota Highlander	Enhanced	79.7	81.1	97.9	71.9	102.5
Enhanced Averages		249.6	272.8	307.3	314.2	342.4
211 2004 Toyota Camry XLE	Near Zero	104.6	83.7	56.3	138.3	410.6
212 2006 Ford Taurus	Near Zero	184.5	115.8	201.2	148.9	116.8
Near Zero Averages		144.6	99.8	128.8	143.6	263.7

Summary – The dynamic permeation rate (measured during vehicle operation) was higher with the E10 fuel compared to E0 for the enhanced vehicles. The E20 permeation rate was higher than E0 and the E10 fuel. The small sample size and limited data precludes us from making statements about statistical confidence, but this may indicate a trend. The near zero vehicle average increased as the ethanol level increased. Trends with volatility were mixed, or inconclusive.

Hot Soak ("True Hot Soak") Permeation – The Hot Soak emissions as defined in this report are the net increase in permeation rate following vehicle operation. We measured the mass increase in the SHED for one hour immediately following vehicle operation, and subtracted the previously measured static (or normal) permeation at the same temperature. While this is not the traditional Code of Federal Regulations (CFR) definition, we feel it is appropriate for the intent of this project.

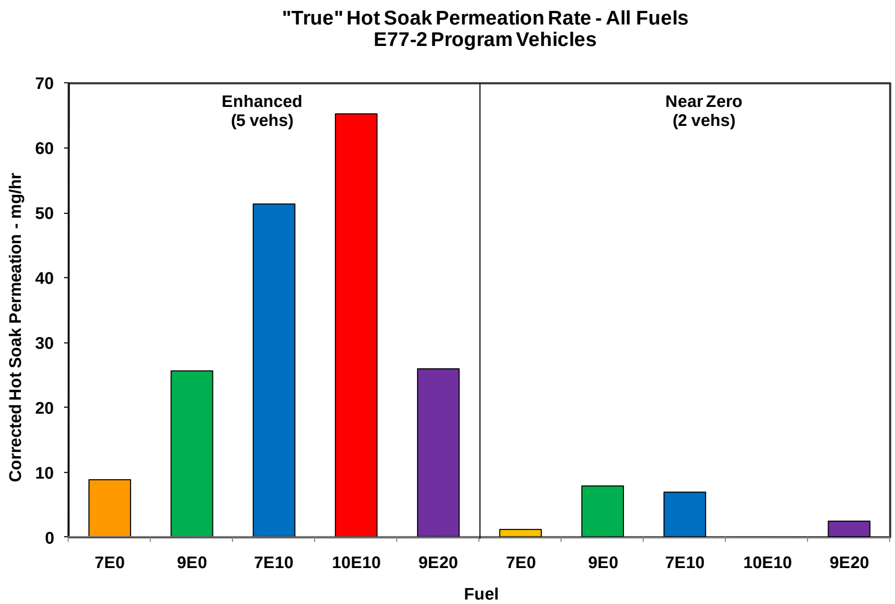

Figure 15 – True Hot Soak Permeation Comparison

The "True Hot Soak" performance for the average of the Enhanced Vehicles is summarized in Figure 15 above. There was a large increase in the hot soak value with the E10 fuel compared to the E0. The hot soak value with the E20 fuel was comparable to the E0 results, and lower than the E10.

The Near Zero vehicles (2) had zero hot soak emissions when tested on the 10 psi E10 fuel (Figure 16). With only two vehicles and the very low levels attained, no statistically significant conclusions can be drawn from the data available. Table 5 presents the individual tests used in calculating the average values plotted in Figure 15.

Table 5

CRC E-77-2 Program - True Hot Soak Permeation Results

		True Hot Soak Permeation Rate - mg/hr				
Vehicle ID	Technology	7psi E0	9 psi E0	7 psi E10	10 psi E10	9 psi E20
204 1999 Honda Accord	Enhanced	18.7	44.3	29.7	0.4	13.4
205 2001 Toyota Corolla	Enhanced	0.0	1.0	71.9	29.5	60.3
207 2001 Dodge Caravan	Enhanced	0.0	5.8	122.2	237.7	0.0
214 2004 Ford Escape	Enhanced	3.3	52.1	32.9	57.4	56.0
215 2005 Toyota Highlander	Enhanced	22.5	25.1	0.0	1.6	0.0
Enhanced Averages		8.9	25.7	51.3	65.3	25.9
211 2004 Toyota Camry XLE	Near Zero	0.7	15.3	13.8	0.0	0.0
212 2006 Ford Taurus	Near Zero	1.8	0.4	0.0	0.0	4.9
Near Zero Averages		1.3	7.9	6.9	0.0	2.5

Summary - The True Hot Soak permeation (permeation rate measured following vehicle operation less the static constant temperature permeation rate) rate was higher with the E10 fuel compared to E0 for the enhanced vehicles. The E20 permeation rate was higher than E0 and lower than the E10 fuel. The near zero vehicle trends with both ethanol content and volatility were mixed, or inconclusive. The small sample size and limited data precludes us from making statements about statistical confidence.

Diurnal Permeation Performance – Figure 16 presents the diurnal permeation results for the first day of the three-day diurnal test (65° to 105°F).

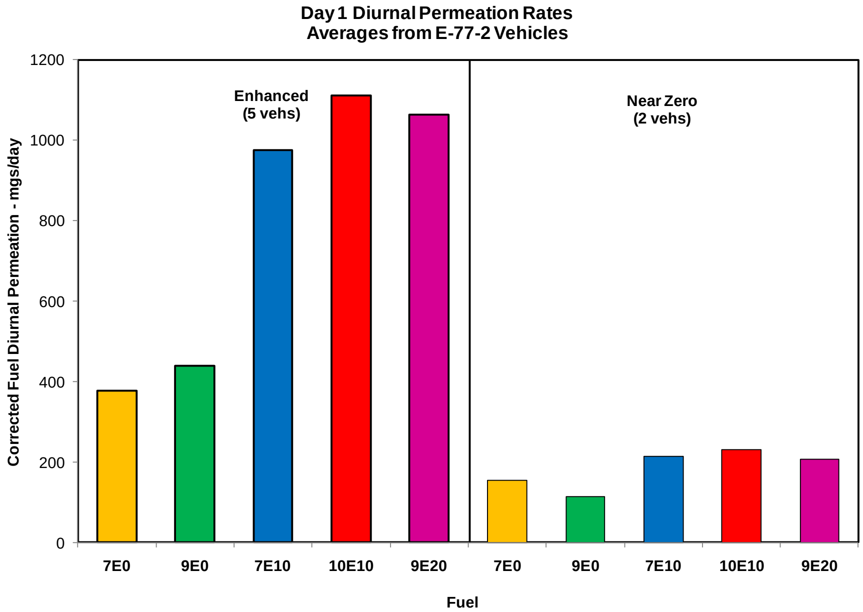

Figure 16 – Day 1 Diurnal Permeation Comparison

The average day 1 diurnal permeation for the five Enhanced Vehicles tended to increase as ethanol content increased (with the exception of the E20 fuel). Again, sample size and limited data makes statistical conclusions inappropriate. Table 6 presents the individual test used to generate the averages used in Figure 16. The table includes the data from days 2 and 3. The ethanol content of the diurnal measurements was calculated, and appear in a series of figures in the Appendix starting at page 37. Unlike Figure 16, the figures shown in the appendix have not been corrected to exclude the non-fuel emissions (methanol and refrigerant) that were present during these tests.

Table 6

CRC E-77-2 Program Results - Diurnal Permeation

Vehicle ID	Technology		Diurnal Permeation Rate - mg/day 7psi E0	9 psi E0	7 psi E10	10 psi E10	9 psi E20
204		Day 1	367.2	628.3	1260.1	1547.9	1103.4
1999 Honda	Enhanced	Day 2	287.7	581.0	1165.2	1779.9	958.1
Accord		Day 3	293.6	577.0	1165.3	1771.1	981.2
205		Day 1	383.0	499.5	1783.4	1794.1	1775.2
2001 Toyota	Enhanced	Day 2	365.4	481.0	1715.0	1730.9	1690.0
Corolla		Day 3	367.0	507.2	1523.9	1741.7	1680.2
207		Day 1	397.5	406.4	1086.5	1406.4	1548.0
2001 Dodge	Enhanced	Day 2	302.6	337.3	812.0	1264.4	1370.2
Caravan		Day 3	268.9	308.0	823.6	1223.7	1360.5
214		Day 1	494.3	455.9	524.2	492.0	470.9
2004 Ford	Enhanced	Day 2	319.0	358.5	397.4	839.4	440.0
Escape		Day 3	281.5	1101.7	394.4	11373.8	751.8
215		Day 1	248.3	202.1	224.7	319.2	416.8
2004 Toyota	Enhanced	Day 2	294.1	165.9	231.7	260.2	414.8
Highlander		Day 3	288.8	176.3	267.5	237.0	450.6
Enhanced Averages			378.1	438.4	975.8	1111.9	1062.9
211		Day 1	207.1	130.3	243.8	337.0	284.0
2004 Toyota	Near Zero	Day 2	100.2	115.8	183.8	226.8	221.8
Camry XLE		Day 3	87.4	100.6	184.3	217.9	203.4
212		Day 1	101.6	100.5	184.8	124.3	131.0
2006 Ford	Near Zero	Day 2	71.2	70.8	100.2	87.9	83.3
Taurus		Day 3	57.0	57.4	75.8	102.8	75.0
Near Zero Averages			154.4	115.4	214.3	230.7	207.5

Carbon Canister Breakthrough – Canister breakthrough is measured by the weight change recorded for the trap canister outside the SHED. It quantifies the amount of vapors that overwhelm the evaporative system storage canister. Figure 17 displays the breakthrough resulting from testing of 9 psi E0 fuel. Only four of seven vehicles exhibited breakthrough.

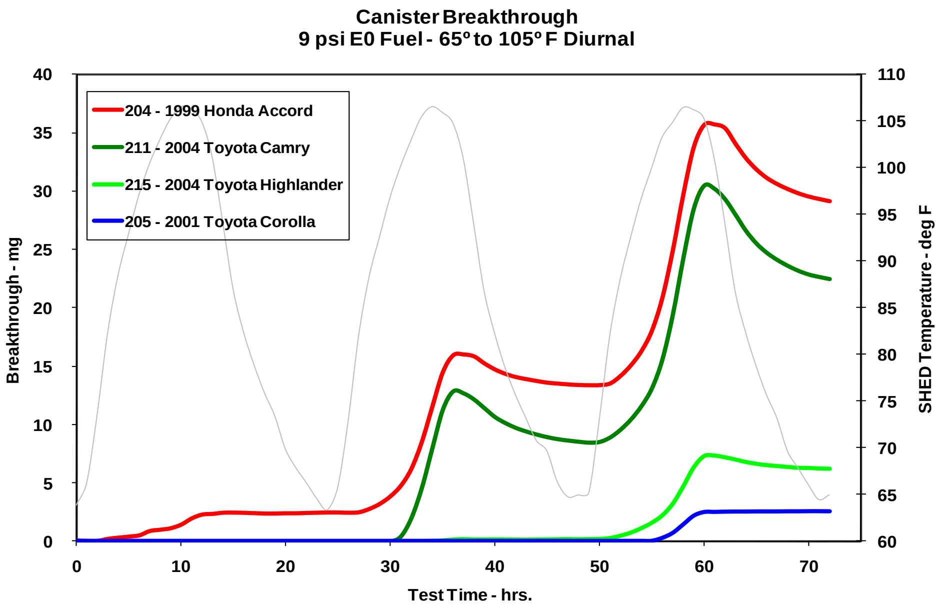

Figure 17 –Diurnal Canister Breakthrough

Table 7 shows the breakthrough generated during the diurnal tests conducted.

Table 7
CRC E-77-2 Program - Carbon Canister Diurnal Breakthrough Results

			Diurnal Breakthrough - grams				
Vehicle ID	Technology		7psi E0	9 psi E0	7 psi E10	10 psi E10	9 psi E20
204		Day 1	---	2.4	---	31.0	---
1999 Honda	Enhanced	Day 2	---	13.6	---	36.0	---
Accord		Day 3	---	19.8	---	36.0	---
205		Day 1	---	---	---	20.4	---
2001 Toyota	Enhanced	Day 2	---	---	---	30.9	---
Corolla		Day 3	---	2.6	---	29.3	---
207		Day 1	---	---	---	---	---
2001 Dodge	Enhanced	Day 2	---	---	---	---	---
Caravan		Day 3	---	---	---	---	---
214		Day 1	---	---	---	---	---
2004 Ford	Enhanced	Day 2	---	---	---	---	---
Escape		Day 3	---	---	---	4.9	---
215		Day 1	---	---	---	---	---
2004 Toyota	Enhanced	Day 2	---	0.2	---	---	---
Highlander		Day 3	---	7.2	---	---	---
211		Day 1	---	---	---	---	---
2004 Toyota	Near Zero	Day 2	---	12.9	---	19.1	---
Camry XLE		Day 3	---	17.6	---	28.9	---
212		Day 1	---	---	---	---	---
2006 Ford	Near Zero	Day 2	---	---	---	---	---
Taurus		Day 3	---	---	---	20.4	---

Summary – The lack of canister breakthrough for the 7 psi fuels (summer grade) indicates that the storage capacity of the seven systems tested is appropriately sized. Breakthrough began to appear when testing of 9 psi E0 fuel (not summer grade), and was more prevalent with the 10 psi E10 fuel (winter grade). The lack of breakthrough with the 9 psi E20 fuel seems to be an anomaly.

Overall Trend Summary - The following chart (Figure 18) visually summarizes the trends seen from all testing performed during this program.

Trend Analysis for E-77-2 Program

Enhanced Vehicles (Sample of 5)

		Ethanol Content		
	Higher Volatility	E0 to E10	E0 to E20	E10 to E20
Static Permeation	↑	↑	↑	↑
Running Loss Permeation	↑	↑	↑	↑
True Hot Soak (TEFVO)	↑	↑	↑	↑
Diurnal	↑	↑	↑	↑

Near-Zero Vehicles (Sample of 2)

		Ethanol Content		
	Higher Volatility	E0 to E10	E0 to E20	E10 to E20
Static Permeation	↑↔	↑	↑	↑
Running Loss Permeation	↑	↑	↑	↑
True Hot Soak (TEFVO)	↑	↕	↓	↓
Diurnal	↑	↑	↑	↔

Figure 18 Trend Analysis Summaries

Vehicle 202 – 1996 Ford Taurus - Special Case

We have treated vehicle 202 as a special case. This was the oldest of the vehicles tested, and had been subjected to limited exhaust emission tests with a 20-volume percent ethanol fuel (E20) during the CRC E-74b test program.

Vehicle 202 completed the E10 portion of the test program (10 and 7 psi fuels) successfully, and completed the road preconditioning on the E0 fuel prior to the E0 evaluations. The first test on the E0 fuel was excessively high, indicating a fuel leak. It was traced to a leaky fuel injector o-ring, and there was considerable discussion as to an appropriate repair. Tests were made on the 9 and the 7 psi E0 fuel to measure the magnitude of a vehicle in a “leak” condition, and the tests were labeled as “202L (Leak).” The fuel injector o-rings were replaced as a complete set, and the vehicle resumed testing as “202R’ (Repaired). A new, elusive vapor leak was present, later identified as a very small leak at the top of the fuel fill pipe.

The circle on Figure 19 at the right shows the location of the small leak. This leak was problematic as to its effect on the emission measurements because its magnitude or presence seemed to depend on the torque exerted on the fuel cap. The tests on the E0 fuels (9 and 7 psi) are noted as 202R, but with a vapor leak.

We attempted to fix this leak, and repeated the E10 test with the vehicle re-identified as 216 with reasonable results. We also ran the E20 test sequence and declared the vehicle done.

Figure 19 – Vehicle 202 Fuel Fill Pipe Leak

The testing history for this vehicle is shown in Tables 8 (Static), 9 (Dynamic), and 10 (Diurnal). The tests highlighted in yellow are those that exhibited a liquid or vapor leak as identified during the static test leak validation.

Table 8

Static Permeation Results

1996 Ford Taurus

Veh	Fuel psi/EtOH	Test	Type	Date	Test#	Corrected Permeation mg/hr	SHED Results mg/day 'Corrected	Canister Loss g	
202	10.0/E10	Static	Perm	07/18/07	7018	34.5		0.00	
			Press. Incr.			0.0			No Leak
			Prs+Fuel Incr.			0.0			
202	7.0/E10	Static	Perm	08/21/07	7031	22.3		0.00	
			Press. Incr.			0.0			No Leak
			Prs+Fuel Incr.			0.0			
202L	9.0/E0	Static	Perm	03/04/08	7169	229.2		0.00	
			Press. Incr.			DNA			
			Prs+Fuel Incr.			492.1			Liquid Leak
202L	7.0/E0	Static	Perm	03/20/08	7183	299.1		0.00	
			Press. Incr.			DNA			
			Prs+Fuel Incr.			1989.6			Liquid Leak
202R	9.0/E0	Static	Perm	05/08/08	7228	17.8		0.00	
			Press. Incr.			13.6			Vapor Leak
			Prs+Fuel Incr.			0.0			
202R	7.0/E0	Static	Perm	05/22/08	7239	20.4		0.00	
			Press. Incr.			38.0			Vapor Leak
			Prs+Fuel Incr.			0.0			
216	10.0/E10	Static	Perm	08/14/08	7299	32.4		0.00	
			Press. Incr.			0.0			No Leak
			Prs+Fuel Incr.			0.0			
216	7.0/E10	Static	Perm	09/17/08	7326	32.5		0.00	
			Press. Incr.			0.0			No Leak
			Prs+Fuel Incr.			0.0			
216	9.0/E20	Static	Perm	10/30/08	7363	20.4		0.00	
			Press. Incr.			0.0			No Leak
			Prs+Fuel Incr.			0.0			

Table 9

Dynamic Permeation Results

1996 Ford Taurus

Veh	Fuel psi/EtOH	Test	Type	Date	Test#	Corrected Permeation mg/hr	SHED Results mg/day (Corrected)	Canister Loss g	From Static Test
202	10.0/E10	Dynamic	RL	07/20/07	25662	127.8		0.00	No Leak
			TEFVO			38.6		0.00	
202L	9.0/E0	Dynamic	RL	03/05/08	25695	387.0		0.00	Liquid Leak
			TEFVO			0.0		0.00	
202L	7.0/E0	Dynamic	RL	03/24/08	25699	726.9		0.00	Liquid Leak
			TEFVO			0.0		0.00	
202R	9.0/E0	Dynamic	RL	05/09/08	25704	109.1		0.00	Vapor Leak
			TEFVO			5.0		0.00	
202R	7.0/E0	Dynamic	RL	05/23/08	25706	78.7		0.00	Vapor Leak
			TEFVO			0.0		0.00	
216	10.0/E10	Dynamic	RL	08/15/08	25718	174.2		0.00	No Leak
			TEFVO			1.4		0.00	
216	7.0/E10	Dynamic	RL	09/18/08	25721	168.3		0.00	No Leak
			TEFVO			42.3		0.00	
216	9.0/E20	Dynamic	RL	11/07/08	25730	54.3		0.00	No Leak
			TEFVO			0.0		0.00	

Table 10

Diurnal Permeation Results

1996 Ford Taurus

Veh	Fuel psi/EtOH	Test	Type	Date	Test#	Corrected Permeation mg/hr	SHED Results mg/day (Corrected)	Canister Loss g	From Static Test
202	10.0/E10	72 DHB	65-105	07/31/07	7023				
		Day 1					1042.9	6.12	No Leak
		Day 2					706.9	32.64	
		Day 3					704.3	38.69	
202	7.0/E10	72 DHB	65-105	08/28/07	7034				
		Day 1					627.8	0.00	No Leak
		Day 2					506.5	0.00	
		Day 3					453.5	0.00	
202L	9.0/E0	72 DHB	65-105	03/11/08	7173				
		Day 1					2258.9	0.00	Liquid Leak
		Day 2					3231.0	0.00	
		Day 3					2306.9	12.60	
202L	7.0/E0	72 DHB	65-105	04/01/08	7196				
		Day 1					4742.5	0.00	Liquid Leak
		Day 2					4451.7	0.00	
		Day 3					3179.8	0.00	
202R	9.0/E0	72 DHB	65-105	05/13/08	7230				
		Day 1					327.0	0.00	Vapor Leak
		Day 2					266.7	0.00	
		Day 3					274.6	10.83	
202R	7.0/E0	72 DHB	65-105	05/28/08	7243				
		Day 1					211.7	0.00	Vapor Leak
		Day 2					220.8	0.00	
		Day 3					208.1	0.00	
216	10.0/E10	72 DHB	65-105	08/20/08	7305				
		Day 1					2590.7	57.77	No Leak
		Day 2					3477.9	62.99	
		Day 3					3601.4	63.43	
216	7.0/E10	72 DHB	65-105	09/23/08	7331				
		Day 1					397.5	0.22	No Leak
		Day 2					355.0	0.06	
		Day 3					362.1	0.37	
216	9.0/E20	72 DHB	65-105	11/11/08	7373				
		Day 1					468.5	0.00	No Leak
		Day 2					452.6	0.00	
		Day 3					419.8	0.00	

The Implanted Leak Test Results

Project E-77-2 included evaluating two vehicles with implanted leaks. This interest followed the information gathered in the Pilot Study where tests were run with a specially modified fuel cap containing a 0.02" dia. hole. The results with the implanted leak from the Pilot Study are repeated in Table 11 below as the diurnal results are shown for a 1996 Chevrolet Cavalier; first without the implanted leak at 0.38 grams per day, and then at 20.7 grams per day (a 54x increase) with the leak.

Table 11

Implanted Leak Impact on Diurnal Permeation					
Day One Results : 65° - 105°F Diurnal					
Veh. No.	Vehicle Description	Evap Tech	Fuel	Results gms/day	gms Increase
6	1996 Chevrolet Cavalier	Enhanced	7 psi E0	0.38	
7*	"	"	"	20.70	20.32
207	2001 Dodge Caravan	Enhanced	7 psi E10	1.09	
207L*	"	"	"	2.13	1.04
211	2004 Toyota Camry LE	Near Zero	7 psi E10	0.24	
211L*	"	"	"	0.68	0.44
* - Implanted .020" leak in fuel cap					

The two E-77-2 vehicles (207 & 211) were given a limited evaluation with an induced leak and saw a significantly lesser impact. Vehicle 207 gave diurnal results increases from 1.09 to 2.13 grams per day (a 2x increase), and Vehicle 211 increased from 0.24 grams per day to 0.68 grams per day (a 2.8x increase). The following Figure 20 displays the imbedded leak impact from Table 11.

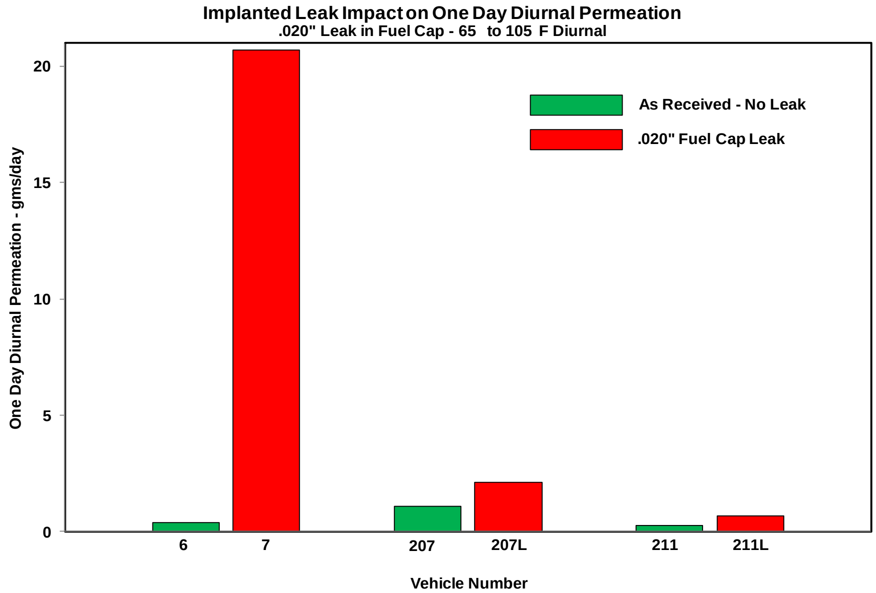

Figure 20 – Implanted Leak Impact

The newer vehicles evaluated in this phase of the study were configured and certified to the Onboard Refueling Vapor Regulations (ORVR). These are capable of containing 95% or more control of the refueling vapors at up to 10 gallons per minute fueling rate. Where the Chevrolet Cavalier had a small (0.055" dia.) orifice and a long vapor tube venting the tank's vapor space to the carbon canister (and then to the atmosphere), the ORVR compliant vehicles have a large (0.688" ID), short vent hose to a low flow restriction carbon canister.

The following bar charts (Figures 21 through 24) show the impacts of the leak on all phases of the evaporative testing performed, and compare those results with all fuels tested. With only two vehicles (207 and 211) evaluated on two fuels, statistically significant effects cannot be quantified, but the trend of increased emissions is apparent.

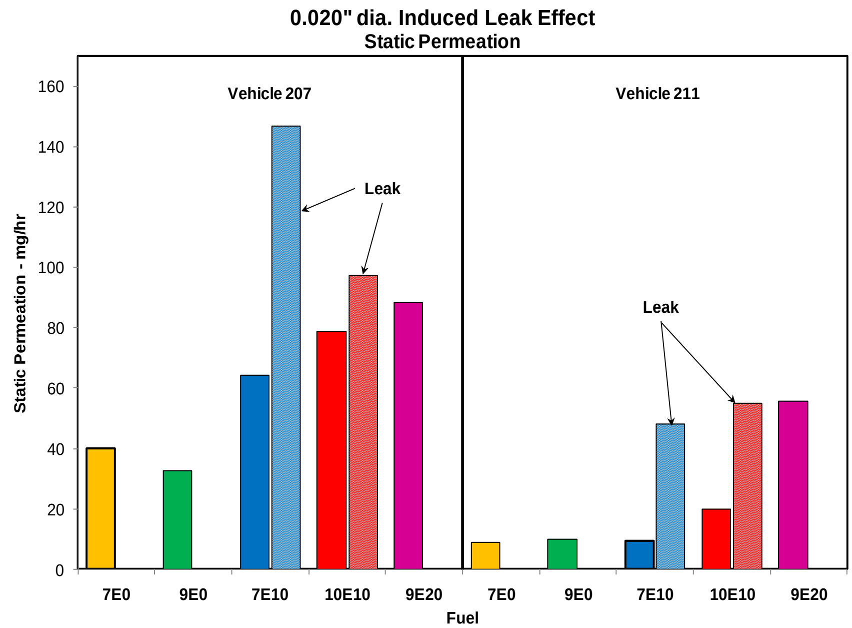

Figure 21 – Vehicles 207 and 211 with Induced Leak - Static

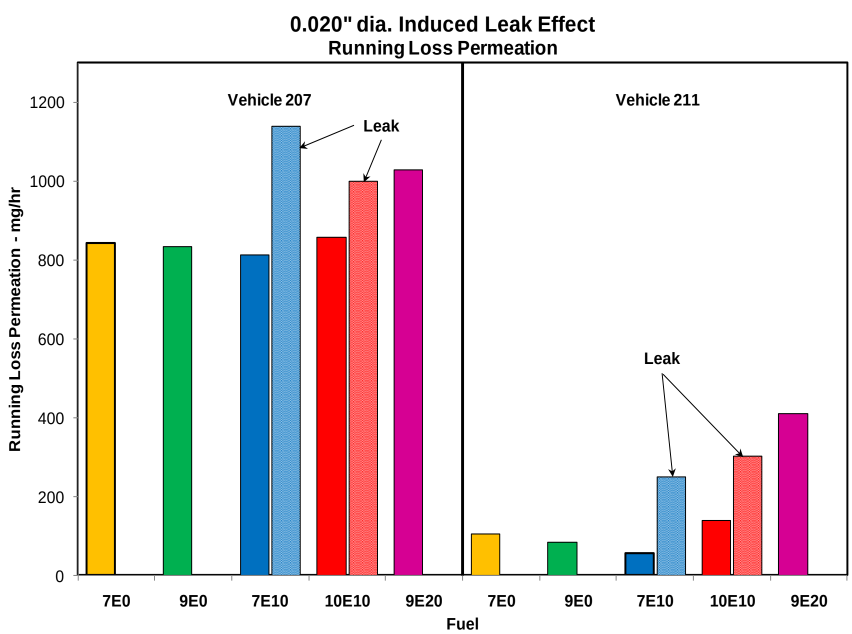

Figure 22 – Vehicles 207 and 211with Induced Leak – Running Loss

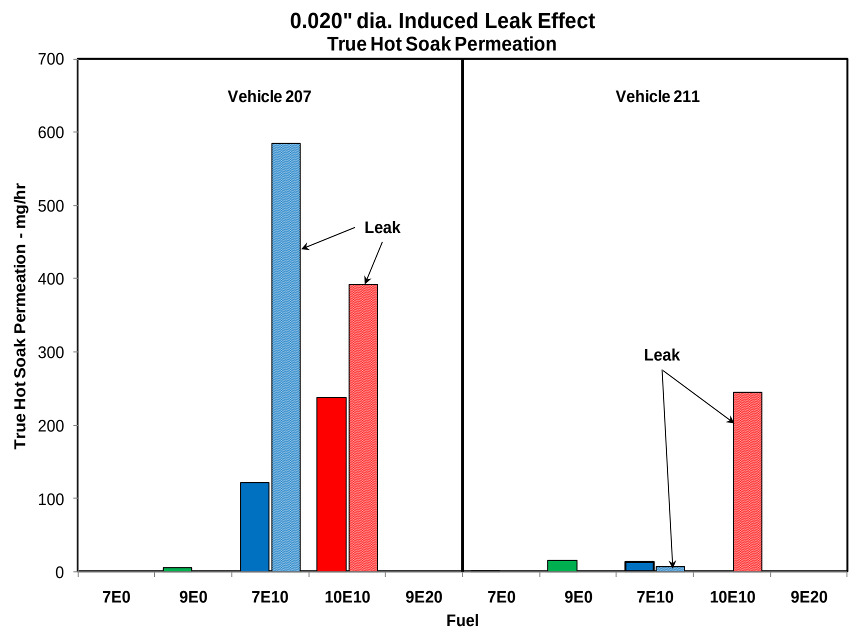

Figure 23 – Vehicles 207 and 211 with Induced Leak – True Hot Soak

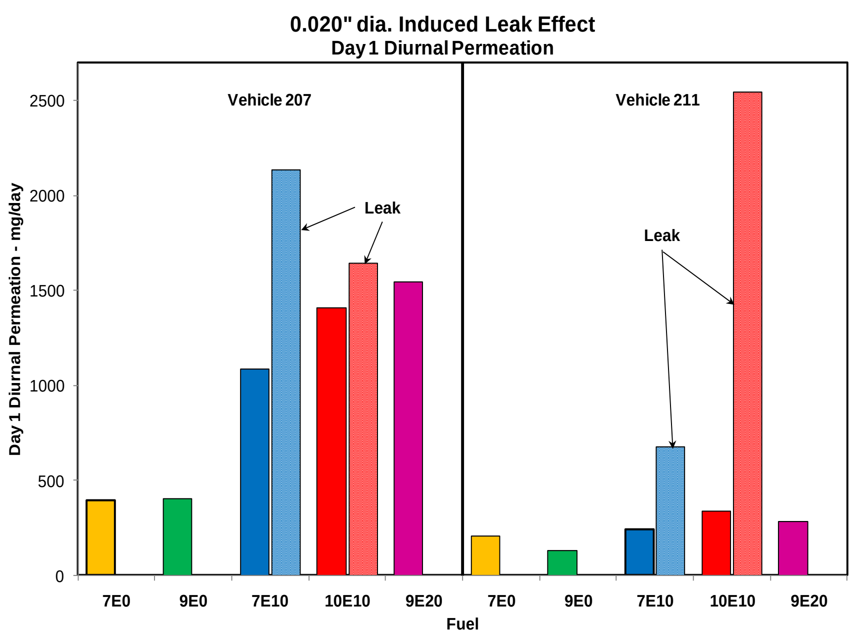

Figure 24 – Vehicles 207 and 211 with Induced Leak - Diurnal

Summary of Findings and Results

The E-77-2 test program was a continuation of the previously published E-77 test project, and added eight vehicles tested on five fuels to the knowledge base. The permeation trends previously shown were again present. The small sample size and limited number of tests preclude making statements about statistical validity, but in general:

- The newer vehicle groups had lower emissions.
- Adding ethanol to the fuel increased permeation over the non-oxygenated levels.
- Increased volatility increased permeation levels.
- SHED emission rates must be corrected for the ethanol error in the FID, and the non-fuel methanol and refrigerant in the measurement.

As this test program evolved and additional experience was gathered, two program modifications were made: 1) The leak validation methodology was changed, and 2) a different metric and definition of the "Hot Soak" was adopted.

The leak validation portion of the static permeation test was found to be very sensitive, and when the data was corrected on a minute-by-minute basis for ethanol, methanol, and refrigerant, the change in apparent permeation rate was due as much to variation as to leaks. See the discussion starting at page 12 for the details of the development.

Concern for and recognition of "Hot Soak" emissions started in the original evaporative emission regulations. Carburetors had float bowls with ~ 50 ml of fuel that absorbed the latent engine heat after the vehicle was shut down after operation. The heat would cause the bowl temperature to increase, driving fuel vapors out through vents and leak paths to the atmosphere after vehicle operation. Today's fuel injection engines do not have the open bowls, and the emission rates following vehicle operation are mainly increased temperature permeation. We recommended and adopted a new name for the "temporary emissions following vehicle operation" (TEFVO), which subtracts the basic permeation rate from the measured emissions. See the discussion starting at page 16 for details.

Appendix

Acknowledgements

E-77-2 Steering Committee

David Brzezinski..................EPA
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Dominic DiCicco ....Ford Motor Company
King D. Eng ....Shell Global Solutions
Ben Hancock.........................CARB
Constance Hart.....................EPA
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Marie Valentine ....Toyota Technical Center
Kenneth J. Wright ....ConocoPhillips

CRC Members

Brent Bailey ....CRC
Chris Tennant.......................CRC
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Table 12

CRC E-77-2 Fuel Inspection Results

Data from CRC E-74

Inspection	Units	**E0** Fuel 6	**E10** Fuel 7	**E20** Fuel 4
API Gravity	°API	60.2	58.5	57.0
Relative Density	60/60°F	0.7382	0.7447	0.7508
DVPE	psi	7.01	7.30	8.49
Oxygenates--D4815				
MTBE	vol %	0.00	0.00	0.00
ETBE	vol %	0.00	0.00	0.00
EtOH	vol %	0.00	9.54	20.34
O2	wt %	0.00	3.53	7.47
Hydrocarbon Composition				
Aromatics	vol %	22.1	24.4	10.8
Olefins	vol %	8.0	8.8	5.5
Saturates	vol %	70.0	57.3	23.4
D86 Distillation				
IBP	°F	97.4	104.0	102.2
5% Evaporated	°F	131.6	128.0	125.2
10% Evaporated	°F	142.3	133.0	131.4
20% Evaporated	°F	156.4	141.0	141.3
30% Evaporated	°F	170.4	145.0	148.6
40% Evaporated	°F	184.0	153.0	154.7
50% Evaporated	°F	197.5	195.0	159.6
60% Evaporated	°F	212.0	219.0	163.6
70% Evaporated	°F	230.5	241.0	227.4
80% Evaporated	°F	258.8	271.0	269.5
90% Evaporated	°F	313.9	317.0	313.9
95% Evaporated	°F	332.2	330.0	325.5
EP	°F	360.3	360.0	340.6
Recovery	vol %	97.8	97.8	98.3
Residue	vol %	1.3	1.0	1.0
Loss	vol %	0.9	1.2	0.7
Driveability Index		1119.9	1101.5	989.8

Table 12 (cont.)

Suppliers Additional Inspections

Fuel	Units	Fuel 6	Fuel 7	Fuel 4
Sulfur Content	ppm	29	27	27
Estimated C/H Ratio		6.2090	6.3323	6.3252
Est. Net Heat of Combustion	btu/lb	18573	18514	18513
Benzene	vol %	0.90	1.00	0.96
Research Octane Number		93.2	94.0	94.6
Motor Octane Number		83.8	83.8	83.4
(R+M)/2		88.5	88.9	89.0

Detailed Hydrocarbon Analysis

Fuel	Units	Fuel 6	Fuel 7	Fuel 4
Aromatics	vol %	23.86	24.81	21.78
Olefins	vol %	7.52	8.92	10.74
Saturates	vol %	67.43	56.21	46.23
Unclassified	vol %	1.15	0.86	0.15
Ethanol	vol %	0.00	9.20	21.11
Benzene	vol %	0.89	1.06	0.97
C/H Ratio		6.200	6.092	5.835
Oxygen	wt. %	0.008 [1]	3.40	7.73
Net Heat of Combustion	btu/lb	18,703	18,016	17,160

[1] Contains 0.04 vol % MTBE

Carbon, Hydrogen, and Oxygen

Fuel	Units	Fuel 6	Fuel 7	Fuel 4
Oxygen	wt. %	0.008	3.396	7.733
C+H	wt. %	99.99	96.60	92.27
H	wt. %	13.89	13.62	13.50
C	wt. %	86.10	82.98	78.77

Net Heat of Combusion -- Btu/lb

Fuel	Units	6	7	4
Haltermann D3338	Btu/lb	18,573	18,514	18,513
Average D3338	Btu/lb	18,579	18,514	18,491
Oxygen Corrected D3338	Btu/lb	18,579	17,860	17,103
DHA	Btu/lb	18,703	18,016	17,160

Table 13

CRC E-77-2 Program Test Results

Vehicle No.	Fuel	Static Permeation - mg/hr Base	+ Press	+ Pump	Dynamic Perm. - mg/hr RL	"True" HS	Diurnal (65º to 105º) - mg/day Day 1 Perm (Brkthru)	Day 2 Perm (Brkthru)	Day 3 Perm (Brkthru)
202	E10 - 10 psi	34.5	---	---	127.8	50.3	1042.9 (6.3)	706.9 (34.8)	704.3 (42.5)
1996	E10 - 7 psi	22.3	---	---	99.4	11.3	627.8 (0.0)	506.5 (0.0)	453.5 (0.0)
Taurus									
202L	E0 - 9 psi	222.9	---	492.1	387.0	0.0	2258.0 (0.0)	3231.0 (0.0)	2306.9 (12.6)
	E0 - 7 psi	299.1	---	1989.6	726.9	0.0	4742.5 (0.0)	4451.7 (0.0)	3179.8 (0.0)
204	E10 - 10 psi	84.3	---	---	316.4	0.4	1547.9 (31.0)	1779.9 (38.3)	1771.1 (41.9)
1999	E10 - 7 psi	66.4	---	---	287.9	29.7	1260.1 (0.0)	1165.2 (0.0)	1165.3 (0.0)
Honda	E0 - 9 psi	33.8	---	---	249.2	44.3	628.3 (2.4)	581.0 (13.6)	577.0 (22.5)
Accord	E0 - 7 psi	12.9	---	---	222.6	18.7	367.2 (0.0)	287.7 (0.0)	293.6 (0.0)
	E20 - 9 psi	55.3	---	---	272.0	13.4	1103.4 (0.0)	958.1 (0.0)	981.2 (0.0)
205	E10 - 10 psi	41.6	---	---	191.6	29.5	1794.1 (20.4)	1730.9 (34.6)	1741.7 (37.5)
2001	E10 - 7 psi	59.6	---	---	232.8	71.9	1783.4 (0.0)	1715.0 (0.0)	1523.9 (0.0)
Toyota	E0 - 9 psi	19.5	---	---	103.1	1.0	499.5 (0.0)	481.0 (0.0)	507.2 (2.6)
Corolla	E0 - 7 psi	9.9	---	---	67.1	0.0	383.0 (0.0)	365.4 (0.0)	367.0 (0.0)
	E20 - 9 psi	46.2	---	---	169.7	60.3	1775.2 (0.0)	1690.0 (0.0)	1680.2 (0.0)
207	E10 - 10 psi	78.7	---	---	858.1	237.7	1406.4 (0.0)	1264.4 (0.0)	1223.7 (0.0)
2001	E10 - 7 psi	64.4	---	---	812.2	122.2	1086.5 (0.0)	812.0 (0.0)	823.6 (0.0)
Dodge	E0 - 9 psi	32.5	---	---	833.9	5.8	406.4 (0.0)	337.3 (0.0)	308.0 (0.0)
Caravan	E0 - 7 psi	40.1	---	---	842.5	0.0	397.5 (0.0)	302.6 (0.0)	268.9 (0.0)
	E20 - 9 psi	88.2	---	---	1028.2	0.0	1548.0 (0.0)	1370.2 (0.0)	1360.5 (0.0)
207L	E10 - 10 psi	97.6	---	120.9	1001.2	392.9	1644.9 (0.0)	NA	NA
	E10 - 7 psi	146.8	---	---	1139.3	585.0	2134.2 (0.0)	NA	NA
211	E10 - 10 psi	19.9	---	---	138.3	0.0	337.0 (0.0)	226.8 (19.1)	217.9 (33.0)
2004	E10 - 7 psi	9.4	26.6	---	56.3	13.8	243.8 (0.0)	183.8 (0.0)	184.3 (0.0)
Toyota	E0 - 9 psi	10.1	---	---	83.7	15.3	130.3 (0.0)	115.8 (12.9)	100.6 (22.1)
Camry	E0 - 7 psi	9.1	---	---	104.6	0.7	207.1 (0.0)	100.2 (0.0)	87.4 (0.0)
XLE	E20 - 9 psi	55.8	---	---	410.6	0.0	284.0 (0.0)	221.8 (0.0)	203.4 (0.0)
211L	E10 - 10 psi	55.1	---	82.1	302.4	245.0	2545.4 (0.40)	NA	NA
	E10 - 7 psi	48.1	---	166.4	251.1	6.2	678.3 (0.0)	NA	NA
212	E10 - 10 psi	10.6	---	---	148.9	0.0	124.3 (0.0)	87.9 (0.0)	102.8 (20.0)
2006	E10 - 7 psi	21.8	---	---	201.2	0.0	184.8 (0.0)	100.2 (0.0)	75.8 (0.0)
Ford	E0 - 9 psi	3.2	---	---	115.8	0.4	100.5 (0.0)	70.8 (0.0)	57.4 (0.0)
Taurus	E0 - 7 psi	0.9	---	---	184.5	1.8	101.6 (0.0)	71.2 (0.0)	57.0 (0.0)
	E20 - 9 psi	4.7	---	---	116.8	4.9	131.0 (0.0)	83.3 (0.0)	75.0 (0.0)
214	E10 - 10 psi	24.4	---	---	133.1	57.4	492.0 (0.0)	839.4 (0.0)	11373.8 (4.9)
2004	E10 - 7 psi	23.9	---	---	105.7	32.9	524.2 (0.0)	397.4 (0.0)	394.4 (0.0)
Ford	E0 - 9 psi	10.7	---	---	96.7	52.1	455.9 (0.0)	358.5 (0.0)	1101.7 (0.0)
Escape	E0 - 7 psi	25.2	---	---	36.3	3.3	494.3 (0.0)	319.0 (0.0)	281.5 (0.0)
	E20 - 9 psi	16.8	---	---	139.4	56.0	470.9 (0.0)	440.0 (0.0)	751.8 (0.0)
215	E10 - 10 psi	10.4	9.0	---	71.9	1.6	319.2 (0.0)	260.2 (0.0)	237.0 (0.0)
2004	E10 - 7 psi	12.2	---	---	97.9	0.0	224.7 (0.0)	231.7 (0.0)	267.5 (0.0)
Toyota	E0 - 9 psi	8.5	---	---	81.1	25.1	202.1 (0.0)	165.9 (.2)	176.3 (7.2)
High-	E0 - 7 psi	8.7	---	---	79.7	22.5	248.3 (0.0)	294.1 (0.0)	288.8 (0.0)
lander	E20 - 9 psi	19.3	---	---	102.5	0.0	416.8 (0.0)	414.8 (0.0)	450.6 (0.0)
	E10 - 10 psi	32.4	---	---	174.2	11.8	2590.7 (57.8)	3477.9 (63.0)	3601.4 (64.3)
	E10 - 7 psi	32.5	---	---	168.3	19.2	397.5 (0.2)	355.0 (0.1)	362.1 (0.4)
216	E0 - 9 psi	17.8	13.6	---	109.1	25.4	327.0 (0.0)	266.7 (0.0)	274.6 (10.8)
	E0 - 7 psi	20.4	38.0	---	78.7	0.0	211.7 (0.0)	220.8 (0.0)	208.1 (0.0)
	E20 - 9 psi	20.4	---	---	54.3	7.4	468.5 (0.0)	452.6 (0.0)	419.8 (0.0)

Individual Vehicle Diurnal Performance on the Various Fuels

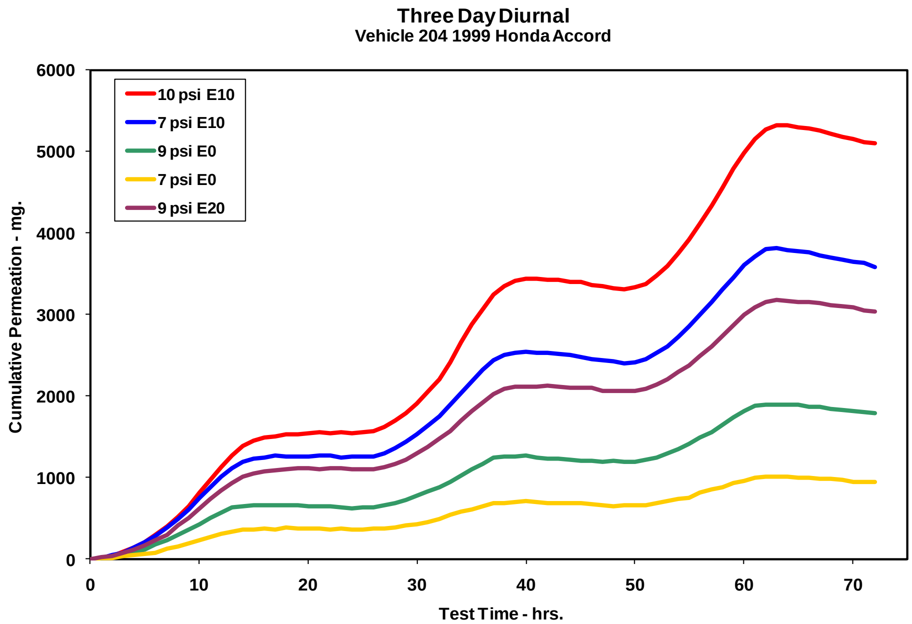

Figure 25 – Vehicle 204 Diurnal Performance

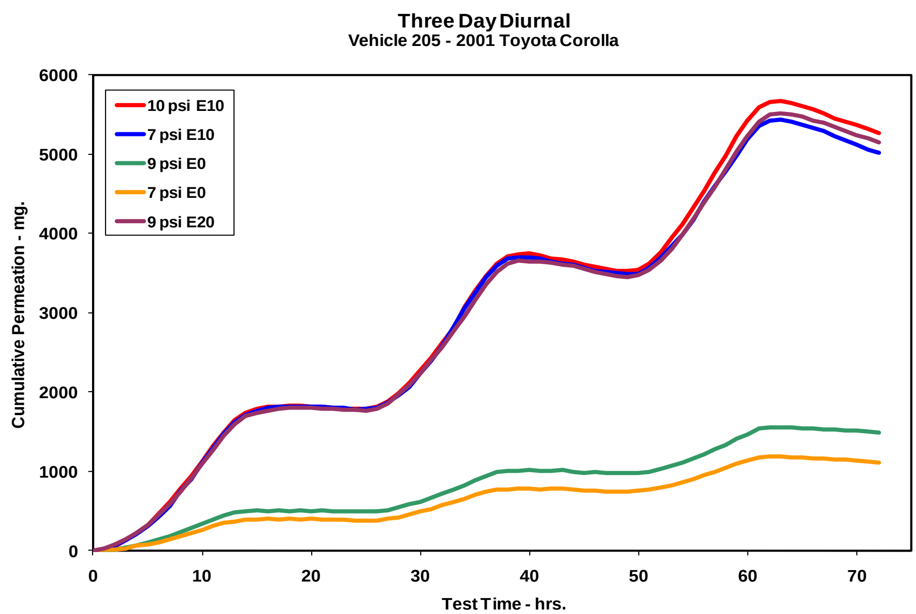

Figure 26 – Vehicle 205 Diurnal Performance

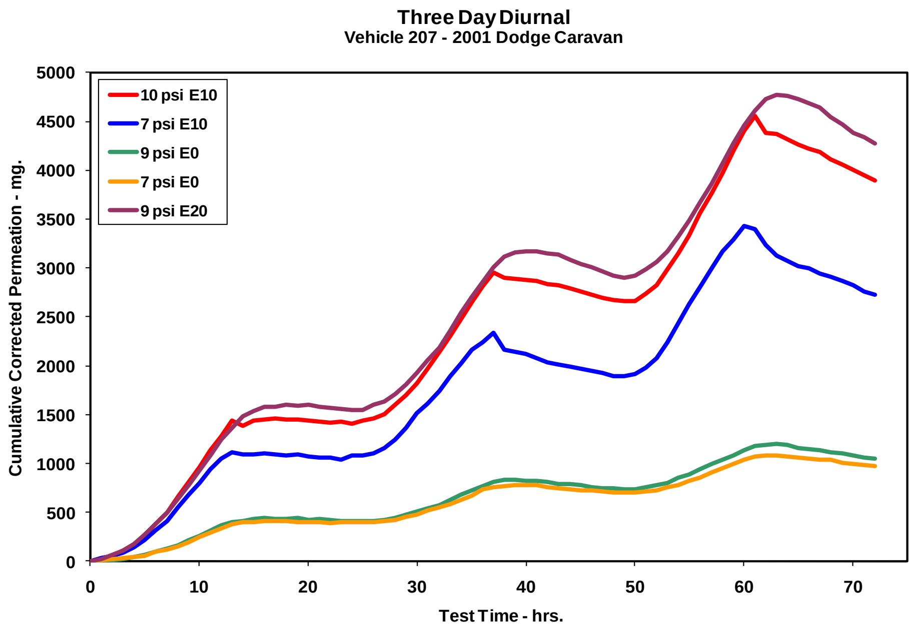

Figure 27 – Vehicle 207 Diurnal Performance

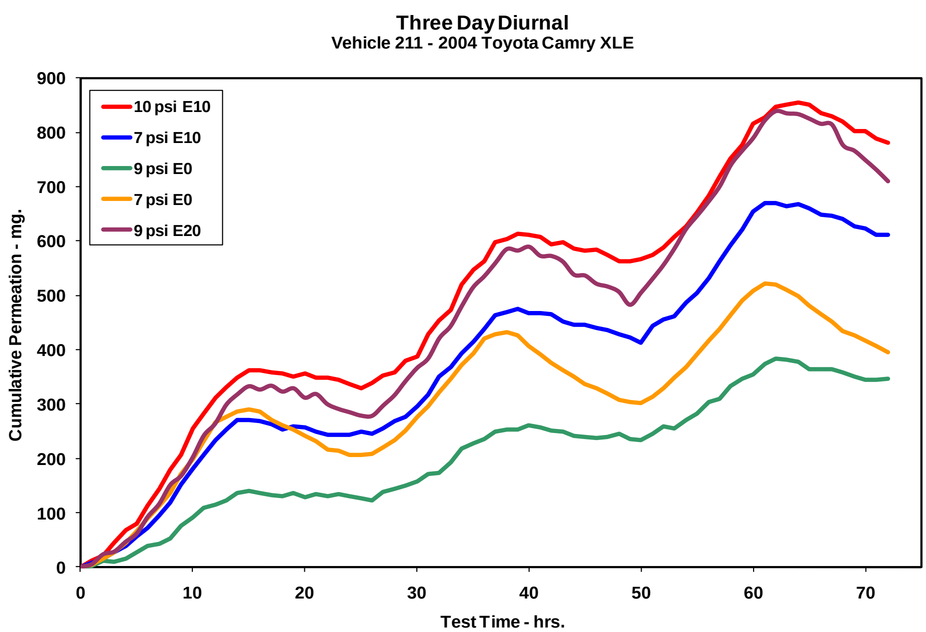

Figure 28 – Vehicle 211 Diurnal Performance

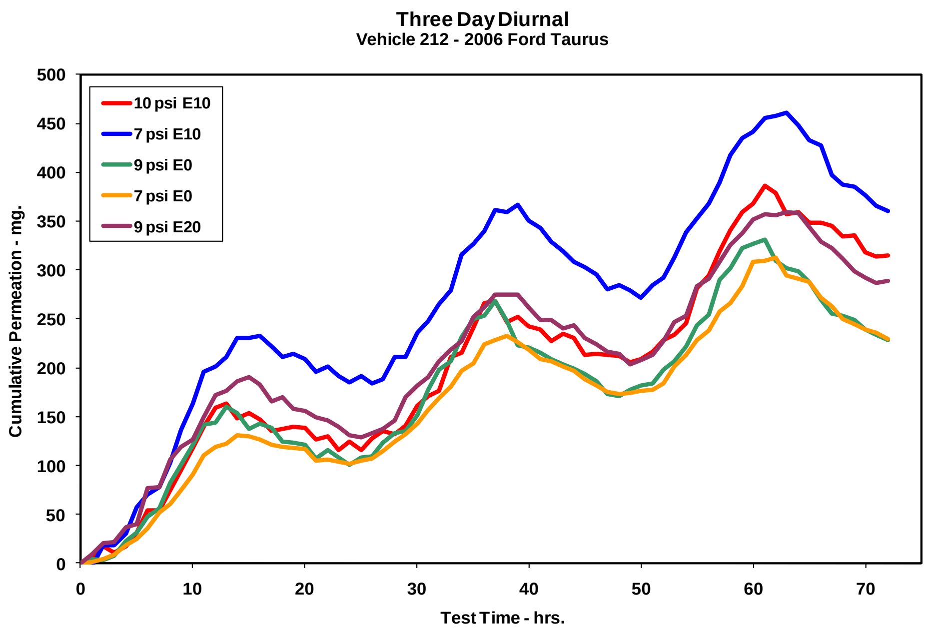

Figure 29 – Vehicle 212 Diurnal Performance

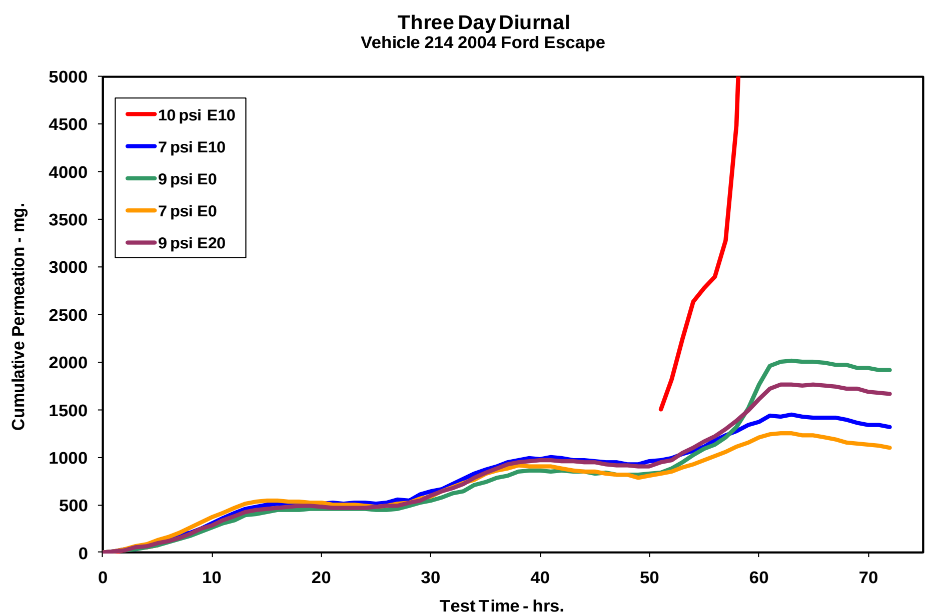

Figure 30 – Vehicle 214 Diurnal Performance

Note: The incomplete cumulative results for the 10 psi E10 results resulted from a conflict for the use of the INNOVA analyzer during the test. The INNOVA analyzer is required to correct for the FID's ethanol error, and the presence of methanol and refrigerant (R-134a). The data was available for the 50+ hour results, and the data is valid as shown. We have no explanation for the high levels experienced on the third day of the test. No test errors were identified.

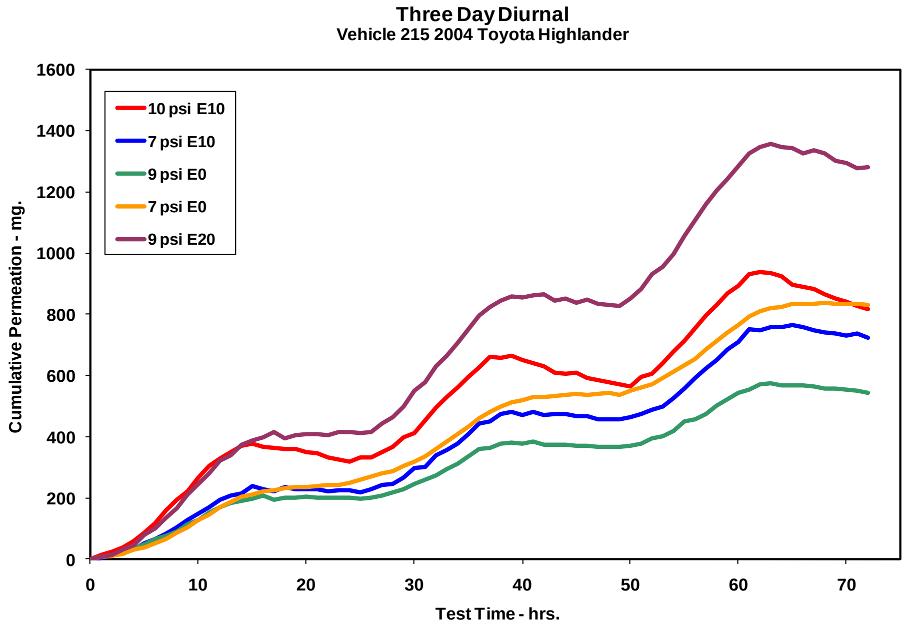

Figure 31 – Vehicle 215 Diurnal Performance

Table 14

CRC E77-2 Program Diurnal Results

All values are in mg

Vehicle	Test Fuel	3 Day Diurnal Results Corrected Total Fuel	EtOH	R134a	Methanol
204	10 psi E10	5098.99	1440.40	182.98	167.54
1999 Honda	7 psi E10	3590.57	1308.06	175.51	152.21
Accord	9 psi E0	1786.35	138.43	182.30	98.96
	7 psi E0	948.46	18.56	166.31	23.79
	9 psi E20	3042.71	1284.08	182.61	121.43
205	10 psi E10	5266.59	1865.99	233.54	208.95
2001 Toyota	7 psi E10	5022.29	2042.46	259.90	191.98
Corolla	9 psi E0	1487.75	0.00	204.34	46.13
	7 psi E0	1115.36	54.89	224.08	56.19
	9 psi E20	5145.40	2127.08	256.77	195.84
207	10 psi E10	3894.50	1962.48	120.13	303.99
2001 Dodge	7 psi E10	2722.01	1140.27	117.31	196.16
Caravan	9 psi E0	1051.67	18.20	122.24	152.84
	7 psi E0	969.06	11.18	221.41	142.76
	9 psi E20	4278.82	2414.88	142.68	254.32
211	10 psi E10	781.64	197.33	151.59	469.70
2004 Toyota	7 psi E10	611.90	202.11	159.29	465.25
Camry LE	9 psi E0	346.68	16.81	143.29	426.59
	7 psi E0	394.68	0.00	161.97	573.03
	9 psi E20	710.13	267.26	162.13	368.79
212	10 psi E10	315.08	72.22	148.31	78.96
2006 Ford	7 psi E10	360.79	101.32	154.81	34.00
Taurus	9 psi E0	228.70	24.09	151.82	37.61
	7 psi E0	229.73	0.00	153.93	43.62
	9 psi E20	289.35	111.56	141.16	26.29
214	10 psi E10	12578.87	0.00	199.47	279.92
2004 Ford	7 psi E10	1315.93	245.71	160.25	88.79
Escape	9 psi E0	1916.11	29.40	164.87	72.13
	7 psi E0	1094.81	53.86	806.50	31.06
	9 psi E20	1662.71	240.97	144.91	60.96
215	10 psi E10	816.44	121.78	146.58	426.09
2004 Toyota	7 psi E10	723.99	150.92	155.32	360.61
Highlander	9 psi E0	544.31	0.00	148.06	258.22
	7 psi E0	831.15	0.00	140.72	262.55
	9 psi E20	1282.23	388.22	128.41	344.20

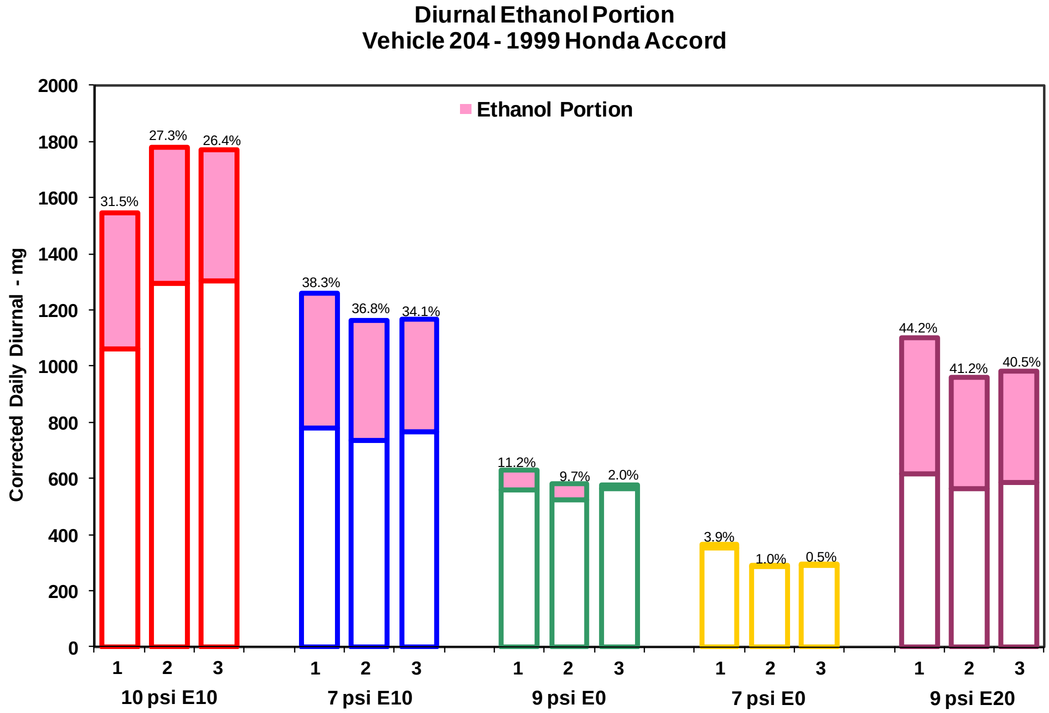

Figure 32 – Vehicle 204 Diurnal Ethanol Portion

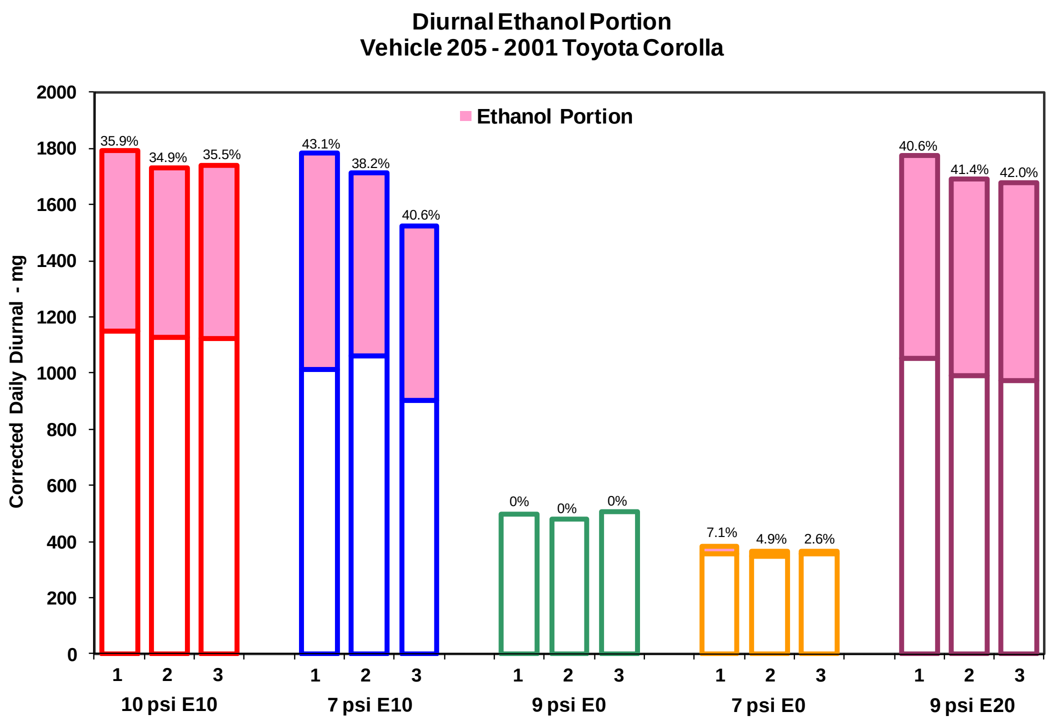

Figure 33 – Vehicle 205 Diurnal Ethanol Portion

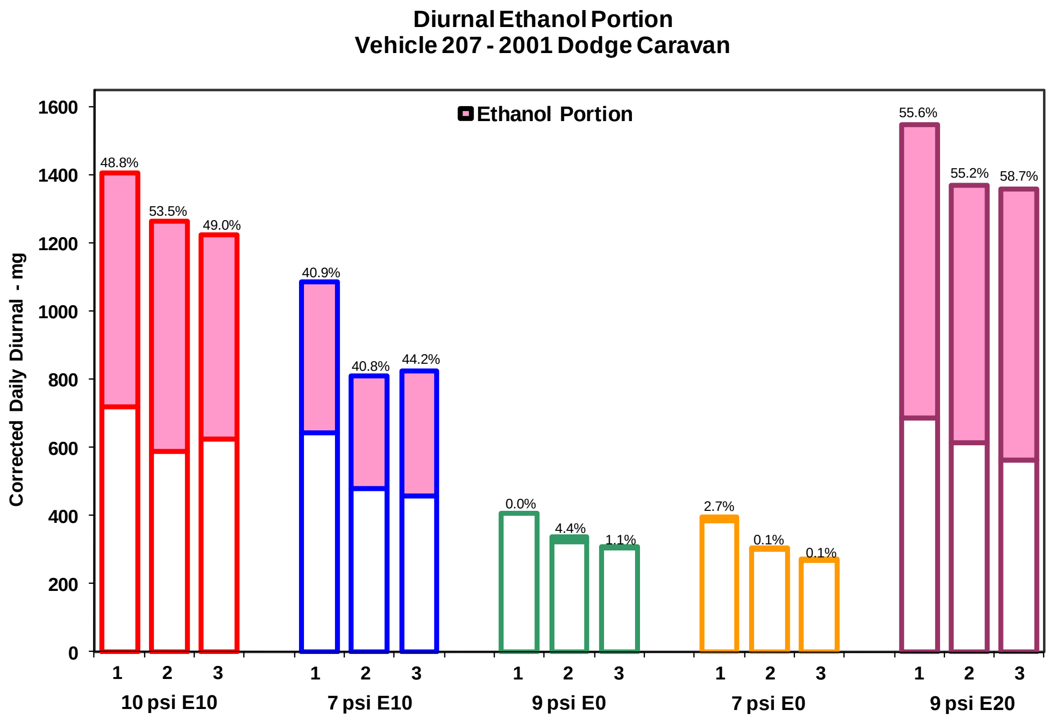

Figure 34 – Vehicle 207 Diurnal Ethanol Portion

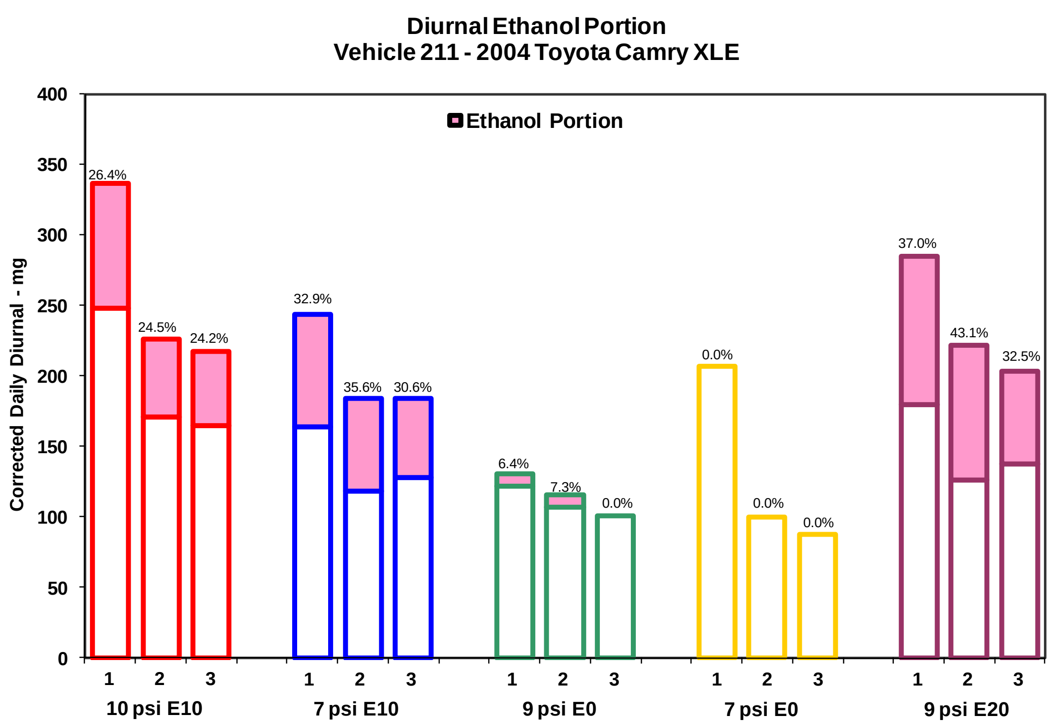

Figure 35 – Vehicle 211 Diurnal Ethanol Portion

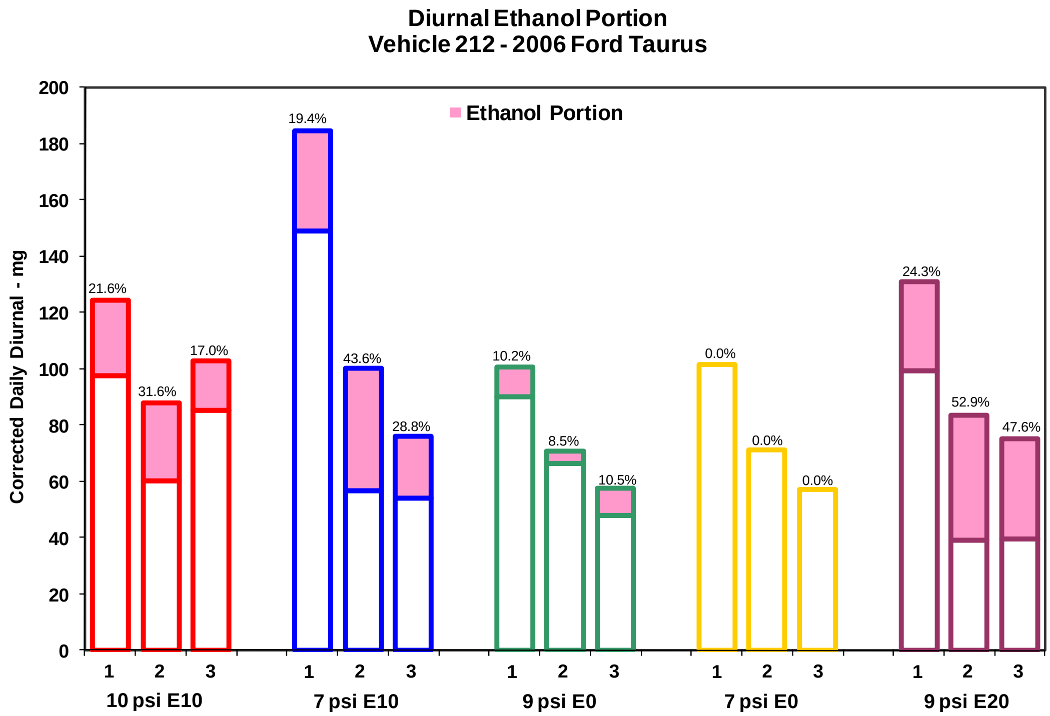

Figure 36 – Vehicle 212 Diurnal Ethanol Portion

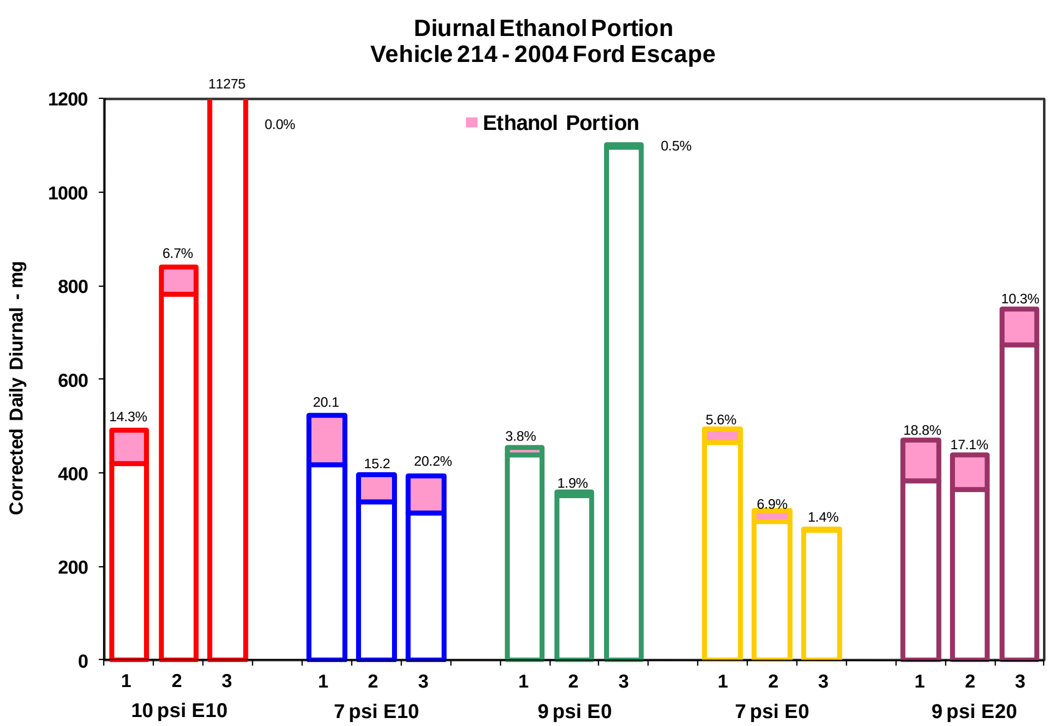

Figure 37 – Vehicle 214 Diurnal Ethanol Portion

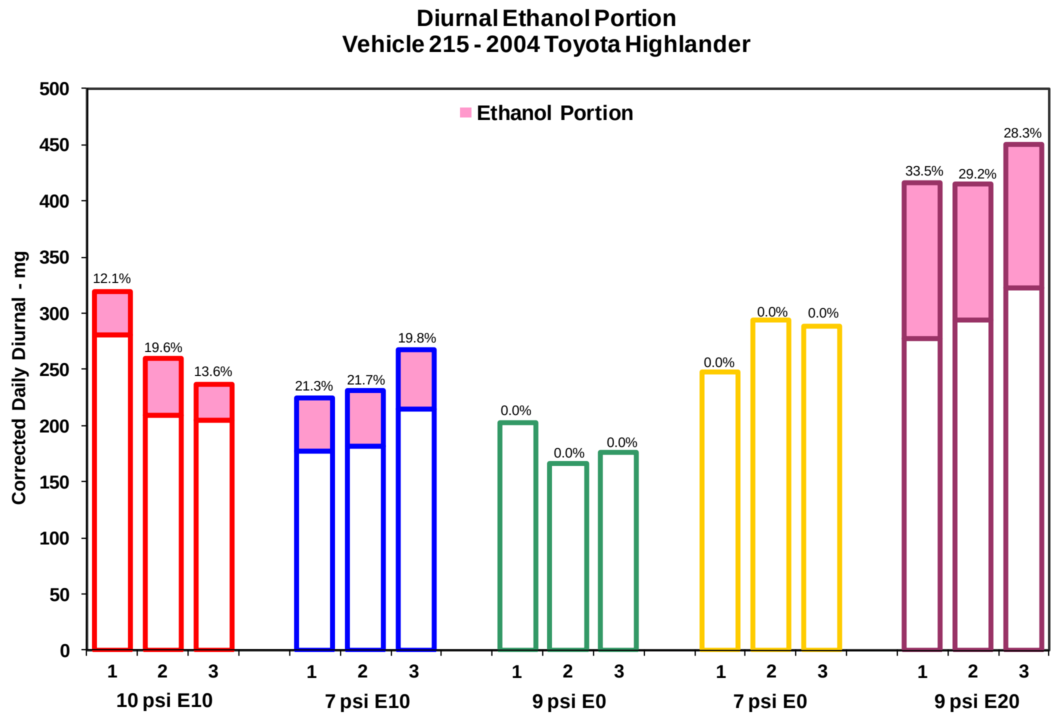

Figure 38 – Vehicle 215 Diurnal Ethanol Portion